Appendix A. Qualitative Assessment of Climate Change Vulnerability of National Fish Hatcheries in the Pacific Region: Quilcene 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 a MS-Excel spreadsheet template that was developed in the Headquarters Office (HQ) of the Service and distributed to all NFHs. This appendix summarizes the methods, results, and conclusions of those initial vulnerability assessments for Quilcene NFH.

Methods

The initial vulnerability assessment for Pacific Region hatcheries 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 NFH and local watershed and did not account for areas where 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 NFH where they can be recaptured as adults for broodstock. Consequently, the Service's initial evaluations of climate change effects for NFHs in the Pacific Region were subdivided into two categories: (a) the "NFH and local watershed", and (b) the "migration corridor". This latter category included all stream and river areas between the NFH and the ocean (Table A1).

Worksheet 2

The purpose of *Worksheet 2* (Table A2) was to identify and prioritize – for each NFH - management actions that could potentially 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. Rather, *Worksheet 2* was developed specifically for Pacific Region NFHs to facilitate the recording of the requested information.

Temperature, precipitation and hydrology projections, 2020s-2080s

Climate change projections for mean air temperature, precipitation, and several stream/hydrology parameters were obtained in the form of summary graphs from the Climate Impacts Group at the

University of Washington (CIG-UW; http://www.hydro.washington.edu/2860/). The summary graphs were generated for the 2020s, 2040s, and 2080s from the outputs of 10 general circulation models (GCMs) representing downscaled projections for monthly mean air temperature and precipitation at nearly 300 specific streamflow locations and representative watersheds throughout the Pacific Northwest. Those projections are based on the A1B greenhouse-gas emissions scenario from the Fourth IPCC Report (IPCC 2011) that assume some future actions will be taken to reduce the emission of carbon dioxide and other greenhouse gases relative to historic and recent trends. CIG-UW has coupled those downscaled temperature and precipitation projections to historic and future streamflow patterns within watersheds via the *Variable Infiltration Capacity* (VIC) hydrologic model (Liang et al. 1994; http://www.hydro.washington.edu/2860/new_users/). The manager and staff for each NFH used a subset of those graphs, primarily the ones for the 2040s and the specific watershed in which the hatchery is located (and/or adjacent ones), to complete *Worksheet 1* based on their best professional judgment and experiences.

Temperature, precipitation and hydrology projections for Quilcene NFH

Hydrology projection graphs for the Big Quilcene River watershed were not available in 2011. Consequently, projection graphs for two nearby watersheds were used instead by staff at Quilcene NFH to complete *Worksheet 1*: (1) the Dungeness River basin on the northeast slope of the Olympic Peninsula at the Dungeness, Washington gaging station near the town of Sequim; and (2) the Skokomish River basin on the southeast slope of the Olympic Peninsula at the Potlatch, Washington gaging station near the town of Union (Figure A1).

