CHAPTER 11. CONCLUSIONS AND IMPLICATIONS

Humans have made a great hydroelectric, irrigation and transportation system out of the Columbia River and in so doing provided a primary driver for regional economic development. The river today has been characterized as a great organic machine (White, 1995), meaning that even though significant, natural attributes remain (e.g., salmon production in the Hanford Reach and wilderness rivers like the Middle Fork of the Salmon), the river environment is dominated by technological operations (e.g., flood control, hydropower production, irrigation systems, commercial barging). The machine metaphor (Pepper, 1942; Capra, 1982) drives not only economic considerations of water usage and intrastate claims to water ownership, but also conservation efforts for aquatic resources and water quality, including anadromous and resident salmonid fishes (Botkin, 1990).

Indeed, salmon restoration in the Columbia River emphasizes the use of hatcheries, complex bypass systems, artificial habitat structures and other fundamentally technological operations, in part, because managers and policy-makers have adopted the machine metaphor. These technologies evolved over the years and have been used almost exclusively to mitigate, not correct, habitat degradation caused by decades of cultural development. The belief that habitat degradation can be technologically mitigated, as opposed to restoration of normative habitats for all life history stages of salmonids, is ingrained in the Fish and Wildlife Program. The prevailing belief is that the primary problem for anadromous fish is mortality associated with juvenile passage through the dams and reservoirs. The prevailing solution is a combination of hatchery technology, to maximize the number of smolts produced, combined with flow augmentation, to move them as rapidly and efficiently as possible through the hydropower system. This strategy is reflected in restoration expenditures (General Accounting Office, 1992) and in the assumptions implied in the Fish and Wildlife Program (see Chapter 3).

Unfortunately, the restoration program based on the machine metaphor has failed to curtail the decline of salmonid fishes. Moreover, it may be actively interfering with conservation efforts for resident fishes or other management goals in headwater areas not accessible to salmon, e.g., eutrophication controls in Flathead Lake are influenced by discharges from Hungry Horse Reservoir to accommodate late summer smolt movement in the lower Columbia River (Stanford and Hauer, 1992).

Fish and Wildlife Program

We conclude that the Council's Fish and Wildlife Program reflects the dominant paradigm that has governed fisheries management and recovery efforts in the Pacific Northwest for most of this century. This paradigm is based on two principles we find to be fundamentally flawed. The

first is that economically desirable fish populations can be managed in isolation from other components of the ecosystem. Consideration of individual species, runs and populations of salmon that are of interest for economic, social or legal reasons (e.g., Snake River spring chinook) in isolation from other species or components of the ecosystem leaves the region with a narrow set of solutions to a complex problem. Problem definition based on an ecosystem perspective would likely lead to a different course of action. This is not to say that the populations currently emphasized by the region are not important or that major actions should not be taken to rebuild these populations. Our message is simply this: how the region asks the questions -- the conceptual foundation for the region's actions -- ultimately restricts the range of options available for consideration. To date, the implied conceptual foundation has led to asking how we can devise technological fixes for a restricted set of problems affecting a few remaining populations, rather than asking how the basin as an ecosystem should operate within the existing social context.

The second principle of the existing paradigm, and one that flows inevitably from the first, is that technological solutions can be devised for each ecosystem alteration that occurs as a result of development of the basin. In effect, it says that we can engineer an alternative system that works as well as the natural ecosystem. Because of the pace and magnitude of technological development in the basin, this suggests the analogy of frantically sticking patches on a sinking ship rather than asking long ago whether the ship was going in the right direction or whether we should steer out of troubled waters. We find the concept that we can engineer our way out of the present crisis to be at odds with the prevailing scientific knowledge. This is not to say that technological solutions to particular problems will have no part in a successful recovery strategy or that the only solution is a return to natural conditions. On the contrary, we conclude that the social context of the Columbia River mandates the use of technology. However, to be successful, that technology must work with the natural physical and biological processes of the salmonid-bearing ecosystem rather than attempting to circumvent it. Strictly applied, this conclusion will lead to fundamentally different ways of approaching and applying technology to the recovery of the Columbia Basin.

Many of the Fish and Wildlife Program measures are responsive to individually documented problems and represent credible scientific approaches to these problems. The Fish and Wildlife Program actions to date represent a good faith effort by the Council and the region's fishery managers to recover salmon and steelhead in the Columbia Basin. Although many measures may show positive incremental results, in total, they have failed to stem the decline of salmon and steelhead. Populations are at all time lows; many do not appear to be able to withstand natural downturns in the ocean or in other conditions that are beyond direct human control.

