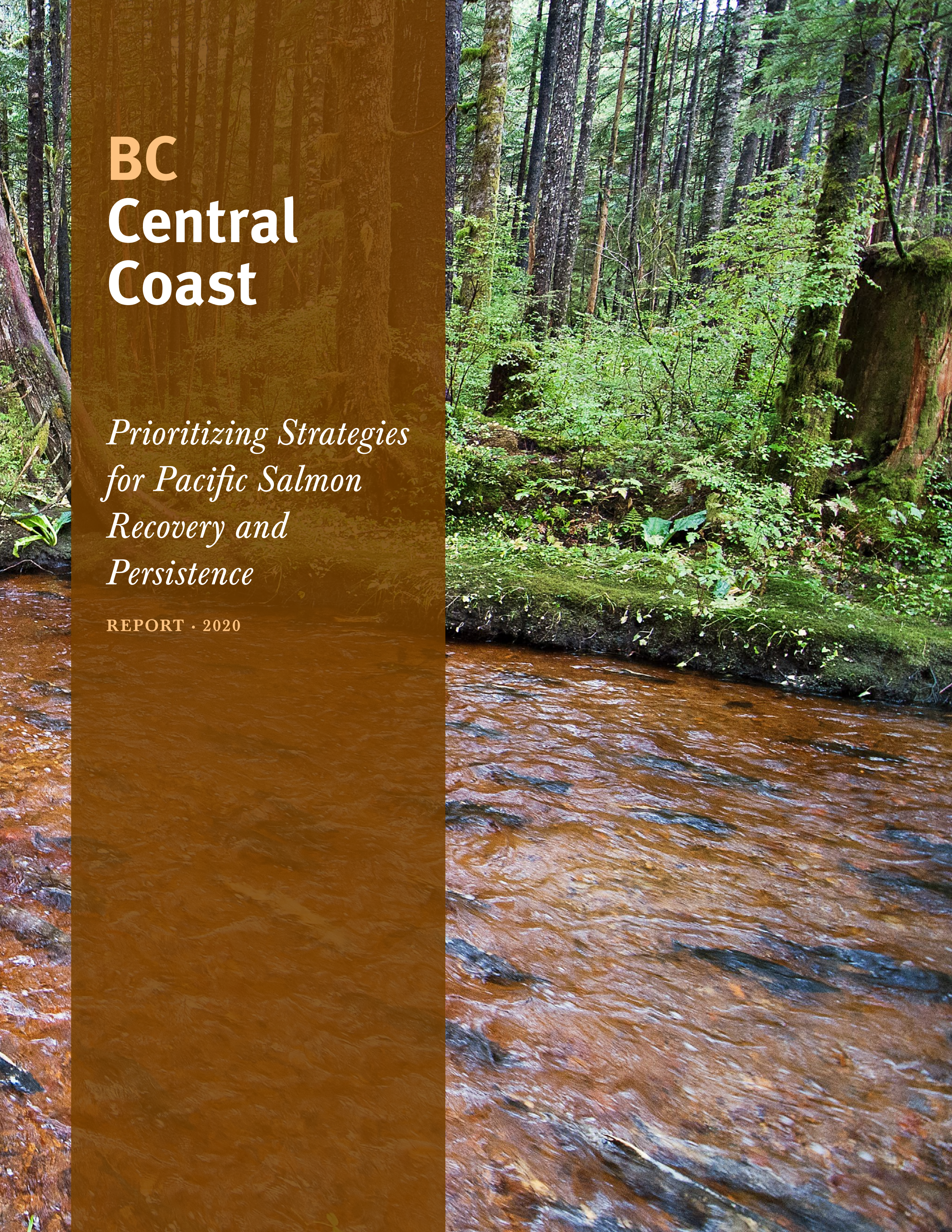

BC Central Coast

Prioritizing Strategies for Pacific Salmon Recovery and Persistence

REPORT · 2020

CITATION

Jessica C. Walsh, Katrina Connors, Eric Hertz, Laura Kehoe, Tara G. Martin, Brendan Connors, Alejandro Frid, Cameron Freshwater, Michael H. H. Price, John D. Reynolds. (2020). *BC Central Coast: Prioritizing Strategies for Pacific Salmon Recovery and Persistence*. Report produced for the Central Coast Indigenous Resource Alliance. Vancouver, British Columbia.

AUTHORS Jessica C. Walsh [1, 2] · Katrina Connors [3] · Eric Hertz [3] · Laura Kehoe [4, 5, 6] · Tara G. Martin [6] · Brendan Connors [7] · Alejandro Frid [8, 9] · Cameron Freshwater [10] · Michael H. H. Price [1] · John D. Reynolds [1]

1 **Earth to Ocean Research Group, School of Biological Sciences, Simon Fraser University,** 8888 University Drive, Burnaby, BC, V5A 1S6, Canada

2 **School of Biological Sciences, Monash University,** Wellington Rd, Clayton, Melbourne, VIC 3800, Australia

3 **Salmon Watersheds Program, Pacific Salmon Foundation,** 300 – 1682 West 7th Avenue, Vancouver, BC, V6J 4S6, Canada

4 **Department of Biology, University of Victoria,** PO Box 1700, Station CSC, Victoria, BC, V8W 2Y2, Canada

5 **The Nature Conservancy,** 26 Ely Place, London, EC1N 6TD, United Kingdom

6 **Department of Forest and Conservation Sciences, University of British Columbia,** 2424 Main Mall, Vancouver, BC, V6T 1Z4, Canada

7 **Institute of Ocean Sciences, Fisheries and Oceans Canada,** 9860 West Saanich Road, Sidney, BC, V8L 5T5, Canada

8 **Central Coast Indigenous Resource Alliance,** 2790 Vargo Road, Campbell River, BC, V9W 4X1, Canada

9 **School of Environmental Studies, University of Victoria,** PO Box 1700, Station CSC, Victoria, BC, V8W 2Y2, Canada

10 **Pacific Biological Station, Fisheries and Oceans Canada,** 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7, Canada

PUBLISHED BY

Pacific Salmon Foundation
300 – 1682 West 7th Avenue
Vancouver, BC, V6J 4S6, Canada
www.psf.ca

PACIFIC SALMON FOUNDATION

SALMON WATERSHEDS PROGRAM

BC Central Coast

Prioritizing Strategies for
Pacific Salmon Recovery and Persistence

REPORT

2020

Cover photograph is by Conor McCracken (CDM Images).

Photo on page 21 is from Bella Coola, via Shutterstock.

The graphic design is by Rocketday Arts (www.rocketday.studio).

Acknowledgements

We thank the Central Coast Indigenous Resource Alliance (CCIRA) and staff from the Heiltsuk, Nuxalk, Kitasoo/Xai'xais, and Wuikinuxv Nations Stewardships Offices for their support and feedback throughout the project.

We also thank the following individuals for providing valuable advice and feedback: P. Siwallace, M. Reid, D. Chan, D. Rolston, B. Edgar, D. Neasloss, D. Dobson, D. Stewart, J. Moore, M. Bradford, and the experts involved in the workshops and broader consultations.

Thank you to the Salmon Watersheds Program staff at Pacific Salmon Foundation for use of the Pacific Salmon Explorer, K. Kellock for producing maps, J. Halverson for developing workshop materials, and E. Jones, J. Belzile, C. Stevenson, and L. Chalifour for facilitating workshop discussions.

Mitacs, CCIRA, Pacific Salmon Foundation, and the Tom Buell Endowment Fund provided funding for this project.

SFU SIMON FRASER UNIVERSITY

CCIRA

PACIFIC SALMON FOUNDATION SALMON WATERSHEDS PROGRAM

UBC

University of Victoria

Fisheries and Oceans Canada Pêches et Océans Canada

KITASOO/XAI'XAIS First Nation

Executive Summary

Pacific salmon are of immense ecological, social, economic, and cultural importance on the Central Coast of British Columbia, Canada.

However, many populations are declining or imperiled. These declines may be due to human-driven threats such as overfishing, and habitat loss and degradation, and be exacerbated by recent periods of poor marine survival and the impacts of climate change on oceanic and freshwater habitats.