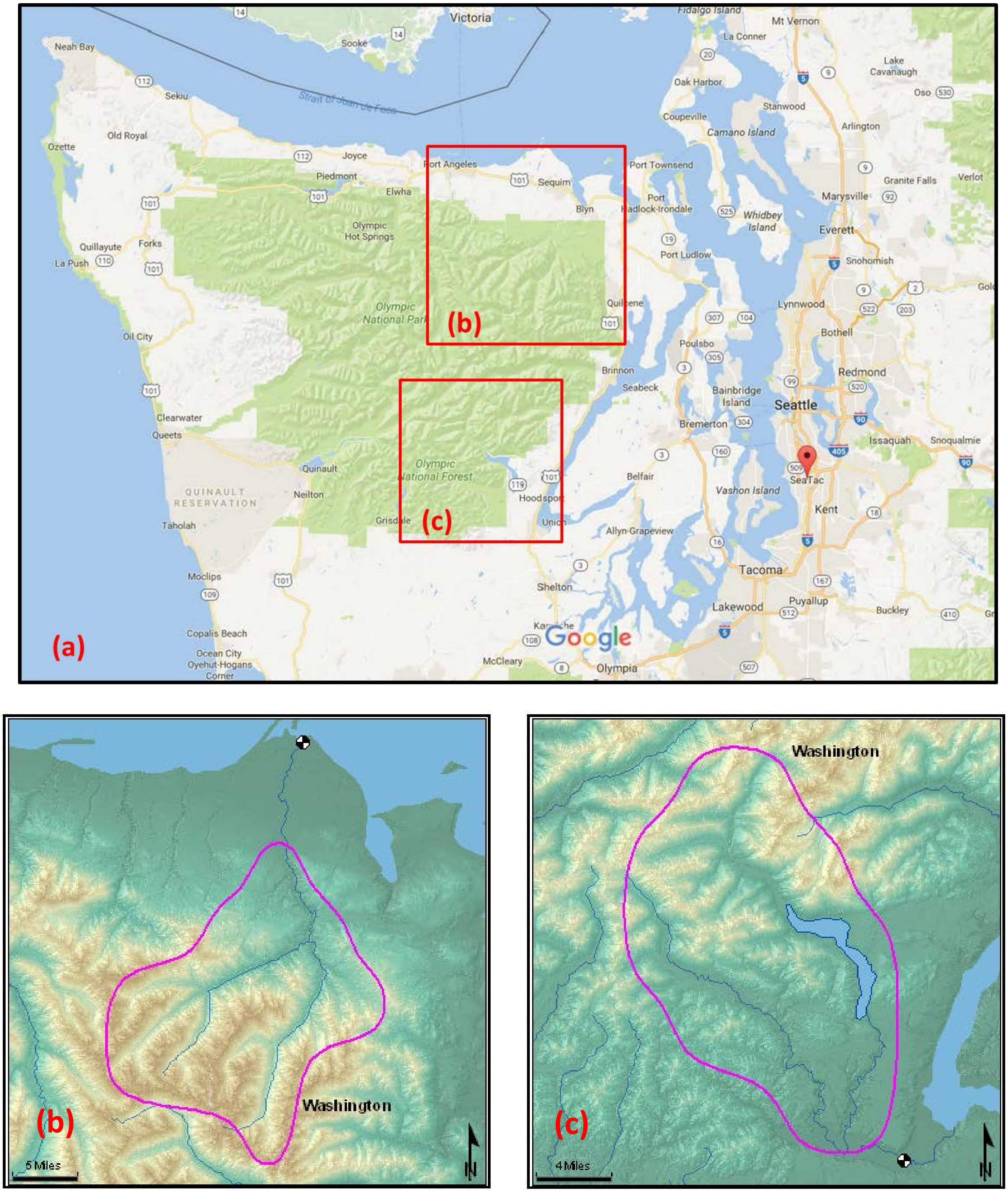

Figure A1. (a) Olympic Peninsula and Puget Sound of Washington State. The mouth of the Big Quilcene River is just south of the town of Quilcene, approximately at the location of the U.S. Highway 101 symbol shown on the map. Downscaled, climate change projection graphs were obtained for the Dungeness and Skokomish river basins. (b) Dungeness River basin on the northeast slope of the Olympic Peninsula. (c) Skokomish River basin on the southwest slope of the Olympic Peninsula. The locations of the U.S. Geological Survey reference gaging stations are shown by the black and white quartered circles.

Figures A2 and A3 on the following two pages show the climate-hydrology projections for the Dungeness and Skokomish River basins, respectively, used by the staff at Quilcene NFH to complete *Worksheet 1*. Each figure has six graphs labeled (a) through (f). Brief descriptions of those graphs follow.

Graph (a): Raw streamflow. This is the average monthly streamflow at the gaging station point of measurement (Figure A1) in cubic feet per second (cfs). The blue line shows the simulated historic mean value for the years 1971-1999; the red line shows the ensemble average of the outputs for 10 downscaled GCMs; and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

Graph (b): Simulated low streamflow at the gaging station measurement point in the watershed (Figure A1) measured in cubic feet per second (cfs), quantified by 7Q10 statistics. "7Q10 low flow" is the estimated minimum flow that occurs over seven consecutive days in 10% of the years (i.e., the estimated 7-day lowest flows that occur, on average, once every10 years). The blue circle shows the simulated historic mean value; red circles show the values for the 10 downscaled GCMs; the horizontal black line shows the ensemble average of the 10 downscaled models; and the orange circle shows the values for the composite delta downscale method (units = cfs).

Graph (c): Monthly average air temperature over the entire watershed upstream from the point of measurement (units = degrees F). The blue line shows the simulated historic value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

Graph (d): Monthly average total precipitation (rain + snow) over the entire watershed upstream of the measurement point expressed as an average water depth (units = inches). The blue line shows the simulated historic value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

Graph (e): Simulated peak streamflow at the measurement point in the watershed for 20, 50 and 100-year peak flows (units = cfs). These graphs show simulated projected peak flows expected in 5%, 2% and 1% of the years, respectively over a 100-year period for each of three time periods. Blue circles show the simulated historical values; red circles show the values for 10 downscaled GCMs; the horizontal black line shows the ensemble average of the 10 downscaled models, and the orange circles show the values for the composite delta downscale method.