An overarching conclusion of our review is that the region must change the way it views the Columbia River. We must move from a view that the Columbia River is largely a vehicle for economic development to one that accommodates short-term economic gain and the longer-term regional benefits of a functional salmonid bearing ecosystem. Donald Worster (1985) characterized the Colorado River as "..a part of nature that had died and been reborn as money." He cautioned that the Columbia River was struggling toward this fate as well. The region has the opportunity to fundamentally shift its relationship with the river. We submit that a conceptual foundation like that outlined in Chapter 2 is a key step in this shift.

An Alternative Conceptual Foundation

The conceptual foundation (Chapter 2) is based on three fundamental principles. First, restoration of Columbia River salmonids must address the entire natural and cultural ecosystem, which encompasses the continuum of freshwater, estuarine, and ocean habitats where salmonid fishes complete their life histories. This consideration includes human developments, as well as natural habitats. Second, sustained salmonid productivity requires a network of complex and interconnected habitats, which are created, altered and maintained by natural physical processes in the freshwater, the estuary and the ocean environments. These diverse and high-quality habitats, which have been extensively degraded by human activities, are crucial for salmonid spawning, rearing, migration, maintenance of food webs and predator avoidance. Ocean conditions, which are variable, are important in determining the overall patterns of productivity of salmonid populations. Third, life history diversity, genetic diversity and metapopulation organization are ways salmonids adapt to their complex and connected habitats. These factors contribute to the ability of salmonids to cope with environmental variation that is typical of freshwater and marine environments.

Because a wide array of habitats historically existed, salmonid stock diversity was high. Dispersed production by many stocks provided resilience (i.e., buffering) to natural environmental variation. The conceptual foundation proposes that salmonid productivity is based on a wide array of populations coexisting in a complex and interconnected mosaic of habitats. These habitats are created and maintained as a consequence of natural environmental variation in the freshwater, estuarine and oceanic components of the ecosystem.

The Columbia River Basin historically was dominated by multiple populations and life history types of salmon and steelhead, perhaps organized geographically into complex metapopulations that sustained genetic diversity (National Research Council, 1996) and provided resilience in the face of natural environmental fluctuations . Not only were chinook salmon and steelhead abundant, but, sockeye salmon from 23 rearing lakes contributed to the commercial fisheries. Much, if not most, spawning of fall and perhaps summer chinook occurred in the

mainstem of the Columbia and Snake Rivers and in alluvial reaches of the lower sections of the larger tributaries (e.g., Yakima River and others). Available historic evidence (Lichatowich and Mobrand, 1995), the current high abundance of fall chinook in the Hanford Reach, and principles of large river ecology (Stanford, 1996), suggest that large alluvial reaches in the mainstem and lower sections of many tributaries were the fish factories of the Columbia River ecosystem. Mainstem spawning populations may have functioned as vital core populations important in sustaining metapopulation persistence (Chapters 2 and 4). Furthermore, alluvial mainstem areas likely were important rearing areas for juvenile salmonids moving downstream (Chapter 5). Although critically important with respect to biodiversity, many tributaries in the headwaters of sub-basins were probably not significant production areas, owing to their smaller size, lack of nutrients to support food webs, steep gradients, long distances from the ocean and other considerations. Lakes, now mostly blocked to fish passage, contributed substantial anadromous and resident salmonid biomass and diversity.

In the course of human development of the Columbia River Basin, important mainstem spawning and rearing habitat was degraded as a consequence of the construction of dams and associated large water storage reservoirs and various land use activities. Most large mainstem spawning populations and many headwater populations were extirpated, which drastically altered metapopulation organization. At present, salmon production in the basin occurs chiefly in isolated headwater areas with intact habitat and in hatcheries. The current Fish and Wildlife Program focuses restoration efforts on increasing the abundance of these few remaining headwater salmon populations, many of which historically never were very productive, rather than on restoration of productivity through restoration of stock and life history diversity and metapopulation integrity. Moreover, the Fish and Wildlife Program lacks continuity of measures for enhancing remaining stocks. This is, in part, a consequence of the lack of an explicit, conceptual foundation that would provide continuity and internal consistency among measures (Whitney et al., 1993). Large river habitats, which were the key production areas for many productive stocks and essential to all migrants, are largely ignored in the Fish and Wildlife Program. Indeed, the Hanford Reach, which contains the most healthy naturally spawning chinook stock above Bonneville Dam, is not explicitly addressed in the Fish and Wildlife Program. In the same context, measures to protect and reconnect remaining intact habitats containing native resident salmonids are missing or de-emphasized. Lake Okanagan, which contained one-fifth of the rearing lake surface area in the Columbia Basin for sockeye and probably contains about three-quarters of the remaining sockeye is presently occluded with a low head diversion dam and no fish passage facilities.

