OWEB Grant #208-8009-5783 "Integrated Dynamic Landscape and Coho Model." Progress Report

Mapping of historical splash damming in the Oregon Coast Range

Kelly Burnett (USFS)

Rebecca Miller successfully defended her Masters Thesis, including an oral presentation at Oregon State University:

Miller, Rebecca R. 2010. Is the past present? Historical splash-dam mapping and stream disturbance detection in the Oregon Coastal Province. MS Thesis seminar, Oregon State University, Corvallis, OR. September 23, 2010.

The thesis is titled: Miller, R.R. 2010. Is the Past Present? Historical Splash-dam Mapping and Stream Disturbance Detection in the Oregon Coastal Province. MS thesis. Oregon State University, Corvallis, OR. 96pp. and is available online at: http://hdl.handle.net/1957/18998.

We created publicly available geodatabases with Federal Geographic Committee Data compliant metadata for the mapped historical splash dams and log drives in western Oregon which can be found at: ftp://ftp.fsl.orst.edu/pub/kellyb/splash_dams/

The research was featured on Oregon Field Guide: http://www.opb.org/programs/ofg/segments/view/1761.

The research is summarized on Kelly Burnett's PNW Research Station Team website: http://www.fsl.orst.edu/lwm/aem/people/burnett#splashdams

The research was presented in talks at several venues including the 2010 meeting of the Oregon Chapter of the American Fisheries Association and seminars at Oregon State University.

Miller, Rebecca R., Kelly M. Burnett, Joseph Ebersole, S. Mark Meyers. 2010. Is the past present? Historical splash-dam mapping and stream disturbance detection in the Oregon Coastal Province.

- National Oceanic and Atmospheric Administration, Portland, OR. April 12, 2010. invited presentation.
- USFS PNW Olympia Research Station Aquatic Ecology Management Fall Seminar Series, Olympia, WA. October 26, 2010. invited presentation.
- Northwest Scientific Association Conference, Centralia, WA. March 24, 2010. invited presentation.
- Research Advances in Fisheries, Wildlife and Ecology Symposium, Oregon State University, Corvallis, OR. February 2, 2010. offered presentation.
- Annual meeting of the Oregon Chapter American Fisheries Societ 4, 2010. offered presentation.

Linking landscapes with adults Coho salmon, juvenile Coho salmon, and Coho salmon habitat

E. Ashley Steel (USFS)

The first manuscript linking adult Coho salmon abundances at index sites with landscape conditions was accepted at Transactions of the American Fisheries Society. The analyses linking adult Coho salmon at randomly-sampled sites with landscape condition are currently in revision. Themanuscript reporting these findings will be resubmitted to the Canadian Journal of Fisheries and Aquatic Sciences in January. Together these two papers will complete our investigation of how landscape conditions relate to adult Coho salmon abundance and these results can inform mechanistic, population-scale models.

We have also completed analyses exploring how landscape conditions drive multiple different in-stream habitat features such as percent wood or pool distribution. These models were developed by first considering variables known to influence stream power; then adding variables that are not routinely influenced by human actions or landscape management; and, finally, assessing any additional explanatory power that management variables (e.g., riparian forest condition or road density) had in predicting the distribution of important in-stream habitat characteristics (Figure 3. from Anlauf et al.). We found that management variables had strong effects for some habitat features but little explanatory power for others. These analyses are completed and will be submitted for publication in January 2011.

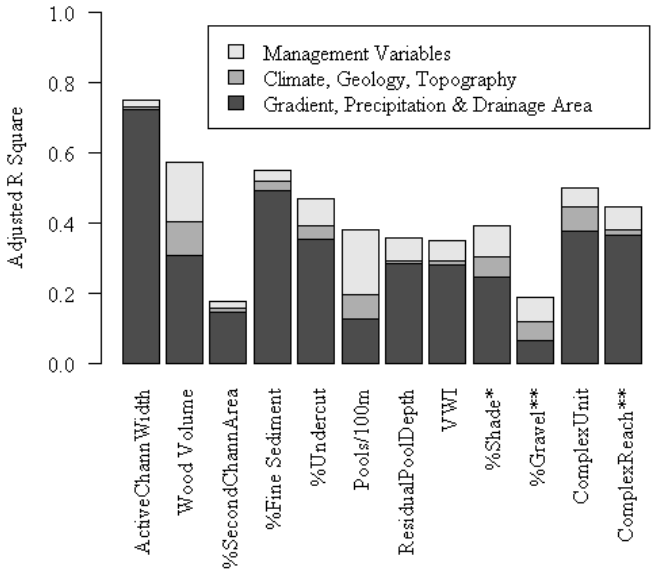


Figure 3 from Anlauf et al - IN PREPARATION. Proportion of variability attributed to management, immutable (climate, geology, topography), or stream power indicator (gradient, precipitation, drainage area) variables for the twelve stream habitat variables evaluated. The analyses linking juvenile Coho salmon with landscape conditions are the final step in our project.

