WASHINGTON TROUT

Land Use and Coho Prespawning Mortality in the Snohomish Watershed, Washington.

EPA Agreement ID: MM97061201-0

Final Report

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Introduction:
Prespawning mortality (PSM) occurs when adult salmon return to freshwater but die before they are able to spawn. Between 1999 and 2003 Washington Trout has documented alarming rates of coho salmon (*Oncorhynchus kisutch*) prespawning mortality, ranging from 17% to 100%, in urban and rural residential/agricultural western Washington watersheds. In some urban watersheds, the majority of the adult coho returning to spawn died within hours of stream entry. NOAA Fisheries, with assistance from Washington Trout and Seattle Public Utilities, is analyzing stream / storm water quality and performing ecotoxicology bioassays on a subsample of Seattle metropolitan area coho tissue, bile, and blood collected during the fall 2001 and 2002 spawning seasons to investigate the mechanism of the premature mortality in Seattle streams. Preliminary results indicate that the crisis is likely driven by compromised water quality, but the mechanism, relationship to land-use, and geographic scope of the phenomenon are as yet unknown.

Given the threatened or depressed status of populations of trout, salmon, freshwater mussels, and other aquatic biota in the Pacific Northwest, water quality conditions that are so inhospitable as to kill adult salmon within hours of initial exposure are ecologically intolerable. Geographically limited data collected by Washington Trout and NOAA Fisheries prior to 2003 document a disturbing trend – coho salmon in some urban, rural residential, and agricultural watersheds in the Pacific Northwest are experiencing elevated rates of prespawning mortality. From a local salmon recovery standpoint, those lands managed as rural residential / agricultural areas support the greatest extent of wild coho spawning and rearing habitat. From a human health standpoint, urban, suburban, and rural residential landscapes support the greatest human interaction with and potential exposure to stream contaminants. The biological magnitude and geographic extent of prespawning mortality must be better understood so additional water quality and eco-toxicological efforts can be effectively targeted, with the ultimate goal of identifying and addressing the ultimate mechanisms of mortality. Single point-in-time grab samples of water quality may not accurately characterize the extent of water quality degradation, and Washington Trout and NOAA Fisheries data from 1999-2003 demonstrate that coho salmon (*O. kisutch*) are a suitable indicator species for this water quality issue.

Objectives:
The phenomenon of elevated coho prespawning mortality rates has only recently been identified. To date there have been no coordinated efforts to document the relationship between dominant land use within a watershed and the rates of coho pre-spawning mortality observed there. Identifying the relationship between land use and coho pre-spawning mortality will assist the detection of the mechanisms elevating the rates of coho prespawning mortality, and ultimately may facilitate the reduction of this threat to coho populations throughout the Pacific Northwest.

In 2003-2004, Washington Trout performed coho salmon spawning-success surveys within sub-basins of the Snohomish watershed in Western Washington. This first-year field investigation

did not attempt to determine the causal mechanism of coho prespawn mortality, but did pursue the following objectives:

(1) Document the spatial and temporal extent of coho salmon prespawning mortality in the Snohomish watershed, and

(2) Catalogue and investigate the relationship of these occurrences with watershed characteristics and land use patterns.

Methodology:

Study Site Selection: Washington Trout performed coho spawning success surveys in sub-basins within the Snohomish watershed in Western Washington (Figure 1). The Snohomish watershed was chosen because it presents important opportunities to account for variables that may affect adult coho premature mortality rates. The Snohomish coho populations, among the largest in Puget Sound, are predominantly wild (non-hatchery) fish. Four distinct coho stocks are recognized by the Washington fisheries co-managers: Snohomish, Skykomish, South Fork Skykomish, and Snoqualmie river stocks. Comprehensive and current GIS layers are available to determine dominant land-uses, percent impervious areas, road densities, and the locations of point-source pollution in the study basins. Additionally, Washington Department of Fish and Wildlife (WDFW) has compiled extensive background data regarding coho escapement over time, including baseline data from 54 index reaches revealing temporal trends in coho abundance. Coho spawning success survey study sites coincided with the locations of WDFW index reaches.

Washington Trout, working with representatives from NOAA Fisheries, WDFW, Washington Department of Ecology (WDOE), Snohomish County Surface Water Management (SSWM), and King County Water Pollution Control Division (KCWPCD), determined that the surveys should be conducted first at an extensive scale, and then at an intensive scale. Respectively, this allowed both a broad overview of the spatial extent and relative abundance of coho adult spawning throughout the river system, as well as allowing for more detailed examination of adult coho spawning success and pre-spawning mortality at locations encompassing known levels of riparian and upland land use. These two spatial scales are described below.

Extensive Scale: Washington Trout crews surveyed 29 Snohomish basin WDFW index reaches and one non-WDFW index reach between 10/28/03 and 2/12/04. Within seven days of the WDFW field staff documenting the beginning of the coho run in individual index reaches, Washington Trout crews surveyed that index reach to evaluate coho spawning success. This timing was chosen because the preliminary coho prespawn mortality data previously collected by Washington Trout and NOAA Fisheries suggest the phenomenon is most apparent early in the temporal phase of the coho run, possibly because runoff from early-season storms may contain high concentrations of toxic chemicals.

Intensive Scale: Based upon the results of the extensive surveys, three WDFW index

reaches in sub-basins stratified by each of three land use categories (Urban/suburban, Agricultural, and Forestry) were surveyed once a week for four to nine weeks during the peak of the 2003 coho return. Selection of the nine index reaches was based on the following criteria:

- Sites that exhibited prespawn mortality during the extensive surveys.
- Sites for which long-term coho escapement data exist.
- Access and logistical considerations.