The tendency with the Fish and Wildlife Program has been to emphasize hatcheries, passage technology, and other activities that may be effective for one or a few stocks or in specific places or at particular times and may yield small increases in specific runs or reduce

juvenile mortality at a few places or at certain times. Those measures have considered life history diversity and metapopulation structure and have failed to make significant progress toward the Council's goals. Moreover, the Fish and Wildlife Program does not have an implementation plan or a formalized mechanism for evaluating success or failure of individual measures in general.

Human development of the Columbia basin has led inexorably to loss of life history and population diversity, disruption of metapopulation organization, and declines in salmonid productivity. However, we believe that life history and population diversity can be reestablished and declines in salmonid populations can be reversed by management actions that restore more normative conditions throughout the ecosystem. Technology that attempts to circumvent the normative river (e.g., hatcheries and transportation) should only be implemented on a large scale after intensive evaluation.

Specific Conclusions

We identified three conclusions regarding the alternative conceptual foundation:

1. *We conclude that the lack of progress towards salmon recovery in general and under the Fish and Wildlife Program, is due at least in part to the lack of an explicitly defined conceptual foundation based on ecological principles.*

We recommend that the Council adopt an explicitly defined conceptual foundation that is based on ecological principles, such as the alternative conceptual foundation described earlier in Chapter 2. Failure to adopt a conceptual foundation and to change the approach to salmon restoration in the basin will lead to more extinctions of salmon populations and little progress towards the rebuilding goal. Temporary increases in some populations may occur in response to fluctuations in ocean conditions, but the overall downward trend in returns that has occurred throughout this century will likely continue without a change in approach.

2. *The potential social, economic and biological tradeoffs that will accompany significant increases in normative conditions throughout the Columbia River salmon bearing ecosystem are not known.*

The potential social, economic and biological costs and benefits of moving the basin toward more normative conditions should be compared as part of the regional debate regarding salmon restoration. As a first strategic step, the Council could examine the implications of the normative ecosystem concept; in particular, what steps would move the Columbia River along the continuum from its current state to a more normative state (i. e., the restoration of natural

ecological processes consistent with the needs of native fish and wildlife species). Steps including watershed-level restoration in subbasins, manipulation of mainstem flows, permanent drawdowns and dam removal should be evaluated in terms of the social and economic costs to the region, as well as the potential benefits for salmon recovery.

3. *Although there is uncertainty associated with the restoration approach described in RETURN TO THE RIVER, it offers an opportunity to move from the status quo of continuing decline and begin to realize progress toward recovery of salmon and the goals of the Fish and Wildlife Program.*

Because the region lacks experience in the approach to restoration described in RETURN TO THE RIVER, we cannot predict the exact relationship between increasingly normative conditions and salmon production. For example, as the river moves toward more normative conditions, little improvement may be observed until a threshold is reached causing an increase in production to a new level or plateau. Our knowledge of how to restore key attributes in an ecological system as large and complex as the Columbia River is imperfect. A rigorous program of evaluation, monitoring, research and adaptive management will be required. The ecosystem's response to restoration actions has important implications for scaling the region's expectations and the amount of effort required to elicit identifiable changes in salmon abundance. We conclude that an approach based on the principles described in RETURN TO THE RIVER, combined with an implementation program governed by the principles of adaptive management, offers the best hope for preventing large-scale extinction of salmon in the basin and making meaningful progress toward the Council's goals.

The Normative Ecosystem

The opportunity for restoration of normative ecosystem conditions within the Columbia River Basin depends on the location within the basin and the extent of human development. Based on our review of science (Chapters 4-10), enhancement of normative conditions includes careful consideration and implementation of at least the following seven actions:

1. *Recognize explicitly that salmonid fishes in the Columbia River exist naturally as aggregates of local populations, possibly organized as metapopulations, and manage for life history and population diversity as essential to increased total production.*

The normative ecosystem concept is based on the natural adaptive capacity of salmonid fishes and their tendency to develop diverse life histories in response to diverse habitat and other environmental conditions that occur across the different landscapes of the Columbia River basin.