In Canada, there is no overarching strategic framework for determining how and where to invest limited funds to address the multiple threats facing Pacific salmon. While Canada's Wild Salmon Policy[1] calls for the strategic prioritization of salmon conservation and management actions, there is little guidance on how to evaluate and prioritize actions. Existing budgets available for salmon conservation are insufficient to effectively abate all current threats and ensure the persistence and recovery of all populations. It is therefore essential to adopt a systematic and transparent prioritization process that allocates funding to actions that will achieve the greatest return on investment (i.e., maximize the recovery of at-risk salmon populations, while safeguarding populations that are healthy and not currently a conservation concern).

Using a decision-support tool — the Priority Threat Management framework — we identified and prioritized the most cost-effective conservation strategies for Pacific salmon on the Central Coast of British Columbia (BC). Specifically, we focused on five species of Pacific salmon and 79 groups of genetically, ecologically, and spatially distinct populations of wild salmon, known as Conservation Units (CUs) under Canada's Wild Salmon Policy. Using a structured expert-elicitation process, we worked with regional salmon experts, including natural resource managers from four First Nations whose traditional territories are within the Central Coast, to quantify the benefits, costs, and feasibility of implementing 10 different conservation strategies over the next 20 years.

Summary of key findings

1. **Current investments in salmon conservation are insufficient to support healthy and thriving populations over the next 20 years.** In the absence of implementing the management strategies outlined in this report, only one in four CUs on the Central Coast will have a greater than 50% probability of being healthy and thriving within the next 20 years (Table 3; Figure 3).

2. While experts felt that the overall outlook for Pacific on the salmon is concerning, experts believe that **implementing the identified conservation strategies is expected to significantly improve the overall prospects for salmon**. If all 10 proposed conservation strategies were implemented, almost all CUs (78 of 79) are predicted to have greater than 50% probability of reaching or maintaining a thriving condition after 20 years (Table 3; Figure 3). Of these CUs, 34 chum, Chinook, coho, pink and some sockeye CUs were predicted to reach a higher than 60% probability of recovery. The cost of implementing all proposed strategies is estimated to be $17.3 million (CAD) per year over 20 years.

3. Experts predicted that **limiting future industrial development in salmon habitats was beneficial and relatively cheap** (Figures 4 & 6), suggesting that proactively safeguarding salmon habitat and avoiding future threats is more cost-effective than allowing industrial development to occur and acting after salmon populations become of conservation concern.

4. **Implementing three of the habitat strategies would achieve similar benefits to implementing all 10, for less cost.** These strategies are protecting and restoring habitat and watershed hydrology from the impacts of forestry; restoring stream habitat to increase egg and juvenile survival; and removing artificial barriers to migration. Together, they cost an estimated total of $11.3 million per year, which is 35% cheaper than implementing all strategies (Figure 5).

5. Independent of the management strategies, **an additional $0.7 million per year is needed to conduct monitoring and assessment** of salmon CUs, above what is already spent on monitoring in the Central Coast (Table 4). Monitoring and assessment is considered to be an enabling strategy — a strategy that underpins the success of all other strategies identified by the experts.

Contents

Introduction

PACIFIC SALMON have been exceptionally important to communities on the Central Coast of BC for millennia.[2,3] Unfortunately, many salmon populations in the region are in decline.[4,5,6] A recent assessment of the current conservation status of salmon on the Central Coast has shown that several Conservation Units (CUs)* are in urgent need of conservation intervention due to declining abundance relative to historical abundance.[7] These declines have resulted in diminished fishing opportunities[8,9] and the loss of livelihoods, and have impacted the cultural identities of Indigenous communities.[10] In addition, declining abundances and associated reductions in salmon biodiversity may adversely impact aquatic and terrestrial ecosystems in this region.[11,12,13]

Currently, there is no overarching strategic framework for determining how and where to invest limited funds across multiple actions to maximize the probability of recovery and persistence for salmon CUs. While Canada's Wild Salmon Policy and regional First Nation communities[14] recognize the need for a strategic prioritization of management actions, there is little guidance on how to successfully achieve this.[15,16,17] Typically, resources are allocated to the most threatened populations or species (e.g., Cultus, Sakinaw, or South Atnarko sockeye CUs).[18,19,20] However, they may have the lowest probability of recovery, and may require the most expensive management actions, compared to less threatened populations with higher recovery potential. If the overall objective is to increase the number of healthy populations or species (through recovery of at-risk CUs, and maintenance of those CUs currently in good condition), then focusing on the most threatened CUs might not be the most cost-effective approach.

Deciding where and how to invest in recovery and conservation efforts for salmon on the Central Coast therefore remains a pressing challenge. The factors responsible for declining salmon populations are complex and poorly understood, and include overharvest, habitat loss and degradation, barriers to salmon migration, disease, predation, poor marine survival, and climate change.[21,22,23] Existing funding available for salmon conservation is inadequate to mitigate all threats and conserve all salmon populations.[24] Limited resources mean that trade-offs are required between various recovery actions. Decision-support tools that explicitly incorporate both the cumulative benefits across all species or populations of interest, and the costs and feasibility of implementing actions, can help to identify the most cost-effective solution, while maximizing the benefits to biodiversity.[25,26]

This project used a decision-support tool called Priority Threat Management (PTM) to help identify which conservation strategies are likely to maximize both the probability of recovering at-risk Central Coast Pacific salmon CUs and the probability of safeguarding healthy CUs against future threats. The output of this work is intended to provide the Central Coast Indigenous Resource Alliance (CCIRA) and the four First Nations (Heiltsuk, Nuxalk, Kitasoo/Xai'xais, and Wuikinuxv), whose traditional territories span the Central Coast region, with information on where and how to cost-effectively prioritize strategies to manage and reduce threats for salmon CUs.

The project focused on the Central Coast of BC, a region that includes the marine and terrestrial traditional-use areas of the Heiltsuk, Nuxalk, Kitasoo/Xai'xais,

* *Conservation Units (CUs) are geographically, ecologically and genetically unique groups of wild salmon populations identified under Canada's Wild Salmon Policy.*

FIGURE 1. Map of the Central Coast study area encompassing the traditional use territories of the Heiltsuk (Bella Bella), Kitasoo/Xai'xais (Klemtu), Nuxalk (Bella Coola), and Wuikinuxv (Wuikinuxv Village) Nations.

and Wuikinuxv Nations (Figure 1). This region is in the temperate rainforest, with relatively low levels of industrial development, supporting hundreds of wild salmon spawning locations comprising 79 CUs.

This project was undertaken in collaboration with these four First Nations and CCIRA, who together are instrumental in the management and conservation of salmon in the Central Coast. Recent work by the Pacific Salmon Foundation, in collaboration with the four CCIRA-member Nations, Fisheries and Oceans Canada (DFO), and regional salmon experts, assessed the current status of Central Coast salmon CUs and their freshwater habitats, which provides the baseline information for this project.[7]

Priority Threat Management Framework

The Priority Threat Management (PTM) framework can help decision-makers determine which management strategies will recover and safeguard as many species or populations as possible per dollar invested.[27,28] The PTM framework evaluates the cost-effectiveness of conservation strategies using structured expert-elicitation workshops. This method prioritizes conservation strategies, rather than prioritizing specific areas or individual species. The PTM Framework has been applied extensively worldwide, including here in Canada,[29] and offers great potential to guide strategic planning efforts for salmon CUs in a way that reflects community objectives and priorities.

The PTM framework involves a six-step process, including identifying strategies that mitigate threats to the biodiversity features of interest (in this case salmon CUs), and estimating the costs, feasibility, and benefits of each strategy (Figure 2). For this project, STEPS 1–3 were conducted during a day-long workshop in Vancouver, BC, with First Nation representatives and Pacific Salmon Foundation in May 2018, followed by several conference calls. STEPS 4 and 5 were conducted during a two-day workshop in June 2018, with a panel of 19 experts who had expertise in salmon threats, the feasibility and costs of conservation options in the Central Coast and/or the ecological response of salmon to each strategy. Experts included representatives from the CCIRA and the four CCIRA-member Nations, academics, and resource managers, scientists, and practitioners from federal and provincial governments and non-governmental organizations. Further details on the methods are provided in the scientific paper describing this project.[30]

FIGURE 2. Priority Threat Management framework. Figure adapted from Carwardine et al. (See reference #27.)