Graph (f): Water volume equivalent of projected snow pack on first day of month averaged over the entire watershed upstream of the point of measurement, expressed as an average water depth (units = inches). This variable is a primary component of the simulated water balance, and quantifies natural storage as snowpack. The blue line shows the simulated historical value, the red line shows the ensemble average of the outputs for 10 downscaled GCMs, and the red shaded area shows the range of outputs for the 10 GCMs for each of three future time periods.

Dungeness River Basin

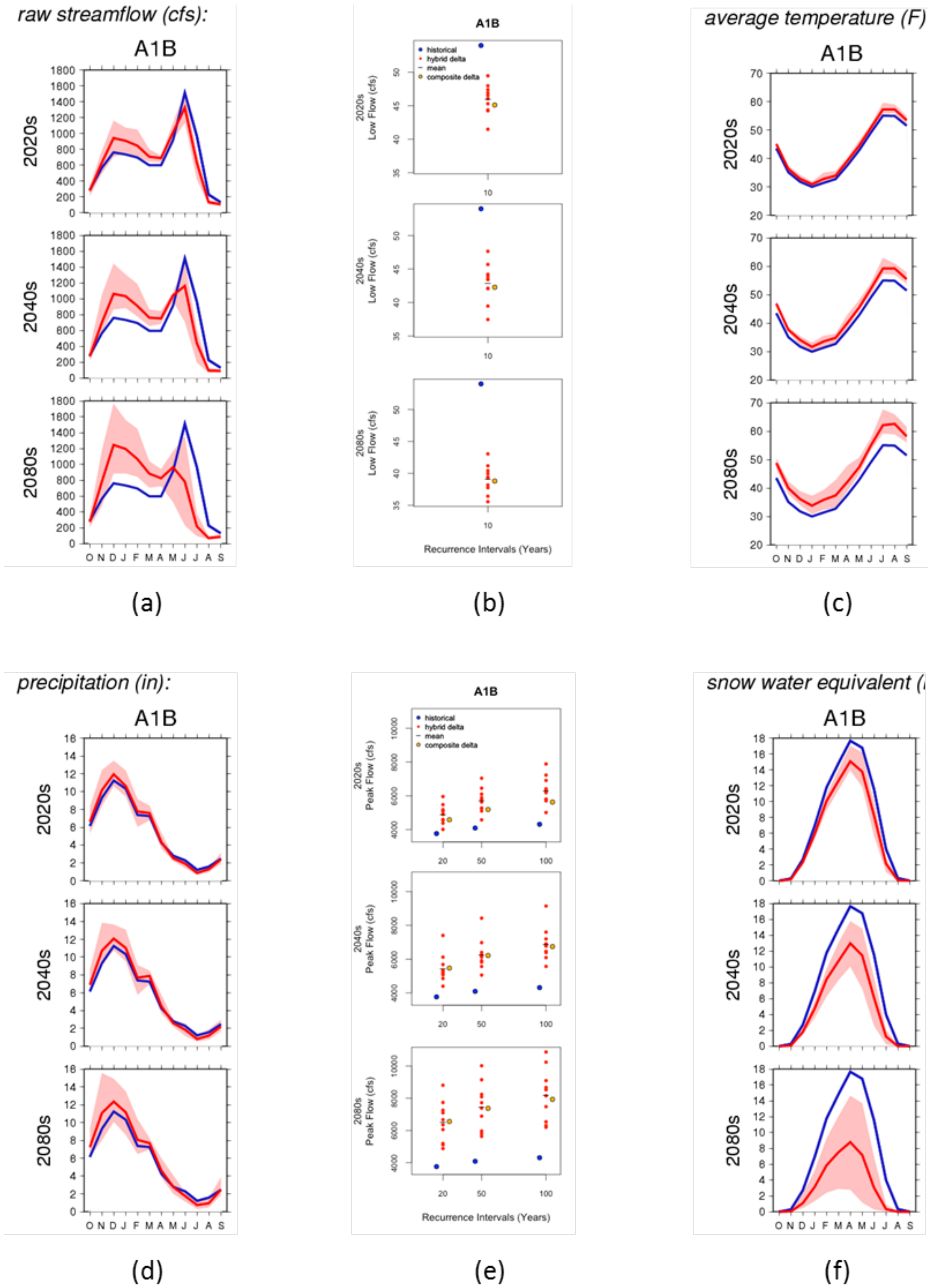

Figure A2. Climate and hydrology projections for the Dungeness River Basin, Washington (CIG 2011). The blue lines (a, c, d, and f) and dots (b, e) are the1971-1999 simulated historic means. The red line and red shading in (a), (c), (d), and (f) are the mean and range, respectively of outputs from 10 GCM models. For low and peak flows (b and e), the red dots are the projections from the 10 models, the horizontal line is the average of the 10 projections, and the orange dot is the composite model output.