The analyses linking juvenile Coho salmon with landscape conditions are the final step in our project. These analyses require significantly more advanced modeling tools due to the hierarchical nature of the data and the number of sites which were only sampled once during our window of observation. In addition, we plan that the final juvenile Coho salmon analyses will synthesize, statistically, our understanding of how adults, juveniles, and habitat are distributed by and controlled by landscape conditions. We expect this work to be completed by the end of Summer 2011 and final manuscripts to be submitted by the end of 2011.

Developing a statistical backbone for the modeling efforts: Although not proposed as part of our original project, we identified important issues regarding spatial covariation between human development and landscape gradient while attempting to develop the best statistical models for linking landscape conditions and salmon distribution. We explored the spatial structure of the landscape data using the Oregon Coastal Coho salmon dataset for a case study. The explorations were drafted into a manuscript and submitted to River Systems. The title of the manuscript was "Untangling human development and natural gradients: Implications of underlying correlation structure for linking landscapes and riverine ecosystems." This work will allow us to proceed correctly in building landscape-scale models of Coho salmon. The manuscript has been returned for relatively minor revisions which are currently in progress.

Abstract: Increasingly, ecologists need to identify and quantify relationships between landscape gradients and aquatic ecosystems. Considerable statistical challenges emerge in this effort, some of which are attributable to collinearity between human development and landscape gradients. In this paper, we measure the covariation between human development such as agriculture and urbanization and natural landscape gradient such as valley form, climate and geology. Using a dataset of wade-able stream sites from coastal Oregon (U.S.A.), we use linear regression to quantify covariation between human activities and landscape gradients. We show that the correlation between human development and natural landscape gradients varies dramatically with the scale of observation. Similarly, we show how the correlation varies by sub-region, even within a scale of interest. We then use a simulation experiment to show how this inherent covariation undermines statistical efforts to measure mechanistic links between landscape gradients and significant features of aquatic ecosystems, such as abundance. With the simulation, we illustrate the negative consequences of the underlying correlation structure for statistical efforts: goodness-of-fit metrics and inflated error terms on key coeffcients that may undermine model building. We conclude by discussing the current best statistical practices for dealing with multicollinearity as well as the limitation of existing statistical tools.

This work was presented at the North American Benthological Society Meeting in New Mexico in June 2010 to get feedback from river ecologists and at the Western North American Regional (WNAR) meeting of the International Biometrics Society to get feedback from statisticians.

Dynamic Landscape and Coho Salmon Modeling

Peter W. Lawson (NOAA)

Summary. Mark Meleason, post-doc, made substantial progress toward the goal of advancing the habitat-based Coho life cycle model developed by Nickelson and Lawson (1998) for Oregon coastal Coho populations. A major addition to this model prior to this post-doc work was the coupling of the Coho model with the Dynamic Landscape model (ESI website). This coupling could potentially enhance our ability to simulate Coho populations in a changing environment. The main focus of this year's work was to improve the linkage between the two models. In addition, a method to populate stream reaches with an initial wood standing stock was developed. Finally, the linkage between over-winter survival and realized habitat

Major Accomplishments. We have two manuscripts in preparation from this work and one presentation of this work was given at a scientific conference. We also organized and hosted a two-day conference on simulating Coho populations in a dynamic habitat.

1. Coho modeling workshop. The purpose of this workshop was to explore possible refinements to our coho modeling project through an open discussion with fisheries scientists from the Pacific Northwest. We had 22 people participate and the open discussion at the end of the workshop was extremely informative. Please see Appendix A for details on the workshop.

2. Assess the linkage between the two models. The Dynamic landscape model predicts in-stream wood and sediment loads through time, along with a variety of stationary variables such as stream width, stream gradient, and basin area. The linkage function between the two models must translate outputs from the Dynamic Landscape model (wood and sediment loads) to habitat metrics used in the Coho model (maximum Coho capacity by reach). There were two linkage methods proposed prior to this work – the method presented in Lawson et al (2007) and the IHab method (an index of habitat quality that ranges between 0 – 1) developed by the Coho modeling group. To test these approaches, we used the ODFW's Habitat Limiting Factors model v7.1 (HLFM) to assess our GIS-based prediction of habitat capacity. For our initial investigation, we obtained reach and unit-level data from ODFW's random reach surveys from their Oregon Plan (Figure 1). Given these data, the two linkage methods had a poor agreement with the HLFM capacity estimates (Figure 2). In fact, the two linkage methods were unresponsive to changes in habitat as predicted by the Dynamic Landscape model.

3. Develop more responsive linkage function. The Dynamic landscape model predicts wood and sediment loads on an annual time step for each reach, as well as static GIS-based variables such as active channel width, stream gradient, valley width, and basin area. The habitat-based Coho life cycle model uses the winter capacity per reach, estimated from HLFM using pool area, to calculate over-winter survival. Thus the "currency" that the output of the Dynamic Landscape model must be translated to is proportion of the reach area in pools.

