"Many of the things that must be done are little things - small things each citizen can do...things little in themselves, but vital, urgent, and far-reaching in cumulative results. Therefore, the matters here discussed are not to be dismissed lightly as the concerns of scientists, engineers, and government alone. Every citizen must understand the problems and play a part in the solution"

PERSON, 1935

CONCLUSIONS

Native salmon and trout are an important symbol of our connection with the natural landscape of the Pacific Northwest (PNW). What has been said of ecosystems in general is also true for salmon and their ecosystems; they are probably more complicated than we will ever be able to fathom completely. It is true that natural systems are inherently complex and dynamic. No matter how long we study them and how much we learn, there will always be some degree of uncertainty in our understanding of these systems. However, if we are to save our salmonid resources, we will be required to deal with nature as it is, with all its complexities and uncertainties. Saving salmon will require us to try to understand them and their habitats in new ways. Salmon are not predictable parts of a mechanistic system that we can manipulate for predictable results. We do know for certain that the natural ecosystems of the PNW are able to support a diverse and abundant community of organisms, including native salmonids.

Therefore, from both a scientific and common sense perspective, it is logical that we should make conservation of the remaining properly functioning, natural ecosystems a high priority in the overall salmon recovery strategy. This is the basic premise behind the salmonid refugia concept. Protection of these ecosystems as refugia is an excellent first step in the overall protection of native salmonids. The principles of *ecosystem management* should guide land-use activities.

The refugia concept is built on the ecological principle that protecting existing high quality salmon habitats is essential to the long-term survival of salmon. This is not the only action needed, but without conservation or restoration actions to safeguard these areas it may not be possible to recover salmon populations. Moreover, it will be much more expensive, and perhaps infeasible in many respects, to restore high-value habitats should they be further damaged. Long-term protection will require a partnership with the landowners and creative approaches tailored to the local circumstances. In many cases, the priority habitats identified in the assessment only remain intact because of the good stewardship of existing landowners. This history of good stewardship needs to be recognized and supported. In areas where stewardship is lacking or has been poor, public outreach and education should be emphasized to help improve long-term stewardship.

What is also true about our aquatic ecosystems is most are in a degraded condition as a result of many years of abuse and neglect under our stewardship. Salmonid depletion is nearly always the result of cumulative stresses on various parts of its life cycle in freshwater, estuarine-nearshore areas, and in the ocean. Many of these stressors are natural, but many more are the direct of indirect result of human activities. Habitat degradation is not the only stress, but it is one of the most significant in many situations. In a functional, naturally resilient ecosystem, stresses are absorbed with little significant change in ecosystem structure or function. However, as stresses accumulate and intensify,

the natural resiliency and resistance of the ecosystem is gradually degraded or lost altogether. At some point, as more stress is added, the cumulative impacts become too great and the ecosystem begins to unravel or even collapse. This is the case with many of our rivers and streams that historically supported diverse and productive salmonid populations.

As was discussed earlier, data utilized in the preparation of this report include watershed analysis reports compiled by natural resource agencies, formal habitat inventories or studies specifically directed at evaluating fish habitat, other watershed data not specifically associated with fish habitat evaluation, and the body of scientific literature related to salmonid conservation. In addition to scientific literature reviewed, the data and observations used in this report are primarily based on the collective experience of local biologists and ecologists that are actively working in the freshwater drainages and marine nearshore habitats of the study region and have a firsthand knowledge of the watersheds of interest. Although there are a significant number of past studies and reports on these watersheds, a large number of salmonid related "data gaps" remain, which will require additional detailed watershed research and assessment. This is especially true of the nearshore environment, which we are just beginning to fully understand. The available data indicate several common problems throughout the study region. These include (in no specific order):

- Natural stream ecological processes have been significantly altered due to the cumulative effects of watershed land-use practices and human encroachment into the stream-riparian ecosystem.

- There has been a significant shift in the natural hydrologic regime of many watersheds, especially those undergoing urbanization. This is characterized by increases in peak flow frequency, duration, and magnitude due to increased stormwater runoff from lands that have been converted from native forest and wetlands to developed landscapes dominated by impervious surfaces.

- Streambed stability and spawning gravel quality have been degraded by high stormflow scour and fine sediment deposition. Major fine sediment sources include logging roads, construction sites, and agricultural fields.

- Stream channel morphological changes have resulted from direct alterations such as agricultural channelization or floodplain diking. In addition, streambank erosion has increased in frequency and extent due to higher stormflows, loss of natural vegetation cover, and subsequent streambank armoring.

