Review of the "Salmon Habitat Matrix"

by
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Executive Summary

The objective of the present report was to review the salmon habitat matrix as developed and promoted by scientists from state and federal agencies, notably the National Marine Fisheries Service (NMFS). The matrix (as it relates to properly functioning habitat conditions for salmonid species in rivers and streams draining redwood forest ecosystems) was specifically identified in the Habitat Conservation Plan (HCP) developed by the Pacific Lumber Company (PALCO) for application in the company's holdings in northern California.

Regarding the specific choices of habitat metrics used in the matrix, these were well recognized variables that are important for ensuring good habitat conditions for salmonids. However, there were concerns regarding the values and thresholds of the different metrics, and criticisms over some obvious omissions in the matrix. For example, water temperature thresholds did not recognize the connectivity of all parts of the river system and the dependence of lower reaches on physical regimes upstream. The lack of clear, quantifiable target values for suspended sediments and turbidity and their impacts on salmon at different life-stages was a serious omission. There was a similar lack of quantifiable targets associated with the habitat indicators of refugia and off-channel habitats.

The most serious omission in the matrix was some measure of fish population response to the physical habitat variables. Unfortunately, the fisheries database is not as strong as the physical habitat information and this needs to be corrected if agencies are serious about conserving the populations of salmonids. Suggested parameters for inclusion were site-specific density estimates; size-at-age data for juveniles to compare between watersheds and years; smolt abundance, size and age; and the number and size of spawners. The relative scarcity of fish population data for streams in the region was surprising given the 'threatened status' for two of the species of concern.

As a result of such serious deficiencies, it was concluded that the matrix, in its present form, was inappropriate for ensuring the conservation needs of salmonids in coastal redwood streams. Several suggestions are offered to improve the situation. These include improved relatedness between physical habitat variables and biological responses, more quantification of fish population information, and the development of a truly integrated management plan for the threatened salmonid species in northern Californian streams – one requiring dialogue between stakeholders from all disciplines and sectors of society. Such a plan should incorporate timely, regional fish population data and regular assessments of the responses of aquatic biota to changes in habitat conditions.

Background and Description of Review Activities

In November 2000, I was contacted by Mr. M. Shivlani of the University of Miami's Independent System for Peer Review to review a Pacific salmon habitat matrix model. I agreed to the request and subsequently received various documents by mail related to the subject. My background in salmonid research adequately qualifies me to carry out the task at hand. I am a full professor at the University of New Brunswick, in Fredericton, NB, Canada, where I am cross-appointed in Biology and the Faculty of Forestry & Environmental Management. I have been studying the ecology of wild stream salmonids in central and eastern Canadian streams for >20years, much of it devoted to quantifying habitat use and impacts from land-use activity. Presently, I am the holder of a Canada Research Chair in River Ecosystem Science, and the Meighen-Molson Professorship for Atlantic Salmon Research. I am the Director of the Canadian Rivers Institute as well as the head of the Catamaran Brook Habitat Research Project, a multi-disciplinary research project started in 1990 to quantify the impacts of forestry activity in a salmon stream ecosystem.

The present review is a reflection of reading numerous articles and reports (see list in Appendix I) related to the salmon habitat matrix (hereafter referred to as "the matrix") and coastal redwood ecosystems, and a 4-day site visit to northern California, November 27-30, 2000. Indeed, it was the site visit that proved most valuable in my opinion, as this allowed me to see, first-hand, the systems and topics of concern. More importantly, the visit permitted the panel of reviewers to conduct interviews and to discuss the issue(s) with many individuals, of varying backgrounds and expertise related to the matrix, forestry activity in the region (and PALCO lands in particular), and biophysical habitat conditions in local catchments. It should be noted that, in every case, individuals were extremely forthcoming with information. However, any opinions and comments offered in this review are strictly the views and interpretation of the author, who takes full responsibility for any inaccuracies.