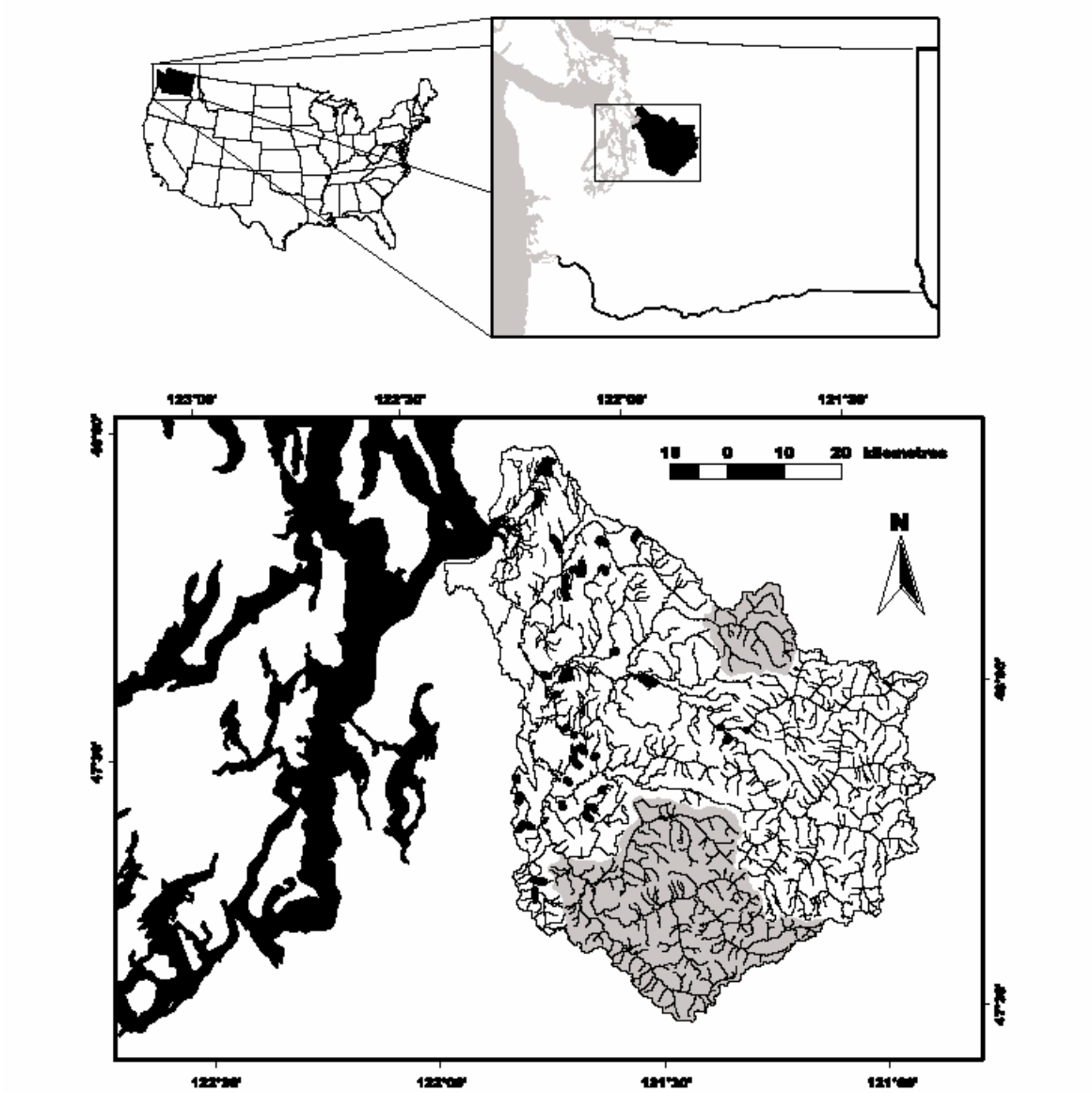

Figure 1. Map of the 4610-km^2 Snohomish River watershed in northwestern Washington. Solid black areas within the basin denote 54 WDFW adult coho salmon index reaches. Grey watersheds within the basin denote areas inaccessible to anadromous fishes (Pess et al. 2002).

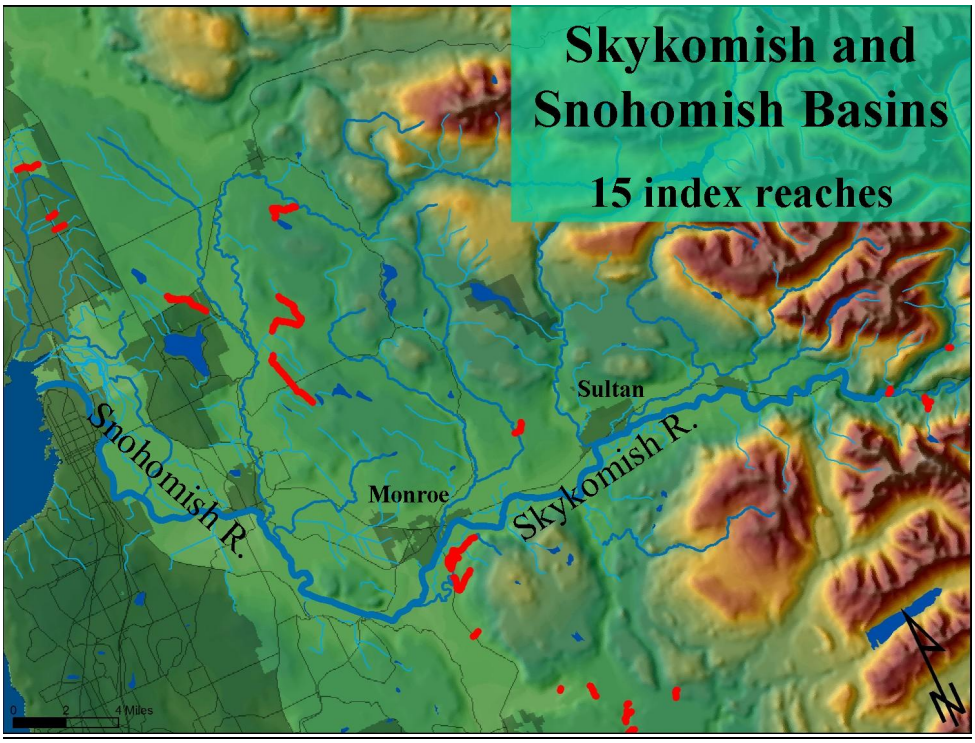

Figure 2. Coho prespawning mortality survey index reaches (in red) within the Skykomish and Snohomish River portions of the Snohomish watershed in northwestern Washington.