- There is a general lack of adequate large woody debris (LWD) in streams, particularly large, stable coniferous "key" pieces that are critical to forming pools, providing cover for juvenile fish, retaining organic matter, and maintaining instream habitat complexity. In addition, there is a general lack of adequate, high-quality rearing habitat (pools) for juvenile salmonids and the lack of deep "holding" pools for adult salmon migration.

- There has been a significant degradation and loss of natural floodplain processes in our rivers and larger stream systems, including the loss of functional off-channel wetland habitat. This is mainly due to dredging, bank armoring, and stream channelization. Past and current agricultural land-use has had a significant impact on floodplain and riparian processes in a number of lowland watersheds. In addition, development has also continued this process of stream channel manipulation.

- Almost all local streams have experienced a loss of natural riparian function due to removal or alteration of natural riparian forest vegetation. This degrades water quality, increases streambank erosion, reduces shade needed for water temperature regulation, and impacts instream habitat conditions through the decline in LWD recruitment.

- Stream-riparian corridor fragmentation is a major problem in many watersheds. This fragmentation has impacted the structure and function of our stream-riparian ecosystems. In addition, there are a significant number of culverts, diversion dams, and other fish passage barriers throughout these same watersheds.

- Estuarine and nearshore processes have been significantly impacted by physical alteration of nearshore ecological structure and function. These impacts include extensive shoreline bulkhead construction, loss of shoreline forest and LWD recruitment, loss of shoreline riparian cover and shade, and degraded water quality. In addition, natural sediment transport and beach nourishment processes have been disrupted as nearshore drift-cells have been altered by shoreline armoring, dock construction, and other human activities. All of these modifications have impacted salmonid habitat in the nearshore environment to some extent.

- Other impacts (e.g. hatcheries and harvest) have also significantly affected salmonid populations, however those issues are beyond the scope of this report.

Using the refugia concept as a starting point, regional efforts to protect and restore Puget Sound salmon should first focus on protecting the last remaining high quality habitat. This report provides a prioritized listing of the highest value habitat throughout the study region. The identification and descriptions of these areas, as well as the scientific ranking for each potential refugia area will allow resourse managers to prioritize conservation actions in the near term. Safeguarding or improving ecological conditions and salmon populations within these areas may not alone be sufficient to bring about salmon recovery, but it represents critical first step in a long-term process. However, no scientific analysis has shown that preservation of these designated refugia would be sufficient to protect salmonid populations from extinction, nor that it would necessarily prove adequate to sustain viable salmon populations in the long-term. The question of the net effect of future habitat damage or loss to salmon can only be addressed through specific analyses of local and regional population dynamics and detailed studies of ecosystem change, which is beyond the scope of this report, but is the focus of on-gong research in the Puget Sound ESU. What we can say with some certainty is that the ecological consequences of degrading or losing habitat areas identified in this report will be significant for salmonid populations in the study region.

Conservation efforts will likely have the greatest near-term benefit for salmon by focusing in watersheds where large areas of intact habitat still remain, but conservation efforts will be necessary in each sub-watershed or riparian corridor to maintain the diversity of local salmon populations. This study provides a useful framework for establishing regional and watershed-wide priorities for conservation efforts intended to benefit salmon. While this study identifies most of the important refuge habitats for salmon, it does not mean that areas not designated as refugia are not worthy of some level of protection. This prioritization of salmonid habitat is a provisional attempt to identify areas of recognized high value to natural salmonid productivity and diversity. Areas may exist that have high biological value as salmon refugia but that remain unrecognized due to lack of data. While there is a high level of confidence that the areas identified in this report as salmon refugia represent the vast majority of existing refugia areas, it is strongly emphasized that areas that were not designated as refugia should not necessarily be considered to be unimportant. As was discussed

earlier in the report, salmonid refuge habitat consists of a shifting mosaic of habitats that are continuously changing in quality and salmonid utilization potential. There will be a need for update and revision of this report as new information becomes available or as analysis techniques are refined.

Ecologically, it is probably true that long-term conservation efforts are likely to be more effective in watersheds with extensive and high quality refugia than in those with limited and poor quality refugia. However, social and cultural priorities, as well as scientific considerations pertaining to local adaptation, ease of recolonization, and the need to geographically dispersed refugia to spread the risk against catastrophic local loss, argue for some level of protection and restoration of ecological function in almost every watershed in the PNW region. Based solely on this report, it is not appropriate to avoid conservation investments in "poor-quality" basins and focus it exclusively on "high-quality" watersheds. The majority of the most productive salmonid habitat, lowland rivers and streams, have been severely degraded by the cumulative impacts of multiple human activities. Salmon abundance and diversity are low in many of these important lowland areas where many salmonid populations spawn and rear and where salmon production was once greatest. In addition, many lowland systems, while not prime spawning or rearing habitat areas, do provide migration corridors for salmonid moving from and to Puget Sound.

