Recommendations for

New Zealand

Chinook Salmon Enhancement

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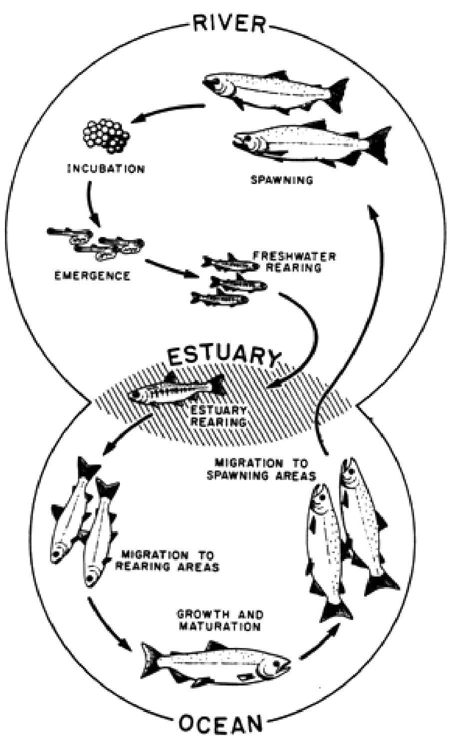
Executive Summary

This report recommends that a program of habitat protection, restoration and creation be combined with an expanded program of juvenile stocking to enhance the returns of adult Chinook salmon to North Canterbury rivers. The report gives suggestions for planning a fish stocking program and suggests a minimum level of fry/smolt marking so that the results can be assessed in future years. The programs will be expected to be mostly carried out by volunteers with the cooperation of land owners and with the assistance of New Zealand Fish and Game staff.

Introduction

In April and May of 2009, I travelled to New Zealand to observe some of the operations involved with the management of Chinook salmon in the North Canterbury Region near Christchurch. For about 10 days, I was escorted by Steve Terry and others to view some hatchery operations and on a helicopter tour of spawning streams. I had discussions with many people, from fishermen to fish researchers, about the issues facing the Chinook populations, both present and historical. After this very short introduction to the subject, I provided some preliminary perspectives and recommendations at a couple of workshops for Fish and Game New Zealand staff and interested members of the public. Upon returning to Canada, I did some further reading on Chinook salmon in New Zealand and compiled some reference material from Canadian projects that I think would be useful to people in New Zealand in moving their program forward. This report is a summary of the recommendations that I made at the workshops, supplemented by some more detailed work on some topics and pointers to other resources that I think would be helpful.

The main two areas covered in the workshops in New Zealand were 1) the Canadian Salmonid Enhancement Program (SEP) approach to stock enhancement and 2) how this approach can be applied to the New Zealand situation. These topics were discussed using PowerPoint, so these slide shows are also included as a supplement to this report. Since they provide the background for the recommendations that I made, they should probably be viewed before reading this report. I have annotated the slides to reflect the points I discussed during the presentations.



The basic nature of salmon enhancement is fairly simple: 1) Find out what is limiting the population and 2) Try various techniques to reduce the limiting factor. Salmon go through various life stages during which their environmental requirements are distinctive:

- Spawning adults require unencumbered passage to their spawning grounds;
- Spawning grounds need good quality substrate and sufficiently high flow of quality water throughout the incubation period;
- Rearing waters need to have abundant forage, good refuge conditions and few predators;
- Estuarine waters may need a gradual transition to high salinity accompanied by abundant forage; and
- Ocean waters require forage, refuge and currents that allow return to the natal streams (or others).

Each life stage requires an environment with enough capacity to allow the population to pass through to the next life stage with sufficient numbers to populate it fully. Each life stage, and the habitat in which it lives, is a potential bottle-neck that can limit the productivity of the whole system.

Enhancement techniques can be used to supplement or replace natural environmental carrying capacities (There are many techniques available, but this report will only focus on a few deemed most relevant to the New Zealand situation).

The preference of the Canadian Salmonid Enhancement Program is to:

- First, maximize the natural carrying capacity of an ecosystem,
- Second, supplement that capacity artificially if it is insufficient for particular life stages, and
- Finally, replace that capacity if it is missing from particular life stages.

Natural capacity is maximized by regulating fisheries to allow sufficient escapement and by protecting and restoring productive habitat. Supplementation of capacity involves creating new habitat and culturing fish during early life-history stages to augment natural production. Replacement of carrying capacity involves determining where bottlenecks in productivity occur and providing an artificial means of meeting the requirements of those missing life history components.