Objective

The objective of the present report was to review the salmon habitat matrix as developed and promoted by scientists from state and federal agencies, notably the National Marine Fisheries Service (NMFS). The matrix (as it relates to properly functioning habitat conditions for salmonid species in rivers and streams draining redwood forest ecosystems) was specifically identified in the Habitat Conservation Plan (HCP) developed by the Pacific Lumber Company (PALCO) for application in the company's holdings in northern California. Although *not a direct review of the HCP*, the relatedness of the matrix and the HCP means that the present review of the salmon habitat matrix has implications regarding the appropriateness of the PALCO HCP.

Review

As a first step in the review, I have attempted to answer the following questions as posed in the Statement of Work

1. *Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs of threatened and candidate salmonid species ?*

I am in general agreement with the choice of habitat metrics used in the matrix. These are typically recognized habitat variables that are important for ensuring good stream habitat conditions for salmonids.

I have some concerns regarding the values and thresholds of the different metrics as well as suggestions for other metrics. These are discussed below (please see Questions 2, 3 and 4).

2. *Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs of threatened and candidate salmonid species in coastal redwood systems ?*

Temperature - the values seem logical and are based on findings in the literature for the salmonid species in question. However, what is the relative basis for these values/thresholds? In order to be most meaningful, the temperature regime (optimal and maximum weekly average temperature [MWAT]) in a given stream needs to be related to some control or reference condition. As presented in the matrix, headwater streams with MWAT 14ºC could conceivably be 'allowed' to increase by 2.7ºC in the study area, and still be below the MWAT threshold of 16.8ºC. This could have important implications on the biota depending on the extent of the *thermal change*. Moreover, such a thermal increase in the headwaters, although within the tolerable range for the study streams (headwaters) can have impacts in the lower reaches and estuary of a river system that may be intolerable for resident fishes and especially anadromous species that need to move through these reaches (e.g. reduction or loss of smolt' window' - see McCormick et al. 1998). Such a temperature threshold range needs to recognize the connectivity of all parts of the river system and the dependence of lower reaches on physical regimes upstream. Perhaps a way around this potential problem is to relate threshold values to some control stream of similar size (order) nearby but relatively unaffected by land use activity (e.g. one of the streams in the National Parks' lands). Alternatively, a threshold range of *permissible temperature change* could be used - one that recognizes the potential for impacts of a temperature increase elsewhere within the catchment. This recognition is important because salmonid (habitat) conservation needs to consider the entire river ecosystem, not only those areas within PALCO holdings

Sediment / Turbidity - The potential impacts from sedimentation and turbidity to streams and their biota in northern California (and in PALCO lands in particular) were clearly demonstrated during the presentations by B. Trush and S. Flanagan (NMFS office, November 27, 2000), and also by the field trip (November 29, 2000) to the Eel River basin where evidence of severe aggradation and elevated suspended sediment

concentration were observed in Jordan Creek (from 1997 storms) and Cuneo Creek (extreme case of mass wasting).

By all accounts, this indicator is a major concern in terms of affecting salmonid habitat in northern California streams. The problem is the relative lack of quantification. Much of the information in the matrix associated with the "properly functioning" values for this indicator are qualitative in nature and, therefore, difficult to assess in terms of their ability to ensure conservation goals. Attachment B for this matrix indicator shows a strong bias for quantifying physical habitat features (pool volume, substrate permeability, scour, etc.) and sediment values associated with salmon spawning gravels and egg/alevin microhabitats but little else. That measures of residual pool volume (V*) and pebble counts (D50) are sufficient to quantify sediment impacts to juvenile and adult rearing habitat is simplistic at best and potentially misleading. Further, the reliance on pebble counts confuses the distinction between bedload and suspended loads (see comments by Montgomery 1998, p. 11).

I agree with the inclusion of parameters such as V*, Fredle Index, GMD and % fines. The lack of similarly strong quantifiable target values for suspended sediments and turbidity (*these are different!)* and their impacts on salmon at different life-stages is a serious omission. Bill Trush, during his excellent presentation on November 27, 2000, made a strong case for the potential importance for quantifying suspended sediment as it may influence salmon performance and population dynamics. Most likely, directed research on this topic will be necessary before reliable targets can be associated with this parameter.