Conservation and restoration efforts also need to be focused geographically and significantly expanded to ensure the long-term productivity of the high quality habitats in the region. The refugia approach assumes that areas with high-quality habitat, relatively intact and naturally functioning ecosystems, and supporting relatively strong salmon populations, constitute a high priority for protection and restoration efforts. This implies that conservation efforts will be most successful where healthy population-habitat-ecosystem relationships remain. This is an important consideration to ensure the success and value of conservation efforts as a whole. The number, size, and geographic distribution of these refugia areas will be a critical factor in the success of salmonid recovery efforts. The size of each designated habitat refuge must be large enough to encompass the migratory range and life-stage requirements of all species of concern. This is why watershed-scale refugia are preferred where possible. This is also why nearshore, marine refugia were designated in conjunction with freshwater habitat areas. In addition, this is also why some refugia areas of lower habitat quality will need to be protected and restored to provide refuge habitat in key geographic locations within the study region. These areas likely have lost some portion of their historic productivity for salmon, but they remain among the most important parts of the landscape for present and future salmon conservation. As was discussed earlier, meta-population dynamics in general and in the case of salmon in particular, implies that local sub-populations may go extinct for a variety of reasons (both natural and anthropogenic). This occurs on both a spatial and temporal scale. Therefore, simply protecting the habitat in which salmon are currently doing well (current high-quality refugia) is not enough. In addition, it is necessary to protect habitat where the fish may not be currently thriving or be present (historic habitat). Furthermore, degraded habitat that has the potential to support these species must also be restored so that these areas will be available as *potential or future refugia*. It is also critical to understand that protecting only one sub-population (the single preserve concept) is not enough to ensure the long-term survival of native salmonids. The overall survival and persistence of meta-populations requires sufficiently numerous sub-populations (the exact number of which we do not know as yet) located sufficiently close together to allow the establishment of new sub-populations through natural dispersal. The distribution and geographic arrangement of refugia must support the dispersal (recolonization and straying) of salmonids from one habitat patch to another. This was, in part, the basis for the selection of refugia in this study. The optimum distribution of habitat patches to support natural salmonid populations is not fully understood. Therefore, a conservative approach was taken in designating refugia for this project. Refugia size, distribution, and location also influence the vulnerability of each population to catastrophic disturbances and affect

their ability to recover from natural or human-induced disturbance. In that there were not sufficient high-quality refugia remaining in the region, the majority of the designated refugia will require long-term, active stewardship and restoration efforts. These efforts are already underway. Such efforts as the culvert replacement program are already showing positive results. The removal of fish blockages and the upgrading of passages is one of the single most important actions that can be taken because it opens additional habitat to salmon utilization and increases the refuge habitat available within each system.

Conservation of salmonid refugia areas will require substantial investment of resources in both protection and active restoration actions. Purchases of development rights or title to preclude disturbance and development of sensitive lands, active restoration of streamflow to depleted reaches, and hydrologic rehabilitation or obliteration of existing roads and railroad grades are among the common needs for these areas if the existing salmon habitat conditions are to be maintained into the future. For many of these refugia, effective conservation will not be as simple as maintaining existing patterns of land and water use and ownership. In general, restoration needs in these and similar areas should be the priority for investment of salmon restoration resources. In these areas, enough salmon production and diversity remains that populations can be expected to respond positively as habitat responds to restoration actions. In parts of the landscape that are more depleted of salmon populations, restoration of physical habitat conditions may not lead to the desired biological response because salmonid populations are constrained by small population size, inadequate distribution, lack of life history or behavioral diversity, the masking effects of other untreated mortality sources, or adverse interactions with other species that respond more favorably to habitat changes.

The identification, evaluation, and prioritization of salmonid refugia areas is not a static, one-time project. It should be an ongoing and improving process. Incorporation of adaptive management principles into the refugia process is essential for the long-term success of salmon recovery efforts as a whole. We must continually upgrade our knowledge of the ecosystems we share with salmon and be willing to adapt our behavior, as new information becomes available.

An excellent example of this is our nearshore areas. Little is known about the specific ecological characteristics of this critical habitat, however, the structural and functional attributes of these marine shorelines are believed to be very similar to their freshwater counterparts. This is the main reason why the nearshore-estuarine (NSE) refugia designated in this report should be considered as interim, to be updated as our level of knowledge and our assessment techniques improve.