STEP 1 —
Define objectives, scope, and timeframe

The objective of this strategic planning process was to maximize the number of thriving Central Coast Pacific salmon CUs, over a timeframe of 20 years. A 'thriving' population was defined as one that fulfills its ecological function and role, and provides livelihood opportunities for present and future generations. This objective is analogous to maximizing the number of CUs in the 'green status zone' under the Wild Salmon Policy, where the need for conservation intervention is low and fishing for First Nation Food, Social, and Ceremonial (FSC), and commercial and recreational purposes, is possible.

STEP 2 —
Identify salmon CUs to conserve

We included 79 salmon CUs from five Pacific salmon species that are within, or overlap with, the traditional territories of the four CCIRA Nations — Kitasoo/Xai'xais, Heiltsuk, Nuxalk and Wuikinuxv (Figure 1). These 79 CUs were clustered into nine groups for the analysis, with the idea that those grouped CUs would experience similar threats and have similar responses to management strategies (Table 1). Including CUs with green status into the analysis, in addition to those with amber, red and data-deficient status, ensures that conservation strategies (STEP 3) are designed to promote recovery of amber- and red-status CUs while also avoiding future declines of green-status CUs.

TABLE 1. Salmon species included in the analysis, their CU groups, and the CUs included in each group. Status is based on data current to 2017, using historic spawner abundance benchmarks. (See reference #7.)

CU group		CUs included in group	Status of CUs			
			Green	Amber	Red	Data-Deficient
Chinook		**6 CUs —** *Rivers Inlet, Wannock, Bella Coola-Bentinck, Dean River, NCC-late timing, NCC-early timing*		5	1	
Chum		**9 CUs —** *Smith Inlet, Rivers Inlet, Wannock, Spiller-Fitz-Hugh-Burke, Bella Coola-Dean Rivers, Bella Coola River-Late, Hecate Lowlands, Mussel-Kynock, Douglas-Gardner*		5	2	2
Coho		**6 CUs —** *Smith Inlet, Rivers Inlet, Bella Coola-Dean Rivers, Mussel-Kynoch, Hecate Strait Mainland, Northern Coastal Streams*	1	5		
Pink		**5 CUs —** *Hecate Lowlands, Hecate Strait-Fjords, Homathko-Klinaklini-Rivers-Smith-Bella Coola Dean, Hecate Strait-Lowlands, Hecate Strait-Fjords*	3	2		
Lake-type sockeye	Green	**8 CUs —** *Canoona, Kainet Creek, Koeye, Kwakwa Creek, Namu, Port John, Roderick, Tankeeah River*	8			
	Amber & Data Deficient – Coastal	**35 CUs —** *Bloomfield, Borrowman Creek, Busey Creek, Chic Chic, Fannie Cove, Dallain Creek, Elizabeth, Elsie/Hoy, Evinrude Inlet, Higgins Lagoon, Kadjusdis River, Kdelmashan Creek, Kent Inlet Lagoon Creek, Kildidt Creek, Kildidt Lagoon Creek, Kisameet, Kunsoot River, Limestone Creek, Mary Cove Creek, Mcdonald Creek, Mcloughlin, Powles Creek, Price Creek, Ship Point Creek, Stannard Creek, Talamoosa Creek, Treneman Creek, Tuno Creek East, Tuno Creek West, Tyler Creek, Wale Creek, Watt Bay, West Creek, Yaaklele Lagoon, Yeo*		4		31
	Amber & Data Deficient – Inland	**6 CUs —** *Owikeno, Wannock[Owikeno], Soda Creek, Dome, Kimsquit, Pine River*		1		5
	South Atnarko	**1 CU —** *South Atnarko Lake Sockeye*			1	
River-type sockeye		**3 CUs —** *Rivers-Smith Inlets, Northern Coastal Fjords, Northern Coastal*				3

STEP 3 – Identify threats, strategies, and actions

We identified major threats to Pacific salmon on the Central Coast based on a literature review and expert knowledge elicited through workshops, conference calls and meetings with First Nation representatives, managers and researchers. The primary threats to Pacific salmon on the Central Coast of BC that we identified included overharvest, habitat loss and degradation due to forestry, anthropogenic barriers in streams and rivers that prevent salmon migration, industrial development in critical salmon habitat, salmon aquaculture (due to risk of disease, parasites and pollution), hatcheries (due to competition and genetic introgression), and predation by marine mammals and other predators. Strategies to mitigate other threats such as climate change, deglaciation, and marine survival were not explicitly considered in this project, as the resource managers at at the spatial and governance scale of this project have little control over these threats.

We identified 10 strategies that would address each threat, and each strategy contains several specific actions (Table 2). Strategies and underlying actions were initially proposed based on a literature review and examination of existing recovery plans, regional landscape-scale marine and watershed plans, and recent habitat assessments conducted by Pacific Salmon Foundation, CCIRA, and the CCIRA-member Nations,[7] and were finalized at the second workshop. Three combinations of strategies also were considered, as experts thought their combined benefits could be synergistic if implemented together (Table 2). We developed an Overarching Enabling Strategy for Monitoring & Assessment that was considered essential for effective implementation and evaluation of all other strategies. We also developed an Overarching Harvest Strategy that included several actions related to governance, management planning, and the development of harvest targets across fishing sectors, and would be assumed to facilitate both the *Sustainable Commercial Harvest* and *Sustainable Recreational Harvest* strategies.

TABLE 2. Strategies and underlying actions designed to abate threats to Pacific salmon Conservation Units (CU) on British Columbia's Central Coast

Conservation Strategy	Actions	
Overarching Enabling Strategy for Monitoring & Assessment *	▸ Conduct integrated Wild Salmon Policy status assessments for CUs. ▸ Conduct intensive monitoring of adult escapement and smolt abundance for CU indicator streams.	▸ Establish monitoring programs for data-deficient CUs.
Overarching Harvest Strategy †	▸ Establish quantitative management targets for groups of CUs. ▸ Support and collaborate with First Nation Food, Social, and Ceremonial (FSC) initiatives to sustainably manage fisheries and improve FSC catch data.	▸ Establish co-management of fisheries between First Nations and Fisheries and Oceans Canada regarding commercial and recreational catch limits, monitoring and enforcement. Co-develop an Integrated Fisheries Management Plan for the Central Coast.

* *The costs of the Overarching Enabling Strategy for Monitoring & Assessment were considered essential regardless of whichever other strategies were implemented.*

† *Overarching Harvest Strategy had its costs divided across the* Sustainable Commercial Harvest *and* Sustainable Recreational Harvest *strategies.*