Recommendations

Following are the recommendations that I made at the NZ F&G workshops, with some explanatory text:

1. "Protect the salmon habitat that exists, add to it if possible."

a) Habitat Protection: The first and most obvious improvement that I could see would be

to make every effort to eventually exclude cattle and other livestock from the few spawning streams in the high country. I think that the impact of livestock in these streams is well-understood in New Zealand and does not have to be belaboured here. This would entail changes in range management practices and probably fairly extensive fencing in some areas. The current approach being pursued by NZ F&G and its volunteer army, of working with the landowners in a cooperative and respectful way, reflects the practice that has shown the most successful outcomes in Canada. Through education and mutual understanding, many areas of Canadian rivers have been restored to productivity after severe degradation from agricultural practices. The process takes time but a healthy salmon population is a long-term investment that is worth the patience required to attain it.

b) Habitat Restoration: The second improvement that I would recommend would be to develop a long-term plan for the rehabilitation of damaged habitat that would include providing meaningful roles for both landowners and volunteers in making pre-assessments of the productivity of stream habitats, implementing restorative measures and making post-assessments of productivity a few years after the habitats have been restored. I have included some reference material from Canada that shows techniques for 'bio-engineering' streams so that fish habitat is improved and stream bed stability is improved, mostly through fencing, rock placement and riparian planting. These techniques may require extensive adaptation to New Zealand conditions due to differences in the preferred riparian vegetation and different flow and flood conditions. That is why it is important to assess the pre- and post- conditions to see what kinds of measures work best in the various environments that New Zealand has to offer.

c) Habitat Creation: The third improvement recommendation involves planning for potential salmon habitat creation projects along the mainstem rivers of the Canterbury Plains. It is clear that the mainstem rivers, which flood frequently, are not ideal habitats for rearing juvenile salmon, and in some cases even inhibit the ability of adult salmon to reach the spawning grounds during floods. I am proposing that it might be possible to try to control some of the riparian zones of these rivers to provide refuges during floods. If riparian planting were combined with side channel protection or construction, the impact of floods on juvenile fish populations might be reduced considerably.

Potential for side-channel rearing in braided streams.

d) Resources: I have provided the very large manual used for habitat restoration and creation for projects in Canada on my website at: www.fishbiologycongress.org/newzealand.

2. "Stock fish in both productive and marginal parts of ecosystems."

The key to stocking for enhancement is to be able to determine what numbers to stock and where to stock them. To try to determine these, I have created the Salmon Stocking Decision Tool in Excel. The SSDT takes inputs such as stream length and quality and calculates habitat capacity, from which are calculated the maximum numbers of fish that could survive in those habitats at various life stages. It is important to stress that the SSTD is a TOOL and not a final analysis. All of the inputs can be modified to reflect a better understanding of the input criteria (highlighted in the tables), and the tool can be used to 'play around' with different scenarios for each river. Also, other rivers/streams can be easily added to the tool for evaluation.

The SSDT strives to answer a number of questions about salmon in NZ:

a) What output of juveniles is likely to produce the maximum number of salmon?

I used information that indicated that the maximum sustainable stock size (assumed to be the ocean carrying capacity, at least for the years in the record I saw) for the Rakaia and Wiamakariri Rivers were approximately 20,000 and 10,000 returning salmon adults, respectively. At a 1% smolt-to-adult return rate (current estimate), this would require 2 million and 1 million smolts entering the ocean. Reasonable estimates of wild-spawned survival rates for Chinook salmon from Canadian streams (with wide ranges depending on stream conditions) would be: ~50% of eggs would be fertilized (range of 30-70%), ~50% of those would survive in-stream incubation to the fry stage (range of 20-80%) and ~20% of fry would survive to the smolt stage (10-30%). These estimates are meant as a 'first cut' and can be easily changed in the SSTD in response to better information. The SSTD calculates that to achieve the 2 million smolt target for the Rakaia would require 10 million fry, 20 million eggs and about 27,000 spawners. This is actually larger than the targeted 20,000 population size, which indicates that at these rates of survival, the population would not be self sustaining, and would not be able to sustain any level of harvest.