Hot spots/Refugia and Off-channel Habitats - I applaud the inclusion of these indicators of habitat quality. Such locations are often critical for population survival, and are often referred to as "bottlenecks" to increased production. The problem is identification and quantification of these habitats. Recognition of such refugia is often limited by the short and unpredictable temporal and spatial scales that identify such habitats, and by the thorough understanding and observational data for a watercourse or fish population. For

example, a “hot spot’ during one stressful event may not be similarly used during another event. Groundwater discharge areas provide important thermal refugia for juvenile salmonids (Nielsen et al. 1994; Cunjak 1996) but not always of equal value, often depending on the chemical characteristics of the groundwater. Finally, the means of identifying, measuring and quantifying off-channel habitats were unclear.

3. *Which metrics are the most appropriate for the assessment, monitoring and adaptive management of aquatic candidate salmonid species in coastal redwood systems?*.

Temperature, sediment/turbidity, water quality, substrate quality, LWD, pool quality, off-channel habitat and refugia are *appropriate parameters for the measurement of suitable physical habitat* for salmonid fishes. In addition, several other metrics should be included if a matrix is to be adopted, and if catchment conditions are appropriate:

Substrate Roughness and Interstitial Space - As a measure of substrate quality and condition (degree of embeddedness), especially as it may be negatively impacted by sedimentation, this parameter is becoming increasingly popular amongst aquatic biologists studying habitat quality of fishes (including salmonids) and benthic macroinvertebrates. High roughness (low embeddedness) typically translates to higher rearing densities of juvenile salmonids and benthic fishes (e.g. sculpin) that use rock crevices and voids, often during the day at low winter temperatures (Cunjak 1996). Relatively warm winter temperatures and the high mobility of streambed particles especially during the rain-dominated winter hydrographs of northern California may reduce the importance of interstitial spaces as overwintering habitats for juvenile salmonids in this region. However, the habitat complexity provided by this feature (at micro- and meso-habitat scales) likely contributes to higher stream productivity for macroinvertebrates, and would still provide important cover for sculpins, and for young-of-the-year salmonids at seasons other than winter. Several suggestions for measuring this parameter were given by Peterson et al. (1992).

Interstitial water quality - some recent research performed by Massa (2000) on brown trout (*Salmo trutta*) in streams in Brittany, France, suggested that the water quality in interstitial spaces in redds can severely impact egg/alevin survival, particularly in streams receiving sediments with moderate to high organic loading. Specifically, dissolved oxygen and nitrate-nitrite concentrations in interstitial water were measured.

Thermal stratification in pools - inclusion of such a measure of pool quality would be useful in determining the potential for thermal refugia in Class I and II streams during periods of high temperature stress. For more information on the relevance of this parameter, see the papers by Nielsen et al (1994) and Matthews et al (1994), both of which deal with salmonid streams in California.

In my opinion, one of the glaring omissions in the matrix is some measure of the *response of the fish species* of concern. Ideally, I would like to see parameters that measure fish population responses (and not only salmonids) such that I could relate these to physical habitat conditions. Watershed-specific parameters such as juvenile abundance that could be extrapolated from site-specific density estimates (e.g. by electrofishing), size-at-age data for juveniles to compare between watersheds and years, smolt abundance, smolt size and age, number and size of spawners, emergence timing and estimates of egg survival are examples of the data that would greatly enhance the value of the matrix. The relative scarcity of fish population data for streams in the region was surprising given the 'threatened status' for two of the species; generally, the data are 'spotty or anecdotal. Some of these data are available for nearby stream populations (e.g. research on juvenile coho salmon in Prairie Creek by E. Bell, Stillwater Sciences). I would strongly recommend that this situation be rectified, perhaps by concentrating on several "index rivers", inside and outside PALCO lands (such as Prairie Creek and Freshwater River, respectively) to begin accumulating a biological reference database to match that for physical habitat conditions.