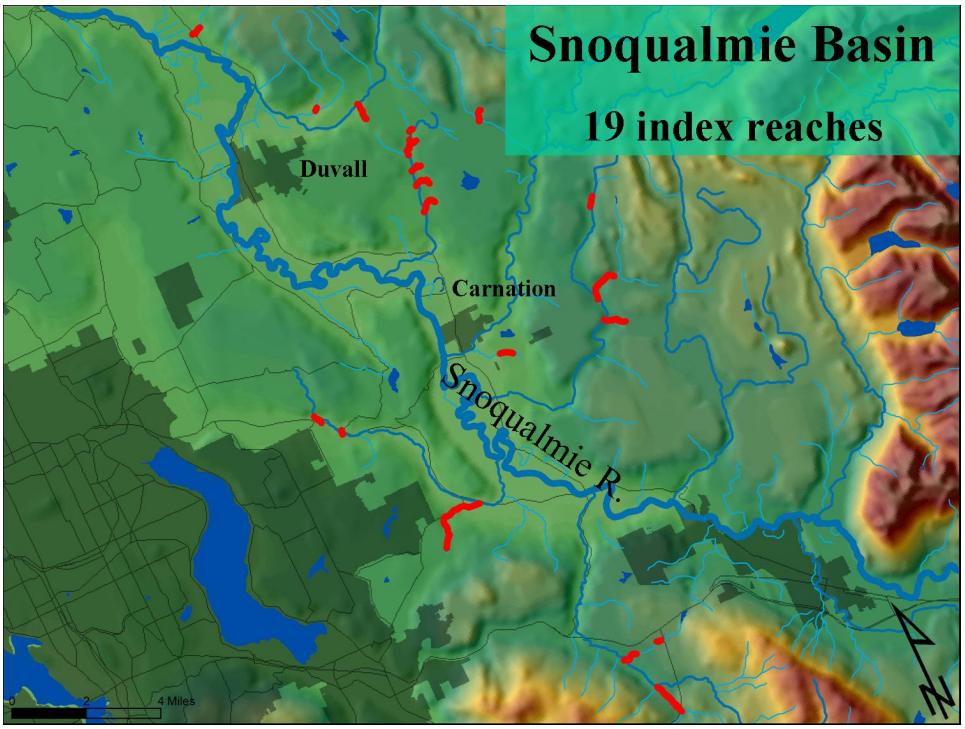

Figure 3. Coho prespawning mortality survey index reaches (in red) within the Snoqualmie River portion of the Snohomish watershed in northwestern Washington

Survey Protocols: Washington Trout, in cooperation with Seattle Public Utilities and NOAA Fisheries, developed and tested the survey protocol, field form, and database to support this project. Survey teams searched for coho carcasses within each identified index reach. Debris jams, boulders, cut banks, rootwads, trailing grasses, etc. were probed to increase the likelihood of uncovering and recovering carcasses in deeper sections of water.

During the course of the survey, the riparian area was carefully inspected for signs of carcasses dragged to shore by animals such as otter, dog, raccoon, bear, opossum and coyote. Crews were also vigilant for the wafting odor of a rotting carcass, prompting a heightened search in those areas.

Upon encountering a coho carcass during the study, all observations were recorded on the field form developed for this study (Figure 4). The location of the fish was documented using either a GPS or by making notes on the field map provided. The species and gender of each carcass were recorded in the notes along with the absence or presence of an adipose fin, the fork length measured in inches, the condition of the body cavity (intact or violated) and the presence of any tags. The carcass was then marked to prevent counting on subsequent surveys; marks included the removal of either the lower jaw or the caudal fin. The belly of each carcass was slit open with a serrated knife to allow an examination of the body cavity. Each crew verified and recorded the spawning success of females based on the absence or presence of eggs retained within the body cavity. Male spawning success was estimated, but due to the subjectivity of the assessment and the variability in the amount of milt retained by successfully spawned males, those data were not used in the analysis of pre-spawn mortality.

Spawning success was determined by examining female carcass gonads. The eggs of females are contained within two separate skeins within the body cavity. If these skeins appeared of equal size, full, firm, and intact, the fish was considered unspawned. If eggs were retained by the fish, they were counted. When counting was impractical, the volume of eggs retained was measured in a beaker, and the diameter of five randomly chosen eggs was measured to estimate the average egg diameter. In the case of carcasses that were too deteriorated to determine species, sex, adipose presence, and/or spawning success, "unknown" was recorded in the notes for each category in question.

OBS	Location	Species	Length	Sex	Adipose	Photo	Age	Body Cav. Intact	Signs of Death (1)	Signs of Death (2)	Male Spawning Condition	Scavanged	Fin(s) Worn	Eggs Retained		Egg Size
#	Dist. from known point		(FL, in)	M/F/ UNK	Y/N/UNK	(Camera/Frame)	<6, 6-48, 48+	Y/N	Spawned, Other (see 2)	Vis. Wounds, Stranded, Unknown	Spawned, Partial, Unspawned, Unknown	Y/N/UNK	Y/N/UNK	(#, UNK, ALL)	Volume, ml	dia of 5 avg. eggs

Figure 4. Fall 2003 Coho PSM Survey Field-form headers.

Data Analysis: Washington Trout used the Puget Sound Regional Council LANDSAT™ Thematic Mapper (2001) to determine land use characteristics and road density in each study sub-basin. Linear regressions were used to determine the relationships among land use, landscape variables, and coho prespawn mortality extent and timing. Because the field data by nature is descriptive, data summaries are presented that provide information on the spatial extent of the observed mortalities and their correlative relationship with key watershed and land use factors. This study was not designed to test hypotheses of cause–effect relationships.

Results

Summary Data: Washington Trout evaluated a total of 2,243 coho carcasses in the Snohomish basin study reaches between 10/28/03 and 2/12/04. Of those, 1,007 were males, 1,203 were females, and sex could not be determined for 33 carcasses. Of all the carcasses, only 12 were clearly adipose fin-clipped, 2,042 had their adipose fin intact, and adipose presence could not be determined for 189 carcasses.

Forklength was collected for 2214 adult coho carcasses. Forklength ranged from 13 inches to 35 inches, with mean forklength of 24.5 inches (Figure 5). Mean male forklength was 25 inches; mean female forklength was 24 inches.