Although much of the natural diversity of salmonid fishes has been lost (Nehlsen et al., 1991; Huntington et al., 1996), we believe that salmonids have the capacity to re-express life history and population diversity if suitable habitat opportunities are provided (Healey, 1994). These habitat opportunities can be provided by normative river processes. Metapopulation structure could be recovered by allowing natural rebuilding from the remaining wild core populations (e.g., fall chinook in the Hanford reach).

2. Freshwater habitat for all life history stages must be protected and restored with a focus on key alluvial river reaches and lakes. Restoring habitat and access to habitat that re-establishes phenotypic diversity in salmonid populations should be a priority.

Native salmonid fishes of the Columbia River cannot be expected to thrive or even persist in the long term without the habitats to which they are adapted. Diversity and productivity of native salmonid populations throughout the Columbia River system cannot recover without restoring spatial (upstream-to-downstream, channel to floodplain, groundwater to floodplain) and temporal connectivity of the habitat mosaic that characterizes the normative river. Because they appear to be centers of population organization for salmonids, large alluvial reaches in the mainstem Columbia and Snake and major tributaries should be foci for management.

At least three generalized actions could be initiated now to begin to rebuild habitat quantity and quality of the mainstem and tributaries. Actions can be refined adaptively as new information is forthcoming through research and monitoring. These actions include: a) provide incentives for watershed planning that emphasizes riparian and upland land use activities that enhance instream and lake habitats; insist on empirical evaluation of effectiveness of management practices; b) re-regulate flows to restore the spring high water peak to revitalize the mosaic of habitats in riverine reaches and stabilize daily fluctuations in flow to allow food web development in shallow water habitats; and c) determine food web composition, trophic interactions and bioenergetics of migrating juveniles in key habitats.

<u>a. Provide incentives for watershed planning that emphasizes riparian and upland land use activities that enhance instream and lake habitats; insist on empirical evaluation of effectiveness of management practices.</u>

Restoration of normative conditions has to be done in the tributaries, as well as the mainstem. Despite extensive expenditures under the Fish and Wildlife Program and other state and federal programs, there is little evidence that habitat restoration has actually improved the productive capacity of streams and rivers for salmonids (Rhodes et al., 1994). In some areas of the basin, habitat degradation of headwater reaches is pervasive from mining, logging and road

building (Chapter 5). Priority should be given to key alluvial reaches in tributary streams. A very important point is that these key reaches are not in wilderness or other protected zones; they occur in zones of intense human activity, so incentives will be required to unify stakeholders to restore habitat conditions for anadromous and resident salmonids.

b. Re-regulate flows through the mainstem Columbia and Snake rivers.

1) Use the spring high-water peak to revitalize the mosaic of habitats in riverine reaches.

Peak spring flows can restructure and revitalize habitats in riverine reaches, however, in the existing mainstem sections of the Columbia and Snake rivers where reservoirs dominate, peak flows will not accomplish much habitat restoration. The possibility of restoring historical, but presently inundated, production areas in the mainstem should be evaluated including, permanent drawdown of John Day and, perhaps, McNary pools. Peak spring scouring flows, then could be used to restructure and revitalize habitat in these currently inundated areas. Potential advantages are great in the John Day pool because: the large alluvial reach drowned by John Day pool was a key spawning and rearing area prior to inundation, the upstream part of the reservoir is not developed, and the existing reservoir is a source of high mortality from predation.

Peak flows can be created by using water storage released in concert with natural runoff in the catchment. On wet years, peaks can be re-regulated to provide scouring flows, depending on the storage capability and the flood control realities of the particular river segment. Very high flows are not needed every year to maintain instream and flood plain habitats, nor is the historical duration of floods required because most of the sediment is moved on the rising limb of the hydrograph. In years of average water availability, a modest peak flow can be generated, while also elevating baseflow to accomplish the purposes for which the dams were built. In dry years, little additional water is likely to be available to generate spring peak flows for the purpose of scouring and revitalizing habitat, however, natural spring runoff will still occur. The strategy simply is to lower the baseflow some to build peaks in relation to catchment runoff. Peak or scouring flows have to be tailored for individual riverine segments based on channel morphometry and size distribution of bed materials. In general, scouring flows of sufficient magnitude to move the bed materials of median size are needed.