Estimates of Wild Spawners needed to sustain maximum yield

River	Ocean Capacity	Smolts Required	Wild Fry Required	Wild Eggs Required	Wild Spawn Required
Rakaia	20,000	2,000,000	10,000,000	20,000,000	26,667
Waimak	10,000	1,000,000	5,000,000	10,000,000	13,333

If hatchery releases were used to provide the 2 million smolts required to meet the ocean-return target of 20,000 adults for the Rakaia, only 1,850 adults would be required to produce the 2 million smolts (at a fecundity of 3000 eggs per female, fertilization success of 95%, incubation survival of 95%, rearing survival of 80%). This would theoretically allow over 18,000 to be caught without endangering the population.

Estimates of Hatchery Spawners needed to sustain maximum yield

River	Ocean Capacity	Hatch Fry Required	Hatch Eggs Required	Hatch Spawn Required
Rakaia	20,000	2,500,000	2,631,579	1,847
Waimak	10,000	1,250,000	1,315,789	923

Survival Rate Criteria (input table):

	Spawn-Egg	Egg-Fry	Fry-Smolt	Smolt-Adult	Spawn-Fry	Spawn-Smolt	Spawn-Adult
Wild	0.50	0.50	0.20	0.01	0.25	0.05	0.0005
Hatchery	0.95	0.95	0.80	0.01	0.90	0.72	0.0072

Fecundity: 3,000

The take-home message is that wild spawning will be insufficient to meet harvest expectations, and some hatchery supplementation will be required.

b) What output of juveniles can be expected from current spawning streams?

The Habitat Capacity portion of the SSDT estimates the current capacities of the spring-fed creeks in the upper Rakaia and Waimakariri Rivers. Adult spawner/incubation capacity and juvenile rearing capacity are very different things, so they are treated separately. The area required per adult of optimal spawning habitat (~1 square metre) is coincidentally nearly equivalent to the area that is required to rear one smolt (based on Canadian experience, and again, highly variable dependent on the quality of the habitat), even though a pair of adults start out with ~3000 eggs. **Therefore, a great deal more area is required to rear the progeny from mating salmon than is required to spawn and incubate them.**

The data on length and width for the NZ streams was provided by Steve Terry of NZ F&G, who also included an estimate of the proportion of the stream length that would be considered productive habitat (separate values were given for spawning and rearing proportions).

River	Stream	Length	Width	Total Area	Spawnable	Rearable
Rakaia	Hydra Waters	17	4	68,000	0.6	0.8
	Manuka Pt	6	3	18,000	0.6	0.4
	Double Hill	2	3	6,000	0.6	0.4
	Glenariffe	14	3	42,000	0.3	0.4
	Mellish	20	2	40,000	0.6	0.6
	Goat Hill	2	2	4,000	0.6	0.6
	Montrose	2	1	2,000	0.4	0.6
	Total	63	18	180,000		
Waimak	Poulter	3	3	9,000	0.6	0.8
	Thompson	4	5	20,000	0.6	0.4
	Winding	10	3	30,000	0.4	0.4
	Cass Hill	8	4	32,000	0.4	0.3
	Cora Lynn	3	5	15,000	0.6	0.4
	Hacketts	2	3	6,000	0.3	0.4
	Silverstream	10	3	30,000	0.1	0.3
	Total	76	26	142,000		

Using the life-stage survival rates discussed above, the SSDT calculated the habitat capacities for these streams (adult spawning and smolt rearing). It also calculated the minimum number of spawners required to fully seed the streams with juveniles to match their juvenile-rearing capacity (minimum spawn column). It also used the actual 2009 escapement estimates for each stream to estimate the number of juveniles expected to be produced and whether that number exceeds the carrying capacity or not, and estimates the ‘excess’ fry produced for that stream. A negative ‘excess’ value indicates that the current spawners will not have fully seeded that stream with fry.

The calculated spawner capacity is very high for these streams and far exceeds the required maximum capacities for their salmon populations (as determined by the ocean capacities discussed above). This simply means that there is sufficient spawning area available (which is good news), so available spawning area does not appear to be a bottleneck for these rivers.

