Report on Review of Salmon-Related Research at Auke Bay Laboratory (ABL)

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Prepared for

University of Miami
Center for Independent Experts

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Executive Summary

As agreed, I have reviewed the genetics and conservation biology aspects of the salmon-related research at ABL. Overall, there is some excellent research being carried out, particularly that on chinook and steelhead at Little Port Walter, the theoretical analysis of stock contributions, and the analysis of harvest on pink salmon in PWS. Other data sets, such as the long term salmonid and environmental data set at Auke Creek and the CWT analysis of bycatch, are valuable but apparently have not been published in peer-reviewed publications. The Genetic Stock Identification (GSI) program used in bycatch, illegal catches, and migration studies has depended upon allozyme data in the past. This program needs to adopt new molecular techniques, such as the standardized array of microsatellite markers being used elsewhere. In this effort, baseline data for microsatellite loci on a large number of populations, such as has been generated for allozyme data in the past, should be developed.

Overall, more support should be given to the GSI program to bring it up to current standards. Some new equipment is available and the new laboratory should help. This is an area that ABL could make an important contribution to a number of important salmon issues. Eight other labs currently are developing standard microsatellite loci and can analyze the array of 13 loci; ABL should become part of this group. Part of the problem at ABL is the low staff number in the fish genetics lab and there also seemed to be some hesitancy to embrace the use of these new markers.

Background

The salmon-related research at the Alaska Fisheries Science Center is carried out at the ABL. A panel of four scientists, three from the Canadian Department of Fisheries and Oceans (DFO) and myself, were contracted to carry out a review of this research. Because of my expertise in genetics and conservation biology, I agreed to emphasize these aspects of the review, which include some issues related to hatcheries. As a result, most of my findings, conclusions, and recommendations are focused on these aspects of the review as agreed to by Steve Ignell, Acting Director of ABL, and the other three reviewers, Mike Bradford, Jim Carscadden, and Larry Marshall. My findings, conclusions, and recommendations are given below in response to the detailed list of five questions on Conservation Biology and Genetics provided by ABL as a focus for our review on this topic (I have highlighted these questions in boldface before my comments).

Description of Review Activities

My activities related to this review included extensive reading of background information and articles provided by ABL before the meeting, attending and participating in the three-day review at ABL, reading further extensive material after the meeting, and preparing this report.

The Terms of Reference for this review were reduced in part during the review meeting and are addressed by the answers to the following questions prepared by the Auke Bay Laboratory. Two sets of questions were prepared, Conservation Biology and Genetics (CB & G) and Ocean Ecology and Climate (OE & C), and are included at the end of the report. The Terms of Reference items are addressed within these questions.

TOR #1: ***The AFSC's primary research mission is to generate the best scientific data available for understanding, managing, and conserving living marine resources in Alaskan waters and the environmental quality essential for their existence. Primary species of interest are groundfish, crab, and marine mammal populations. Salmon are an important secondary species due to research responsibilities derived from international agreements. In addition, AFSC salmon programs receive direct funding from Congressional PPAs and NOAA research initiatives pertaining to ESA-related issues, the ecological role of salmon in the marine environment, and enhancement technology and impacts. The review panel should provide input on recommended directions in AFSC salmon related research in Alaska, and identifying appropriate levels of research directed at salmon management questions and at Alaskan ecosystem and habitat issues.***

ToR 1-A. What applications of marine salmon research at AFSC best provide an understanding on the effects of climate/physical drivers that may cause changes in aspects of North Pacific ecosystems such as trophic food webs and forage fish populations?

(CB&G) 3. Large scale hatchery programs for pink salmon in Prince William Sound and chum salmon in Southeast recently have been implicated in declines in wild stock productivity for these species in those regions. ABL scientists participate and take leadership roles, along with university, state, and private sector partners, in related research programs in these regions, including retrospective modeling studies, to examine if and how these hatchery programs may be affecting productivity of wild stocks. One objective of ABL hatchery-wild stock interaction research is to better understand if hatcheries pose a threat to healthy wild stocks, including through ecosystem change. Does this project meet this objective and why? What other research could be conducted to address this objective?

As stated in the question above, hatchery programs for pink salmon in Prince William Sound (PWS) and chum salmon in the Southeast recently have been implicated in declines in wild stock productivity for these species in those regions (by Hilborn and Eggers, 2000 for the pink salmon in PWS). There is a long history of the influences of hatchery programs on salmon in the lower 48 states, particularly for endangered runs in the Northwest. Although the absolute numbers in the wild runs of pink and chum are not as small, the numbers relative to that produced from the hatcheries are low. In other words, it seems completely possible that these hatchery runs are having significant impacts on the wild runs. And because this is a real possibility, it would appear prudent both to intensively monitor these wild runs (and genetically identify them) and investigate thoroughly any potential interactions with the hatchery fish. In light of the obvious changes in water temperature occurring now, additional negative impacts from hatcheries may have greater effects as the environment changes and wild population persistence become more tenuous.

There is some controversy about hatchery impacts on wild runs, but the careful research at ABL on chinook salmon discussed above shows fairly rapid, and generally maladaptive, phenotypic change in hatchery fish. In other words, there does not seem to be any reason to suggest that genetic and other impacts from hatcheries would be different in Alaska than elsewhere. In fact, because of the extremely large scale of the hatcheries in Alaska may suggest that the impacts, when they occur, may occur more quickly than elsewhere.