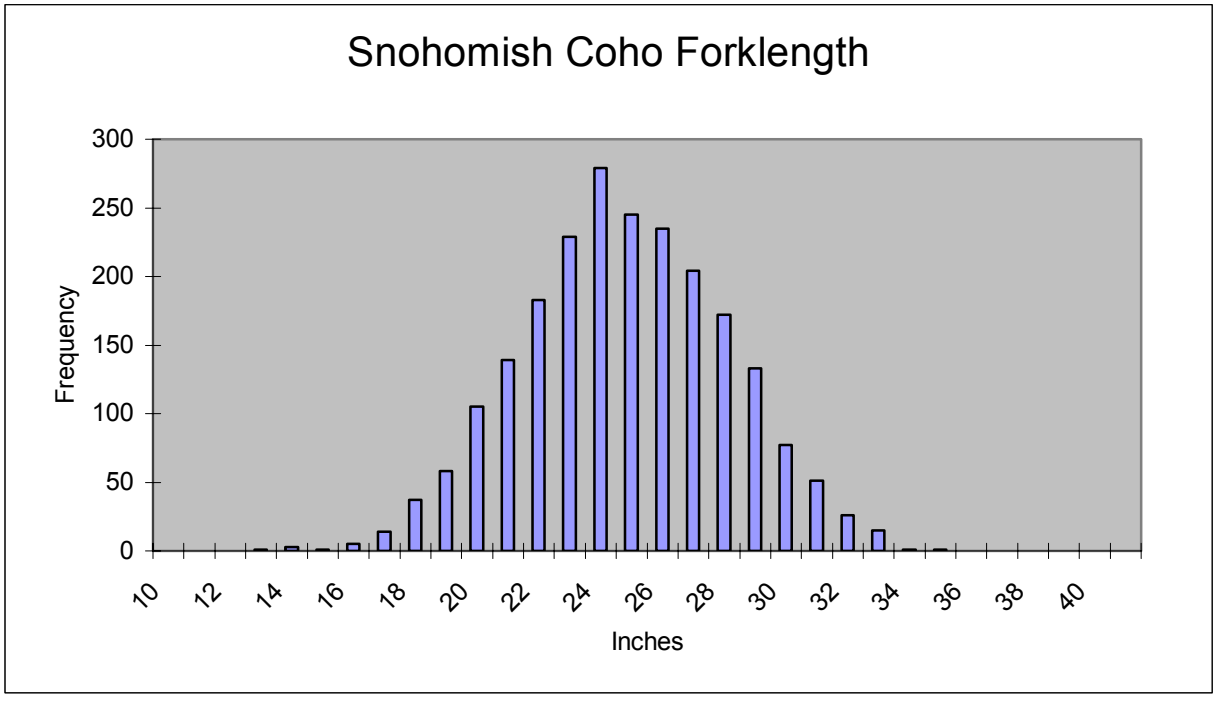

Figure 5. Coho carcass forklengths measured during the study (n=2214). Mean length was 24.5 inches.

Coho Prespawning Mortality: A total of 1,011 female coho carcasses with body cavity intact (BCI) were included in the prespawning mortality analyses (Figure 6).

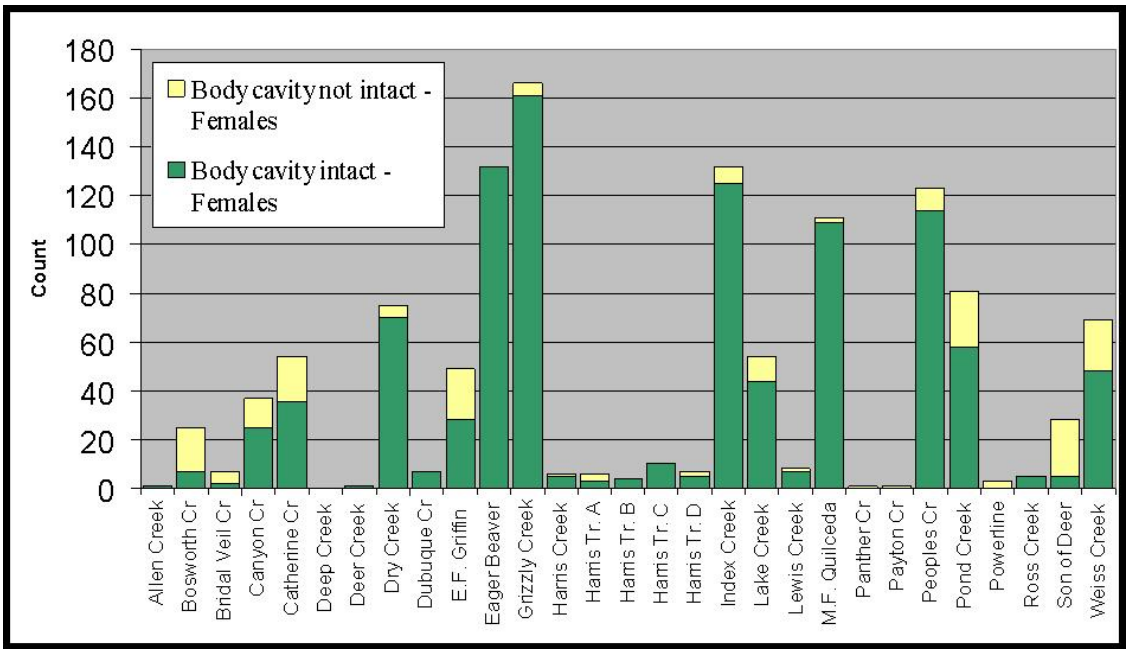

Figure 6. Proportion of female coho carcasses with body cavity intact vs. not intact, at each study reach. Body cavity not intact is a surrogate for scavenging pressure. Only female carcasses with body cavity intact (n = 1,011) were included in the PSM analyses.

Of the BCI female carcasses included in the analyses, the number of eggs retained ranged from 0 to 2,509, with an average of 83 eggs retained per female (Figure 7).

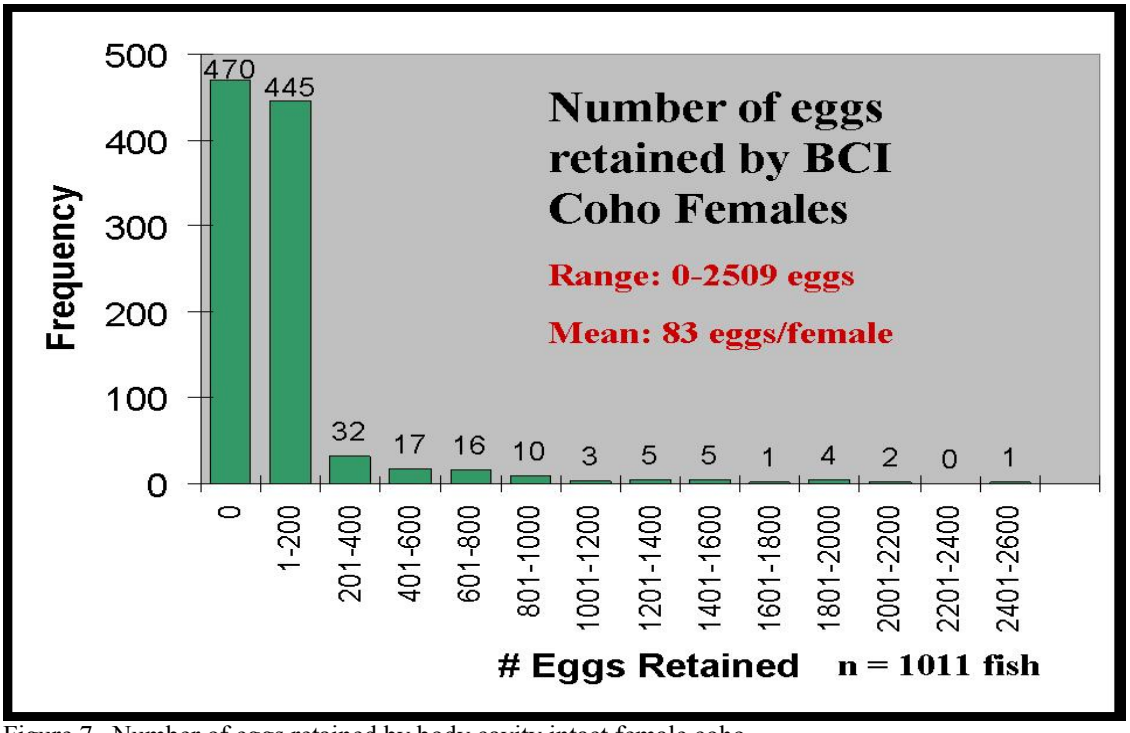

Figure 7. Number of eggs retained by body cavity intact female coho.