River	Stream	Capacities Spawners	Smolts (4+g)	Fry (0-2g)	Min Spawn Required	Actual Return	Excess Fry
Rakaia	Hydra Waters	40,800	54,400	272,000	725	1372	242,500
	Manuka Pt	10,800	7,200	36,000	96	618	195,750
	Double Hill	3,600	2,400	12,000	32	647	230,625
	Glenariffe	12,600	16,800	84,000	224	958	275,250
	Mellish	24,000	24,000	120,000	320	350	11,250
	Goat Hill	2,400	2,400	12,000	32	60	10,500
	Montrose	800	1,200	6,000	16	450	162,750
	Total	95,000	108,400	542,000	1,445	4,455	1,128,625
Waimak	Poulter	5,400	7,200	36,000	96	537	165,375
	Thompson	12,000	8,000	40,000	107	50	21,250
	Winding	12,000	12,000	60,000	160	109	-19,125
	Cass Hill	12,800	9,600	48,000	128	244	43,500
	Cora Lynn	9,000	6,000	30,000	80	127	17,625
	Hacketts	1,800	2,400	12,000	32	100	25,500
	Silverstream	3,000	9,000	45,000	120	360	90,000
	Total	56,000	54,200	271,000	723	1,527	358,375

On the other hand, the smolt-rearing capacities of 108,000 for the Rakaia and 54,000 for the Waimakariri are a tiny fraction of the 10 million and 5 million fry targets, respectively, calculated above to reach the maximum target adult return. **This indicates that these rivers will not be able to reach their potential maximum production solely through wild spawning and rearing in the spring-fed streams.** The catch is that it is very likely that considerable production of juveniles also occurs in the braided channels of the mainstem rivers and other areas downstream of the spring-fed streams. However, a massive flood might be able to wipe out the mainstem production in a given year, reducing production of smolts to the small number that come out of the spawning streams. This is another very compelling reason to have a substantial hatchery supplementation program, as a safety precaution against severe flooding (which is all too common).

c) Which habitats are under-seeded with juveniles?

The SSTD calculation indicates that only the Winding stream is under-seeded with fry – all of the others have enough fry from existing spawners to fully seed them with fry to match their juvenile rearing capacity.

The point here is that there is probably no benefit to adding fry to a stream that already has enough fry in it to provide the maximum smolt output.

If there are sufficient spawners to fully seed the rearing habitat of the spring-fed streams, it might be concluded that fishing pressure is not a limiting factor to population abundance. However, there is clearly a great deal more rearing capacity in these river systems than is seen just in the spring-fed streams. Much of the over-production from spawners in these streams must survive to smolt in other parts of the system; in the braided parts of the rivers, in refuge channels at the margins of the rivers or in low-salinity zones in the estuaries. This means that, while the obviously good rearing habitats are well-seeded with fry, most of the actual production comes from habitats that have been ranked as 'secondary' to date. It is these areas that have the potential for seeding with hatchery-produced juveniles.

d) How much stocking is required to make up for missing freshwater capacity?

The SSTD indicates that the spawners in the creeks are probably seeding the downstream portions of the mainstem rivers with considerable numbers of fry (the excess fry in the table). However, the total of the excess fry and the spring-fed smolt capacity is still less than what is required to meet the smolt targets discussed above in a). There is still room for millions of stocked fry in each of the rivers to meet their ocean-capacity targets.

The SSTD, while calculating the numbers of fish to stock, also gives us an indication of where to stock them – mainly in the mainstem rivers and other streams that are not on the list of spawning streams. The aim is to not over-seed streams that have already been adequately seeded by natural spawners, but to provide fry recruits to those other areas of the river system that have rearing capacity.

e) These questions lead to the final question of what would be a good plan to approach juvenile stocking.

Suggested Considerations for Planning Future Stocking Programs:

- Test the difference between stocking in 'productive' and 'secondary' streams, to determine whether assumptions about what is considered good rearing habitat versus poor rearing habitat are correct. In Canada, we have found that many streams that are highly turbid (similar to flooding NZ streams) are actually very productive rearing habitat.
- Test the difference between stocking in some locations and not stocking in other, similar locations, to determine whether stocking will provide an increase in overall adult return or whether stocking in apparently well-seeded habitat simply replaces one group of fish with another. In Canada, we try not to stock fish on top of existing well-seeded habitat to avoid replacing wild fish with hatchery fish, but there may be an additive effect in New Zealand. Using this stocking/not-stocking approach in similar un-seeded habitat may also help determine the amount of straying between populations, both stocked and wild. These effects would be expected to be quite variable from year to year, so this kind of test should be part of a long-term plan.
- Test stocking success by marking all or a proportion of the stocked fish with adipose fin-clips (see item 4 below).
- As much as can be afforded, rear fish to at least 4-5 grams before stocking, to maximize potential survival. I believe there are surplus fry currently available at the Montrose Hatchery for stocking. I suggest that, if it is affordable, these fish be

reared to smolt size before release, rather than being used for fry stocking. Fry stocking would be expected to work best if it uses large numbers of fish spread throughout the potential rearing areas. If the fish are released high in the system, they should be able to disperse themselves downstream, as wild-spawned fish do.