The salmon landscape is composed of a complex and dynamic mosaic of habitat conditions that is maintained by several importance natural processes. Salmon are adapted to local environmental conditions, including the associated temporal and spatial variability. Natural landscape factors and human land uses affect ecosystem functions and processes (e.g. hydrologic regime, riparian function, etc.) that shape the local habitat conditions on which native salmonids rely. Multi-scale comparisons between current and historic or reference (optimal) conditions can help assess the productivity, diversity, and overall health of salmon populations. Land use practices associated with habitat degradation or loss can also be correlated with biological integrity (or salmon population viability) and help identify potential causes of decline. Identification of the underlying, root cause of ecosystem degradation is important such that we treat the cause (usually a disruption of natural watershed-based processes) and not just the symptom of the problem(s).

Until we know more about these complex ecosystems, our best chance for recovery lies in protecting the remaining salmonid resources. The cornerstone of this conservation effort should be the refugia program. Based on the ecosystem approach to conservation, the ecological needs of species other than salmonids must also be considered. Salmon are considered "keystone" species,

and as such they are a critical component in their ecosystems, having close interrelationships with many other species. This should be the basis for management of both watershed and riparian corridor refugia. In addition to protecting salmonids and other wildlife, these refugia will benefit humans, providing recreational areas and other natural amenities.

REFUGIA MANAGEMENT RECOMMENDATIONS

- Continue to evaluate freshwater habitat conditions throughout watershed and correct identified salmonid habitat limiting factors.

- Develop salmonid habitat conservation programs that include protective purchases, conservation easements, and voluntary stewardship elements.

- Because salmonids are adapted to spatially and temporally varied local habitat conditions, it does not make sense to manage for the same conditions at all locations, or to expect conditions to remain constant at any one location. A "one-size-fits-all' solution is rarely appropriate in the case of salmonid habitat conservation and restoration.

- Evaluate all known and potential adult and juvenile salmonid migration barriers in the watershed. Prioritize and correct all migration barriers as necessary.

- Protect stable natural hydrology within the watershed. Conserve native forest cover throughout the watershed and minimize impervious surfaces in all developed areas.

- Restore floodplain function, natural channel configuration, and stream channel migration zone. This should include consideration of dike and levee removal, road and residential relocation, and restoration of off-channel and historic slough habitat.

- Develop and implement a forest road management plan to reduce erosion and other impacts from logging roads. Ensure timber harvest operations are conducting with long-term sustainability as a goal. The principles of ecosystem management should guide all logging activities.

- Protect and enhance natural estuarine structure and function. Maintain connectivity with the adjacent nearshore.

- Restore natural riparian integrity throughout the watershed; encourage conifer regeneration in deciduous stands that historically had a conifer component, particularly in disturbed areas. This effort should include planting conifers (cedar, hemlock, and spruce), reducing riparian corridor fragmentation, and the establishment of ecologically appropriate riparian buffer zones.

- Reconnect and restore historic riparian wetlands and other off-channel habitat, where possible.

- Develop and implement a short-term LWD strategy until full riparian function is restored.

- Reduce impacts of roads and road crossings, including increased stormwater runoff to surface waters, non-point source water quality impacts from stormwater runoff, and increased fine sediment delivery from road surfaces and associated ditch maintenance. Correct all fish passage barriers as soon as practicable.

- Reduce habitat impacts from hobby farms and agricultural lands, including development and implementation of farm plans that restore stream functions; identify and correct areas in the watershed that have unrestricted livestock access.

- Implement a long-term biological monitoring program for the creek using the macroinvertebrate-based benthic index of biotic integrity (B-IBI). Biological monitoring is an excellent tool for diagnosing and qualifying watershed health and is a good way to involve citizens in the assessment process.

- Implement an exotic vegetation management program in the watershed.

- Identify and correct sources of known water quality problems. Continue to monitor for water quality problems.

RECOMMENDATIONS FOR IMPROVEMENT OF THE REFUGIA PROCESS

- From a regional (Puget Sound) perspective, it is also important this refugia plan "fits" with other refugia plans. It is almost a certainty that protection and restoration of habitat throughout the Puget Sound will be necessary for the successful recovery of salmon stocks in the PNW region as a whole.

- Utilize higher resolution GIS data such as LIDAR to replace DEM-derived data, and DAIS multi-spectral data or digitized aerial photos to replace the 30 m LandSat LULC data.

- Obtain data on forest stand age or forest maturity and incorporate it into the GIS model.

- Conduct quantitative habitat assessment surveys on all streams that lack this data and incorporate this data into the GIS model.

- Better quantification of the level of uncertainty associated assessments and analyses can increase the effectiveness of modeling efforts.