Skokomish River Basin

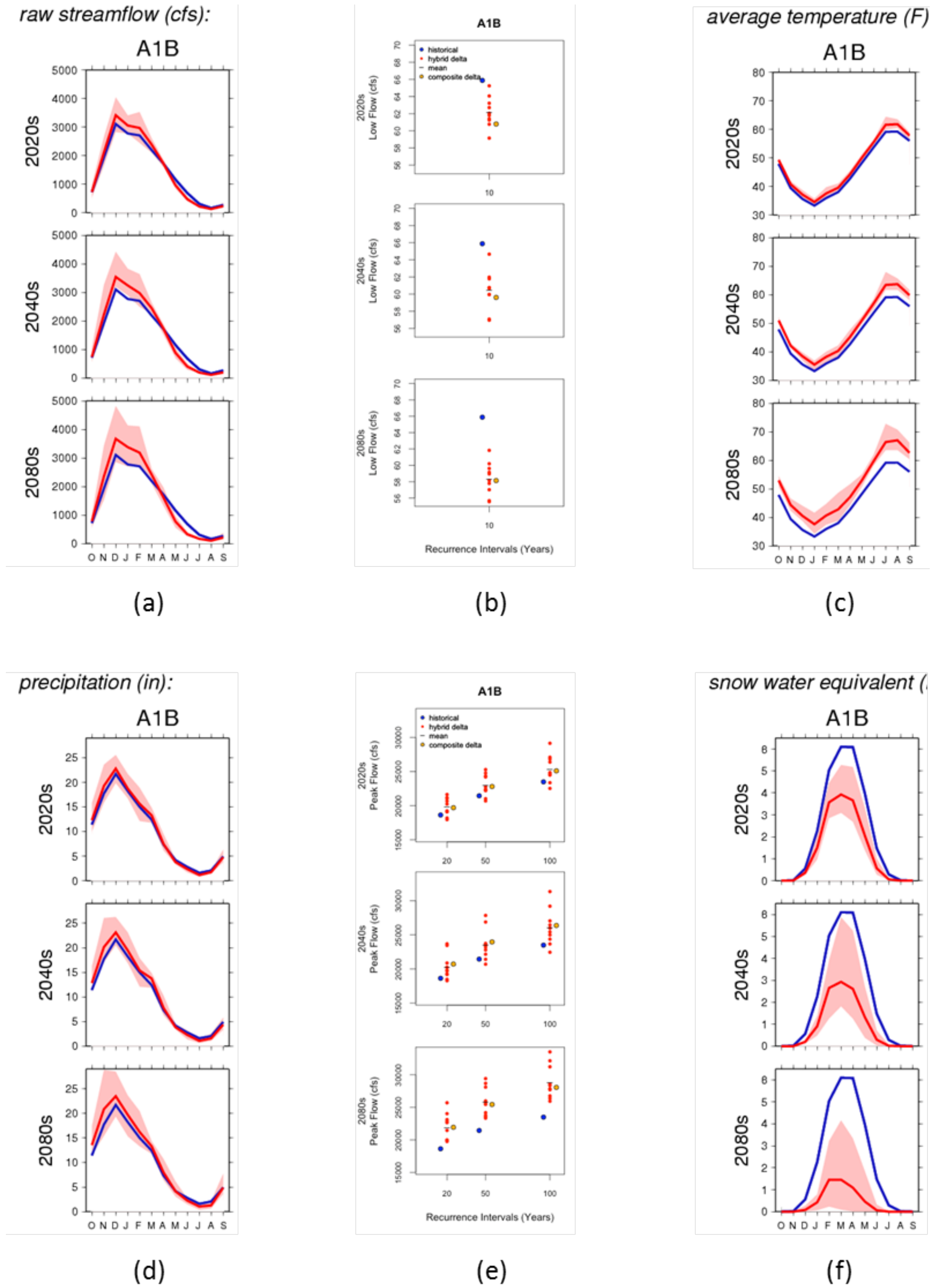

Figure A3. Climate and hydrology projections for the Skokomish River Basin, Washington (CIG 2011). The blue lines (a, c, d, and f) and dots (b, e) are the1971-1999 simulated historic means. The red line and red shading in (a), (c), (d), and (f) are the mean and range, respectively of outputs from 10 GCM models. For low and peak flows (b and e), the red dots are the projections from the 10 models, the horizontal line is the average of the 10 projections, and the orange dot is the composite model output.