- The fish destined for the Waimakiriri might be preferably reared at the Isaacs Hatchery, to encourage return to that system.
- If necessary, allow stocking from one watershed to another. There may be an advantage to using fish from the same stock in trials in different watersheds. In addition, hatchery fish obtained from Montrose Hatchery stock may be more suitable for upland stream stocking in the Waimakariri than fish obtained from returns to Silverstream Hatchery, which is located near the river mouth. The difference in survival rate could be studied by stocking adjacent secondary streams with fish from different sources and seeing whether the returns were measurably different.

f) Limitations of the Salmon Stocking Decision Tool

The calculations in the SSDT are based on values that are rough estimates for the populations evaluated. Increasing the precision of these estimates will increase the utility and accuracy of the tool:

- Spawner estimates: the current Area Under the Curve technique relies on aerial counts that are usually fairly reliable since the stream waters are very clear, and an estimate of residence time that may be quite variable from year to year. Work with the Didson fish counter should improve the accuracy of the estimates of total spawners.
- Catch estimates: the total population size for each river is comprised of the combination of the catch and escapements to the tributaries. Catch monitoring is done through phone surveys, which seem to be an inexpensive and effective way to get good information. The data could be tested and perhaps improved if a larger proportion of licensed fishers were surveyed, and compared to on-site inspections of anglers by F&G staff.
- Survival rates: the life stage survival rates used by the SSDT are estimates based on Canadian experience. These values may not be applicable to New Zealand streams, since the graywacky shingle found in NZ streams is quite different from the glaciated gravel in Chinook salmon spawning streams in Canada.
- Stream rearing capacity: the estimation of stream carrying capacity, especially for rearing juveniles, could be much improved by the collection of some field data over several key sites over different years. The numbers that I have used come from Canadian experience, but, for instance, we do not even have tall tussock grass riparian habitats (like the Hydra Waters) in Canadian salmon streams, so the estimates may not be characteristic of New Zealand streams.

g) Resources: I have provided a working copy of the Salmon Stocking Decision Tool on my website at: www.fishbiologycongress.org/newzealand.

3. "Don't worry about genetics – this is not your main problem."

The northern hemisphere literature about salmon contains many cautionary tales about how the use of hatchery fish may have negatively affected the genetics of native populations and may have been a factor in the decline of productivity over time. However, as I have indicated in my PowerPoint presentation, these concerns that come mainly from the US hatchery system are basically irrelevant to the NZ situation (as they are to a large extent to the Canadian situation). I have provided some cautionary guidelines for readers of this literature in Appendix 2 of this report.

In short, the US Pacific Northwest (Washington, Oregon, Idaho and California), there has been a long history of stocking fish from one watershed into other watersheds, over top of existing wild populations. Therefore, a 'hatchery' fish in this case is also an 'introduced' fish that may not have the correct local adaptations for optimum survival in the new environment. Current 'hatchery reform' initiatives in the USA recommend that fish stocking be limited to the use of local stocks if those fish might also try to spawn in the wild. The purpose of this cautionary approach is to preserve locally adapted gene complexes that are postulated to have taken hundreds or thousands of years to develop into distinctly different populations.

Since all of the Chinook salmon in New Zealand were introduced to the Waitaki only 100 years ago, gradually colonized the other streams since then, and have been exposed to considerable straying (both natural and artificial) during the interim, there has likely been very little reproductive isolation to produce genetically distinct populations. In North American parlance, these populations would be considered to be closely related meta-populations of a single genetic unit, (Conservation Unit according to the Canadian Wild Salmon Policy and Evolutionarily Significant Unit according to the US Endangered Species Act).

In Salmon Enhancement, it is always wise to use the closest, most clearly locally-adapted population for stocking purposes. Failing availability of the local population, the next-best source for fry- or smolt-stocking would be the next closest population, geographically or genetically. For New Zealand, I suspect that the populations are so closely related genetically that there should be no problem (and history seems to have borne this out) stocking fish from one stream or watershed into another.