Conservation Strategy	Actions	
1 *Sustainable Commercial Harvest*	▸ Shift towards terminal fisheries, and limit mixed-stock catches to a lower percentage of total catch. ▸ Improve enforcement of commercial fishery regulations. ▸ Reduce bycatch of non-target salmon species.	▸ Improve how the Pacific Salmon Treaty manages mixed-stock fisheries in Alaska to reduce impacts on Central Coast CUs. ▸ Research: Routinely collect genetic samples for CUs to identify catch composition of mixed-stock fisheries.
2 *Sustainable Recreational Harvest*	▸ Improve regulations to limit fleet and operations expansion by tourism and sport fishing operators; monitor/regulate independent sport fishers. ▸ Monitor and restrict Fish and Wildlife permits. ▸ Set more restrictive daily and annual harvest limits per person, based on number of licenses and management reference points. ▸ Set size limits for Chinook salmon (e.g., mandatory catch and release of older/larger fish).	▸ Limit catch and release mortality by reducing interactions with non-target salmon species. ▸ Improve recreational catch monitoring and estimated mortality rates from catch and release fisheries for coho and Chinook salmon. ▸ Research: Estimate carrying capacity of tourism operators on the Central Coast, and their impact on salmon.
3 *Watershed Protection*	▸ Increase compliance, auditing, and enforcement of logging regulations and forestry practices. ▸ Identify streams vulnerable to high temperatures and variable flows. Then, implement relevant actions to ensure future sufficient flows.	▸ Restore watershed vegetation to pre-logging conditions in addition to above existing work (e.g., reduce surface erosion from roads in priority areas by road decommissioning).
4 *Stream Restoration*	▸ Maintain and restore riparian habitat characteristics and processes (e.g., install large woody debris and engineering stream banks to ensure habitat complexity).	▸ Conduct fine-scale habitat condition monitoring in priority areas using established assessment procedures (e.g., Watershed Assessment Procedure). ▸ Research: Develop central database for habitat restoration actions, with measures of effectiveness.
5 *Removal of Barriers to Fish Passage & Migration*	▸ Remove significant barriers (e.g., culverts) to upstream adult migration, or provide safe passage over these barriers (locations identified in first action) and remove significant barriers to juvenile dispersal to rearing habitats.	▸ Research: Assess passability of barriers and stream crossings in Central Coast to identify priority barriers for removal.
6 *Marine & Estuary Habitat Restoration & Protection*	▸ Protect eelgrass and other juvenile salmon rearing habitats, including prohibiting dredging and dumping in nearshore habitats. ▸ Restore estuaries degraded by forestry operations (e.g., marine loading sites, log sorts, helicopter-drop sites, booming areas, derelict vessels or fishing gear, abandoned sites). ▸ Implement strategies and best practices to reduce future resource extraction impacts in the estuaries and marine ecosystems.	▸ Ensure that pollution policies and laws use international best practice guidelines and are implemented (i.e., develop and enforce provisions related to compensation for the destruction of fish and fish habitat). ▸ Research: Identify critical habitats (i.e., nearshore rearing/benthic habitat) for juvenile salmon on the Central Coast.

Conservation Strategy	Actions	
7 ***Limit Industrial Development in Salmon Habitat***	▸ Limit future development and industrial activities (e.g., mining, oil and gas infrastructure, wind farms, aquaculture) that have the potential to impact salmon habitats by developing protocol agreements between First Nations and proponents and maintaining existing tenures held by First Nations.	▸ Manage water discharges from mines, gravel pits, and roads to reduce water pollution. ▸ Research: Identify impacts of dumping sites (e.g., from clay mines) on out-migrating salmon. ▸ Research: Assess risks of shipping traffic to salmon.
8 ***Supplement Small Populations***	▸ As a last resort for CUs in the critical red zone, initiate hatcheries. Mark all hatchery fish to ensure adequate monitoring and prohibit fishing on stocks enhanced for conservation. ▸ Monitor and improve the effectiveness of hatcheries supplementing target CUs (e.g., parental based tagging).	▸ Provide full or partial fish ladders over natural barriers (e.g., waterfalls) affecting access to new spawning and rearing habitat (i.e., increase capacity of systems). ▸ Build spawning channels, where appropriate. ▸ Research: Evaluate current hatchery practices on Central Coast and conduct a risk analysis of the use of hatcheries and other options to supplement small salmon populations.
9 ***Predation Control***	▸ Trap sculpins when juveniles are migrating, especially for populations in decline. ▸ Conduct hatchery releases at night to minimize predation risk by sculpins and trout. ▸ Research: Identify importance and significance of predation by pinnipeds on Central Coast.	▸ Research: Conduct experimental culls (or traditional First Nation harvest) of pinnipeds to investigate effects at reducing predation pressure on juvenile and adult salmon. ▸ Research: Evaluate contribution of human-mediated predation and haul-outs (e.g., docks or around fishing vessels). ▸ Research: Understand historical relationship between First Nations, marine mammals, and salmon.
10 ***Salmon Aquaculture Management***	▸ Ensure existing salmon aquaculture facilities implement best practices that prevent the spread of parasites and disease to wild salmon. ▸ Develop siting guidelines that preclude salmon aquaculture tenures from overlapping with critical habitats for wild salmon and juvenile migratory routes. ▸ Incentivize land-based salmon aquaculture.	▸ Create tenures owned by First Nations to control new and existing aquaculture licenses. ▸ Research: Synthesize monitoring data to assess the impact of aquaculture on the Central Coast. ▸ Research: Assess potential interactions and risks to salmon populations transiting through aquaculture operations.

Combined Strategies	Contained Individual Strategies
Combined Harvest Strategies	▸ *Sustainable Commercial Harvest* strategy ▸ *Sustainable Recreational Harvest* strategy
Combined Habitat Strategies	▸ *Watershed Protection* strategy ▸ *Stream Restoration* strategy ▸ *Removal of Barriers to Fish Passage & Migration* strategy
Combined Supplement Populations & Predation Control Strategies	▸ *Supplement Small Populations* strategy ▸ *Predation Control* strategy
All Strategies Combined	All 10 strategies together

STEP 4 –
Estimate costs and feasibility of actions

Experts estimated costs of labour, consumables and equipment, travel, capital assets, overhead, monitoring, and coordination for each action[31] within each strategy. Opportunity costs (i.e., foregone profits as a result of a strategy) were not included in these calculations. Experts also estimated the probability of uptake of each action and the probability of success for each action. The feasibility of each strategy was calculated as the product of the probability of uptake and probability of success, averaged across each underlying action.

STEP 5 –
Identify benefits of strategies

We used the modified Delphi technique[32,33] — which is a structured expert-elicitation method — to estimate the benefits of each strategy to the CU groups. Fourteen experts were involved in this step to estimate the expected benefits of each strategy for each CU group. For each strategy, each expert provided their best guess of the probability that each CU within a group would be thriving after 20 years, along with estimates of confidence. These estimates of probability of achieving the objective for each strategy were compared with the experts' estimates of a business-as-usual scenario. This baseline scenario included all the current management actions and policies that would continue for the next 20 years, while also considering current and emerging threats. These actions included recovery planning, Integrated Fisheries Management Plans that outline annual harvest plans and management, and ongoing monitoring and assessment programs for salmon CUs.

The 'benefit' of a strategy for a given CU group was calculated as the difference between the probability of achieving the objective under the baseline scenario, and the probability of achieving the objective if the strategy was implemented, averaged across experts.[27] The 'cumulative benefit' for a strategy was the sum of benefits for all CU groups.

STEP 6 –
Cost-effectiveness calculation

The cost-effectiveness of each strategy was calculated using two methods: (1) ranking based on a simple cost-effectiveness equation, and (2) a complementarity approach. In the ranking method, strategies (i) were sorted based on their cost-effectiveness (E_i), which is the cumulative benefits (B_i), multiplied by the feasibility per strategy (F_i), divided by the costs per strategy (C_i):

$$E_i = \frac{B_i F_i}{C_i}$$

The complementarity analysis identified strategies that, when combined, would increase the benefits across as many CU groups as possible for any given budget.[34] Rather than choosing two cheap strategies that would benefit the same CU group, the complementarity analysis would select one of those strategies and another slightly more expensive strategy that would benefit a different CU group. Implementing one of the cheap strategies and the more expensive strategy would conserve a complementary suite of CU groups, whereas implementing the other cheap strategy would offer minimal additional benefit.

For this analysis, we defined arbitrary 'thresholds of conservation' to determine the number of CU groups that would reach a satisfactory level of protection under any given budget. We selected conservation thresholds of 50%, 60%, and 70% probability of achieving the conservation objective — i.e., being a thriving CU with green status in 20 years. The benefit metric per strategy per CU group used in the complementarity analysis was the 'benefit' estimated for that strategy, multiplied by the feasibility, which was then summed with the baseline probability of achieving the conservation objective.

Results

Predicted outcomes for 'baseline' and 'all' strategy scenarios

Under the baseline scenario (i.e., business-as-usual, with no additional investment in salmon conservation), only 25% of the 79 Pacific salmon CUs on BC's Central Coast (8 green-status lake-type sockeye, 5 pink, and 6 coho salmon CUs) were predicted to have a greater than 50% chance of 'thriving' and being in a green state (i.e., the conservation objective) within the next 20 years (Figure 3). No CUs were predicted to have a greater than 70% probability of reaching the stated conservation objective under the business-as-usual scenario (Figure 3; Table 3).