The GIS-based capacity method developed here has three steps. First, determine if the reach is a small or large stream as defined in the HLFM (summer wetted width ≤ 10 m) by calculating summer wetted width using the regression with active channel width, which we developed using data from ODFW. Second, estimate the proportion of reach area in fast and slow water using the

multiple linear regression equation that uses active channel, valley width, total wood volume, and mean sediment depth as independent variables (Figure 3). Third, we estimate habitat capacity from a simplified version of the HLFM that we developed (Figure 4). We then compared our GIS-based linkage function to HLFM capacity estimates using the Nehalem data set (Figure 5). Our conclusion is that this method has great promise. We are now developing this linkage method based on an expanded data set representing the entire Oregon coast. Our goal is to have this work complete and published in 2011 (first draft based on the Nehalem data set only).

4. Develop a method to predict initial wood loads as a function of landuse type. The Dynamic Landscape model requires an initial wood standing stock for each reach at time 0. We obtained wood data from ODFW that also contained stream habitat variables (e.g., width, gradient, valley width etc.) and riparian variables (e.g., tree density, percent conifer, etc.). Numerous researchers, including scientists in this group, have attempted to relate wood abundance to forest and stream conditions with limited success in accounting for the variability. Fortunately, our goal here was not to account for the variability of wood loads by stream and forest attributes, but to populate reaches with initial wood loads given the observed distributions of wood abundance around several GIS-based attributes. After numerous models, we selected primary land ownership as the primary variable to base a sampling scheme to populate streams with an initial wood load (Figure 6).

There are two confounding influences on the wood standing stock attributed to the way the data was collected. First, the length of reach sampled and second, the location of the sample in the basin. To further contribute to this pattern, the shorter reach surveys were conducted in the small streams with higher gradient and lower valley width indexes. We conducted a 2-way ANOVA to test if the length of survey (two categories – short < 750 m) and land ownership influenced standing stock (Figure 7). Both factors were highly significant. By adding the covariates active channel width and channel gradient, the effect of reach length and basin position were accounted for. We are continuing to develop the final form of the method we will use to populate stream reaches with initial loads and anticipate publishing these results in 2011.

5. Examine over-winter survival as related to capacity using the Lobster Creek data supplied by ODFW. Issues with the Lobster Creek data (indirect estimate of wood, no sediment depth, reach end points changing year to year) limited the usefulness of this comparison and additional modifications were not applied. However, the usefulness of these data are in comparison to the fish survey data where the predicted capacities can be compared to summer juvenile and smolt population estimates as in Nickelson (1998) (Figures 8 and 9). I calculated the percent of predicted smolt capacity as 100*(smolt adundance estimate / HLFM smolt capacity). Figure 8A is as close as possible, the same approach as in Nickelson (1998) Fig 1, which includes the same Lobster Creek data. This is a graph of the percent of predicted smolt capacity (smolt population estimate / HLFM smolt capacity estimate) versus the juvenile density of the previous summer expressed on a per m^2 of pool area. There is roughly a similar pattern - 100% capacity near 1.5 parr / m^2 pool area. Figure 8B is a slight variant of A by replacing the x variable with smolt density per m^2 of the entire reach area. Here, 100% capacity is around 0.12 smolts/ m^2, but with considerable variation given the small sample size.

Figure 9 is in the format of Fig. 2 in Nickelson (1998). It is a graph of the observed over-winter survival as a function of estimated smolt capacity. The regression equation for these data is $y = 0.0752\ln(x) + 0.4683$, $r^2 = 0.38$ as compared to Nickelson (1998) of $y = 0.136 \ln(x) +0.487$, $r^2 = 0.72$. I would suggest that two graphs are similar, at least for estimated smolt capacities < 0.4. It is worth noting that 2 of the 30 observations in the Nickelson (1998) analysis were from beaver-dominated streams, and I would suspect it is the two points around 1.2 smolt capacity.
The main issue with these analyses concerns the areas sampled among the various habitat and fish surveys. For HLFM capacity estimate, I used the sum of the unit areas and assumed that this was also the area associated with the smolt trap. In Nickelson (1998) the area sampled was reach length X active channel width. I have obtained reach survey lengths, which varied by year and by survey but do not have active channel width. I would suggest that given the uncertainties in area for the summer and winter habitat surveys (wetted width vs active channel width) and the sample areas associated with summer juvenile, winter parr, and smolt estimates, that the results should be expressed on a per kilometer basis.

6. We gave a presentation of our Coho modeling work at the *Special Workshop on Salmon Escapement Goal Science*, November 18 and 19 in Portland Oregon. Please see Appendix B for the abstract. The presentation was placed on the workshop website at: http://www.wabc-afs.org/news/eventspage/upcoming-meetings-and-events/salmon-escapement-science-workshop/workshop-abstracts/

Figure 1. The Nehalem reaches used in this analysis (A) include 25 from the "random" surveys (filled triangles) and 31 from the "continuous" surveys (yellow line). The reach numbers assigned to the continuous reach data are presented in (B). These figures were provided by Kelly Christiansen.