The integrated rule curves (IRCs) for drawdown and refill of the large storage reservoirs, as developed for Hungry Horse and Libby Reservoirs (Marotz et al., 1994; Marotz et al., 1996), coupled to an empirical understanding of channel and flood plain morphometry, flood plain land uses, runoff and storage forecasting, and riverine sediment transport efficiency in relation to peak (freshet) flow timing and duration within key alluvial segments, can provide a mechanism for restoring habitats in key alluvial reaches. However, research is needed to clearly relate IRCs to food web dynamics, including reproduction, growth and behavior of salmonids.

2) Stabilize daily fluctuations in flows in riverine reaches to allow food web persistence in shallow water habitats of alluvial reaches that provide important juvenile rearing areas.

In all years, it is essential to prevent short-term dewatering of the nearshore (varial) zone. Such fluctuations often are associated with hydropower peaking operations and effectively kill all organisms in shallow-water habitats in the nearshore zone. These habitats are essential features of the normative riverine landscape and are characterized by both surface and interstitial flow. As a starting point, this means that daily changes in flow (ramping rates) should not exceed the range of variation that likely occurred before regulation.

c. Determine food web composition, trophic interactions and bioenergetics of migrating juveniles in key habitats.

We concluded that the mainstem reservoirs likely are areas of high juvenile mortality, as are reaches of tributaries severely influenced by water diversions (e.g., sections of the Yakima, John Day, Grand Ronde, Umatilla). Problems include lack of riverine habitat, insufficient food, presence of large numbers of native and non-native predators and potentially lethal late summer temperatures. These pressures, and any increased energetic demands related to reduced summer flows, likely compromise energetic requirements of the native salmonids leading to poor health of survivors, particularly those passing through the Snake River reservoirs. Poor condition could contribute to increased mortality at a later stage of downstream migration or in the ocean. Research on food web conditions, mechanisms for improving them, and improved measures of the vitality of migrants is needed.

3. Manage stocks with a more complete understanding of migratory behavior and the limitations that migratory behavior places on modes of river regulation.

Current views of fish migration are insufficient for recovery (Chapter 6). The Fish and Wildlife Program should include research and management measures to determine and protect habitat requirements during fish migration that go beyond increasing bulk water velocity and reducing water travel time through flow augmentation and drawdowns.

4. Reduce sources of mortality and improve effectiveness of mitigation activities within the hydroelectric system. Planning and implementation of mitigation measures should occur

within the context of the normative ecosystem concept and evaluated for effectiveness in reaching stated objectives.

a. Couple seasonality of flow with usage of spill and most efficiently bypass juveniles and adults around mainstem dams and cue (not flush) them through the mainstem.

Our review showed that spill clearly is effective in reducing mortality of juveniles passing mainstem dams; however, high volume spill at some dams can cause gas supersaturation at levels thought to be lethal to juveniles. More information is needed to clarify this tradeoff because the lethalness of gas supersaturation may be less of a problem inriver (owing to the ability of the fish to move to deep water to adjust to the gas concentrations) than experimental data currently suggest.

Turbine screens, including extended-length screens, do not appear to be effective in achieving the Council's goals for fish guidance efficiency (FGE) for all species, stocks and life history types. It seems unlikely that more than slight incremental improvements can be made to improve the effectiveness of turbine screen bypass systems.

A more promising approach applicable to some dams, appears to be the use of surface collection devices for bypassing migrating juvenile salmonids. This approach takes advantage of the natural surface oriented behavior of juvenile migrants, compared to the turbine bypass systems that force the juveniles to sound prior to entering the bypass system.

b. Resolve mortality from gas bubble trauma with focused field research and installation of devices that reduce turbulence.

Spill can improve survival of smolts up to the point where gas saturation adds mortality beyond what is saved by passage of fish in spill. That point has to be determined for each dam in the mainstem. Freshet flows have to be tailored to optimize the tradeoff of spill and gas bubble disease as more information becomes available and as more of the dams are equipped with better turbulence-reducing devices to reduce gas entrainment.