I have examined the arguments of Hilborn and Eggers (2000, 2001) and Werthheimer et al. (2001) in the series of point-counterpoint articles. It appears that Hilborn and Eggers have overstated and under-parameterized some of their estimations and predictions, but from the counterpoints by Werthheimer et al. (2001), it is not clear that there is definitive evidence that Hilborn and Eggers are completely wrong. In my view, the tenor of the interaction almost seems like a courtroom battle where the goal is to score debate points and not necessarily to understand as best possible the complicated forces that influence pink salmon numbers in PWS. It appears that ABL appears to be supporting the use of large scale hatcheries and I am not sure that is the side that the best science, and experience in the lower 48 states, would support for the wild runs. On the other hand, it may be that hatchery production of pink salmon in PWS has greatly increased the fisheries harvest, but the cost to the wild runs and other aspects of the environment does not appear to be well understood. From the presentations during the review, it appears that prediction of run size and harvest is very difficult. This apparently occurs because it is not known what factors are most important in determining these numbers in a particular year, species, and run but it also appears that the significance of particular factors may change dramatically in different years.

Generally, the large-scale Alaskan hatcheries are relatively recent and their impacts may be just starting. For example, it is not impossible that the impacts of hatcheries on genetics, competition with wild runs, etc. may have a very large impact if the wild runs go below some threshold number (they already appear to be having an impact on fish size). Subsequently, restoring the wild runs after such an eventuality may be very difficult and the hatchery fish are likely to be an added hindrance.

The statistical analysis of factors affecting harvest for PWS pink salmon is sophisticated and appears to incorporate many of important factors correlated with productivity. Continuing analysis and more years of data may provide better predictions of harvest. Detailed molecular genetic work identifying wild pink salmon runs using microsatellite loci within PWS may give another way of determining the health of these runs.

After reviewing the chinook and steelhead research at Little Port Walter, it is clear that to more fully understand the impact of hatcheries on wild pink salmon in PWS, direct research into the genetic changes brought about by hatcheries should be undertaken. Although ABL does not have a research facility in PWS, to fully understand the impact of hatcheries on pink salmon there, a research program similar to that at Little Port Walter should be established there to compare hatchery and wild fish. It could be that large changes have already occurred and that with the very large numbers produced, even very low straying rates may greatly impact the wild runs, particularly if they decline for unrelated reasons.

ToR 1-B. Given that hatchery operations in the Pacific Northwest are identified as one of many causes for the decline in wild stock abundance (leading to multiple ESA listings), and given that Alaska, with generally abundant and healthy wild stocks also has a significant large-scale hatchery program, what level and types of hatchery-wild stock interaction studies are needed to address present and future Alaska salmon issues?

(CB&G) 1. *Chinook salmon hatchery programs in Southeast Alaska, a region with a limited number of relatively small wild stocks of Chinook salmon, were developed to compensate for catch limitations imposed under US-Canada salmon treaty accords even though hatcheries in other areas have been identified as one significant cause of stock declines and ESA listings. ABL conducts research on two experimental hatchery stocks of Chinook salmon at a remote field station by making comparisons with multi-generations of hatchery fish and their wild founder counterparts that are unaffected by habitat loss, introductions of other fishes, or hatchery influences. The objective of this research is to understand if, how, and why changes in hatchery stocks differ from their wild founders and to help avoid pitfalls related to hatchery-caused declines in wild stocks. Does this project meet this objective and why? What other research could be conducted to address this objective?*

Hatcheries may influence wild runs of salmon in a number of ways, including interbreeding with wild fish, competing with wild fish for resources, and introducing disease to wild stocks (for discussion of the genetic impacts, see Waples, 1991). Genetic management policy for hatcheries in Alaska requires that local wild salmon be used as stocks for hatchery populations. In addition, many hatcheries are placed so that they should have little impact or interactions on the wild runs. However, hatchery practices may result in changes in salmon behavior mimicking domestication, such as foraging and predator-avoidance behavior, and other changes in phenotypic characteristics related to fitness even more difficult to document.

The research at ABL comparing chinook salmon with five generations in a hatchery and the ancestral stock may provide important information about the impact of hatchery rearing on salmon. Joyce et al. have shown that female hatchery chinook salmon mature earlier than wild salmon, there was a non-significant decrease in fecundity in hatchery salmon, and there was no significance difference in egg weight. The change in female maturity appears to be a reflection of the difference in temperature at the hatchery and the site of the wild stock. In other words, in a few generations, two of three important components of fitness that were compared between wild and hatchery stocks changed substantially.

These findings suggest that hatcheries will produce fish that differ in some important ways influencing fitness from their wild ancestors. As suggested above, if these hatchery fish interbreed with wild fish, then F_1 or future generations may produce fish that cannot survive as well in the wild. On one level, this may keep hatchery fish and wild fish separate, but if there are very large numbers of hatchery fish and the few remaining fish from wild runs mate with them, then severe endangerment or extinction of the wild runs may occur.

Other factors affecting fitness may also be influenced by hatchery rearing. It would also be useful to examine behavioral traits, such as foraging and predator-avoidance behavior, survival in the marine environment, and male mating traits in this chinook study. For example, because in hatcheries males are not required to compete for mates and therefore mate successfully, these characteristics may not be selected for as they would be in wild populations. Although it may be difficult to examine these and other traits related to fitness, if some of them are also not selected for, or selected against in a manner different from that in the wild population, then further differences between the hatchery and wild runs could develop.

If the wild populations of either of the two stocks used in this study appeared to be going extinct, would it be appropriate to use the hatchery fish derived from these stocks to try and save the wild runs? Given the changes that were seen for two of three traits examined in the Chikamin River stock, using these hatchery fish may result in an increase in the probability of extinction in the wild run. For the more limited changes observed in Unuk River stock, the impact there would be expected to be less.

This project may produce important general findings for understanding hatchery effects on wild stocks of salmon. If possible, I recommend that further traits be examined, quantitative genetic techniques be used to analyze the data and that molecular work using microsatellite loci to complement the phenotypic research be carried out (to determine the amount of genetic variation in the different generations of hatchery fish and in wild fish). Publication of this important research appears to be limited to the Summer 2004 AFSC Quarterly Report. This research appears to be of broad enough significance such that it should be published in a high visibility peer-reviewed journal.