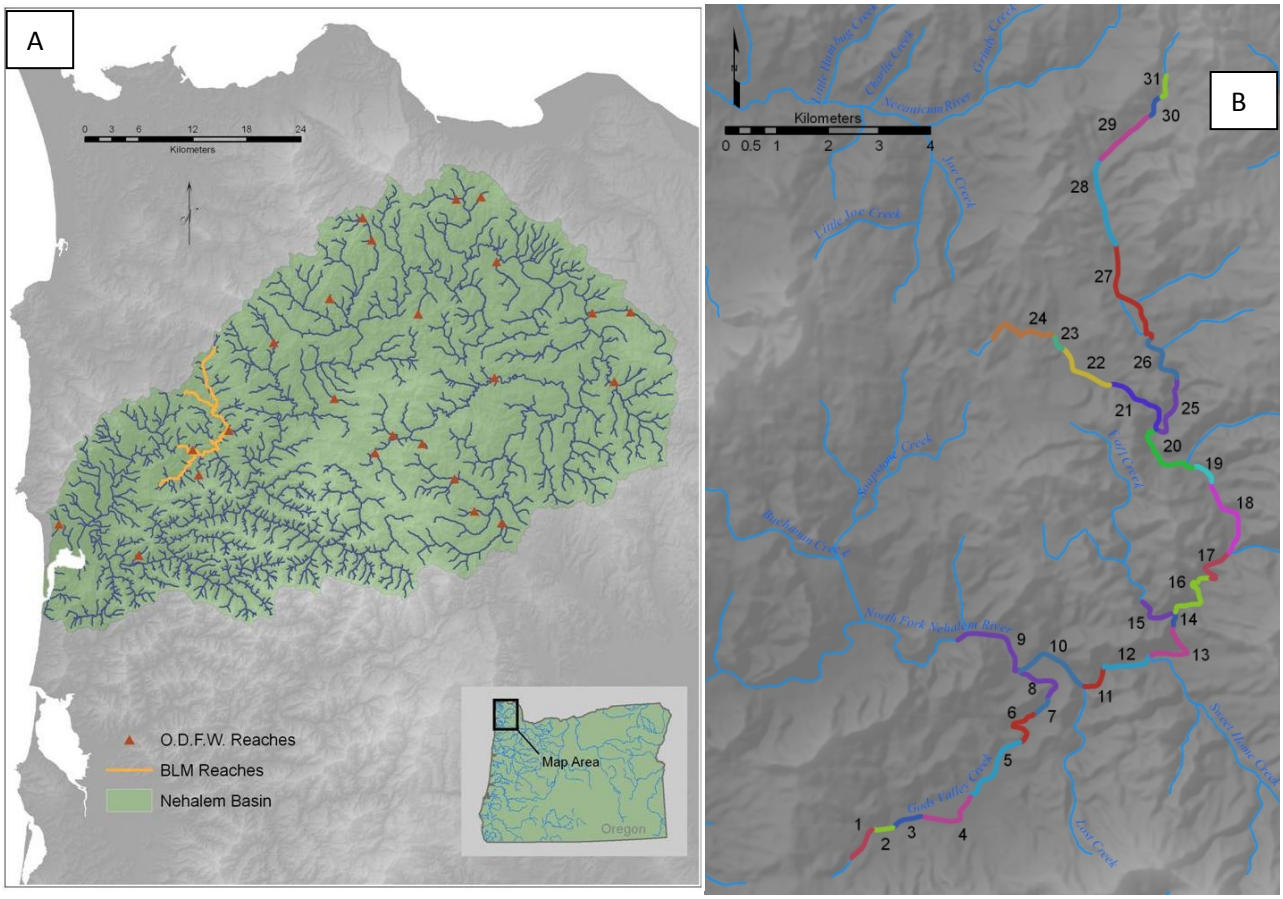


Figure 2. Performance of the initial linkage functions - T17 is the original equation (Lawson et al 2007) and T1 is the unmodified version of the GIS model using IHab as the limiting factor. Note that the maximum "high" gradient values = 0.17025 and the maximum "low" gradient values = 0.0741. The line represents a "perfect fit" between the capacity estimate of the HLFM and the GIS model.