In contrast, if all 10 strategies were implemented, all CUs (except the South Atnarko Lake Sockeye salmon CU) would have a greater than 50% probability of achieving the conservation objective (Figure 3). However, less than half of all CUs (43%) — including green-status lake-type sockeye, pink, coho, Chinook and chum salmon CUs — were estimated to reach greater than 60% probability of recovery (Table 3). Amber-status, red-status, or data-deficient lake- and river-type sockeye salmon CUs were estimated to have less than 60% chance of recovery with all strategies (Figure 3; Table 3).

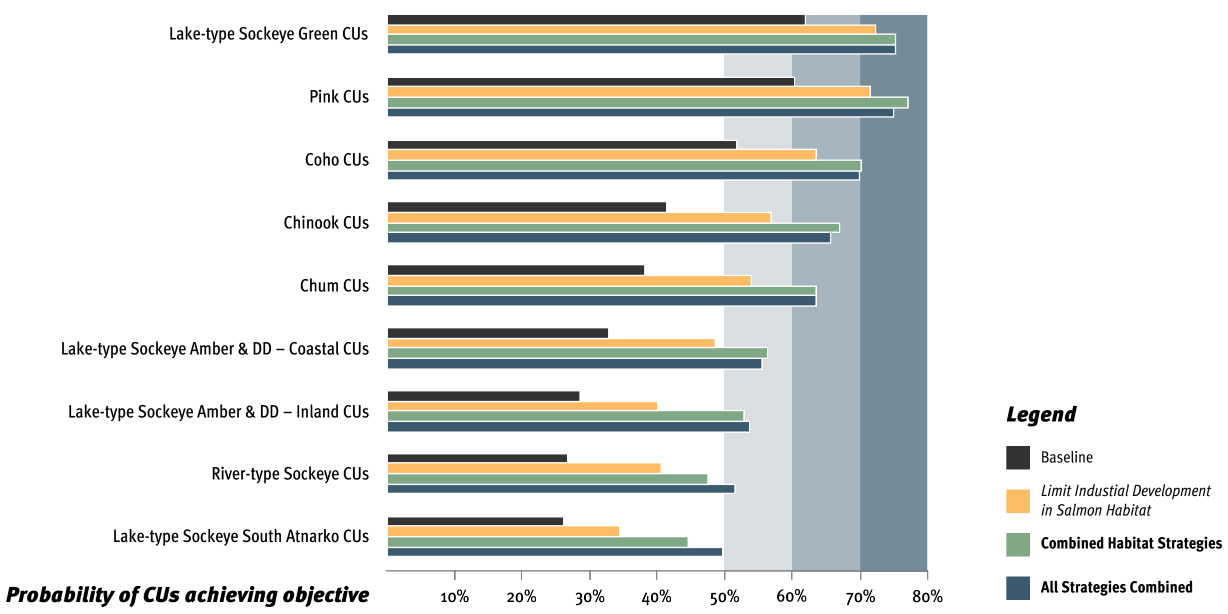

FIGURE 3. Probability of CUs within each CU group obtaining a thriving status in 20 years (while accounting for the feasibility of the strategy) under the (I) baseline strategy (business-as-usual), (II) *Limit Industrial Development in Salmon Habitat* strategy, (III) the Combined Habitat Strategies (*Watershed Protection*, *Stream Restoration* and *Removal of Barriers to Fish Passage & Migration*), and (IV) All Strategies Combined. The vertical lines show which strategies would ensure each CU group would have at least 50%, 60% and 70% probability of achieving the objective. Note: the experts estimated the probability of achieving thriving CUs was higher if All Strategies Combined were implemented, compared to the Combined Habitat Strategies. However, once feasibility was factored into these calculations, the Combined Habitat Strategies resulted in a higher probability for some CU groups. This figure presents a subset of strategies from Table 3.

TABLE 3. Probability of CUs within each CU group reaching a thriving status within 20 years under different strategies, while accounting for feasibility; DD = data-deficient. Darker shading shows the strategies that are predicted to result in >70% probability of each CU within that CU group thriving in 20 years (i.e., more likely to be thriving and with a green status). Lighter and medium shading demonstrates the strategies that will result in >50% or >60% probability of CUs thriving. White cells suggest that the strategy has less than a 50% probability of recovering the CUs to thriving green status. Some strategies result in similar outcomes and there may only be minimal additional benefits of implementing two strategies when one strategy may be sufficient to achieve a particular conservation threshold. The complementarity analysis identifies which strategies would achieve certain thresholds for the highest number of CUs for the least cost (shown in Figure 5).

	CU group								
	Lake-type Sockeye Green	Pink	Coho	Chinook	Chum	Lake-type Sockeye Amber & DD – Coastal	Lake-type Sockeye Amber & DD – Inland	River-type Sockeye	Lake-type Sockeye South Atnarko
Baseline	62.0%	60.4%	51.9%	41.5%	38.4%	33.0%	28.7%	26.9%	26.1%
Sustainable Commercial Harvest	64.9%	64.8%	55.2%	48.6%	45.6%	40.6%	38.3%	36.4%	35.8%
Sustainable Recreational Harvest	65.3%	64.8%	63.4%	59.2%	45.3%	38.8%	31.1%	29.0%	31.0%
Watershed Protection	71.6%	71.2%	63.6%	56.5%	51.8%	45.6%	42.6%	41.9%	35.6%
Stream Restoration	71.5%	70.7%	64.7%	56.7%	55.4%	46.7%	43.7%	42.5%	36.5%
Removal of Barriers to Fish Passage & Migration	69.4%	69.8%	63.8%	53.8%	51.4%	47.5%	42.3%	41.8%	33.7%
Marine & Estuary Habitat Restoration & Protection	69.2%	67.7%	59.9%	52.9%	48.3%	42.3%	39.5%	37.1%	32.0%
Limit Industrial Development in Salmon Habitat	72.5%	71.5%	63.5%	56.9%	53.9%	48.7%	40.1%	40.7%	34.5%
Supplement Small Populations	68.9%	68.7%	61.5%	53.5%	52.1%	42.7%	38.8%	38.6%	35.7%
Predation Control	66.3%	65.5%	58.8%	53.0%	46.3%	40.6%	35.7%	33.5%	30.4%
Salmon Aquaculture Management	63.8%	62.9%	53.1%	45.3%	42.3%	36.8%	32.7%	30.9%	29.5%
Combined Harvest Strategies	68.2%	69.2%	63.6%	61.5%	53.5%	46.8%	45.3%	43.1%	43.1%
Combined Habitat Strategies	75.3%	77.1%	70.2%	67.1%	63.7%	56.3%	53.0%	47.5%	44.6%
Combined Supplement Populations & Predation Control Strategies	70.3%	69.7%	63.6%	59.1%	54.2%	48.1%	41.8%	41.3%	38.8%
All Strategies Combined	75.2%	75.2%	69.9%	65.8%	63.7%	55.7%	53.7%	51.5%	49.7%

Costs and benefits of strategies – simple ranking method

Limit Industrial Development in Salmon Habitat was the most cost-effective strategy based on the simple ranking method (Table 4). This strategy aimed to restrict future development in critical areas of salmon spawning and rearing habitat. This strategy had a relatively low cost of $150,000/year (compared to the average annual cost of individual strategies = $1.73 million), and a high cumulative benefit across CU groups (Figure 4). However, it is important to note that the analysis did not include the opportunity costs of this strategy. *Predation Control* (i.e., reduction of predation by problem marine mammals and other predators) was the second most cost-effective strategy (Figures 4 & 5; Table 4), and also had a low annual cost of $110,000 million. The average annual equivalent cost of conducting all 10 strategies for the Central Coast region was predicted to be $17.3 million per year (total cost over 20 years = $346 million present value, which accounts for discounting into the future; Figure 4).