4. *How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression?*

Most of the habitat parameters identified in the matrix are "in-channel" or riparian measures. If a problem is noted as a result of some land-based condition (e.g. mass wasting), it will already be too late to take preventative action for the conservation of aquatic biota. Hence, it is important to have parallel monitoring activities throughout the catchment (up slope) especially in areas identified as high risk of erosion, mass wasting, etc.

During the review process, especially during my visit to California, I constantly found myself asking questions about historical and recent fish population responses to various physical conditions and habitat disturbance. Unfortunately, the fisheries database is not as strong as the physical habitat information. This needs to be corrected if agencies are serious about conserving the populations of salmonids, some of which are already identified as threatened. This does not require a "reinventing of the wheel". Many other regions in Canada and the United States and Europe have regular and effective assessments of the population status of fishes in river systems. Many of these programs are (federal) government-managed and regulated but with substantive input from state/provincial, private, native and university sectors. Given fiscal restraints and the common interest by various stakeholders in an issue such as species conservation, such an integrated approach is a sensible avenue towards addressing this problem.

This question of linkages is critical. It also implies the assessment of cumulative effects as to how they might impact on salmonid populations. Given the existing matrix structure, such assessment is difficult. Therefore, it may be best to set up a framework that links habitat variables/thresholds and the consequent biological response (e.g. fish abundance or performance) over variable temporal and spatial scales, especially with respect to "bottleneck" conditions (e.g. summer temperature extremes, spawning habitat, emergence periods). This could provide the means for being able to adapt the matrix to limiting and dynamic conditions within watersheds.

Communication and sharing of information is probably the best means to resolving the dilemma of linking instream conditions to watershed scale processes. A great example of inter-disciplinary information exchange is the publication of the proceedings of the Caspar Creek conference (Ziemer 1998). If most people, regardless of discipline or expertise, were aware of what others were doing, the opportunities for linking landscape processes to instream metrics would be greatly improved. Simple in theory, such action is admittedly more difficult to put in practice. Albeit brief, my experience in northern California clearly impressed upon me the wealth of expertise that exists in a relatively small geographic area. Also impressive was the genuine interest of many individuals to resolve the problem and conserve the ecosystems in those magnificent redwood forests. All the components for success are there; so is much of the necessary information, and the common problem around which people can focus. Perhaps a workshop format, similar to that used for the Caspar Creek project, but centered on the theme of salmonid conservation could initiate the communication process.

Criticisms and Recommendations

Having dealt with the specific questions posed in the Statement of Work, I feel that it is important to present my impressions of the appropriateness of the matrix. In general**, I feel that the matrix is inappropriate for ensuring the habitat and conservation needs of salmonids in coastal redwood streams**. There are several reasons for this opinion:

a) Lack of relatedness between habitat metrics and biological abundance/performance, especially of fishes - i.e. how does one assess the population *response by salmonids* in the streams? There appears to be an implicit assumption that "properly functioning habitat conditions" (the goal of the matrix) somehow equates to a healthy salmonid population with no attempt at assessing abundance or response by the individual/population in relation to the habitat condition(s). This assumption is reminiscent of the phrase "build it and they will come". For example, ensuring that cool water temperatures are available (according to the matrix) in pools does not necessarily translate into fish habitat use by threatened salmonids or other resident species (Matthews et al. 1994), even during

temperature stress (Nielsen et al. 1994). Other complicating variables may preclude such use (e.g. low dissolved oxygen) or the role of cool water in deep pools may serve to cool localized stream temperatures rather than providing thermal refugia per se (Matthews et al. 1994).

b) There is a general lack of quantitative data on fish populations whereas the physical data are comparatively better in terms of available data. Indeed, the matrix is strongly biased to developing an optimal set of physico-chemical conditions for salmonids but with no means for testing the biological relevance of these conditions and the subsequent response by salmonids and the other aquatic biota to these conditions. This seems an obvious flaw as the "properly functioning habitat condition… " [as identified by the variables in the matrix] " … is essential for the long term survival of anadromous salmonids"(B. Condon, presentation, Nov. 27, 2000, Arcata, CA) . A similar point (lack of analysis of fish numbers in order to evaluate relevance of proposed measures of PALCO HCP) was raised by Dr. Montgomery in his 1998 critical review of the HCP and matrix. Similarly, the October 1998 review by G. Pess noted the lack of data on fish production that would limit the ability of the HCP to adequately protect habitat because it was not possible to identify limiting factors, or "bottlenecks" in the system. In my opinion, this is a major shortcoming of the matrix if its intention is to ensure habitat and conservation needs of fish species.