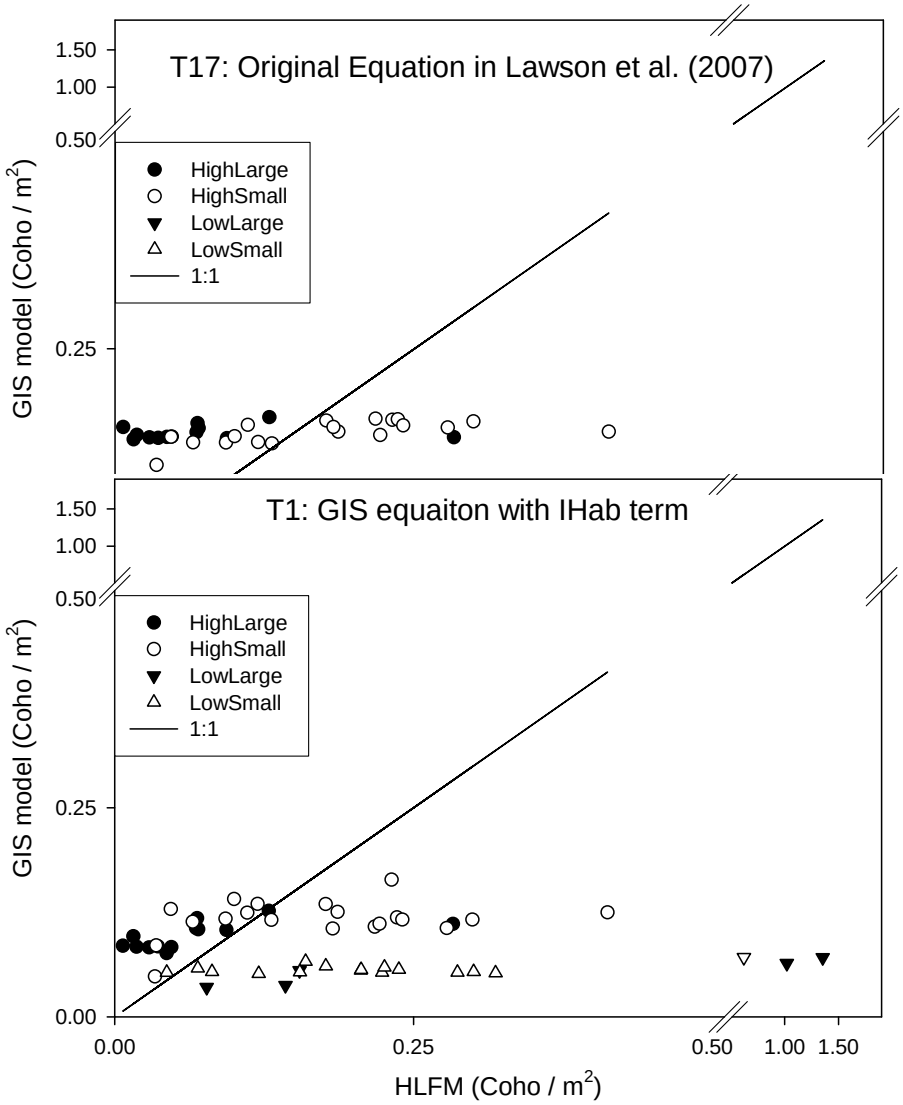


Figure 3. Comparison of the percent pool area in winter reach habitat predicted using GIS-based variables and the percent pools measured in the field. These data are the winter reach habitat data for the Nehalem and excludes reaches with beaver ponds > 3% of pool area (n = 44). The solid line is the 1-to-1 fit of these data (perfect fit).

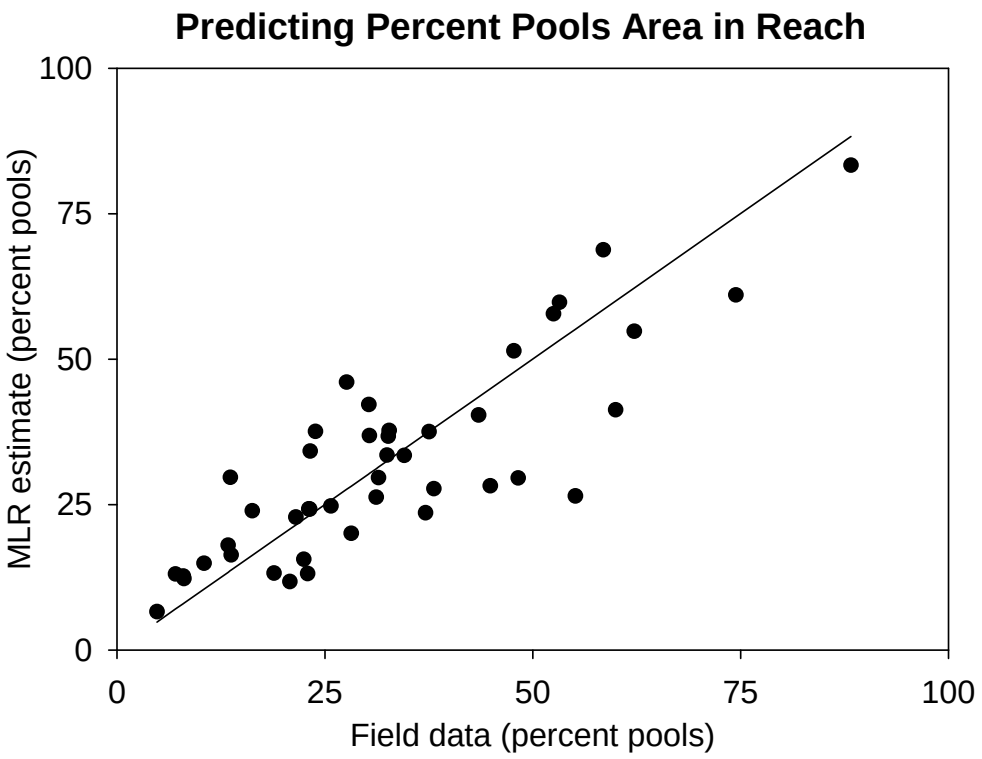


Figure 4. Comparison of the winter habitat capacity estimates from the HLFM and the GIS-based capacity equation developed to replace those in Figure 2. This trial is the best fit possible with the GIS-based capacity equation because the percent of the reach in pools and percent of the pools as beaver ponds and alcove were taken from the field data.