TABLE 4. Benefits, costs, feasibility, and cost-effectiveness (CE) of each strategy to conserve salmon on the Central Coast of British Columbia, ordered by cost-effectiveness from the ranking method. Benefit is the difference between the probability of achieving the conservation objective (i.e., thriving CUs with green status) after 20 years under each strategy and the baseline scenario per CU group, averaged across experts, and summed across all CU groups (see page 13). Cost is the average annual present value (total cost of each strategy discounted at 4%, divided by the 20-year timeframe). (See reference #30.)

Conservation strategy	Benefit	Cost (CAD)	Feasibility	CE	CE rank
Limit Industrial Development in Salmon Habitat	1,490	$150,000	74%	362	1
Predation Control	1,241	$110,000	46%	253	2
Removal of Barriers to Fish Passage & Migration	1,395	$210,000	72%	239	3
Salmon Aquaculture Management	772	$90,000	34%	147	4
Watershed Protection	1,407	$540,000	70%	92	5
Marine & Estuary Habitat Restoration & Protection	1,293	$790,000	56%	46	6
Sustainable Commercial Harvest	1,406	$590,000	38%	45	7
Sustainable Recreational Harvest	707	$990,000	73%	26	9
Supplement Small Populations	1,102	$3,270,000	72%	12	11
Stream Restoration	1,421	$10,550,000	76%	5	13
Combined Harvest Strategies	1,818	$1,590,000	59%	34	8
Combined Supplement Populations & Predation Control Strategies	1,911	$3,390,000	57%	16	10
Combined Habitat Strategies	2,366	$11,300,000	73%	8	12
All Strategies Combined	2,896	$17,300,000	59%	5	14
Overarching Enabling Strategy for Monitoring & Assessment	NA	$700,000	71%	NA	NA

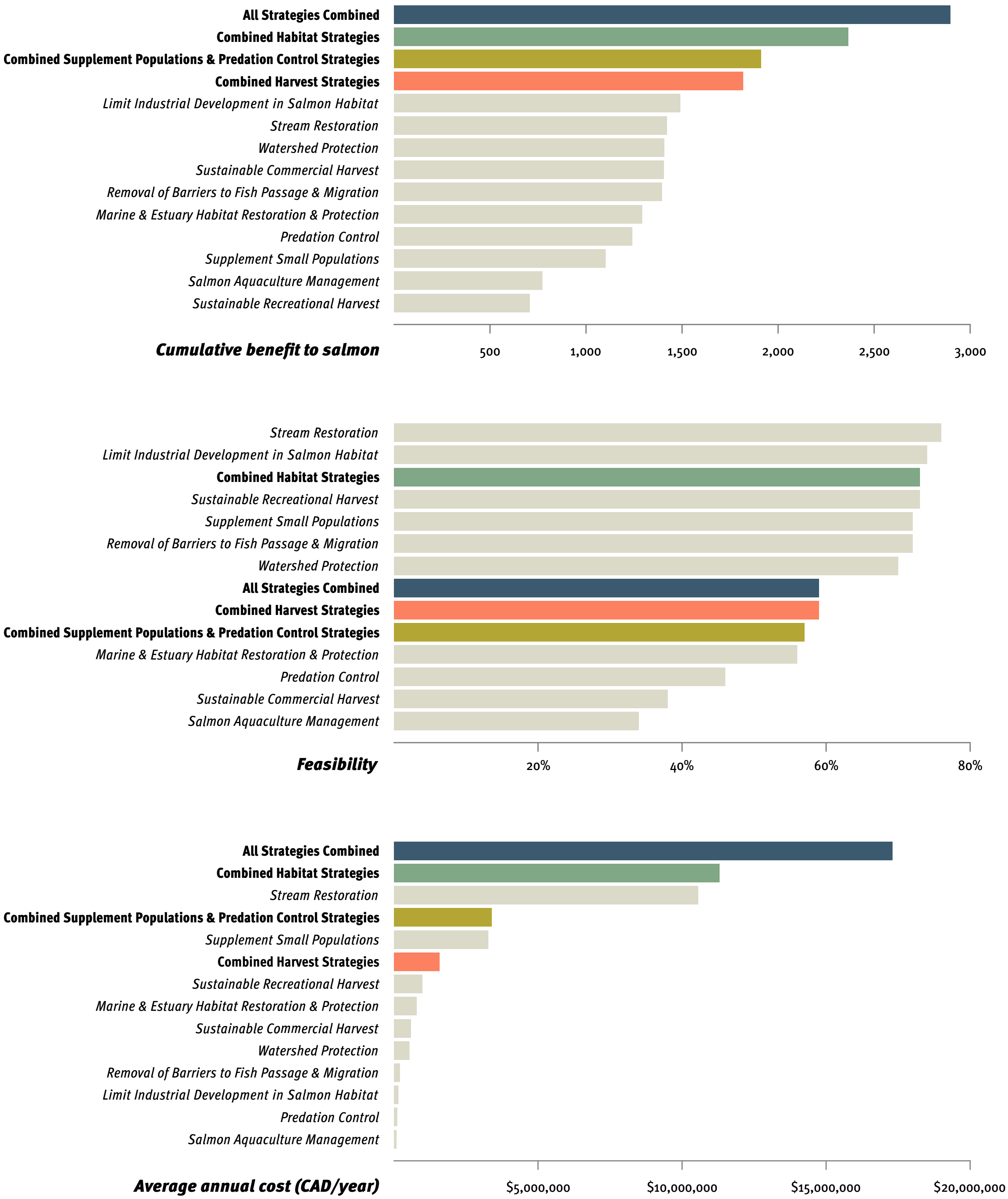

FIGURE 4. Benefits, feasibility and cost of strategies for Pacific salmon conservation on BC's Central Coast. Average annual cost is the full cost (present value) over the 20-year plan calculated using a 4% discount rate divided by 20 years. Coloured bars show combined strategies.

The combined strategy that was predicted to achieve the greatest cumulative benefit was Combined Habitat Strategies, which included three strategies: *Watershed Protection*, *Stream Restoration*, and *Removal of Barriers to Fish Passage & Migration* (Figure 4). However, this combined strategy had a low cost-effectiveness rank due to high implementation costs relative to other strategies. Other costly strategies, including *Stream Restoration* and *Supplement Small Populations* with hatcheries and other enhancement methods, were the least cost-effective (Table 4).

The Overarching Enabling Strategy for Monitoring & Assessment of biological status of all salmon CUs required an additional $0.7 million/year (including data-deficient CUs; Table 4). Experts considered investment in this strategy essential to support the successful implementation of any other management strategy. The wider social and economic benefits of all proposed strategies would include job provision, secured fishing opportunities, reduced risk of pollution and habitat loss, increased capacity for First Nation leadership in natural resource management, stewardship and governance, and development of new skills within remote communities. The project also identified six specific research questions that could form Masters or Doctoral research projects.

Complementary strategies to maximize conservation success

To identify which strategies would safeguard and recover the largest number of CUs for any given budget, we conducted a complementarity analysis. For any given budget, the analysis identifies the strategy that maximizes the number of CUs that would achieve greater than 50%, 60% or 70% probabilities of having a green status and be thriving after 20 years.

Across all these thresholds, we found two levels of investment (and associated management strategies) that maximized the number of CUs reaching the conservation objective (Figure 5). The first investment threshold is $0.15 million/year, which would fund the most cost-effective strategy *Limit Industrial Development in Salmon Habitat*. This level of investment would result in 19 CUs reaching greater than 60% probability of thriving, and 13 CUs having greater than 70% probability of thriving. Next, for a budget of $11.3 million, investing in the Combined Habitat Strategies is predicted to deliver the highest number of CUs conserved across all probability thresholds (Figure 5; Table 3; i.e., 34 of 79 CUs would reach >60% probability of thriving, and 19 CUs would have >70% probability of thriving).