c) There is also an obvious lack of exchange of information between disciplines and organizations with similar interests (e.g. state agencies, NMFS, university, environmental groups).

d) The matrix treats the habitat metrics as isolated factors in space and time with no means of quantifying the relatedness of factors (despite the acknowledgment of inter-relatedness of habitat variables at the start of the matrix document!), or of the continuum that links all components in the river ecosystem. Such a limitation was also noted by B. Condon during his description of the matrix to the review panel (November 27, 2000). The paper by Nielsen et al. (1994) provides a good case for the importance of

understanding temporal variation in habitat use by salmonids. The authors described the use of thermally stratified pools in northern California streams during periods of high ambient temperature thus noting the importance of the availability of cool water refugia. However, Nielsen et al (1994) also stress that "…field surveys of fish habitat made at one time of the year under one thermal condition ignore the critical temporal element…" that such pools play in streams and how different species and age-classes use the refugia .

e) Cumulative impact assessment on environmental matters is recognized by most scientists as an important tool in understanding biological response to environmental disturbance(s). Admittedly a difficult concept to study and quantify, the matrix fails to incorporate such complex relations between variables, and the responses by fishes and other aquatic biota.

Personal Reflections and Conclusion

I was most impressed with the candor and willingness of all individuals (to whom the review panel spoke) to provide information related to the matrix, the HCP, the forestry industry, regional environmental conditions. However, I can't help but feel that the conclusion was inevitable. Although I cannot speak for my panel members, it was my distinct impression that there already existed a general dissatisfaction with the application of the matrix for use in the HCP. Whether it was forest company personnel, environmental consultants, academics, or government professionals (state and federal), the feeling seemed to be a lack of confidence in the matrix to achieve its goal of conservation for salmonids in streams of redwood ecosystems. Much of the literature reviewing the habitat matrix and PALCO HCP was generally negative. So, why bring in a review panel of experts who come from distant regions to tell you what already seems obvious? Perhaps for such a politically charged topic as redwood harvesting guidelines and threatened salmon species, reviewers were needed who were viewed as truly neutral and, so, from far away.

From the many documents that I have read, and subsequent discussions with other scientists familiar with the matrix, the consensus has been that the matrix is flawed and not worth the effort to revise its inadequacies. Consequently, I often found myself asking the same question. That is, are we better off using a different approach to achieving the conservation goals or will a revised matrix serve the purpose? My conclusion, interestingly enough, is the same one I reached in late November after several days in Arcata - the matrix is inadequate and not easily salvageable. In my opinion, conservation of the threatened salmonid species in northern Californian streams within private forest lands would be better served with a management plan that was truly integrated among disciplines and stakeholders. Such a plan should incorporate timely, regional fish population data and regular assessments of the responses of aquatic biota to changes in habitat conditions.

APPENDIX I

SALMON MATRIX REVIEW-RELATED LITERATURE

1. USDA (Forest Service Research/National Forest System). March 1993. Visibility assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest: The report of the Scientific Analysis Team. Appendix 5-K.

2. Armour, Carl L. December 1991. Guidance for evaluating and recommending temperature regimes to protect fish: Instream Flow Information Paper 28. Biological Report 90 (22): 13 pp.

3. Brungs, W. A., and B. R. Jones. May 1977. Temperature criteria for freshwater fish: Protocol and procedures. Environmental Research Laboratory/ Office of Research and Development/USEPA.

4. Martin Fox, Muckleshoot Indian Tribe Fisheries Department. June 1994. Memo to CESC, CMER concerning the revisions to the WSA Fish Module Diagnostic Matrix and LWD assessment.