Results

Climate change risks at Quilcene NFH

No climate change stressor at Quilcene 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: decrease in surface water quantity (NFH and migration corridor), decrease in ground water quantity (NFH), decrease in surface water quality (NFH and migration corridor) degradation of ground water quality (NFH), temperature increase (NFH), surface water temperature increase (NFH and migration corridor), ground water temperature increase (NFH), decrease in amount of snow pack (NFH), increase in number of flood events annually (NFH), increase in number of drought events annually (NFH), increase in the average duration of drought events annually (NFH), increase in the number of ice storms (NFH), increase in number of fire events (NFH), increase in invasive species (NFH and migration corridor) increase in disease (NFH and migration corridor), increase in parasites (NFH and migration corridor), and increase in pathogens (NFH and migration corridor).

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

The manager and staff at Quilcene 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 (Table A2): (a) reduce rearing densities and/or number of fish reared, (b) install improved water treatment for re-use system, (c) install water chillers to decrease water temperature and slow development, (d) initiate water conservation measures, (e) reduce or eliminate work with T&E species because of lack of pathogen free water, (f) increase monitoring, diagnosis, and treatment of fish disease, (g) install pond covers for shade, (h) improve habitats (includes invasive species control), (i) work with partners to control spread of invasive species, (j) increase training requirements for fish culture staff so they may assist with increased risk of biological threats, and (k) coordinate with US Forest Service and local Fire Department with regards to fire.

Discussion and Conclusions

A primary concern at Quilcene 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) at the NFH and migration corridor. Their concerns were further supported by quantitative analyses (Appendix B).

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 NFH 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.

Overall, the manager and staff at Quilcene 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 and if outbreaks of disease and new invasive species are countered with increased training and vigilance.

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 Quilcene NFH is presented as Table A1.

Step 1: Identify climate change stressors (columns 1 and 2). The climate and hydrology projection graphs (Figures A2, A3) were used to identify climate change stressors for the evaluated hatchery: 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	Percent (%) 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		**Severity**				
		5	**4**	**3**	**2**	**1**
Likelihood		**Catastrophic**	**Major**	**Moderate**	**Minor**	**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

	Legend:
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 Quilcene 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.

Quilcene 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
	1= Stressor for hatchery; 0 = Not a stressor	1= Insignificant; 2= Minor; 3=Moderate; 4= Major; 5 = Catastrophic	1= <10%; 2= 10-33%; 3= 33-66%; 4=66-90%; 5= 90-99%	1= Negligible; 2= Low; 3= Moderate; 4= High; 5= Extreme
SURFACE WATER QUANTITY (Hatchery and local watershed)				
decrease in water quantity (hatchery)	1	3	4	4
increase in water quantity (hatchery)	0			
SURFACE WATER QUANTITY (Migration Corridor)				
decrease in water quantity (migration corridor)	1	3	4	4
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	3	3	4
increase in water quality (hatchery)	0			
SURFACE WATER QUALITY (Migration Corridor)				
decrease in water quality (migration corridor)	1	3	3	4
increase in water quality (migration corridor)	0			
GROUND WATER QUALITY (Hatchery and local watershed)				
degradation of water quality (hatchery)	1	3	3	4
improvement of water quality (hatchery)	0			
SURFACE WATER TEMPERATURE (Hatchery and local watershed)				
temperature increase (hatchery)	1	3	3	4
temperature decrease (hatchery)	0			
SURFACE WATER TEMPERATURE (Migration Corridor)				
temperature increase (migration corridor)	1	3	3	4
temperature decrease (migration corridor)	0			
GROUND WATER TEMPERATURE (Hatchery and local watershed)				
temperature increase (hatchery)	1	3	3	4
temperature decrease (hatchery)	0			

Table A1. Continued.