(CB&G) 2. The experimental conditions for steelhead research at ABL, broadly supported by cooperative participation with partners including NOAA scientists and others from the Pacific Northwest (including in some cases funding support), are not available in other regions. Unique genetic gene banks exist in Alaska such as 70 years of freshwater isolation of an anadromous-origin population of steelhead in a lake, which may be useful in ESA recovery programs in the Pacific Northwest where, for example, ten Evolutionarily Significant Units (ESUs) of steelhead are listed under ESA. The objective is to determine if these unique genetic gene banks can be used in the ESA recovery programs. Does this project meet this objective and why? What other research could be conducted to address this objective?

The experimental research on steelheads has the potential to make an important general contribution to understanding the differences between anadromous and non-anadromous stocks. It is unlikely that these stocks could be used in the Pacific Northwest as stated above (this statement appears to be an error in editing) but general information about the genetic basis of anadromy may be obtained from these studies. The research here is of very high quality and uses excellent experimental design and current data analysis approaches.

First, Smoker et al. found that the likelihood for smoltification is still in high frequency in the resident fish even after 70 years of isolation and presumably strong selection against smolting. The explanation given is a negative genetic correlation with maturation in the resident population. Whatever the cause, it is remarkable that after this period that resident fish still produce a large proportion of smolts. This has potential implications for the likelihood that residual resident rainbow trout populations in the lower 48 states may have the potential to form anadromous steelhead runs if environmental conditions change so that they are able to migrate. Second, Smoker et al. found that resident fish had significantly lower marine survival rates than did anadromous fish. In other words, there does appear to have been strong selection on this trait, resulting in lower marine survival for fish that have spent 70 years in fresh water.

Other research on these runs using crosses have allowed measurement of inbreeding depression and outbreeding depression (as yet unpublished), quantities essential for understanding persistence of endangered salmon runs and difficult to obtain in other situations. Overall, this project appears to be succeeding in publishing high quality results and making general contributions to the understanding of anadromy and fitness-related traits.

ToR 1-C. What GSI research is needed to support ecosystem research in the North Pacific Ocean and forensic or enforcement activities? Are the technical methods used at ABL appropriate for the task?

(CB&G) 4. Objectives of the salmonid portion of the fish genetics research unit at ABL, using allozymes, mtDNA, microsatellite DNA, and single nucleotide polymorphism (SNP) techniques, are to:

1) Identify discrete stocks of unique geographic groupings of salmon stocks caught in mixed stock fisheries

For stocks that are greatly differentiated, such as Asian and Alaskan chum salmon, allozyme markers and the large baseline data set that has been accumulated over the years appears to be generally adequate. However, for determinations of discrete stocks that are less differentiated, the battery of 13 microsatellite loci that is now being used appears to be the most appropriate set of markers at this time. This group of loci appears similar to the 13 microsatellite loci of CODIS (Combined DNA Index System) of the Federal Bureau of Investigation. I recommend that the ABL switch over to microsatellite markers as rapidly as possible and if only lower resolution is necessary, then fewer microsatellite loci could be used.

SNPs may be markers of choice at some time in the future (and they may be easier to automate), but microsatellite loci are the standard used now in many organisms. At present, SNPs are only used widely in human genetic studies for locating disease genes and linkage studies. Although the argument that allozymes can be used in specific situations is sometimes tenable, it is unlikely that other salmon genetic labs will use allozymes in the future; allozymes are virtually not used in any other organisms at the present, and allozymes provide such low resolution in most cases that there is little reason to use them. It appears that the slow and complete transition from allozyme to microsatellite loci at ABL is partly due to shortage of personnel and waiting for the move to the new laboratory facilities, but I would urge that this change be given the highest priority.

The statistical power to detect differentiation appears dependent upon the number of independent alleles (Kalinowski, 2002). If there are k_i alleles at the ith locus, then given n loci, this would give $n(k_i - 1)$ independent alleles. For microsatellite loci, which may average 8 to 10 alleles per locus, this gives much more resolution than do allozyme loci, which generally average only 2 or 3 alleles per locus. For lower resolution, fewer than 13 microsatellite loci would give the similar resolution to allozyme surveys.

Generally, determination of different stocks has depended upon a large baseline data set of different populations (using allozymes). A particular sample of fish is then partitioned between these stocks based on similarity in allele frequencies to the different stocks. The same approach can be used for microsatellite (or SNP) data, given that there is a good baseline data set of different populations.

There have been a number of theoretical developments in the determination of different groups using molecular data. One of the most widely used approaches is the Bayesian approach in the software STRUCTURE (Pritchard et al. 2000 and www.pritch.bsd.uchicago.edu), which partitions a sample into statistically significant groups (this approach requires that the true population of origin was sampled). Manel et al. (2002) evaluated several different approaches to partitioning a sample and found that individuals from two different populations with a $F_{ST} > 0.15$ (medium level of differentiation) can be assigned to the correct population with very high certainty (99.9%), given that there are 10 loci with heterozygosity > 0.6 and a sample of 30 to 50 individuals. I haven't seen the approach used in Pella and Masuda (in press) but I was informed that it is similar to STRUCTURE. I would recommend that the new approach of Pella and Masuda be compared with STRUCTURE and other methods to determine when and if it gives conclusions not possible with the other approaches. If the approach of Pella and Masuda is found to be preferable, then both those results and those from the widely used STRUCTURE could be reported so that others can evaluate the conclusions from both the new approach and the widely used one. If population structure is found by one of these approaches, then allocation to specific stocks can be done by using a baseline data set of microsatellite loci from different populations.