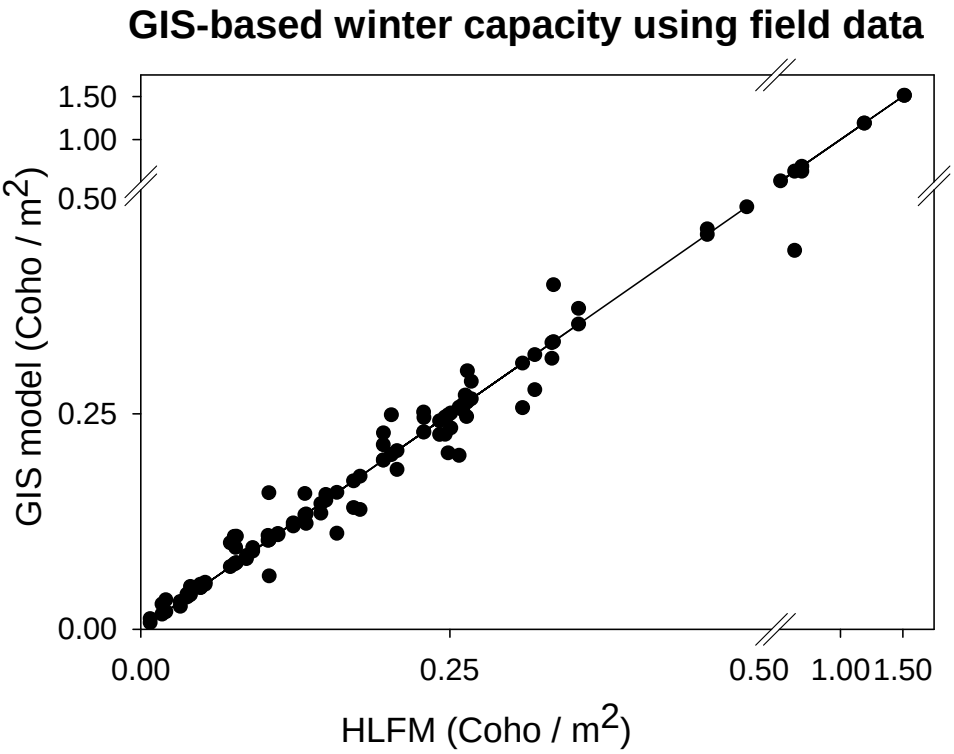


Figure 5. Comparison of winter parr estimates of the HLFM with the GIS capacity model for the Nehalem data set. Reaches with > 3% beaver pond area were excluded from this analysis. The GIS capacity model includes the capacity estimate based on the 4 unit types (Table 2), given the stream size (using the summer wetted width regression), and percent pool estimate. All variables were derived from the GIS layer except for wood and sediment depth, which were obtained from the ODFW field data.