Quilcene 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**
	1= Stressor for hatchery; 0 = Not a stressor	1= Insignificant; 2= Minor; 3=Moderate; 4= Major; 5 = Catastrophic	1= <10%; 2= 10-33%; 3= 33-66%; 4=66-90%; 5= 90-99%	1= Negligible; 2= Low; 3= Moderate; 4= High; 5= Extreme
AMBIENT TEMPERATURE CHANGES (Hatchery and local watershed)				
increase in annual average temperature (hatchery)	1	2	3	3
decrease in annual average temperature (hatchery)	0			
increase in number of warm days (aka heat waves) (hatchery)	1	2	3	3
decrease in number of warm days (hatchery)	0			
increase in number of frost days (hatchery)	0			
decrease in number of frost days (hatchery)	0			
increase in spring average air temperatures (hatchery)	0			
increase in summer average air temperatures (hatchery)	0			
increase in fall average air temperatures (hatchery)	0			
increase in winter average air temperatures (hatchery)	0			
decrease in spring average air temperatures (hatchery)	0			
decrease in summer average air temperatures (hatchery)	0			
decrease in fall average air temperatures (hatchery)	0			
decrease in winter average air temperatures (hatchery)	0			
PRECIPITATION CHANGES (Hatchery and local watershed)				
increase in annual average precipitation (hatchery)	0			
decrease in annual average precipitation (hatchery)	0			
increase in spring average precipitation (hatchery)	0			
increase in summer average precipitation (hatchery)	0			
increase in fall average precipitation (hatchery)	0			
increase in winter average precipitation (hatchery)	0			
decrease in spring average precipitation (hatchery)	0			
decrease in summer average precipitation (hatchery)	0			
decrease in fall average precipitation (hatchery)	0			
decrease in winter average precipitation (hatchery)	0			
increase in frequency of extreme thunderstorms (hatchery)	0			

Table A1. Continued.

Quilcene 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**
	1= Stressor for hatchery; 0 = Not a stressor	1= Insignificant; 2= Minor; 3=Moderate; 4= Major; 5 = Catastrophic	1= <10%; 2= 10-33%; 3= 33-66%; 4=66-90%; 5= 90-99%	1= Negligible; 2= Low; 3= Moderate; 4= High; 5= Extreme
PRECIPITATION CHANGES (Hatchery and local watershed)				
decrease in frequency of extreme thunderstorms (hatchery)	0			
increase in frequency of extreme snow storms (hatchery)	0			
decrease in frequency of extreme snow storms (hatchery)	0			
increase in duration of extreme thunderstorms (hatchery)	0			
decrease in duration of extreme thunderstorms (hatchery)	0			
increase in duration of extreme snow storms (hatchery)	0			
decrease in duration of extreme snow storms (hatchery)	0			
increase in amount of snow pack (hatchery)	0			
decrease in amount of snow pack (hatchery)	1	3	3	4
earlier snow melt date (hatchery)	0			
later snow melt date (hatchery)	1	2	3	3
lower snow line (hatchery)	0			
higher snow line (hatchery)	0			
EXTREME WEATHER EVENTS (Hatchery and local watershed)				
increased average wind speed annually (hatchery)	0			
decreased average wind speed annually (hatchery)	0			
increased average wind duration annually (hatchery)	0			
decreased average wind duration annually (hatchery)	0			
change in wind patterns (hatchery)	0			
increased speed and duration of westerly wind flow (hatchery)	0			
decreased speed and duration of westerly wind flow (hatchery)	0			
increased speed and duration of southerly wind flow (hatchery)	0			
decreased speed and duration of southerly wind flow (hatchery)	0			
increase in number of flood events annually (hatchery)	1	3	3	4
decrease in number of flood events annually (hatchery)	0			
increase in the average duration of flood events annually (hatchery)	0			

Table A1. Continued.

Quilcene 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**
	1= Stressor for hatchery; 0 = Not a stressor	1= Insignificant; 2= Minor; 3=Moderate; 4= Major; 5 = Catastrophic	1= <10%; 2= 10-33%; 3= 33-66%; 4=66-90%; 5= 90-99%	1= Negligible; 2= Low; 3= Moderate; 4= High; 5= Extreme
EXTREME WEATHER EVENTS (Hatchery and local watershed)				
decrease in the average duration of flood events annually (hatchery)	0			
increase in the severity of flood events annually (hatchery)	1	2	3	3
decrease in the severity of flood events annually (hatchery)	0			
increase in number of drought events annually (hatchery)	1	3	3	4
decrease in number of drought events annually (hatchery)	0			
increase in the average duration of drought events annually (hatchery)	1	3	3	4
decrease in the average duration of drought events annually (hatchery)	0			
increase in the number of tornadoes (hatchery)	0			
decrease in the number of tornadoes (hatchery)	0			
increase in the severity of tornadoes (hatchery)	0			
decrease in the severity of tornadoes (hatchery)	0			
increase in the number of hurricanes (hatchery)	0			
decrease in the number of hurricanes (hatchery)	0			
increase in the severity of hurricanes (hatchery)	0			
decrease in the severity of hurricanes (hatchery)	0			
increase in the number of ice storms (hatchery)	1	3	3	4
decrease in the number of ice storms (hatchery)	0			
increase in the severity of ice storms (hatchery)	0			
decrease in the severity of ice storms (hatchery)	0			
increase in the number of monsoons (hatchery)	0			
decrease in the number of monsoons (hatchery)	0			
increase in the severity of monsoons (hatchery)	0			
decrease in the severity of monsoons (hatchery)	0			
increase in the number of hail storms (hatchery)	0			
decrease in the number of hail storms (hatchery)	0			
increase in the severity of hail storms (hatchery)	1	1	2	2
decrease in the severity of hail storms (hatchery)	0			