2) Make forensic determinations of stock origins of salmon caught in illegal fisheries

Again, the battery of 13 microsatellite loci should be preferred here over allozyme surveys. If there is any litigation over the findings, the comparison with a similar battery of 13 loci used by the FBI for human forensic purposes would provide a strong basis for any findings.

The forensic determination of stock origins appears to be an opportunistic venture. This is an important service that ABL provides, but if it is to become a significant part of the activities for the genetics aspect of the laboratory, I recommend that it be carried out in a more proactive way if possible. That is, ABL could become the source of such determinations (with a contract to do this), develop an efficient way to carry out the analysis, charge the agencies for the analysis, and publish the results in peer-reviewed journals.

When there are multilocus genotypes for highly variable loci, such as microsatellite loci, then individuals can be assigned to specific populations (Davies et al., 1999). In general, given individuals would have a specific genotype with the probability that the genotype would be found in a given population (usually the $\log_{10}$ of the probability is used). For example, Carmichael et al. (2001) identified two individual migrant wolves from Banks Island to the mainland in northwest Canada. Paetkau et al. (2004) examined the statistical power and accuracy to detect recent migrants using genetic assignment methods and showed that there was generally high power. Similarly, assignment of individuals to particular stocks should provide strong support for genetic data to be used in litigation. As a case study, genetic assignment examination of a prize Atlantic salmon (not to the Finnish lake which was the site of a fishing contest but to the Baltic Sea) was the basis of an out-of-court settlement.

3) Determine stock-specific migration pathways of salmon in oceanic waters.

Determination of the stock source of salmon also should rely on the higher resolution of microsatellite data. The approaches discussed above to partition a sample to different sources or to genetically assign specific individuals to stocks should be used. In addition, both thermally marked otoliths as the result of specific hatchery regimes and coded wire tag data can be used to verify genetic assignment of fish with these markings.

4) Does this project meet this objective and why? What other research could be conducted to address this objective?

The three objectives above of the salmonid portion of the fish genetics research unit at ABL appear to have been generally met. However, much greater resolution and statistical power could be obtained if the lab were to switch to the battery of 13 microsatellite loci now used in other salmon genetic labs. These data would allow definitive statements on identification of stock source in mixed stock fisheries, make forensic identification in illegal fisheries, and determine stock source of migrating salmon and as such provide greater confidence in stock source calculations and support in potential litigation on illegal fisheries.

Although the objectives of the ABL are generally met, I recommend that some of these findings should be published in higher visibility and/or peer reviewed journals. With the sample sizes possible and the resolution provided by microsatellite loci, these studies and their implications should be made available to the broader genetic and conservation biology audience (and not just the salmon fisheries audience).

Overall, more support should be given to the fish genetics lab and the GSI program to bring it up to current standards. The newly acquired equipment and the move to the new laboratory should help. This is an area that ABL could make an important contribution to a number of important salmon issues. Eight other labs currently are developing standard microsatellite loci and can analyze the array of 13 loci; ABL should become one of this group. Part of the problem at ABL is the low staff number in the fish genetics lab but there also seemed to be some hesitancy to embrace the use of these new markers.

ToR 1-D. The North Pacific Anadromous Fish Commission (NPAFC), a five nation International Convention focused principally on salmon resources of the North Pacific Ocean, encourages coordinated and cooperative research by member parties in both Convention Area waters and adjacent territorial seas. As the NPAFC Science Plan calls for research focused on early marine life of salmon, how can ABL research on juvenile salmon best provide a better understanding of the role salmon play in various components of the North Pacific ecosystem?

(CB&G) 5. A major management concern for NOAA Fisheries in Alaska is monitoring and documenting bycatch of prohibited species, including salmon, in large groundfish fisheries in the Gulf of Alaska and Bering Sea. The numbers and stock origins of salmon bycatch become important issues for the management and continuance of the groundfish fishery as well as the well being of salmon stocks involved. Two ABL research programs, the use of genetic stock identification (GSI) techniques and coded wire tags (CWT), are currently utilized in monitoring and documenting stock origins of salmon bycatch in these fisheries. The objective of this work is to determine the stock origin of salmon bycatch in these fisheries. Does this project meet this objective and why? What other research could be conducted to address this objective?

The CWT data provides an excellent source of information for bycatch. However, it appears that many hatchery fish are not given CWT and in particular, the Japanese do not put CWT in any of their hatchery fish. As a result, the data presented were “expanded” to give an estimate of the total bycatch. This is a reasonable approach but it has a very large error, particularly when the number caught with CWT is low (and of course does not work for fish from hatcheries that do not use CWT).

As discussed above, to carry out GSI efficiently it is necessary to implement the array of microsatellite loci used at other labs. This array would give much higher resolution than allozyme data and provide stronger evidence to determine whether fisheries should be closed.

GSI can potentially be carried out on a much larger number of fish and identify fish that do not come from hatcheries using CWT. In addition, GSI may be focused on particular catches, in particular areas, or on particular fish. For example, a large proportion of chinook could be analyzed from areas where CWT indicate that endangered runs have been caught in past years or in a given catch.

ToR 1-E. The AFSC presently operates two permanent field stations in Southeast Alaska, at Little Port Walter(LPW) on Baranof Island and Auke Creek (AC) near the Auke Bay Laboratory. Research on a broad range of resource issues has been conducted for many years where each station, located on or near streams with healthy natural runs of anadromous salmonids, have experimental hatchery capabilities. Research at both stations has typically included cooperative involvement with other federal and state agencies, universities, and constituent groups. The review panel should provide input on the usefulness and relevance of research at these two stations in helping NOAA Fisheries develop a better understanding of the role salmonids play in regional North Pacific ecosystems and in helping to maintain healthy, viable salmon populations and their associated fisheries.