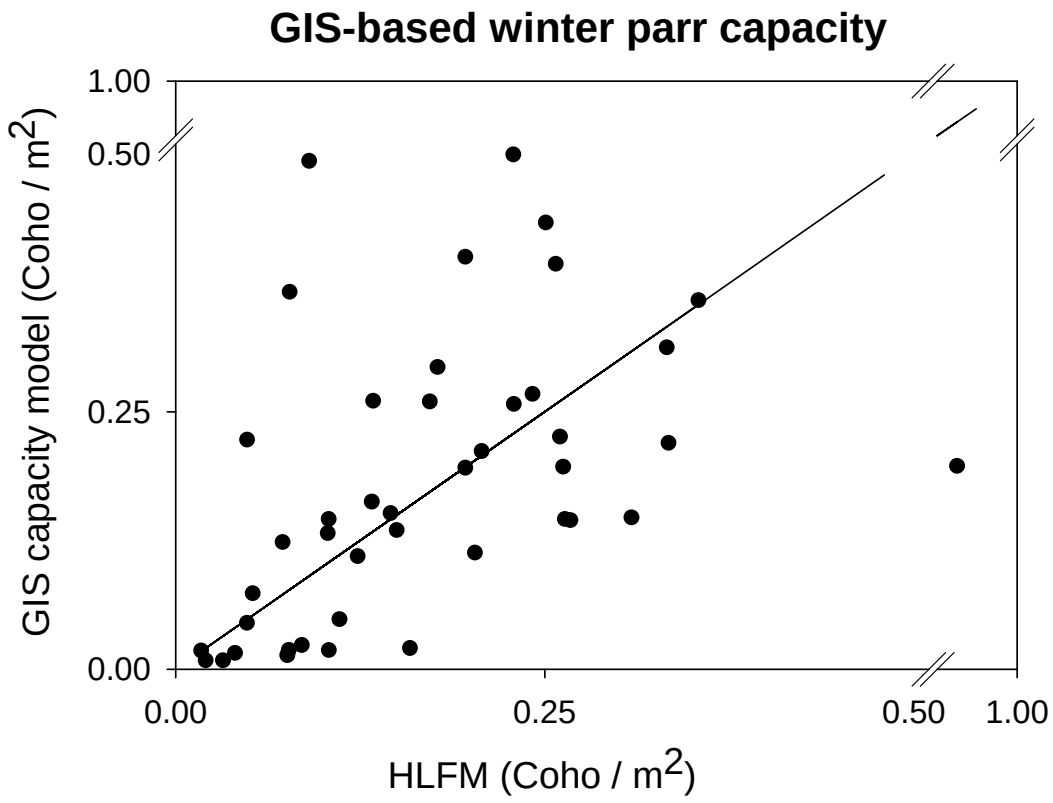


Figure 6. Wood volume by primary land use for Oregon coastal streams. Primary land ownership categories are agricultural (AGR), federal (FED), private industrial forest (PIF), private non-industrial (PNI), state forest (STF), and urban (URB). The median is represented as a dashed line and the mean as a solid line.

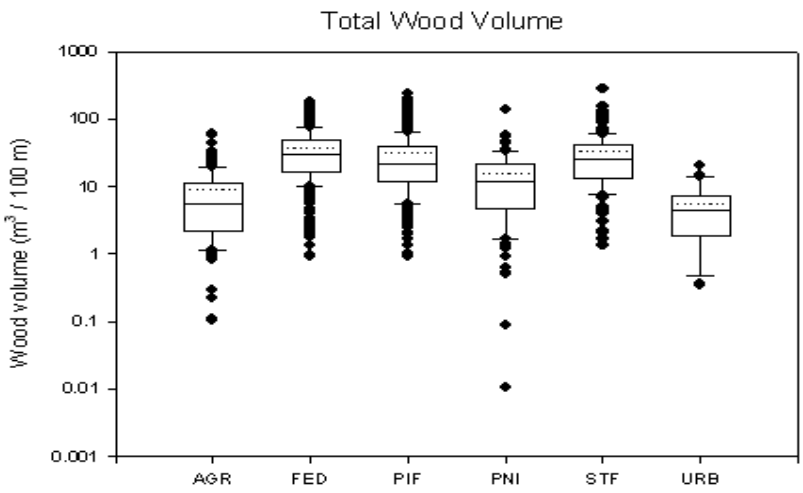


Figure 7. Wood volume by primary land ownership and survey reach category short (S <750 m), and long (L > 750 m).