Using a coho length-fecundity regression (Koski, 1966), the number of eggs retained was converted into percent eggs retained (Figure 8). The term prespawning mortality is typically used to describe a female salmon that dies fully unspawned (or with 100% of her eggs retained). We documented a PSM rate of 2.18% (22 of 1,011 BCI female coho with 100% egg retention).

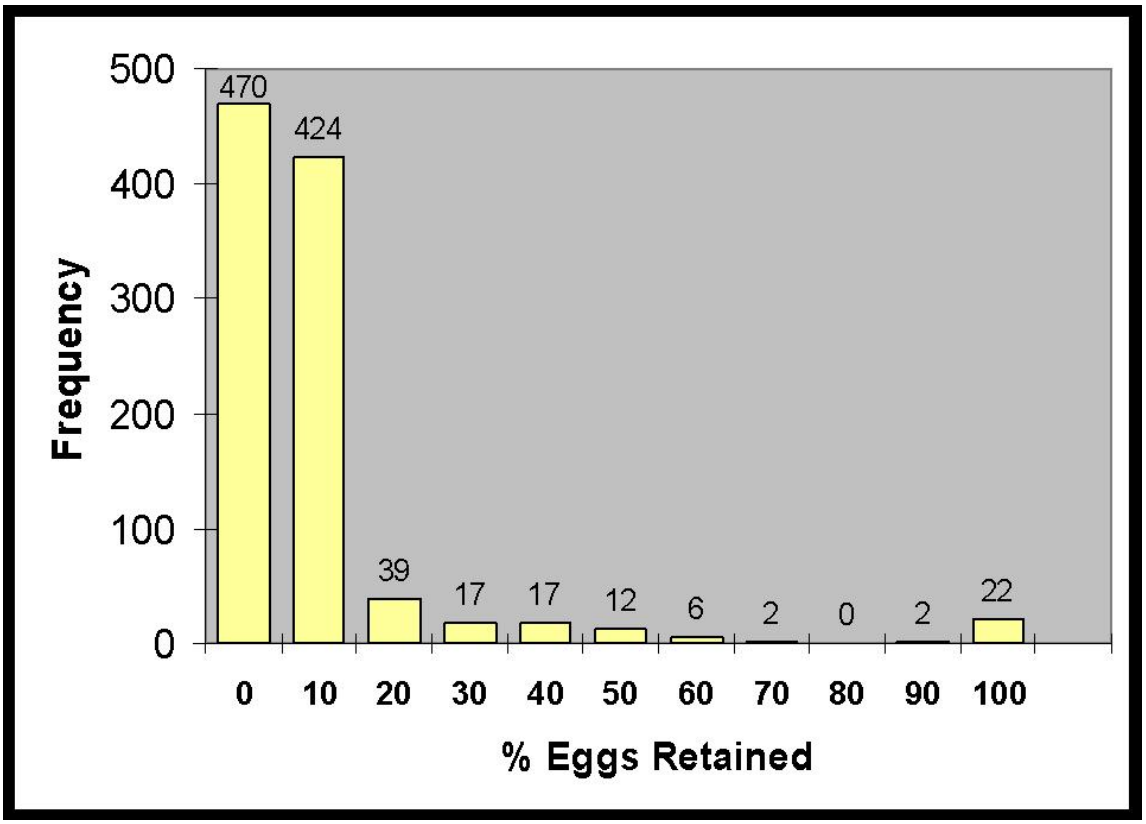

Figure 8. Percentage of eggs retained by BCI females (n=1,011). Fecundity was estimated using a length-fecundity regression (Koski, 1966).

We have characterized female coho that retained more than 10% of their eggs as incidences of High Egg Retention (HER) (Figure 9). One hundred seventeen carcasses (11.57% of the BCI female coho sample) retained more than 10% of their eggs (this amounts to approximately 200 or more eggs, depending on body size). HER was observed in almost every study reach (Figures 9, 10).

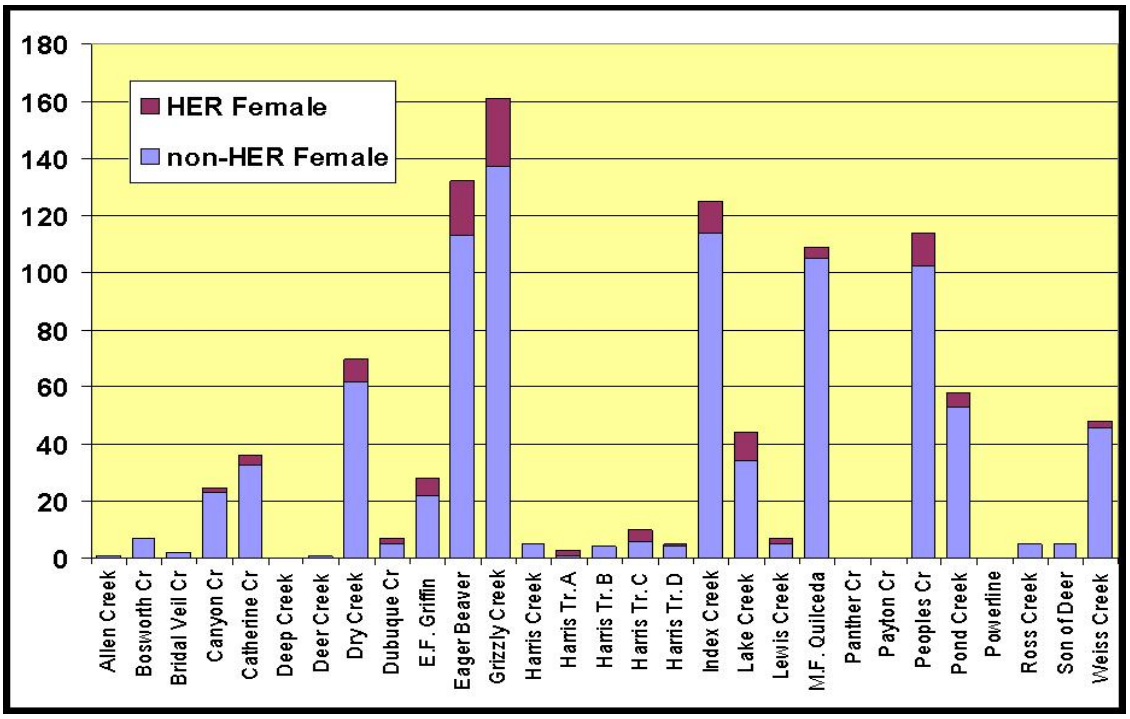

Figure 9. Histogram of high-egg-retention (HER) BCI coho carcass observations in the study reaches.