Gas bubble disease from supersaturation of water with atmospheric gases is a poorly defined, but highly plausible (based on much science), risk to in-river fish, a risk that would need to be better determined to quantitatively establish the net value of spill as a mechanism to reduce mortalities during dam passage. This determination would require a large amount of research and monitoring to achieve desired levels of confidence, and may not be feasible. Because there is still debate on the research approach and need, the best strategy may be to endorse Army Corps of Engineers' plans for installation of gas abatement structures.

c. Transportation likely is selective for particular stocks and life histories

Transportation can provide increases in survival at the point of release for certain life history types of certain species. Transportation has not been shown to be appropriate for completion of the life cycles of all life history types of all endangered salmon species. Furthermore, transportation alone does not appear sufficient to overcome the negative effects on survival of salmon caused by the development and operation of the hydroelectric system. Transportation and additional potential mitigation measures must be developed and evaluated to determine if each is appropriate to protection of the life history diversities of the endangered salmon species. Transportation is desirable only if all life history types are transported, if the currently perceived benefits of transportation are real for all life history stages, and if it is clear that normative habitat in the impounded mainstem cannot be restored. Transportation programs that are selective for specific life histories could run counter to normative attempts to restore life history diversity.

d. Normative conditions will reduce predation rates on migrating juvenile salmon.

The overall rate of predation of squawfish on juvenile salmon has been lowered since 1990. The extent to which any single factor, such as spill or the predator control program, may have contributed to this is uncertain. Spill is a factor that normally should lower the rate of predation by all fish predators in the vicinity of the dams. Restoration of more normative conditions in areas such as the John Day Pool could further reduce predation by creating refugia for migrating salmonids and cooler water temperatures due to increased connectivity with ground-water.

5. Reduce inadvertent negative impacts and improve effectiveness of mitigation actions associated with harvest management and artificial propagation, as well as habitat protection and restoration. Planning and implementation of mitigation measures should occur within the context of the normative ecosystem concept and be evaluated for effectiveness in reaching stated objectives.

a. Habitat restoration has not been emphasized to date in the Fish and Wildlife Program as a primary mitigation need.

Habitat restoration in both mainstem and subbasin areas must receive high priority and be approached in the normative ecosystem context; e.g., restoration efforts should be directed at providing the habitat opportunities that historically supported salmonids in their natural state (Healey, 1994). Restoration effort needs to focus on the tributaries, as well as the mainstem with priority given to key alluvial reaches in tributary streams. An important purpose of habitat

restoration should be to facilitate the reexpression of phenotypic and life history diversity in salmonid populations. Habitat restoration in the major subbasins is likely to take longer and be more difficult than restoration of mainstem habitats. In many cases, this difficulty will be a result of a lack of storage water for restructuring habitats via reregulation, as well as the larger number and a more diverse set of stakeholders. Therefore, incentives will be required to unify stakeholders to restore habitat conditions for anadromous and resident salmonids.

b. Mortalities from all other sources (including incidental harvest) should be low enough to sustain stocks before allowing directed harvest.

Long-term conservation of salmon in the face of human population growth requires habitat protection as a prerequisite and conservative harvest management as a constant presence. While appropriate harvest control is necessary for successful salmon conservation, accounting for only directed harvest is not sufficient to provide for the persistence of salmon populations. With degraded habitats, reduced life history diversity, and reduced abundance, it is essential to account for all sources of mortality in all localities to control harvest to levels consistent with salmon recovery.

c. Hatcheries were intended to mitigate salmon losses due to habitat degradation, but they have failed to do so. Reliance on hatcheries should be de-emphasized and new roles for hatcheries defined.

Artificial propagation has failed to achieve its long-standing objective (Chapter 8) of replacing natural production lost due to habitat degradation and construction and operation of the hydroelectric system, and to compensate for overharvest. Because there has been a lack of comprehensive evaluation throughout the 120-year history of hatcheries in the basin, it is going to be difficult and expensive to learn if it may be possible to integrate hatchery operations with natural production in the basin. Although interactions between wild and hatchery fish have been examined in only a few studies, existing evidence points to negative effects on wild fish. There is clear evidence that the hatchery paradigm coupled with harvest management practices (mixed-stock fisheries, where harvest rates are set according to presumed production of cultured fish) have accelerated the decline of wild stocks.