Table A1. Continued.

Quilcene 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**
	1= Stressor for hatchery; 0 = Not a stressor	1= Insignificant; 2= Minor; 3=Moderate; 4= Major; 5 = Catastrophic	1= <10%; 2= 10-33%; 3= 33-66%; 4=66-90%; 5= 90-99%	1= Negligible; 2= Low; 3= Moderate; 4= High; 5= Extreme
OTHER (Hatchery and local watershed)				
increase in invasive species (hatchery)	1	3	4	4
decrease in invasive species (hatchery)	0			
increase in disease (hatchery)	1	3	4	4
decrease in disease (hatchery)	0			
increase in parasites (hatchery)	1	2	4	4
decrease in parasites (hatchery)	0			
increase in pathogens (hatchery)	1	3	3	4
decrease in pathogens (hatchery)	0			
increase in number of fire events (hatchery)	1	3	3	4
decrease in number of fire events (hatchery)	0			
increase in intensity of fire events (hatchery)	1	1	3	2
decrease in intensity of fire events (hatchery)	0			
extreme precipitation events-hurricane (hatchery)	0			
extreme precipitation events-tropical storm (hatchery)	0			
extreme precipitation events-cyclones (hatchery)	0			
extreme precipitation events (hatchery)	1	2	3	3
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.

Quilcene 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**
	1= Stressor for hatchery; 0 = Not a stressor	1= Insignificant; 2= Minor; 3=Moderate; 4= Major; 5 = Catastrophic	1= <10%; 2= 10-33%; 3= 33-66%; 4=66-90%; 5= 90-99%	1= Negligible; 2= Low; 3= Moderate; 4= High; 5= Extreme
COASTAL (Hatchery and local watershed)				
increase in wave size and intensity (hatchery)	0			
decrease in wave size and intensity (hatchery)	0			
increase in marine cloudiness (decreasing temperature) (hatchery)	0			
decrease in marine cloudiness (increasing temperature) (hatchery)	0			
increase in sea level (hatchery)	0			
decrease in sea level (hatchery)	0			
change in ocean currents (hatchery)	0			
change in wave patterns (hatchery)	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 Quilcene 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:

Designation	**Classification**	**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:

	Feasibility to implement management action (color coded scores, 1 to 5)					
		Time and effort necessary to implement				
		5	**4**	**3**	**2**	**1**
	Cost to implement	**extremely difficult**	**very difficult**	**difficult**	**moderate**	**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

Legend:

5	**Feasibility very low**
4	**Feasibility low**
3	**Feasibility moderate**
2	**Feasibility high**
1	**Feasibility very high**

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, priority, 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 Quilcene NFH.