5. Lotspeich, F. B., and F. H. Everest. January 1981. A new method for reporting and interpreting textural composition of spawning gravel. Research Note PNW-369. Pacific Northwest Forest and Range Experiment Station/Forest Research/USDA.

6. Burns, J. W. 1970. Spawning bed sedimentation studies in Northern California streams. California Fish and Game 56(4): 253-270.

7. Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams, IN Influences of forest and rangeland management on salmonid fishes and their habitats. AFS Special Publication 19: 83—138.

8. Chapman, D. W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117 (1): 1-21.

9. North Coast Regional Water Quality Control Board. August 1993. Testing indices for cold water fish habitat.

10. Peterson, N. P., Hendry, A., and T. P. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: Some suggested parameters and target conditions. Center for Streamside Studies, University of Washington, Seattle, WA.

11. Nakamura, F. and F. J. Swanson. 1993. Effects of coarse woody debris on morphology and sediment storage of a mountain stream system in western Oregon. Earth Surface Processes and Landforms 18: 43-61.

12. Bilby, R. E., and J. W. Ward. 1989. Changes in characteristics and function of woody debris with increasing size of streams in western Washington. Transactions of the American Fisheries Society 118: 368-378.

13. Lisle, T. E., and S. Hilton. April 1999. Fine bed material in pools of natural gravel bed channels. Water Resources Research 35 (4): 1291-1304.

14. Keller, E. A., and W. N. Melhorn. May 1978. Rhythmic spacing and origin of pools and riffles. Geological Society of America Bulletin 89: 723-730.

15. Grant, G. E. , Swanson, F. J., and M. G. Wolman. March 1990. Pattern and origin of stepped-bed morphology in high-gradient streams, Western Cascades, Oregon. Geological Society of America Bulletin 102: 340-352.

16. Nawa, R. K., and C. A. Frissell. 1993. Measuring scour and fill of gravel streambeds with scour chains and sliding-bead monitors. North American Journal of Fisheries Management 13: 634-639.

17. Valentine, B. E. 1995. Stream substrate quality for salmonids: Guidelines for sampling, processing, and analysis: January 4, 1995 Draft. CA Department of Forestry and Fire Protection/Coast Cascade Regional Office, Santa Rosa, CA.

18. California Department of Forestry and Fire Protection. January 1998. California Forest Practice Rules. CA Department of Forestry and Fire Protection.

19. FAX Transmission from Protected Resources Division, NMFS, to Stillwater Sciences. June 11, 1999.

20. USDA- Forest Service, Pacific Southwest Division. June 1995. Forest inventory and analysis user's guide. USDA/Forest Service Region 5.

21. Jimerson, T. M. et. al. DATE? A field guide to the Tanoak and the Douglas-fir plan associations in northwestern California. (Partial copy, 2 pages showing log characteristics for seal stages in the Douglas-fir series)

22. Ganey, J. L., and W. M. Block. 1994. A comparison of two techniques for measuring canopy closure. WJAF 9 (1): 21-23.

23. Richter, D. J. February 1993. Snag resource evaluation (A literature review). Environmental Services Division Administrative Report #93-1. California Department of Fish and Game Timber Harvest Assessment Program.

24. D. J. Richter, CA Department of Fish and Game. October 1994. Memo to Bill Condon, CA Department of Fish and Game, regarding snag/wildlife tree operational procedures – habitat team assignment.

25. USDA/Forest Service/Northern Region. DATE? Stream reach inventory and channel stability evaluation. USDA/Forest Service/Northern Region.

26. Veirs, S. D. 1996. Ecology of the coast redwood, IN The proceedings of the conference on coast redwood forest ecology and management, June 18-20, 1996, Humboldt State University, Arcata, CA, pp. 9-12.

27. O'Dell, T. E. 1996. Silviculture of the redwood region: An historical perspective, , IN The proceedings of the conference on coast redwood forest ecology and management, June 18-20, 1996, Humboldt State University, Arcata, CA, pp. 15-17.