Artificial propagation must be viewed as an experiment to be implemented within an adaptive management framework. It should be used in a manner consistent with the conceptual foundation, and, at the subbasin level, the role and scale of artificial production should be consistent with the rebuilding goal for natural production within that subbasin. An independent review of the purpose and scope of hatchery operations in the basin is needed.

d. An integrated ecosystem monitoring and evaluation program is needed

A great deal of monitoring that is relevant to the Fish and Wildlife Program is being done for index life stages and locations, with appropriate data compilation and reporting. But evaluation and thus, feedback to monitoring design has lagged or been too narrowly focused by current beliefs to fully support management actions by the Council and other agencies. Monitoring, and especially evaluation, remain inadequate for present needs (Chapter 9). Monitoring should not be limited solely to attributes of salmon, or even salmonids in general. Information on habitat dynamics and food web community ecology is also needed. A major impediment to effective evaluation of the Fish and Wildlife Program, is the lack of a clearly defined framework of goals and objectives to provide a standard for evaluation.

6. *Recognize estuary and ocean dynamics as controllers of salmon productivity, which require responses in management actions for all other aspects of the life cycle under human control, such as directed harvest and hydrosystem operations. Management activities should increase or maintain biodiversity in salmon populations to minimize the effects of change in the marine environment. Obtain better understanding of estuarine and oceanic food webs (Chapter 10).*

The Pacific Basin ecosystem does not move toward an equilibrium condition, but oscillates between alternate states. Traditional management approaches based on equilibrium population models and assumptions of environmental stability fail to account for this nonlinear behavior and, therefore, have led to incorrect expectations of response in freshwater management actions on the productive capacity of the Columbia River Basin for salmon.

Not much can be done about biophysical conditions in the ocean, beyond support for fisheries harvest protocols that maintain or enhance favorable food web conditions and insure adequate escapement of salmonids to freshwater spawning areas. Estuarine habitats can be improved by pollution abatement and continuing enhancement of the spring freshet plume associated with restoration of the normative riverine flow regime. Management actions affecting freshwater parts of the salmon's life cycle should emphasize the reexpression of phenotypic diversity as a buffer against fluctuating ocean conditions.

7. *It is critical to protect remaining core populations and restore habitats with the potential to re-establish core populations at strategic locations within the basin. One way to accomplish this would be to reevaluate the concept of salmonid reserves. Reserves could*

protect habitats that currently support remaining viable core populations. They could serve as foci for rebuilding salmonid abundance and metapopulation structure throughout the Columbia Basin. The region should give priority to evaluation of the potential for a salmon reserve in the vicinity of the confluence of the Snake and Columbia Rivers including the Hanford Reach.

The concept of salmon reserves has been discussed by salmon managers for over 100 years, including at least four recommendations for the inclusion of reserves in the Columbia Basin. In spite of this long history, no salmon reserves have ever been implemented in the basin. Curiously, reserves have been used effectively for at least the last several decades or more for protection and management of several resident salmonids. Westslope cutthroat trout in the Clearwater (Kelly Creek) and Salmon rivers (Middle Fork) in Idaho occur in *de facto* reserves as a result of their proximity to wilderness areas and the implementation of catch-and-release angling regulations.

The Hanford Reach in the mid-Columbia River is the only remaining free-flowing river segment and contains the largest natural spawning population of fall chinook in the watershed above Bonneville Dam. Over the last two decades, Hanford Reach fall chinook have continued to be productive while other stocks have declined. These fish exhibit characteristics of a core population both in their resiliency, being the only remaining mainstem population of significance, and because they are contributing to spawning populations elsewhere in the basin (marked individuals have been recovered at other mid-Columbia and Snake river sites). The Hanford chinook stock likely has remained productive because normative conditions were retained by the reregulation of flows. During spawning and incubation on Vernita Bar, a flow regime is maintained that is designed to prevent exposure of the salmon eggs (Bauersfeld, 1978; Chapman et al., 1983). In spite of the apparent viability of the Hanford Reach fall chinook, habitat problems exist in the reach that can be improved through additional reregulation to stabilize daily fluctuations in flow and ensure the occurrence of flood flows during spring runoff.

Establishment of a salmon reserve from the Hanford Reach to the confluence of the Columbia and Snake rivers, combined with flow reregulation and improvement of habitat quality in the lower reaches of adjacent tributaries, would provide the basis for testing the normative concept. Information needed to test the normative concept could be obtained through monitoring habitat quality, complexity and connectivity, along with abundance, life history diversity and fitness of naturally reproducing salmon. In addition, metapopulation theory predicts that large abundant core populations should enhance or restore salmon populations in adjacent tributaries through dispersal of individuals into those systems. Therefore, monitoring of fall chinook

abundance in the lower reaches of adjacent tributaries where habitat improvement has occurred would test the linkage between normative conditions and metapopulation rebuilding.