Quilcene 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)**	**Step 9: Feasibility to implement management action (1, 2, 3, 4, or 5)**	**Step 10, part 1: Priority/rank of management actions to adapt/mitigate for effects of stressor (enter 1, 2, 3, ...etc.)**	**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	Physiological stress to fish	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
	Increase in water temperature	Install water chillers and back up generators	5	4	5	2	This would be costly due to installation and additional operational costs
	Increased fish health risks						
	Decreased carrying capacity of hatchery for rearing fish						
Decrease in ground water quantity	Reduced availability of pathogen-free water for culturing ESA-listed species	Reduce or eliminate work with T&E species	4	2	4	3	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
Decrease in ground water quality	Reduced availability of domestic/drinking water from well	Initiate water conservation measures	2	1	2	1	
		Install improved water treatment system	4	3	5	2	
Decrease in surface water quality	Increased water temperature for outside ponds	Install pond covers	4	3	5	2	
Increase in surface water temperature	Increased fish health risks	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
Increase in groundwater temperature	Increased fish health risks to T&E species	Install larger water chillers in Isolation building	4	3	5	1	
WATER QUALITY AND QUANTITY CHANGES (Migration corridor)							Migration corridor = Hood Canal, parts of Puget Sound, and the Straits of Juan de Fuca
Decrease in surface water quantity	Physiological stress to fish	Reduce sport and tribal fishing	3	2	3	1	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
	Increase in water temperature	Improve habitats (includes invasive species control)	4	3	5	2	
	Increased fish health risks	Reduce rearing densities and/or number of fish reared	4	2	4	3	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
	Reduced number of adult fish available for broodstock						
Decrease in surface water quality	Increased water temperature	Install water chillers and back up generators	5	4	5	2	
	Increased fish health risks	Reduce rearing densities and/or number of fish reared	4	2	4	1	
	Reduced numbers of adult fish available for broodstock						
Increase in surface water temperature (migration corridor)	Reduced numbers of adult fish available for broodstock	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
	Increase risk of invasive species	Work with partners to control spread of invasive species	4	3	5	2	
AMBIENT TEMPERATURE CHANGES (Hatchery)							
Increase in annual average temperature (hatchery)	Increase risk of invasive species	species	4	3	5	1	
Increase in number of warm days (aka heat waves1) (hatchery)							
PRECIPITATION CHANGES (Hatchery and local watershed)							
Decrease in amount of snow pack (hatchery)	Increased risk of fire	Coordinate with Forest Service and local Fire Dept for support	3	2	3	1	
Later Snow melt date(hatchery)	Decrease in surface water quantity (summer)	Reduce rearing densities and/or number of fish reared	4	2	4	2	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
	Reduced carrying capacity of hatchery						
EXTREME WEATHER EVENTS (Hatchery and local watershed)							
Increase number of flood events (hatchery)	Increased sedimentation	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
Increase in the severity of flood events annually (hatchery)	Reduced water quality						
	Increased fish health risks						
	Increased stream erosion						
Increase in number of drought events annually (hatchery)	Decrease in surface water quantity and quality	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared will require meetings and agreements with state and tribal co-managers.
(hatchery)	Increase in surface water temperature	Install water chillers and back up generators	5	4	5	3	
	Increase risk of invasive species	species	5	4	5	2	
	Increased fish health risks						

Table A2. continued.

Quilcene 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)**	**Step 9: Feasibility to implement management action (1, 2, 3, 4, or 5)**	**Step 10, part 1: Priority/rank of management actions to adapt/mitigate for effects of stressor (enter 1, 2, 3, ...etc.)**	**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)							
Increase in the number of ice storms (hatchery)	Increased risk and frequency of pow er outages	Install electric generators (include housing)	5	4	5	1	
Increase in the severity of hail storms (hatchery)							
OTHER (Hatchery and local watershed)							
Increase in invasive species (hatchery)	Increase fish health risks	Reduce rearing densities and/or number of fish reared	4	2	4	2	Changing the number of fish reared w ill require meetings and agreements w ith state and tribal co-managers.
	Reduced w ater quality	species	5	4	5	1	
	Reduced habitat quality						
Increase in disease (hatchery)	Increased fish health risks	Reduce rearing densities and/or number of fish reared	4	2	4	2	Changing the number of fish reared w ill require meetings and agreements w ith state and tribal co-managers.
Increase in parasites (hatchery)		Increase fish health monitoring	2	2	2	1	
Increase in pathogens (hatchery)							
Increase in number of fire events (hatchery)	Reduced w ater quality	Reduce rearing densities and/or number of fish reared	4	2	4	2	Changing the number of fish reared w ill require meetings and agreements w ith state and tribal co-managers.
Increase in intensity of fire events (hatchery)	Increase fish health risks	Increase fish health monitoring	2	2	2	1	
	See: Increase in frequency and duration of flood events						
Extreme precipitation events (hatchery)	See: Increase in frequency and duration of flood events						
OTHER (Migration corridor)							
Increase in invasive species (migration corridor)	Reduced w ater quality	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared w ill require meetings and agreements w ith state and tribal co-managers.
Increase in disease (migration corridor)	Increase fish health risks	Reduce rearing densities and/or number of fish reared	4	2	4	1	Changing the number of fish reared w ill require meetings and agreements w ith state and tribal co-managers.
Increase in parasites (migration corridor)							
Increase in pathogens (migration corridor)							
MANAGEMENT							
Skill set	Reduced ability to adequately monitor, diagnose, and treat fish for disease because of increased w ork 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.