

WHEREAS, Dr. Robert N. Crittenden, an expert with an M.S. in Marine Biology and a Ph.D. in Fisheries, did a Post-Doctoral on the fellowship of salmon habitat and concluded that the recreational mining activities of panning, sluicing and dredging enhance the salmon habitat, and these activities should be encouraged as they provide one the most cost-effective enhancement techniques as a beneficial side-effect of private recreation;

## Crittenden Biometrical

Consulting services in quantitative biology

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I am an independent professional. My qualifications are as follows:

I hold a B.S. in zoology, but also took a significant amount of mathematics and physical sciences;

an M.S. in Marine biology, specializing in mathematical ecology, but did my thesis on modeling the microclimatology of small streams;

a Ph.D. in Fisheries, focusing on biological statistics (that is biometrics), and did my thesis on the statistical analysis of hydroacoustic surveys for fisheries assessment; and

I did a Post-Doctoral fellowship on salmon.

I have published about two dozen scientific articles in peer-reviewed scientific journals and many technical reports.

For the approximately the last fifteen years, I have worked as an independent consultant primarily in Western Washington.

My clients have included individuals; property owners' groups; farmers' organizations; environmental organizations; other consulting companies; industry; and County, State, Federal and foreign governments;

Quantitative methods are applicable to a wide range of applications and over my approximately three decades of professional experience, I have addressed many different topics. The topics I have worked on include but are not limited to developing new statistical methods; ecological and environmental modeling; fisheries; fresh and saltwater zooplankton and phytoplankton; marine benthic communities; hydroacoustics; hydrodynamics of open channels and porous media; ground and surface water; channel migration, microclimatology and ecology of streams and rivers; genetics; and so on... ---

I also have practical experience in local and State politics and, having worked for several years as a volunteer librarian in a law library, I have some familiarity with the law, although, I do not give legal advice.

In addition, I have also published popular works on history, philosophy, and politics and will soon publish on religion.

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## Regarding Dredging, sluicing, and panning

Dredging, panning, and sluicing not only improve salmonid habitat but can also create new habitat.

Salmonid eggs and alevins (alevins are tiny newly hatched salmonids which still reside in the interstitial spaces among the gravel of the streambed) need clean gravels through; which interstitial water can flow, providing them with oxygen. Silts and fine sands reduce the porosity of the streambed, thereby, reducing the interstitial flow and the oxygen supply. It can also reduce the amount of interstitial space for alevins. Reduced porosity has been shown to be directly related to reduced survival of salmonid eggs and alevins.

If properly conducted (for example, according to the present guidelines in Washington State — WDW 1987) dredging, panning, and sluicing reduce the amount of fine sand and silt in the streambed and, thereby, improve its porosity. These activities will, therefore, result in better interstitial flow, a better interstitial oxygen supply for eggs and alevins, and more interstitial space for alevins. The net result is improved survival for salmonid eggs and alevins.

Thus, dredging, panning, and sluicing improve existing salmonid habitat and can also create new habitat. These activities should be encouraged.

## Habitat for salmonid eggs and alevins — the importance of streambed porosity:

**Pink Salmon:** As William R. Heard pointed out in his (1991) review "Pink salmon choose a fairly uniform spawning bed in both Asia and North America. Generally these spawning beds are situated on riffles with clean gravel or along the borders between pools and riffles in shallow water with moderate to fast currents. . . . pink salmon avoid spawning in quiet deep water, in pools, in areas with a slow current, or over heavily silted or mud-covered streambeds."

Pink salmon (*Oncorhynchus gorbuscha*) spawning sites may be characterized as being clean gravels. However these sites may also have a few cobbles, a mixture of sand, but relatively little silt (Semko 1954; Kobayashi 1968; Dvinin 1952; Smirnov 1975; and Hunter 1959).

The faster the current, the larger the particle which will be suspended and carried off by it. Hence, a strong current provides some guarantee that silts and

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fine sands will not plug up the interstitial spaces. The more rapid flow is also turbulent. The eggs and alevins are provided with a good oxygen supply by the turbulent mixing of water into the interstices of the streambed.

The porosity of a streambed and the survival of eggs and alevins has been demonstrated to be directly related to the composition of the streambed, being lower where there are more fine sands and silt (McNeil and Ahnell 1964; Rukhlov 1969; Brannon 1965; Bams 1969).

**Chum Salmon:** In contrast, to pink salmon which preferentially select riffles, chum salmon (*Oncorhynchus keta*) tend to select sites of upwelling spring water (Kobayashi 1968). These sites often have a lower flow rate than is found at pink salmon sites (Bams 1982; Soin 1954; Sano and Nagasawa 1958). Chum salmon spawning sites may be found directly below a pool which is partially obstructed at its lower end by a gravel bar. The water infiltrates the gravel bar, travels through the bar as ground water, and reemerges into the water column below the bar.