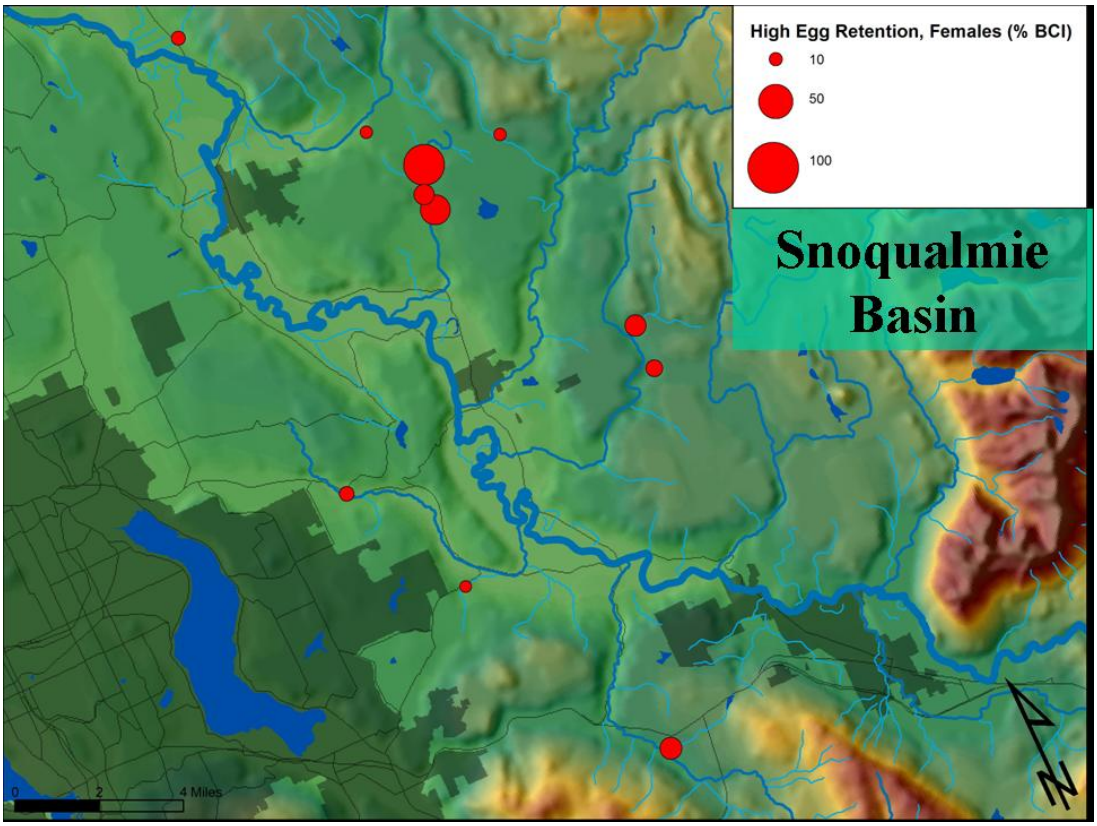

Figure 10. Distribution of high-egg-retention (HER) BCI coho carcass observations in the Snoqualmie study reaches.

HER and Watershed Characteristics: The characteristics of the basins contributing to each study reach were generalized using the Puget Sound Regional Council LANDSAT™ Thematic Mapper (2001). The area upstream from the downstream-most point in each study reach was delineated, and the characteristics of the contributing basin were identified (Figures 11, 12).

We tested three hypotheses to evaluate the relationship between HER occurrence and watershed characteristics:

Hypothesis 1: HER rate is inversely related to forested area in the contributing watershed.

Hypothesis 2: HER rate is directly related to developed area in the contributing watershed.

Hypothesis 3: HER rate is directly related to road density in the contributing watershed.

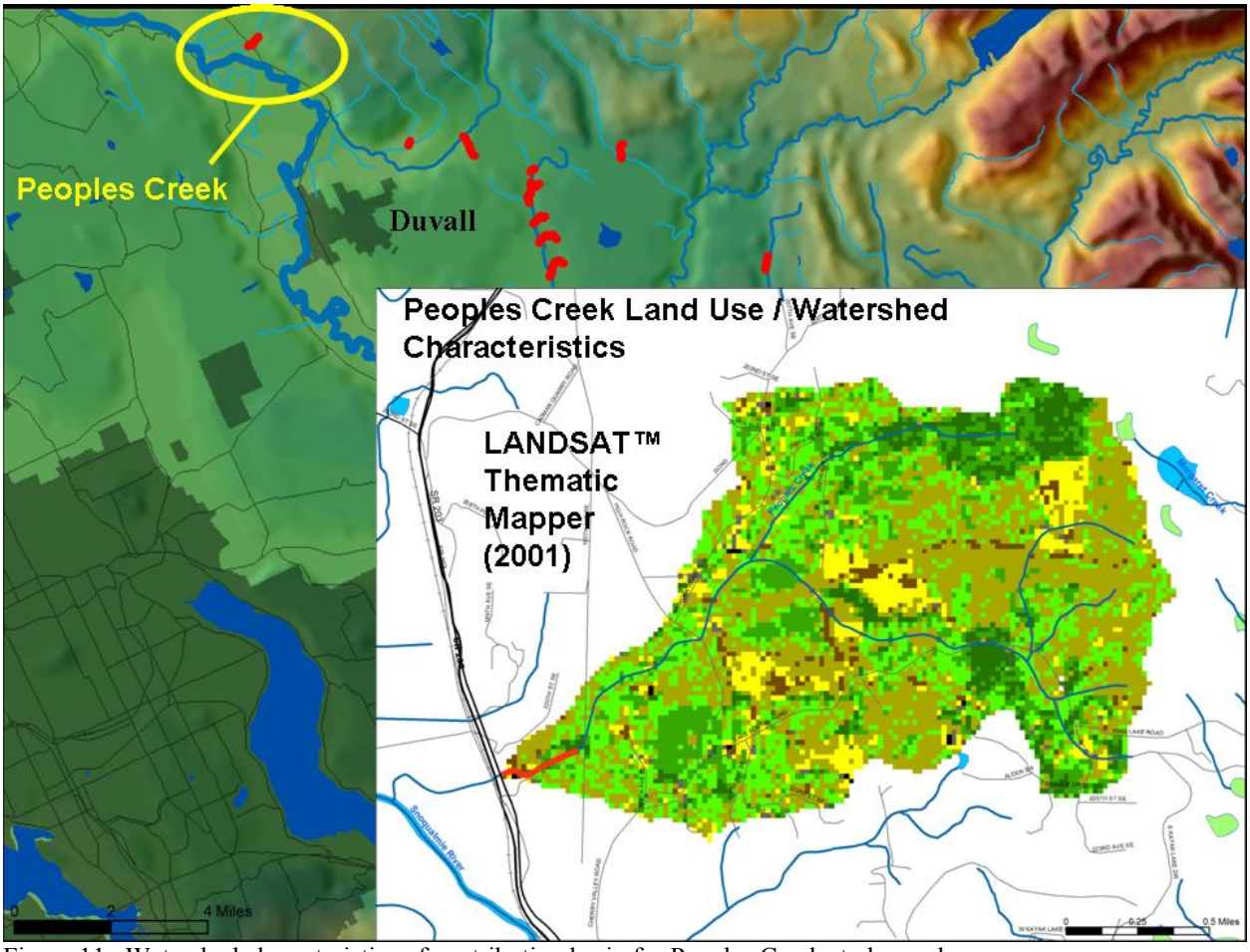

Figure 11. Watershed characteristics of contributing basin for Peoples Creek study reach.