(OE&C) 5. The AFSC presently operates two permanent field stations in Southeast Alaska, at Little Port Walter(LPW) on Baranof Island and Auke Creek (AC) near the Auke Bay Laboratory. The stations provide long time series of data on salmon productivity, life history parameters, and climate. The objective of these time series is to add to our understanding of climate variability, biological productivity, and potential consequences of future climate change. Does this project meet this objective and why? What other research could be conducted to address this objective?

Above I discussed the research on genetics of chinook and steelhead at LPW. These studies are of very high quality and I would strongly support their continuation. In addition, the long term data set of salmonid and environmental data in Auke Creek is of great value. For example, the well documented correlation of earlier pink salmon migration and higher temperature is of great significance in understanding the impact of global warming on salmonids. Continued collection of these long-term data sets should be a high priority and their publication in peer-reviewed journals an important goal.

TOR #2: ***Three years ago, the NPAFC initiated BASIS (Bering-Aleutian Salmon International Survey), a yearly, basin-scale survey of the Bering Sea's pelagic ecosystem using survey vessels from Russia, Japan, and the USA. This international research program was developed by ABL scientists who continue to maintain a strong leadership role in this program. Although BASIS studies ostensibly address salmonid issues in the Bering Sea, research on forage fishes and the Bering Sea ecosystem have been key components of the national BASIS research programs. The review panel should provide input to the AFSC on the utility of BASIS research programs.***

The second Term of Reference pertains primarily to issues relating to BASIS, a north Pacific multi-lateral cooperative effort aimed at ecosystem studies and the applicability of those research programs towards ABL salmon research. As a geneticist I focused most of my efforts in answering genetics-related questions of ToR 1 and defer these ecologically-oriented research related questions to those qualified experts with whom I participated during this review.

Conclusions and Recommendations

I have reviewed the genetics and conservation biology aspects of the salmon-related research at ABL. Overall, there is some excellent research being carried out, particularly that on chinook and steelhead at Little Port Walter, the theoretical analysis of stock contributions, and the analysis of harvest on pink salmon in PWS. Other data sets, such as the long term salmonid and environmental data set at Auke Creek and the CWT analysis of bycatch, are valuable but apparently have not been published in peer-reviewed publications. The Genetic Stock Identification (GSI) program used in bycatch, illegal catches, and migration studies has depended upon allozyme data in the past. This program needs to adopt new molecular techniques, such as the standardized array of microsatellite markers being used elsewhere. In this effort, baseline data for microsatellite loci on a large number of populations, such as has been generated for allozyme data in the past, should be developed.

Overall, more support should be given to the GSI program to bring it up to current standards. Some new equipment is available and the new laboratory should help. This is an area that ABL could make an important contribution to a number of important salmon issues. Eight other labs currently are developing standard microsatellite loci and can analyze the array of 13 loci; ABL should become part of this group. Part of the problem at ABL is the low staff number in the fish genetics lab and there also seemed to be some hesitancy to embrace the use of these new markers.

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APPENDIX A

AFSC Salmon Research CIE Review

Draft Agenda and Panel Discussion Questions

Day	**Topic**	Duration (h)	Presenter
Day 1 8:30 am – 5:30 pm	**Introduction 8:30-10:30**	Welcome (15 min) Rules (10 min) Lab overview (AFSC) (20 min) Salmon: history (abundance, politics, research: build to WHY we are here NOW) (1/2 hour) Problems (1/2 hour): State management/Federal research/International Management Direction from AFSC on salmon management	Steve
	Ocean Ecology and Climate 10:45 – 5:30 *(Lunch provided)*		
	BASIS overview	0.5 h	Jack
	Ocean Ecology and Climate Question 1	2 h overview 10 min discussion 50 min answer questions 30 min	Jack
	Ocean Ecology and Climate Question 2	1-1/2 h overview 10 min discussion 40 min answer questions 20 min	Jack
	Ocean Ecology and Climate Question 3	1 h overview 10 min discussion 30 min answer questions 15 min	Jack
	No-host dinner 7:00 pm - TBA		
Day 2 8:30 am – 6:00 pm	SECM overview	½ h	
	Ocean Ecology and	1-1/2 h	Bill

	Climate Question 4	overview 10 min discussion 40 min answer questions 20 min	
	Ocean Ecology and Climate Question 5	1 h overview 10 min discussion 30 min answer questions 15 min	Bill
	Conservation Biology and Genetics 11:30 – 6:00 *(Lunch provided)*		
	Conservation Biology and Genetics Question 1	1 h overview 10 min discussion 30 min answer questions 15 min	Bill
	Conservation Biology and Genetics Question 2	1 h overview 10 min discussion 30 min answer questions 15 min	Bill
	Conservation Biology and Genetics Question 3	1 h overview 10 min discussion 30 min answer questions 15 min	Alex
	4 Conservation Biology and Genetics Question 4	1 h overview 10 min discussion 30 min answer questions 15 min	Jack
	Conservation Biology and Genetics Question 5	1 h overview 10 min discussion 30 min answer questions 15 min	Jack/Bill
	Dinner on own		
Day 3 8:30 am – 5:30 pm	Panel discussion *(Lunch provided)*	2-1/2	
	Panel followup questions with staff	1	