While testing the normative ecosystem concept in the Hanford Reach area, the region should search for other candidate areas in the Columbia and Snake rivers where spawning and rearing habitat can be restored, and natural population and metapopulation structure reestablished. Efforts should be made to identify both mainstem areas and subbasins where restoration may be possible. Metapopulation rebuilding is likely to be enhanced if candidate mainstem and subbasin areas are adjacent to one another. The John Day summer steelhead, and certain resident stocks of bull trout (e.g., Quartz, Kintla, and Hungry Horse stocks in the Flathead River Basin) and cutthroat trout (e.g., Salmon River, Middle Fork) are the among the last remaining healthy populations of native salmonids in the Columbia Basin. Establishing reserves for the protection of these populations and others that may be identified through a thorough analysis of each subbasin should be given high priority.

Literature Cited

Bauersfeld, K. 1978. The Effect of Daily Flow Fluctuations on Spawning Fall Chinook in the Columbia River, Washington Dept. of Fisheries. Washington.

Botkin, D.B. 1990. Discordant Harmonies: A New Ecology for the Twenty-First Centure. New York, Oxford University Press.

Capra, F. 1982. The turning point.

Chapman, D.W., D.E. Weitkamp, T.L. Welsh and T.H. Schadt. 1983. Effects of Minimum Flow Regimes on Fall Chinook Spawning at Vernita Bar 1978-82. Boise, Don Chapman Consultants, Inc. Idaho.

General Accounting Office. 1992. Endangered Species: Past Actions Taken to Assist Columbia River Salmon. Washington. District of Columbia.

Healey, M.C. 1994. Variation in the life history characteristics of chinook salmon and its relevance to conservation of the Sacramento winter run of chinook salmon. Conservation Biology 8: 876-877.

Huntington, C., W. Nehlsen and J. Bowers. 1996. A survey of healthy native stocks of anadromous salmonids in the Pacific Northwest and California. Fisheries 21(3): 6-14.

Lichatowich, J.A. and L.E. Mobrand. 1995. Analysis of chinook salmon in the Columbia River from an ecosystem perspective, Mobrand Biometrics.

Marotz, B.L., C. Althen and D. Gustafson. 1994. Hungry Horse Mitigation: Aquatic Modeling of the Selective Withdrawal System--Hungry Horse Dam, Montana. Portland, Bonneville Power Administration. Oregon**:** 29.

Marotz, B.L., C. Althen, B. Lonon and D. Gustafson. 1996. Model Development to Establish Integrated Operational Rule Curves for Hungry Horse and Libby Reservoirs - Montana. Portland, Bonneville Power Administration. Oregon**:** 114.

National Research Council. 1996. Upstream: salmon and society in the Pacific Northwest. Report on the Committee on Protection and Management of Pacific Northwest Anadromous Salmonids for the National Research Council of the National Academy of Sciences. Washington D. C., National Academy Press.

Nehlsen, W., J.E. Williams and J.A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2): 4-21.

Pepper, C. 1942. World Hypothesis.

Rhodes, J.J., D.A. McCullough and J. F. A. Espinosa. 1994. A Coarse Screening Process for Evaluation of the Effects of Land Management Activities on Salmon Spawning and Rearing Habitat in ESA Consultations. Portland, Columbia River Inter-Tribal Fish Commission. Oregon.

Stanford, J.A. 1996. Landscapes and catchment basins. Methods in Stream Ecology. F. R. Hauer and G. A. Lamberti. San Diego, Academic Press**:** 3-22.

Stanford, J.A. and F.R. Hauer. 1992. Mitigating the impacts of stream and lake regulation in the Flathead River Catchment, Montana, USA: An ecosystem perspective. Aquatic Conservation 2: 35-63.

White, R. 1995. The Organic Machine: The Remaking of the Columbia River. New York, Hill and Wang.

Whitney, R.R., L.D. Calvin, C.C. Coutant, J. M W. Erho, J.A. Lichatowich, W.J. Liss, W.E. McConnaha, P.R. Mundy, J.A. Stanford and R.N. Williams. 1993. Critical Uncertainties in the Fish and Wildlife Program. Portland, Bonneville Power Administration. Oregon**:** 17.

Worster, D. 1985. Rivers of Empire. New York, Pantheon Books, div of Random House, Inc.