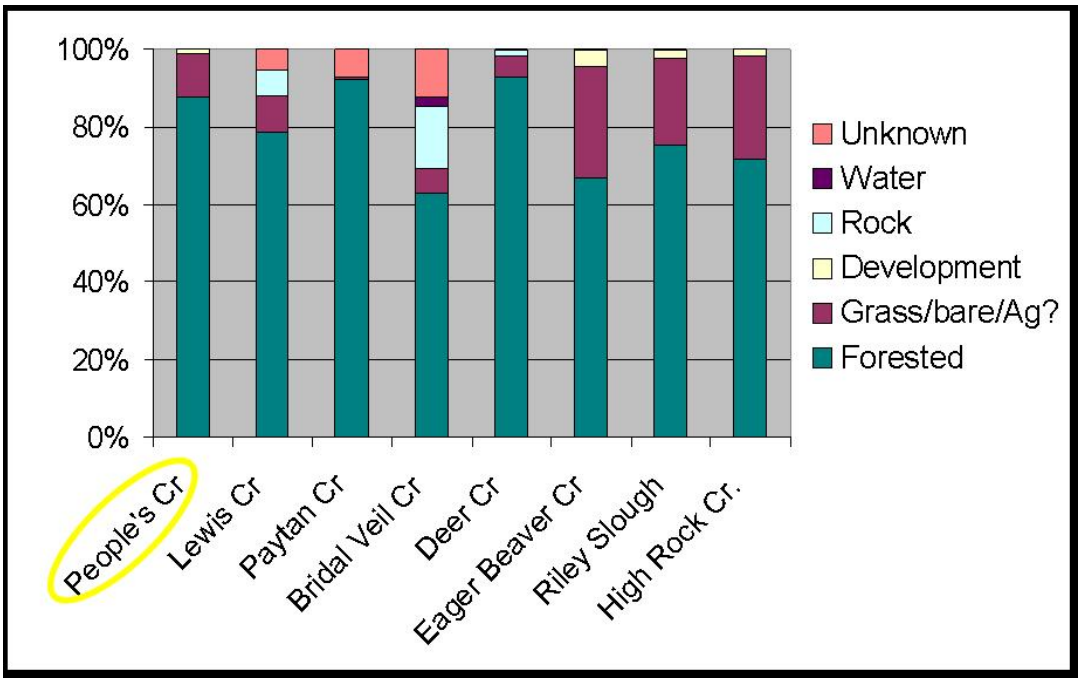

Figure 12. Watershed characteristics of the basin contributing to the Peoples Creek study reach and seven others.

No statistically significant relationships were found to exist between HER occurrence and forested area, developed area, or road density in the Snohomish watershed study reaches (Figures 13, 14, 15).

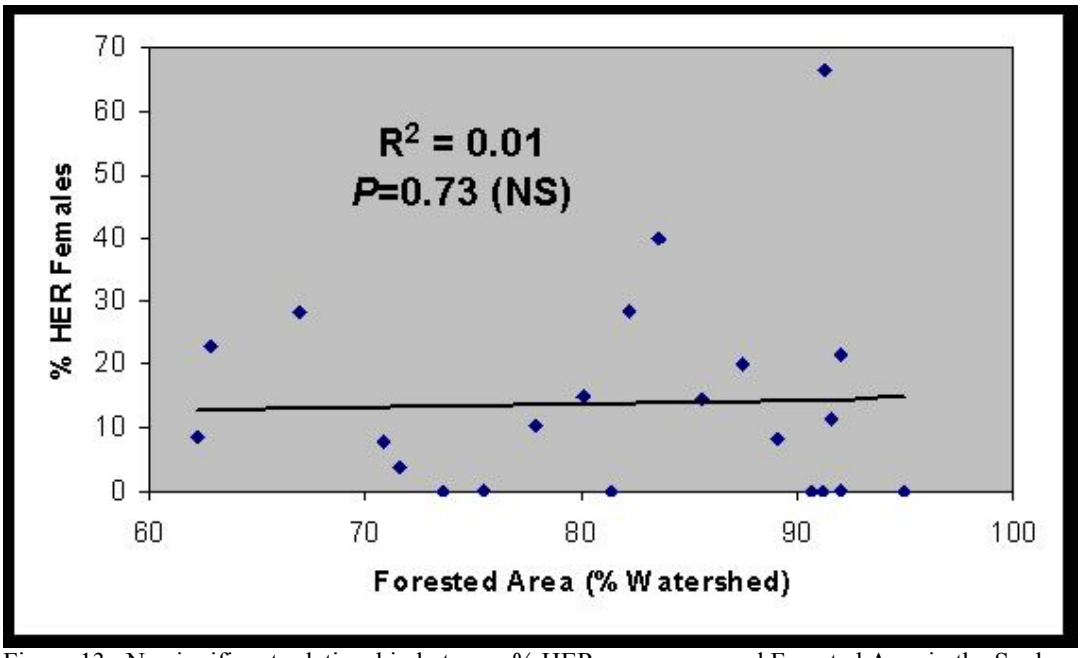

Figure 13. No significant relationship between % HER occurrence and Forested Area in the Snohomish watershed study reaches.