	Panel discussion and writeup	4	
	Closeout	½	
	TOTAL HOURS	24	

Ocean Ecology and Climate Questions

1. The Bering-Aleutians Salmon International Survey (BASIS) project examines the ocean ecology and climate of the Bering Sea. Trophic interactions occur between gadids, salmonids, and clupeids in the epipelagic ecosystem of the Bering Sea. An objective of this project is to understand how trophic dynamics affect distribution, abundance, growth, and condition of fishes of the epipelagic ecosystem of the Bering Sea. Does this project meet this objective and why? What other research could be conducted to address this objective?
2. Large-scale changes in the Bering Sea ecosystem have been attributed to climate changes, such as loss of sea ice and warmer sea temperatures. Another objective of BASIS is to understand how these changing ocean conditions and climate affect distribution, abundance, growth, and condition of fishes of the epipelagic ecosystem of the Bering Sea. Does this project meet this objective and why? What other research could be conducted to address this objective?
3. Climate and ecosystem indicators can be used to support an ecosystem approach to management. Examples of such indicators are time series of fish growth and abundance, zooplankton abundance, and episodic phytoplankton blooms. Another objective of BASIS research is to develop indicators that measure climate and ecosystem change in the Bering Sea. Does this project meet this objective and why? What other research could be conducted to address this objective?
4. The Southeast Coastal Monitoring (SECM) project examines the ocean ecology and climate of southeast Alaska. Research cruises include multiple time series of observations of epipelagic trawling and associated biophysical measurements in an important migration corridor for juvenile salmon. Other important species competing for the same resources include gadids, clupeids, and cetaceans. Objectives of this project are to develop an understanding of the trophic dynamics and ocean conditions of the epipelagic ecosystem of southeast Alaska and to compare the Southeast ecosystem with the Gulf of Alaska and the Bering Sea. Does this project meet this objective and why? What other research could be conducted to address this objective?
5. The AFSC presently operates two permanent field stations in Southeast Alaska, at Little Port Walter (LPW) on Baranof Island and Auke Creek (AC) near the Auke Bay Laboratory. The stations provide long time series of data on salmon productivity, life history parameters, and climate. The objective of these time series is to add to our understanding of climate variability, biological productivity, and potential consequences of future climate change. Does this project meet this objective and why? What other research could be conducted to address this objective?

Conservation Biology and Genetics Questions

6. Chinook salmon hatchery programs in Southeast Alaska, a region with a limited number of relatively small wild stocks of Chinook salmon, were developed to compensate for catch limitations imposed under US-Canada salmon treaty accords even though hatcheries in other areas have been identified as one significant cause of stock declines and ESA listings. ABL conducts research on two experimental hatchery stocks of Chinook salmon at a remote field station by making comparisons with multi-generations of hatchery fish and their wild founder counterparts that are unaffected by habitat loss, introductions of other fishes, or hatchery influences. The objective of this research is to understand if, how, and why changes in hatchery stocks differ from their wild founders and to help avoid pitfalls related to hatchery-caused declines in wild stocks. Does this project meet this objective and why? What other research could be conducted to address this objective?
7. The experimental conditions for steelhead research at ABL, broadly supported by cooperative participation with partners including NOAA scientists and others from the Pacific Northwest (including in some cases funding support), are not available in other regions. Unique genetic gene banks exist in Alaska such as 70 years of freshwater isolation of an anadromous-origin population of steelhead in a lake, which may be useful in ESA recovery programs in the Pacific Northwest where, for example, ten Evolutionarily Significant Units (ESUs) of steelhead are listed under ESA. The objective is to determine if these unique genetic gene banks can be used in the ESA recovery programs. Does this project meet this objective and why? What other research could be conducted to address this objective?
8. Large scale hatchery programs for pink salmon in Prince William Sound and chum salmon in Southeast recently have been implicated in declines in wild stock productivity for these species in those regions. ABL scientists participate and take leadership roles, along with university, state, and private sector partners, in related research programs in these regions, including retrospective modeling studies, to examine if and how these hatchery programs may be affecting productivity of wild stocks. One objective of ABL hatchery-wild stock interaction research is to better understand if hatcheries pose a threat to healthy wild stocks, including through ecosystem change. Does this project meet this objective and why? What other research could be conducted to address this objective?
9. Objectives of the salmonid portion of the fish genetics research unit at ABL, using allozyme, mtDNA, microsatellite DNA, and single nucleotide polymorphisim (SNP) techniques, are to: 1) identify discrete stocks or unique geographic groupings of salmon stocks caught in mixed stock fisheries; 2) make forensic determinations of stock origins of salmon caught in illegal fisheries; and 3) determine stock-specific migration pathways of salmon in oceanic waters. Does this project meet this objective and why? What other research could be conducted to address this objective?
10. A major management concern for NOAA Fisheries in Alaska is monitoring and documenting bycatch of prohibited species, including salmon, in large groundfish fisheries in the Gulf of Alaska and Bering

Sea. The numbers and stock origins of salmon bycatch become important issues for the management and continuance of the groundfish fishery as well as the well being of salmon stocks involved. Two ABL research programs, the use of genetic stock identification (GSI) techniques and coded wire tags (CWT), are currently utilized in monitoring and documenting stock origins of salmon bycatch in these fisheries. The objective of this work is to determine the stock origin of salmon bycatch in these fisheries. Does this project meet this objective and why? What other research could be conducted to address this objective?

Appendix B

STATEMENT OF WORK

Consulting Agreement between the University of Miami and Dr. Philip Hedrick

July 25th, 2005

General

Most salmon-related research at the Alaska Fisheries Science Center (AFSC) is currently conducted by scientists at the Center's Auke Bay Laboratory (ABL) near Juneau, Alaska. There is a long history behind Federally-based salmon research in Alaska waters dating to pre-statehood periods involving predecessor agencies of NOAA Fisheries (the original Bureau of Fisheries in the Department of Commerce and the Bureau of Commercial Fisheries in the Department of Interior). Following Alaska statehood in 1959, management of salmon fisheries within state jurisdictional waters became the purview of the State of Alaska. During the first 20 years of statehood, NOAA Fisheries (then the Bureau of Commercial Fisheries, Department of the Interior) supported state management with extensive basic research on many aspects of freshwater and early marine salmon life history. This research was conducted at the ABL and its five field stations located from Bristol Bay to Southeast Alaska. Outside of state waters and within the U.S. EEZ (between 3 and 200 miles), management of salmon fisheries remained a Federal responsibility and is now under the purview of the North Pacific Fishery Management Council (NPFMC). It should be noted that NOAA Fisheries spends over $50 million annually on salmon issues in the Pacific Northwest and about $3 million in Alaska, not counting pass through funds to states and other entities.