Even when accounting for the large uncertainty in the benefits and costs of the Combined Habitat Strategies, in a sensitivity analysis, it remained the most beneficial and cost-effective option. This combination of strategies was predicted to achieve similar conservation outcomes compared to implementing all management strategies (i.e., the same number of CUs would exceed the 60% and 70% probability thresholds of thriving status). To ensure the three river-type sockeye CUs would reach greater than 50% probability of obtaining green status, an extra $6 million would be required to implement all 10 strategies (for a total of $17.3 million) (Figure 5).

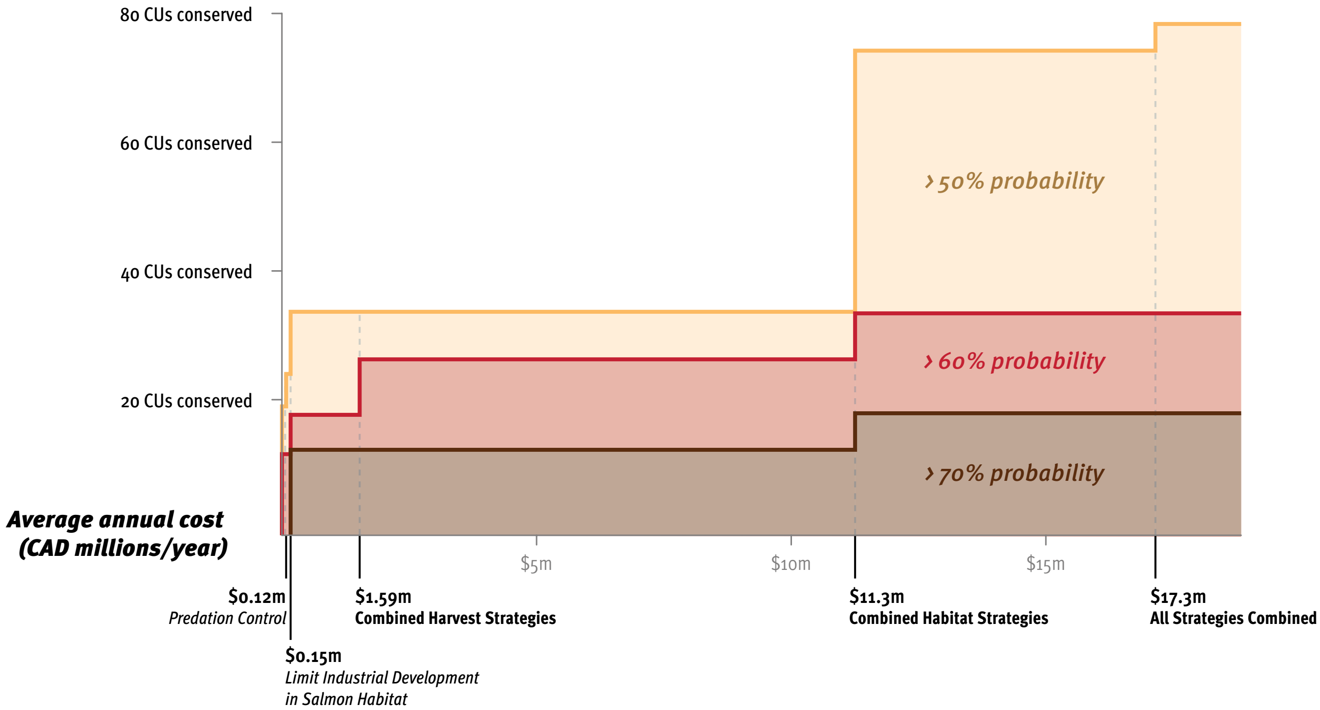

FIGURE 5. Under the complementarity analysis, different levels of annual investment are required to maximize the number of Pacific salmon Conservation Units reaching three probability thresholds (50%, 60%, and 70%). For example, with an annual budget of $11.3 million, the Combined Habitat Strategies (*Stream Restoration*, *Watershed Protection*, and *Removal of Barriers to Fish Passage & Migration*) would achieve the greatest outcomes for salmon CUs across all probability thresholds. This would result in 75 CUs with ›50% probability of achieving a green status, 34 CUs with ›60% probability, and 19 CUs with ›70% probability (shown in Table 3).

Recommendations

RECOMMENDATION 1

We suggest managers invest in conservation strategies that maximize the number of thriving salmon CUs; that is, invest in actions that lead to a high probability of recovery for CUs in the red and amber zones and safeguard healthy CUs that currently are in the green zone. This includes the cost-effective proactive strategy to *Limit Industrial Development in Salmon Habitat*, which would reduce future declines across all CUs, and the Combined Habitat Strategies that involve both the protection and restoration of watersheds and stream habitats.

Deciding which strategies to implement requires the selection of a target probability of achieving the objective (e.g., threshold of 50%, 60%, or 70%). This is particularly important when only small budgets are available (e.g., under $2 million/annum), because the most cost-effective strategies change depending on the target threshold (e.g., *Limit Industrial Development in Salmon Habitat* is most cost-effective using the 60% threshold, while aiming for >70% probability would require the strategy to *Limit Industrial Development in Salmon Habitat* or *Predation Control*; Figure 5).

RECOMMENDATION 2

We recommend developing an implementation plan for the most cost-effective strategies that outlines the specific actions under these prioritized strategies, clear roles and responsibilities of all involved parties, sources of funding, and timelines for implementation.

When developing the implementing plan, **specific actions required under each strategy should be validated, and their associated costs updated to ensure that the implementation plan reflects the most up-to-date information on costs.** For example, a spatial analysis and field validation would provide a more accurate estimate of the number of barriers across streams that require removal, the number of forestry roads to decommission, and the number of streams to restore. Due to time constraints and limited information, we made several assumptions about the spatial extent and intensity of the actions required, and this uncertainty should be accounted for when deciding which strategies and underlying actions to implement.

An analysis of the opportunity costs of each strategy (e.g., foregone economic development in the region) would also be worthwhile, particularly those associated with the *Limit Industrial Development in Salmon Habitat* strategy. Additional investigation into the economic benefits, social preferences, and risks to salmon and other environmental assets across different scenarios of industrial development would provide a more holistic assessment of this strategy.

RECOMMENDATION 3

The implementation plan should outline a **long-term monitoring program for Pacific salmon in the region**, as monitoring and assessment of salmon CUs is essential for the effective implementation and evaluation of all other strategies. A robust and informative annual monitoring program could be delivered through a partnership, whereby provincial, federal, and First Nations governments and other interested parties would work together to increase efficiencies and build capacity. This would involve determining which CUs and environmental variables need to be assessed, the appropriate methodology, and how that information will be gathered, analyzed, and archived. Future investment in community-based monitoring will expand the capacity of local First Nations to play a larger role in the management and standardized monitoring of salmon populations within their traditional territories. Data collected from these partners could be housed in transparent and accessible information systems such as Pacific Salmon Foundation's Salmon Data Library and the Pacific Salmon Explorer (www.salmonexplorer.ca).

RECOMMENDATION 4

This Central Coast **PTM exercise should be updated periodically** (e.g., every 5 years) as more data and information about salmon status, threats, strategies, benefits, feasibility, and costs is collected. This would ensure that new threats are addressed and strategies are evaluated, updated, and refined, providing an opportunity for the objectives, benefits and costs to be re-evaluated.

There also is scope to explicitly include Indigenous social and cultural values of salmon in future PTM exercises by weighting different CU groups according to their relative importance to First Nation communities. This would provide a mechanism for ensuring that resources are directed to those CUs that are more strongly tied to First Nations cultures and communities.

RECOMMENDATION 5

Finally, **we recommend the establishment of a collaborative working group to provide leadership** to ensure successful implementation of the priority strategies identified in the PTM exercise. This working group could be comprised of individuals with diverse knowledge and expertise related to Central Coast salmon and include — at minimum — representatives of the four Nations, CCIRA, Pacific Salmon Foundation, DFO, Province of BC, and other experts involved in this PTM project.

Conclusion

Currently there is no systematic approach that quantifies the trade-offs among mitigating the diverse suite of threats for Pacific salmon, such as overexploitation, habitat loss and degradation, disease, predation, and industrial development. Without a formal prioritization process that assesses the costs, benefits to salmon biodiversity, and feasibility of implementing management actions, there is a risk that current and new funding will be spent inefficiently on actions that deliver sub-optimal outcomes for salmon.