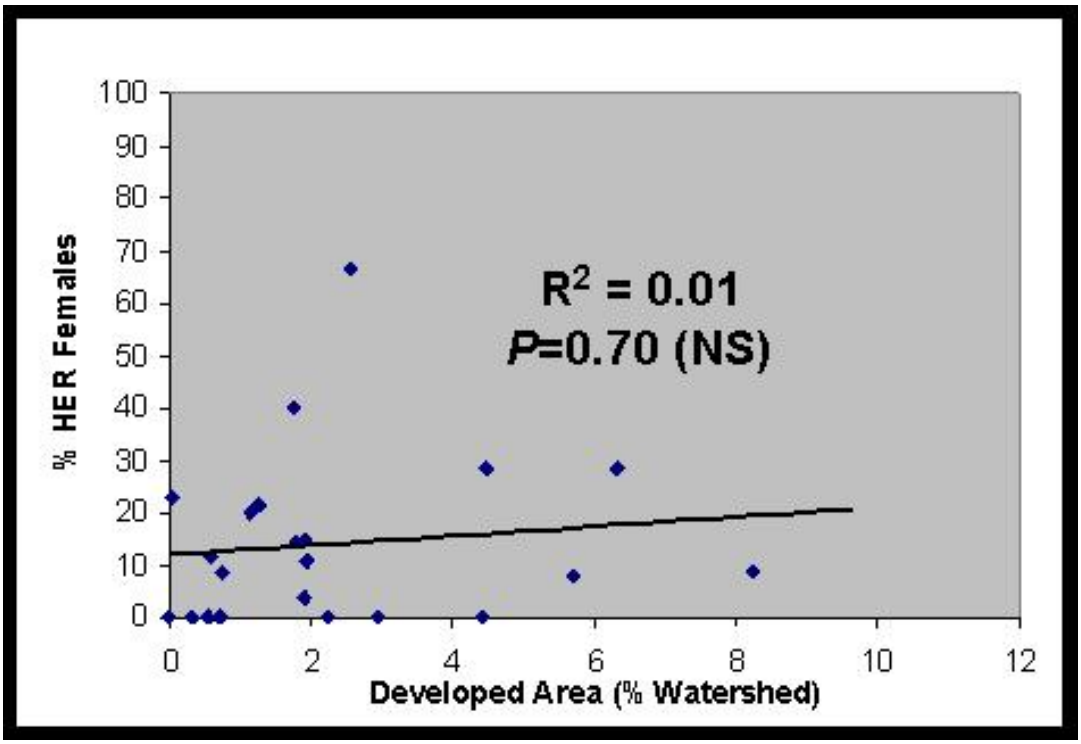

Figure 14. No significant relationship between % HER occurrence and Developed Area in the Snohomish watershed study reaches.

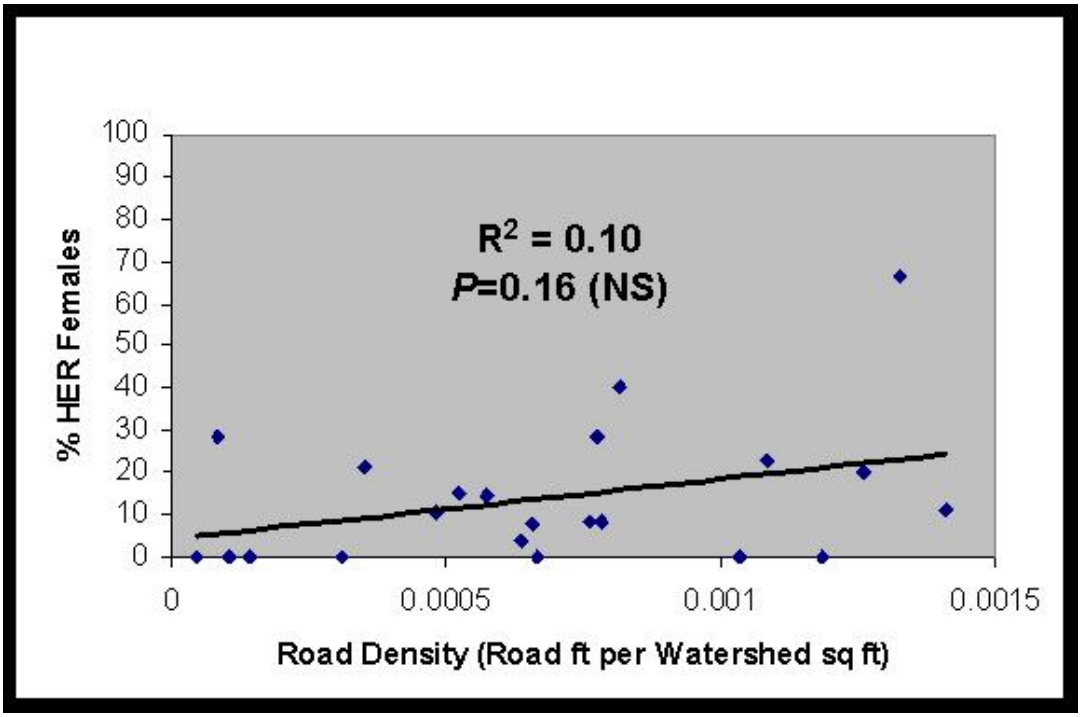

Figure 15. No significant relationship between % HER occurrence and Road Density in Snohomish watershed study reaches.

Conclusions

- Coho prespawning mortality (PSM, 100% egg retention) occurred in 2% of the body cavity intact (BCI) female coho carcasses encountered (n = 1,011).

- High Egg Retention (HER, >10% egg retention) occurred in 12% of the BCI female coho carcasses encountered (n = 1,011).

- Since carcasses with eggs retained may have been preferentially scavenged, and scavenged carcasses (i.e. with body cavity violated) were excluded from our analyses, our results may underestimate the actual occurrence of PSM and HER mortality.

- No PSM-symptomatic fish (i.e. disoriented, gaping, unable to maintain equilibrium) were observed during the surveys.

- HER is a widespread phenomenon in the Snohomish watershed, occurring in 29 of 34 study reaches.

- Both stranding and predation by dogs, coyotes, black bear, and otter are believed to contribute to PSM and HER mortality.

- No significant relationships were detected between HER incidence and the land use or watershed characteristics variables examined (% developed, % forested, road density).

Recommendations

These data collected within the Snohomish watershed allow an assessment of coho egg-retention in a relatively undeveloped watershed. Coho PSM has been well-documented in Longfellow Creek in Seattle, at rates between 50 and 90% (Scholz et al, unpubl.). Approximately 80% of the Longfellow Creek watershed area is classified as impervious. While we chose study sites that represent a wide range of development pressure in the Snohomish, our most intensively developed watershed was still less than 9% developed by area.

In order to more thoroughly investigate the relationship among PSM rates, HER rates, and watershed characteristics, we recommend that additional study reaches representing an intermediate level of development (between 10% and 70% impervious area) should be assessed for PSM and HER occurrence. In order to better define the geographic scope of these phenomena, the intermediate watersheds should be studied over a broad geographic region, with study reaches throughout western Washington, including sites in Bellingham, Everett, Seattle, Tacoma, Olympia, and Vancouver. Also, a coordinated effort should be made to document and consolidate PSM and HER observations made by local (city and county) government agents throughout western Washington and Oregon. Those agencies not aware of the phenomena should be educated and trained in survey and data collection methodologies.

Literature Cited

Koski, K. V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. Masters Thesis, Oregon State University, 88 pp.

Pess et al. 2002. Landscape characteristics, land use, and coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Wash., USA. Canadian Journal of Fisheries and Aquatic Sciences, V59, 613-623.

Scholz et al, unpubl. NOAA Fisheries Northwest Fisheries Science Center. Seattle, WA.