Although this might seem contrary to the current world-wide trend of severely limiting the introductions of new genetic material into old populations, I would suggest that New Zealand Fish and Game consider seeking permission to bring some further genetic diversity to the existing salmon populations by importing some more gametes from other populations. Every salmon population in North America (and Eurasia) receives a constant trickle of genetic material from strays from neighbouring populations.

Resources: I have included a review paper about the 'hatchery/wild' salmon debate on my website at: www.fishbiologycongress.org/newzealand.

4. “Monitor your stocking activities – move to marked fry or smolt stocking in productive areas, and use tests and controls.”

One of the most important considerations in any action to enhance a salmon stock is to be able to determine whether your actions were beneficial or whether the changes that you see in the future were caused by factors outside your control. Therefore, in stock enhancement, it is vitally important to mark at least a proportion of the enhanced fish so that their impact can be assessed.

In the case of enhancing NZ Chinook, I suggest that all of the fish produced through the hatchery program in future years be marked in some way so that they can be distinguished when they return as adults and the hatchery program can take credit for their production. This will also help to determine the actual productive capacity of the natural streams (in their current state).

The best scenario would be if all of the hatchery releases were marked distinctively, so that their origin could be determined. This would require coded-wire tagging, which is prohibitively expensive. The next best scenario would be if the fish were mass-marked in an easily recognizable way so that they could be distinguished from the progeny of wild spawners.

However, even fin-clipping fry can be time-consuming and expensive. An alternative would be to fin-clip a proportion of all hatchery releases. The higher the proportion, the better, but I would suggest that a minimum of 10%, and preferably 25-50% be set as a goal. Thus, when fin-clipped adults (or fingerlings or smolts) are captured, their abundance can be estimated by multiplying by a simple expansion factor. It would be important for all hatchery releases to have the same proportion of fin-clipped fish, which will take some coordination between the different hatcheries.

It should be noted that egg planting, as it has been traditionally carried out in New Zealand, does not allow for determining the origin of any subsequent life stage. It is much preferable to incubate the eggs right through to the fry stage and, after a short period of feeding to the 1-2 gram size, planting them into streams at a time concurrent with the local fry emergence and downstream migration.

Rather than spending time ova-planting, the same volunteer crews could periodically visit various streams (both stocked and not, to see the difference) and conduct fry enumeration tests to get a better handle on their rearing capacities. This kind of work can be fairly simple to do and, properly organized, could be a lot of fun for a day out.

Resources: I have included references on how to sample adult and juvenile salmon on my website at: www.fishbiologycongress.org/newzealand.

5. “Tighten up your fish culture procedures (to avoid future problems).”

The fish culture operations that I saw in New Zealand reminded me of the early years of the Salmonid Enhancement Program when we were starting to learn about how to raise fish. Our current operations have matured a great deal since then, with lots of quite fancy facilities and sophisticated techniques, but the fish culture is basically the same – a group of dedicated people who want to provide the best care for the fish in their charge. The knowledge and skill required for expert fish culture takes time and devotion to develop, but it can be a very rewarding journey with endless opportunities for learning.

At the SEP in Canada, we train our fish culturists on the job and through courses designed to increase their understanding of the issues facing fish in culture. Over time, some of the people who are participating in the fish culture and other activities in New Zealand will become experts and can organize training and set standards for others.

Some resources that I have included on my website at: www.fishbiologycongress.org/newzealand.

New Zealand Fish Culture Management Plan: I have drafted a plan to be revised by local workers that outlines basic principles of good fish culture and works towards setting standard operating procedures for hatchery operations. Each SEP hatchery has written up the main steps that they take in conducting fish culture operations, from brood stock capture and holding to the release of juveniles. They are specific to each hatchery but have many common elements. Likewise, SOPs for NZ operations should also be flexible enough to allow for creativity and initiative, while setting standards of quality for operations.

The Volunteer Egg Take: this guide book was written by a SEP Community Advisor to help volunteers get a good start at good practice in taking eggs.

Fish Health Course and Presentations: this comprehensive manual is the material used in teaching our fish culturists about health issues in salmon.

6. "Nurture your volunteers, they are your best resource."