International treaties and accords requiring conservation and management of Pacific salmon on the high seas among North Pacific Rim countries have provided an additional Federal element requiring active participation in these arenas by NOAA scientists. As a result, research focused on Alaska salmon resources and related issues by NOAA Fisheries has continued to the present day and is centered on the overriding need for wise use and conservation of these resources plus the rationale that Pacific salmon, a vital keystone living U.S. marine resource, are a significant component of major North Pacific marine ecosystems in terms of total biomass and trophic interactions. AFSC salmon related research also involves a broad range of cooperative partnerships with international fora, academia, other Federal agencies, private sector, and industry constituents.

Four Programs are involved in salmon research at ABL; Marine Salmon Interactions (MSI), Ocean Carrying Capacity (OCC), Stock Identification and Analysis (SIDA) and Habitat Investigations (HI).

Marine Salmon Interactions (MSI) research involves two broad areas, Early Ocean Salmon (EOS) and Stock Enhancement Aquaculture (SEA). The EOS component is focused on early marine ecology of juvenile salmon and associated species. This research considers effects of biophysical parameters, climate fluctuations and inter-annual variability on the abundance and distribution of salmonids within various marine habitats and development of year-class strength leading to recruitment and ultimate adult production. EOS maintains a long-term time series of five research cruises conducted annually with repeated sequential sampling at 13 stations along a major migration corridor as young salmon move through different habitats from inshore to offshore waters. The SEA component of MSI is focused on enhancement technology, brood stock development, hatchery-wild stock interactions, and Endangered Species Act related research for listed stocks of salmonids. MSI operates and manages two field stations: Little Port Walter (LPW) Station on Baranof Island and Auke Creek (AC) Station near ABL. Both stations have well developed experimental hatchery capabilities for anadromous studies and operate permanent counting weirs on significant salmon streams. AC maintains a long-term time series of involving environmental and climatic data along with freshwater and marine survival profiles on 7 species of endemic salmonids. MSI also operates and co- manages a modern food habitats, stomach content, and plankton analysis laboratory, an image-analyses laboratory, and a coded-wire tag laboratory.

The Ocean Carrying Capacity (OCC) Program conducts research in the Gulf of Alaska and the Bering Sea to learn what marine conditions limit production of salmon and associated marine species. After the Ocean Regime Change of 1976-77, salmon populations in North America from central British Columbia northward throughout Alaska and in Asia increased to record levels. However, research at the Auke Bay Laboratory showed that by the mid-1980's most species of salmon had become significantly smaller in size and older in age: e.g., by the early 1990's chum salmon had become about 46% smaller in weight than they were in the early 1970's in both North America and Asia. These size and age changes suggested that carrying capacity for salmon in the North Pacific Ocean was limited under certain conditions. The OCC Program was initiated in 1995 to address these issues about carrying capacity. The research strategy for this Program has three major components: 1) research on the distribution and migration of juvenile, immature, and maturing salmon and associated marine species in coastal and offshore waters; 2) monitoring age and size at maturity and abundance of salmon populations; 3) retrospective studies on changes in age and growth of salmon populations. In 2002, the OCC Program became involved in a basin-scale ecosystem study of salmon and forage fish populations throughout the Bering Sea in collaboration with Japan and Russia. This study is called the Bering-Aleutian Salmon International Survey (BASIS) and is coordinated through the North Pacific Anadromous Fish Commission which is made up of the USA, Canada, Japan, Russia, and Korea.

Stock Identification and Analysis (SIDA) research at ABL is centered around the development of genetic markers to identify discreet stocks or geographic groupings of Pacific salmon and several rockfish species and to identify species of larval rockfish. Most of the research is directed at salmon issues which include identification of stocks or groups of stocks of salmon harvested in various mixed stock fisheries, caught as bycatch in U.S. groundfish fisheries, seized from illegal high-seas driftnetters by the U.S. Coast Guard, or migrating through the Bering Sea and the Gulf of Alaska. Techniques used are allozymes, mtDNA, microsatellite DNA and single nucleotide polymorphisms (SNP).

These markers are being developed in cooperation with U.S. State and Federal Agencies and universities, and fisheries agencies of Canada, Japan, Russia, and the Republic of Korea. SIDA researchers are also actively involved in the development of statistical methods for stock identification analyses, the most recent of which is a new Bayesian statistical technique that allows estimation of stock structure in mixed-stock samples without the knowledge of baseline information.

The Habitat Investigations (HI) Program emphasizes chemical and ecological processes that occur in a variety of habitats ranging from coastal, to tidal, to watershed habitats. Current research focuses on contaminants, habitat utilization, bioenergetics, and habitat restoration. Contaminants research quantifies threats from polycyclic aromatic hydrocarbons (PAH) to reproductive, nursery, and feeding habitats for various life stages of salmon, herring, and groundfish. Much of this work has focused on assessing the long term effects of the Exxon Valdez oil spill, but there is PAH research on other issues such as monitoring releases of pollutants from 2-stroke recreational water craft. Research on nearshore habitats is used to identify essential fish habitat, particularly by sensitive life stages of many different fish, and to identify the chemical or physical impacts of human development on quality of eelgrass and kelp bed habitats. Bioenergetic research assesses the nutritional value of forage species, including juvenile salmon, as measured by changes in lipid class, fatty acid, and caloric composition of these forage species. Such studies seek to evaluate how habitat quality changes seasonally and spatially by understanding how a prey organism allocates energy between growth, reproduction, and fat storage. Habitat restoration research focuses on restoring an urban salmon stream to a productive state.