28. Scientific Review Panel. June 1999. Report of the Scientific Review Panel on California forest practice rules and salmonid habitat. Resources Agency of CA/NMFS, Sacramento, CA.

29. Nolan, K. M., Kelsey, H. M., and D. C. Marron. 1995. Summary of research in the Redwood Creek Basin, 1973-83, IN Geomorphic processes and aquatic habitat in the Redwood Creek Basin, northwestern California, pp. A1-A5. USGS Survey Professional Paper 1454, US Government Printing Office, Washington, DC.

30. Gregory, ?, and ? Bisson. DATE? MISSING TITLE, IN Pacific salmon and their ecosystems: Status and future options, eds. Stouder, Bisson, and Naiman, pp. 278-314. Chapman and Hall, New York.

31. Naiman, R. J, et. al. DATE? Elements of ecologically healthy watersheds, IN Watershed management: Balancing sustainability and environmental change, Naiman, ed., pp. 128?-188. Springer-Verlag, New York.

32. Bisson, P. A., et. al. DATE? Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest river systems. IN Watershed management: Balancing sustainability and environmental change, Naiman, ed., pp. 188-232. Springer-Verlag, New York.

33. Public/Private Comments on Matrix for Pacific Lumber HCP (INCLUDES SEVERAL COMMENTS)

34. NMFS Southwest Region. March 1997 Aquatic properly functioning condition matrix, aka species habitat needs matrix, March 20, 1997 work-in-progress for the Pacific Lumber Company Habitat Conservation Plan.

35. NMFS Environmental and Technical Services/Habitat Conservation Branch. August 1996. Making Endangered Species Act determination of effect for individual or grouped actions at the watershed scale. NMFS.

36. Habitat Conservation Plan for the Properties of the Pacific Lumber Company, Scotia Pacific Holding Company, and Salmon Creek Corporation, February 1999.

Other Pertinent literature used in the development of this report

37. Cunjak, R.A. 1996. Winter habitat of selected stream fishes and potential impact from land-use activities. Can. J. Fish. Aquat. Sci. 53 (Supplement 1): 267-282.

38. Massa, F. 2000. Sédiments, physico-chimie du compartiment interstitiel et développement embryo-larvaire de la truite commune (*Salmo trutta*): Étude en milieu naturel anthropisé et en conditions contrôlées. PhD. Thesis, Institut National Agronomique de Paris Grignon, Mention Sciences de l'Environnement. 199p.

39. Matthews, K.R., N.H. Berg, D.L.Azuma, and T.R. Lambert. 1994. Cool water formation and trout habitat use in a deep pool in the Sierra Nevada, California. Trans. Amer. Fish. Soc. 123: 549-564.

40. McCormick, S.D., R.A. Cunjak, B. Dempson, M.F. O'Dea, and J.B. Corey. 1999. Temperature-related loss of smolt characteristics in Atlantic salmon (*Salmo salar*) in the wild. Can. J. Fish. Aquat. Sci. 56: 1649-1658.

41. Montgomery, D.R. 1998. Comments on the PALCO HCP, Public Review Draft, November 12, 1998: 23p.

42. Nielsen, J.L., T.E. Lisle, and ZV. Ozaki. 1994. Thermally stratified pools and their use by steelhead in northern California streams. Trans. Amer. Fish. Soc. 123: 613-626.

43. NMFS Southwest region. 1997 (March). Aquatic properly functioning condition matrix, aka species habitat needs matrix, March 20, 1997 work in progress for the Pacific Lumber Company Habitat Conservation Plan.

44. Pess, G. 1998. Comments on Volume IV - PALCO HCP, Public Review Draft July 1998: 23p.

45. Ziemer, R.R. (editor) 1998. Proceedings of the conference on coastal watersheds: the Caspar Creek story; 6 May, 1998, Ukiah, CA. Gen. Tech. Rep. PSW-GTR-168. Albany, CA:Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, 149p.