Volunteer help is a major component of the Canadian Salmonid Enhancement Program, with over 10,000 people per year participating in projects and thousands of children using SEP resources to learn about salmon. The fairly small-scale program in New Zealand should be able to provide most of its services through volunteer effort. Paid staff should probably concentrate on finding, organizing, training and encouraging volunteers and leveraging resources in combination with partners (for funding, equipment and expertise), rather than on doing the work themselves.

I have included numerous documents that will give direction towards maximizing volunteer efforts on my website at: www.fishbiologycongress.org/newzealand.

Appendix 1. Comments on the South Island Sea Run Salmon Management Plan

This plan is very comprehensive and well written. I agree with and applaud by far the majority of statements, policies and methods outlined in the plan. I only have comments about one section, 3.2 Stocking. My concern is that the cautious approach recommended for using hatchery fish will unnecessarily limit the opportunities for increasing and stabilizing salmon populations.

- Under Objective 3.2. Explanation, there is a statement that changes in body characteristics have been seen between different streams, and this is treated as evidence that there has been divergent evolution within these streams and that transfer of fish between them would "threaten this process of adaptation." The differences between streams is most likely phenotypic and not genetic in nature, since it is highly unlikely that functional genetic differences would have evolved within the short time that Chinook salmon have been in New Zealand. I would recommend that this part of the discussion be removed and discussion of the genetic differences between salmon in different rivers only be discussed after there is concrete evidence derived from genetic testing. It is be expected that the Chinook salmon in all New Zealand rivers will be shown to be very closely related (due to their very recent introduction, many transfers and substantial interbreeding) and would be considered within a single 'conservation unit' (in Canada) or 'evolutionarily significant unit' (in the USA).
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- Bearing in mind that the genetic attributes of 'wild' salmon populations are very new to New Zealand, under little threat from hatchery releases and may in fact not be as ideal as they are assumed, I would suggest rephrasing Policy 3.2.1 to the following: "Stocking programs shall be designed so as to supplement existing wild populations, rather than replacing them." This would encourage the rational use of stocking (as I have argued within the main body of my report under 'Stocking') leading to a more effective outcome, and also allow for opportunities to increase genetic diversity for future populations.
- Under Method 3.2.1.1, I would suggest a modification: "Salmon and salmon ova should preferably be sourced from within the catchment where stocking is to take place, however, some sourcing from outside the catchment to supplement genetic diversity or to provide fish with similar traits to new stocking areas should not be also be considered acceptable."
- Under Method 3.2.1.2, I would suggest changing "for the protection of wild salmon populations" to "for the enhancement of salmon populations."
- I would suggest that Method 3.2.2.1 be dropped, since, if such releases had not occurred in the past, New Zealand would not have had any Chinook salmon populations. I think it would be fine to close off some watersheds to salmon to protect native fish populations (as under Policy 3.2.5), but this seems a bit draconian and contrary to the stated mission of the Plan. This comment also applies to Method 3.2.5.1.

- I also suggest that Method 3.2.5.2 be modified to state that ‘some’ catchment reaches that are inaccessible to salmon will be protected from salmon releases to protect native fish, but I did not get the impression that there is a lot of value in ‘indigenous fisheries values’ in New Zealand, so this Method may be precluding opportunities that would not have negative impacts on other fish populations. I suggest that a survey of potential ‘inaccessible salmon rearing reaches’ be conducted, and if no impact is expected from salmon releases, they be allowed. There seems to be a very limited amount of quality salmon juvenile rearing habitat in New Zealand, so cutting off the opportunity to use reaches above salmon barriers for fry outplanting seems unnecessarily restrictive.
- A final cautionary comment on section 3.3.1 about trying “to develop techniques to predict salmon returns” similar to those used in North America. An enormous amount of effort has been spent in trying to predict salmon run size in Canada and the USA using a wide variety of simple and extremely complicated models. These efforts have, much too often, been to no avail, not even able to accurately predict the general ball park figure for actual returns. It seems to be beyond our current ability to predict the distant future with any accuracy. I would recommend that New Zealand continue to try to understand the dynamics of salmon population productivity in the stream and ocean, but wait until there are actual signs of salmon returning to terminal areas before making predictions of run size for management purposes (in season estimates).