The AFSC salmon research peer review will evaluate the relevance and appropriateness of ongoing research by AFSC scientists focused, at least partially, on Pacific salmon resources occurring throughout the Gulf of Alaska, Bering Sea, and adjacent waters. Due to differing life histories and varied migration patterns salmon involved in these marine waters originate not only from Alaska streams and lakes but also from Pacific Northwest states and other countries around the North Pacific Rim including Canada, Russia, Japan, China, and Korea. This CIE review should evaluate current salmon studies at AFSC, and, if needed, recommend changes in their scope and direction, along with suggested levels of funding and personnel to accomplish this research.

The AFSC salmon research review will require 3-4 nationally and internationally recognized authorities in one or more of the following disciplines: marine ecology, Pacific or Atlantic salmon biology, animal behavior, population dynamics, fisheries genetics, international fisheries treaties and accords, salmon hatchery issues, and freshwater and marine salmon habitat issues.

The AFSC will provide a detailed background document on current salmon-related research at AFSC/ABL along with a set of relevant papers, publications and documents of recent research results to support this review.

Terms of Reference

The terms of reference for the AFSC salmon research review are as follows:

TOR #1: The AFSC's primary research mission is to generate the best scientific data available for understanding, managing, and conserving living marine resources in Alaskan waters and the environmental quality essential for their existence. Primary species of interest are groundfish, crab, and marine mammal populations. Salmon are an important secondary species due to research responsibilities derived from international agreements. In addition, AFSC salmon programs receive direct funding from Congressional PPAs and NOAA research initiatives pertaining to ESA-related issues, the ecological role of salmon in the marine environment, and enhancement technology and impacts. The review panel should provide input on recommended directions in AFSC salmon related research in Alaska, and identifying appropriate levels of research directed at salmon management questions and at Alaskan ecosystem and habitat issues.

Specific questions to be addressed by the review panel in regards to this TOR include the following:

A. What applications of marine salmon research at AFSC best provide an understanding on the effects of climate/physical drivers that may cause changes in aspects of North Pacific ecosystems such as trophic food webs and forage fish populations?

B. Given that hatchery operations in the Pacific Northwest are identified as one of many causes for the decline in wild stock abundance (leading to multiple ESA listings), and given that Alaska, with generally abundant and healthy wild stocks also has a significant large-scale hatchery program, what level and types of hatchery-wild stock interaction studies are needed to address present and future Alaska salmon issues?

C. What GSI research is needed to support ecosystem research in the North Pacific Ocean and forensic or enforcement activities? Are the technical methods used at ABL appropriate for the task?

D. The North Pacific Anadromous Fish Commission (NPAFC), a five nation International Convention focused principally on salmon resources of the North Pacific Ocean, encourages coordinated and cooperative research by member parties in both Convention Area waters and adjacent territorial seas. As the NPAFC Science Plan calls for research focused on early marine life of salmon, how can ABL research on juvenile salmon best provide a better understanding of the role salmon play in various components of the North Pacific ecosystem?

E. The AFSC presently operates two permanent field stations in Southeast Alaska, at Little Port Walter (LPW) on Baranof Island and Auke Creek (AC) near the Auke Bay Laboratory. Research on a broad range of resource issues has been conducted for many years where each station, located on or near streams with healthy natural runs of anadromous salmonids, have experimental hatchery capabilities. Research at both stations has typically included cooperative involvement with other federal and state agencies, universities, and constituent groups. The review panel should provide input on the usefulness and relevance of research at these two stations in helping NOAA Fisheries develop a better understanding of the role salmonids play in regional North Pacific ecosystems and in helping to maintain healthy, viable salmon populations and their associated fisheries.

TOR #2: Three years ago, the NPAFC initiated BASIS (Bering-Aleutian Salmon International Survey), a yearly, basin-scale survey of the Bering Sea's pelagic ecosystem using survey vessels from Russia, Japan, and the USA. This international research program was developed by ABL scientists who continue to maintain a strong leadership role in this program. Although BASIS studies ostensibly address salmonid issues in the Bering Sea, research on forage fishes and the Bering Sea ecosystem have been key components of the national BASIS research programs. The review panel should provide input to the AFSC on the utility of BASIS research programs.

Specific questions to be addressed by the review panel in regards to this TOR include the following:

A. What is the potential for BASIS surveys to address current Bering Sea non-salmonid management and ecosystem research needs: what key management and scientific questions/hypotheses could be addressed by BASIS, either in its current form or through an augmented program?
B. How can the AFSC best utilize BASIS as part of its research mission in Alaska?

The report generated by the consultant(s) should provide recommendations addressing each of the terms of reference and specific questions stated in this statement of work.

Specifics

The consultant's tasks consist of the following:

1) Become familiar with the AFSC salmon research program and other pertinent literature.
2) Attend the salmon research peer review meeting in Juneau-Auke Bay, Alaska from July 11 – 14, 2005.
3) Develop a report based on the terms of reference for the review.
4) No later than July 28, 2005, submit a written report consisting of the findings, analysis, and conclusions (see Annex I for further details), addressed to the "University of Miami Independent System for Peer Review," and sent to Dr. David Die, via e-mail to ddie@rsmas.miami.edu, and to Mr. Manoj Shivlani, via e-mail to mshivlani@rsmas.miami.edu.

ANNEX 1: Contents of Panelist Report

1. The report shall be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report shall consist of a background, description of review activities, summary of findings (including answers to the terms of reference in this statement of work), and conclusions/recommendations.

3. The report shall also include as separate appendices the bibliography of all materials provided by the Center for Independent Experts and a copy of the statement of work.