Interstitial flow is as important for the survival of their eggs and alevins, as it is for the pink salmon. However, in this case the oxygen is carried into the groundwater by convection (that is by the net movement of water into and then out of the streambed) rather than by turbulent mixing. However, in some cases turbulent mixing may also be an important factor at chum spawning sites.

**Sockeye Salmon:** Sockeye salmon (*Oncorhynchus nerka*) spawn either in streams or in areas along lake shores which have underwater springs. There is also a case of beach spawning where turbulence provides the oxygen supply (Olsen 1968). Spring-fed and Beach spawning sites often have lower oxygen levels than stream sites and sockeye eggs have some ecological and physiological adaptations which improve their survival under those slightly reduced oxygen levels. (Smirnov 1950; Soin 1956, 1964). However, their oxygen supply (and, hence, substrate porosity) remain an important factor affecting their survival.

**Coho Salmon:** Coho salmon (*Oncorhynchus kisutch*) mostly spawn in small streams in areas of gravel of 15 cm or less in diameter (Burner 1951). In some cases Burner found that the spawning sites contained mud, silt, or fine sand, but that this was removed in the nest-building activity. Chamberlain (1907) concluded that coho are the least selective of the salmon species about their spawning site — he found them spawning in almost every stream or river in a very broad range of sites from smoothly flowing to white water and from cobble to muddy. His conclusion was also supported by Foerster (1935) and Pritchard (1940).

However coho appear to prefer small streams (Gribanov 1948) and select a site at the head of a riffle where there is a good interstitial flow (Shapovalov and Taft 1954). The porosity of the streambed and the flowrate of the stream are also important factors affecting site selection (Briggs 1953; Gribanov 1948). Survival has been shown to be related to the porosity of the streambed (Tagart 1984).

**King Salmon:** King Salmon (*Oncorhynchus Tshawytscha*) show strong

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selectivity for spawning areas with high interstitial flow rates (Vronskiy 1972; Russell et al. 1983). Mike Healey (1991) suggests that of all the salmon species, king salmon may be the most sensitive to reduced oxygen levels during the egg and alevin stages. Their sensitivity to the oxygen level was experimentally demonstrated by Silver et al. (1963). The strong relationship between survival and the percolation rate of oxygenated interstitial water was experimentally demonstrated by Shelton (1955) and demonstrated under field conditions by Gangmark and Broad (1955) and Gangmark and Bakkala (1960).

As Mike Healey (1991) points out, "There is no doubt that percolation is affected by siltation and that siltation in spawning beds causes high mortality (Shaw and Maga 1943; Wickett 1954; Shelton and Pollock 1966).

Caveats: Bear in mind that spawning habitat limitation may not be the mechanism limiting the abundance of any specific stock of salmon. There is an absence of support for the habitat limitation hypothesis, except in a few isolated cases. Nevertheless, the enhancement of habitat and the improvement of survival for eggs and alevins are generally desirable goals.

Also bear in mind that in areas which have no fish, restrictions on dredging, sluicing, or panning aren't needed. An example of such as area is the region of a watershed above an impassible barrier, whether it is a dam, waterfall, or rapid.

In areas which have fish, recreational mining activities should be restricted to times of the year such that eggs and alevins aren't buried under silt and fine sediment while they are still in the gravel. Such regulations are already in place in Washington State.

## **Effects of dredging, sluicing, and panning on the porosity of the streambed:**

Generally these activities involve the removal of sediment material from the streambed or, more often, from a gravel bar. The fine components of the sediment become suspended in the wash water and are carried downstream. The finer the sediment the further it will be carried. However, it will eventually settle, often in a quiet pool area.

What is involved here is the movement of the smaller particles out of a riffle area and into a pool area. Generally this will improve the streambed porosity in the riffle area. Recall that riffles are generally the preferred spawning habitat.

Medium sized particles may deposit in the riffle area. During the next major peak-flow event both the fine sediments and the medium sized particles will often be carried far downstream.

Thus, the effect of mining is to increase the downstream transport rate for fine and medium sediments. The consequence must be that the stream-system as a whole will have fewer of these sediments. This will result in greater streambed porosity. As the literature I have reviewed above shows, for all salmonid species greater porosity results in better survival and more available habitat for eggs and alevins.

In the case where the sediment is removed from a bar, rather than from the streambed, it is necessary to consider a longer time period — Stream courses aren't stationary but move within the confines of the streambanks. Fine sediments in gravel bars will be resuspended in the stream during these natural movements of the stream over the course of several years.

However, if the bars have been mined on a regular basis, their fine and medium particles will already have been removed before the river naturally resuspends them. Gravel bars which are free of silts and fine sand provide habitat. Although these bars may appear dry, there is often water and interstitial spaces below the surface, which can support alevins and redds (that is, nests of eggs) which were laid during high-water.

### **Recommendation:**

The conclusion is that the recreational mining activities of panning, sluicing, and dredging enhance salmonid habitat. These activities should be encouraged. They provide one of the most cost-effective enhancement techniques as they are a beneficial side-effect of private recreation.

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Sincerely  
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