Appendix 2. Common Mistakes in Assessing Hatchery/Wild Fish Interactions

There is a large literature around the topic of the negative effects of hatchery propagation on populations of wild fish, particularly in the Pacific Northwest of the USA. However, there are several 'misconceptions' that occur throughout this body of literature that should be considered by any reader who is trying to get to the bottom of this issue. These include:

1. Blaming 'hatcheries' for problems that are really the responsibility of fisheries 'management.' This would include:
    - Changing the run timing of a stock by selecting only early- or late-returning broodstock,
    - Not using all age classes of adults for broodstock (e.g. jacks),
    - Over-harvesting wild fish stocks because there are many 'hatchery' fish available nearby,
    - Out-planting more juveniles than the rearing capacity of habitat can handle,
    - Out-planting 'hatchery' juveniles on top of a pre-existing 'wild' stock, causing excessive competition and reduced productivity of the 'wild' stock.

2. Labeling 'introduced' fish as 'hatchery' fish. Many hatchery systems have distributed juveniles without regard to their origin and we would expect that non-native fish should perform worse than fish that are locally-adapted. However, the poorer performance is not because the fish were raised in a hatchery, contrary to the conclusions of several papers, but because management decided to use non-native (poorly-adapted) fish for stocking.

3. Claiming that 'hatchery' fish are inferior to 'wild' fish because they look or act differently. Different stocks of fish have different characteristics (run timing, adult size, freshwater residence time, body shape, behavioural responses), that are both genetically and environmentally (e.g. rearing conditions) controlled. These differences represent the adaptation of fish that may be equally fit to different conditions, not 'better' or 'poorer' adaptation. If fish are to be proven 'less fit,' these simple differences are insufficient evidence.

4. Consider 'phenotypic' differences to be genetic. Salmon with exactly the same genetic make-up can have vastly different expression of their genes in phenotypic characteristics. This is one of the most important weapons in the salmon's arsenal for survival, its phenotypic plasticity. Observation of differences in salmon responses to the environment is not evidence of differences in genes.

5. Blaming 'founder effect' problems on hatchery operations. While it is true that some hatcheries started their programs with very few fish (small genetic diversity), the problem was that there was not many fish available, so the 'founder

effect' would have been just as bad for 'natural' spawners. Of course, the purpose of a hatchery program is to multiply the number of fish available and therefore avoid the genetic bottleneck that is produced by small, naturally spawning populations. Recent studies have shown that if a stock can be kept to a reasonable population size, genetic diversity will not be lost.

6. Saying that survival under 'hatchery' conditions is evidence for 'domestication' or 'adaptation.' Since hatcheries are designed to provide the best conditions for fish to survive (clean, cool water; highly nutritious food; protection from predators), fish do not have to become specially 'adapted' to survive in the hatchery. The 'domesticated' descriptor indicates that fish have become so dependent on the cushy conditions in the hatchery that they are incapable of surviving in the wild. This effect has never been shown.

7. 'Garbage-in, garbage-out' models. Several papers describe computer models that make predictions about future survival or genetic ability of fish stocks. When they make the initial assumption that 'hatchery' fish will perform worse that 'wild' fish, their simulation results that show different performance should be no surprise.

8. Ascribing all mortality to genetic inadequacy. Fish die of many things and with an ocean mortality rate over 90%, most mortality is the result of bad luck, not bad genes. Many studies assume that all the fish that survive have better genetic ability than all those that don't.

9. Mix-up different definitions of 'fitness.' The common understanding of the word 'fitness' is the ability to survive into the future. This can be both the genetic ability (the 'right' genes) and the learned ability (the 'skills' required). The vast majority of fish have these characteristics. However, circumstances (the presence of food or predators, etc.) may not allow these perfectly healthy (both genotypically and phenotypically) fish to survive. The Geneticist's definition of 'fitness,' however, is a measure of the actual number of offspring produced by a fish. It may not have any more 'talent' than a fish that did not produce offspring (in fact, it may have been less 'fit' (strong, fast, etc.) to survive than a fish that died before reproducing), but it was luckier. Therefore, the Geneticist's definition of 'fitness' does not mean that the fish is necessarily more 'fit' (locally adapted) in the common use of the word.

10. Inadequate statistical control of experimental procedures and analyses. This includes a variety of possible errors such as:
    - Failure to have a clear hypothesis – you need to be testing something, not just shopping for interesting relationships
    - Selection of inappropriate experimental subjects and test conditions
    - Lack of adequate replication and sample size
    - Lack of independent controls
    - Failure to account for observer bias in behavioral experiments

- Use of inappropriate statistical analyses/reporting
- Stating conclusions that are beyond the scope of the experimental results