Appendix II
Selected communications that were useful in the development of this report

1. November 27, 2000 presentations to the review panel, NMFS building, Arcata, CA
    - Bryant, G. (NMFS). ESA listing of fish species in northern California
    - Clancy, J. (NMFS). The PALCO HCP
    - Condon, W. (CA Fish & Game). Role of the matrix in the PALCO HCP
    - Flanagan, S. (NMFS). Watershed Analysis; surficial geology of PALCO lands
    - Trush, W. (McBain & Trush). Sediments in streams and fish responses
    - Kline, R. (National park Service). Hydrology and LWD in streams

2. November 28, 2000 - field visit to Prairie Creek catchment and discussions with fish biologist Ethan Bell about research on salmonid ecology.

3. November 29, 2000 - personal interviews
    - Tauzer, M. (NMFS) - hydrologist
    - Madej, M. (USGS/BRD) - geologist
    - Kramer, S. (Stillwater Sciences) - biologist

4. November 30, 2000 - personal interview
    - Reid, L. (Redwood Sciences Lab)- geomorphologist

5. November 30, 2000 - field trip to Little River catchment, Simpson forest lands; discussions with 2 company personnel (Nick ? and Matt?)

STATEMENT OF WORK

Consulting Agreement Between the University of Miami and Richard A. Cunjak

January 10, 2012

General

In March 1997, federal and state agencies developed an aquatic matrix for the Pacific Lumber Company Habitat Conservation Plan (hereafter "salmon matrix"). The matrix puts forth a condition for the landscape which has been determined to be properly functioning in order to meet the habitat needs of anadromous salmonids and other aquatic species in northern California on Pacific Lumber Company properties in Humboldt County.

Consultants shall need to address the following questions for the salmon matrix review:

1. Are the metrics used in the matrix appropriate for assessing aquatic and associated riparian habitat conditions to meet the needs for threatened and candidate salmonid species? If not, which metrics would be appropriate and at what landscape scales?

2. Are the values provided for the metrics appropriate for assessing aquatic and associated riparian habitat condition to meet the needs of threatened and candidate salmonid species in coastal redwood systems? If not, which values would be appropriate and at what landscape scales?

3. Which metrics are the most appropriate for the assessment, monitoring, and adaptive management of aquatic candidate salmonid species in coastal redwood systems?

4. How should in-stream and riparian metrics be functionally and practically linked with upslope and watershed scale processes that, in part, determine their expression?

Specific

The consultant's duties shall not exceed a maximum total of three weeks- several days for document review, a 4-day meeting, and several days to produce a written report of the findings. Please note that the report produced must be based on the consultant's individual opinions of the science in his area of expertise and not that of the group; thus, no consensus report shall be produced.

The itemized tasks of the consultant include:

1. Reading and analyzing the relevant documents provided to the consultant;

2. Participating in a 4-day meeting with the other consultants and NMFS officials in Arcata, CA, from November 27-30;

3. No later than January 15, 2001, submitting a written report of findings, analysis, and conclusions. The report should be addressed to the "UM Independent System for Peer Reviews, " and sent to Dr. David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu).

Signed_____ Date_____

ANNEX I: REPORT GENERATION AND PROCEDURAL ITEMS

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

2. The main body of the report should consist of a background, description of review activities, summary of findings, and conclusions/recommendations.

3. The report should also include as separate appendices the bibliography of materials provided by the CIE and the center and a copy of the statement of work.

4. Individuals shall be provided with an electronic version of a bibliography of background materials sent to all reviewers. Other material provided directly by the center must be added to the bibliography that can be returned as an appendix to the final report.

Please refer to the following website for additional information on report generation:
http://www.rsmas.miami.edu/groups/cimas/Report_Standard_Format.html

BUDGET

1. Salary ($600 per day for 21 days)	$12,600
2. Plane fare (Fredericton, Canada to Arcata, CA)	$1,900 (estimated)
3. Lodging (November 26-December 1: 5 nights)	$750
4. Meals ($30 per diem for 6 days)	$180
5. Car rental ($50 for 6 days)	$300
6. Additional transportation	$200
TOTAL	$15,930