In the Central Coast, under the business-as-usual scenario (i.e., with no additional investments in salmon conservation), only 25% of salmon CUs have greater than 50% probability of recovering to thriving populations within 20 years. Additional investment in cost-effective strategies are likely to result in large improvements in the probability of achieving our conservation objective of maximizing the number of thriving CUs over a 20-year time frame. *Limiting Industrial Development in Salmon Habitat* was the most cost-effective strategy, which focuses on proactive protection to mitigate this future threat, rather than reactive actions for population augmentation.

The PTM framework we applied for BC's Central Coast is a decision-support tool for guiding conservation investment that aims to not only recover depressed CUs, but also safeguard healthy CUs from future declines. The PTM framework also has the unique potential to improve the conservation outcomes for Pacific salmon by explicitly accounting for the benefits, costs, feasibility, and complementarity of strategies. It requires minimal training and technical skills, and it can be updated to add new objectives, species, strategies, actions, and data. The results from this project demonstrate that intentional investments and the strategic allocation of funding is required to support the long-term persistence of Pacific salmon in the region. Beyond BC's Central Coast, the PTM framework could serve as a model for other regions or First Nations interested in systematic and strategic planning for Pacific salmon.

References

1 Fisheries and Oceans Canada. *Canada's Policy for Conservation of Wild Pacific Salmon.* (2005, Vancouver, British Columbia).

2 Cannon, A. & Yang, D.Y. Early storage and sedentism on the Pacific Northwest Coast: ancient DNA analysis of salmon remains from Namu, British Columbia. *American Antiquity* 71, 123–140 (2006).

3 Campbell, S.K. & Butler, V.L. Archaeological evidence for resilience of Pacific northwest salmon populations and the socioecological system over the last ~7,500 years. *Ecology & Society* 15, 17 (2010).

4 Malick, M.J. & Cox, S.P. Regional-scale declines in productivity of pink and chum salmon stocks in western North America. *PLOS ONE* 11, 1–23 (2016).

5 Governor's Salmon Recovery Office. *2018 State of the salmon in watersheds.* https://stateofsalmon.wa.gov/ (Washington State Recreation and Conservation Office, 2018, Olympia, Washington).

6 Price, M.H.H., English, K.K., Rosenberger, A.G., MacDuffee, M. & Reynolds, J.D. Canada's Wild Salmon Policy: an assessment of conservation progress in British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 74, 1507–1518 (2017).

7 Connors, K. et al. *BC Central Coast: a snapshot of salmon populations and their habitats. Technical Report.* (Pacific Salmon Foundation, 2018, Vancouver, British Columbia).

8 Ogden, A.D. et al. *Canadian commercial catches and escapements of Chinook and coho salmon separated into hatchery- and wild-origin fish. NPAFC Document 1531.* (Fisheries and Oceans Canada, 2014, Nanaimo, British Columbia).

9 Walters, C., English, K., Korman, J. & Hilborn, R. The managed decline of British Columbia's commercial salmon fishery. *Marine Policy* 101, 25–32 (2019).

10 Garibaldi, A. & Turner, N. Cultural keystone species: implications for ecological conservation and restoration. *Ecology & Society* 9, 1–18 (2004).

11 Levi, T. et al. Using grizzly bears to assess harvest-ecosystem tradeoffs in salmon fisheries. *PLOS Biology* 10, e1001303 (2012).

12 Field, R.D. & Reynolds, J.D. Ecological links between salmon, large carnivore predation, and scavenging birds. *Journal of Avian Biology* 44, 9–16 (2013).

13 Hocking, M.D. & Reynolds, J.D. Impacts of salmon on riparian plant diversity. *Science* 331, 1609–1612 (2011).

14 Marine Planning Partnership Initiative. *Central Coast Marine Plan.* (Marine Planning Partnership Initiative, Heiltsuk, Kitasoo/Xai'xais, Nuxalk and Wuikinuxv Nations, Province of British Columbia, 2015, British Columbia).

15 Nelitz, M., Murray, C. & Wieckowski, K. *Returning salmon: Integrated planning and the Wild Salmon Policy in BC.* (ESSA Technologies for the David Suzuki Foundation, 2008, Vancouver, British Columbia).

16 Beechie, T., Pess, G., Roni, P. & Giannico, G. Setting river restoration priorities: a review of approaches and a general protocol for identifying and prioritizing actions. *North American Journal of Fisheries Management* 28, 891–905 (2008).

17 Roni, P. et al. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *North American Journal of Fisheries Management* 22, 1–20 (2002).

18 Cultus Sockeye Recovery Team. National conservation strategy for Cultus Lake sockeye salmon (*Oncorhynchus nerka*). *Canadian Technical Report of Fisheries and Aquatic Sciences* 2846, viii + 46 p (2009).

19 Sakinaw Sockeye Recovery Team. *National recovery strategy for sockeye salmon* (Oncorhynchus nerka)*, Sakinaw Lake population, in British Columbia.* (Recovery of Nationally Endangered Wildlife, 2005, Ottawa, Ontario).

20 Connors, B. M. & Atnarko Sockeye Recovery Planning Committee. *Atnarko Sockeye Recovery Plan.* (ESSA Technologies Ltd. for Nuxalk Nation, 2016, Vancouver, British Columbia).

21 Schoen, E. R. et al. Future of Pacific salmon in the face of environmental change: lessons from one of the world's remaining productive salmon regions. *Fisheries* 42, 538–553 (2017).

22 Hoekstra, J. M., Bartz, K. K., Ruckelshaus, M. H., Moslemi, J. M. & Harms, T. K. Quantitative threat analysis for management of an imperiled species: Chinook salmon (*Oncorhynchus tshawytscha*). *Ecological Applications* 17, 2061–2073 (2007).

23 Ruckelshaus, M. H., Levin, P., Johnson, J. B. & Kareiva, P. M. The Pacific salmon wars: what science brings to the challenge of recovering species. *Annual Review of Ecology, Evolution, and Systematics* 33, 665–706 (2002).

24 Gardner, M. P. & Pinfold, T. A. *Performance Review of the Wild Salmon Policy.* (Prepared for Fisheries and Oceans Canada, 2011, Sechelt, British Colubmia).

25 Carwardine, J. et al. Avoiding costly conservation mistakes: the importance of defining actions and costs in spatial priority setting. *PLOS ONE* 3, e2586 (2008).

26 Evans, M. C. et al. Clear consideration of costs, condition and conservation benefits yields better planning outcomes. *Biological Conservation* 191, 716–727 (2015).

27 Carwardine, J. et al. Priority Threat Management for biodiversity conservation: A handbook. *Journal of Applied Ecology* 56, 481–490 (2019).

28 Carwardine, J. et al. Prioritizing threat management for biodiversity conservation. *Conservation Letters* 5, 196–204 (2012).

29 Martin, T. G. et al. Prioritizing recovery funding to maximize conservation of endangered species. *Conservation Letters* 11, e12604 (2018).

30 Walsh, J. C. et al. Prioritizing conservation actions for Pacific salmon in Canada. *bioRxiv*. doi: https://biorxiv.org/cgi/content/short/2020.02.03.931691v1 (2020).

31 Iacona, G. D. et al. Standardized reporting of the costs of management interventions for biodiversity conservation. *Conservation Biology* 32, 979–988 (2018).

32 Hemming, V., Burgman, M. A., Hanea, A. M., McBride, M. F. & Wintle, B. C. A practical guide to structured expert elicitation using the IDEA protocol. *Methods in Ecology and Evolution* 9, 169–180 (2018).

33 Martin, T. G. et al. Eliciting expert knowledge in conservation science. *Conservation Biology* 26, 29–38 (2012).

34 Chadés, I. et al. Benefits of integrating complementarity into priority threat management. *Conservation Biology* 29, 525–536 (2015).

March 1, 2020

PACIFIC SALMON FOUNDATION
SALMON WATERSHEDS PROGRAM