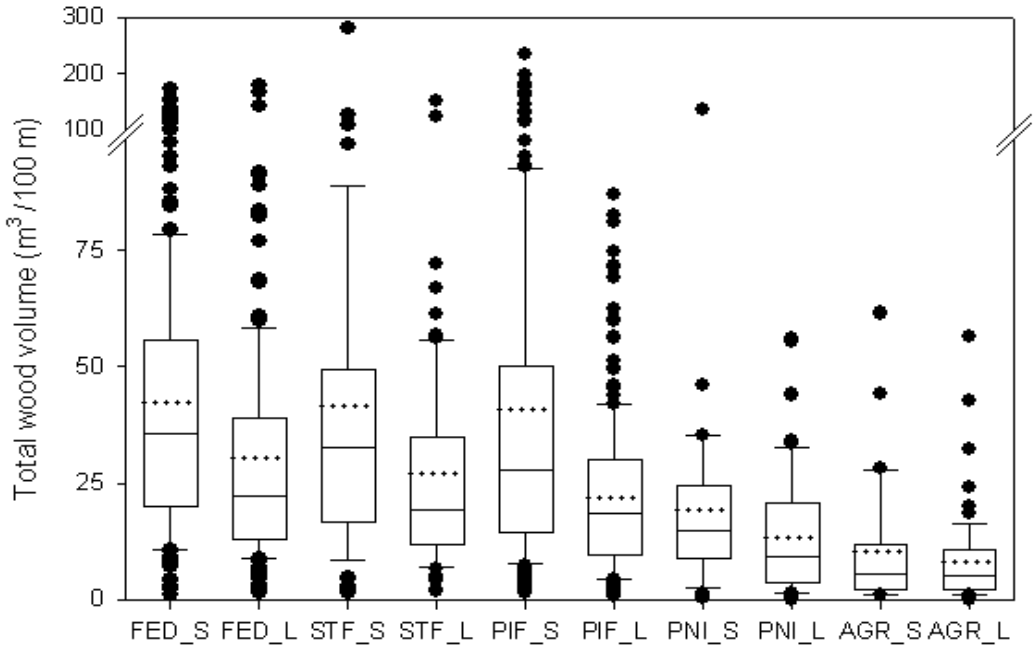


Figure 8. Preliminary evaluation of the HLFM using the Lobster Creek field data. (A) The predicted smolt capacity (100*observed smolt count / HLFM capacity) as a function of the observed summer juvenile density of the previous summer (per pool area only). Note that this is the same format as Fig 1 in Nickelson (1998), which includes Lobster Creek data and there appears to be some agreement in point locations. (B) regresses realized smolt capacity by observed smolt density per entire reach area. These graphs are "Preliminary" in that I used the summer and winter habitat surveys to estimate area sampled for both the fish and habitat surveys. In Nickelson (1998) reach area was calculated as reach length X active channel width. I have acquired survey length by year for summer and winter surveys but do not have active channel widths (only wetted widths).

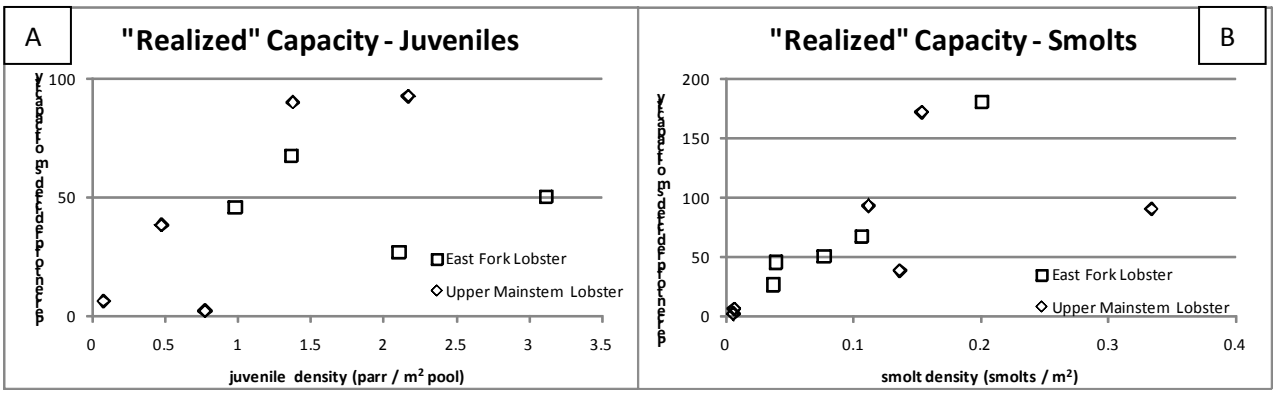
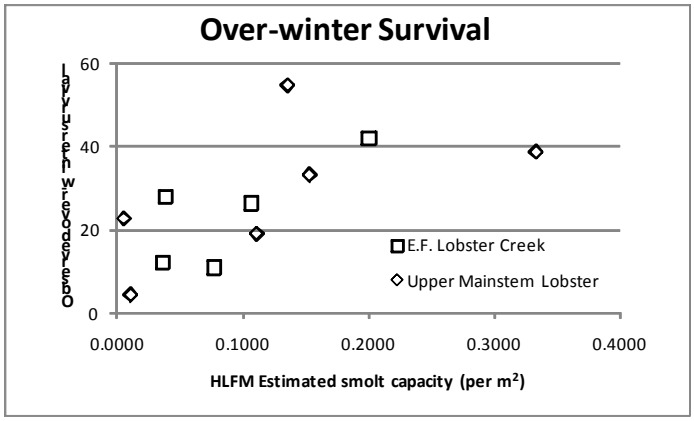


Figure 9. This is the same format as Fig. 2 in Nickelson (1998), which was used to generate the overwinter survival equation used in the NL model.



Appendix A: Coho Modeling Group Workshop

When: 9-5, Tuesday, April 27, 2010
Where: Room 297, Corvallis Forestry Science Laboratory, 3200 SW Jefferson Way, Corvallis
Parking: Passes available at FSL front desk
Contacts: Mark Meleason (541) 750-7485; FSL front desk (541) 750-7250

Coho Modeling Group: This project is lead by Pete Lawson (NOAA), and the members of the modeling group are Dan Miller (Earth Science Institute), Gordie Reeves (USFS), Kelly Burnett (USFS), and Mark Meleason (USFS).
Coho Modeling Approach: Our approach has been to couple a dynamic landscape model developed by Dan Miller (http://www.earthsystems.net/) with Pete Lawson's current version of the Coho life cycle model published in Nickelson and Lawson (1998)[1].
Purpose of Workshop: The purpose of the workshop is to provide a forum to explore alternative approaches to representing Coho life stages within a changing environment.
Workshop Overview: In the morning session, we will describe our Coho / landscape models and then have two presentations on seasonal movements and habitat characteristics of juvenile Coho. The afternoon session will be an open discussion on model refinements. One area we have found challenging to represent is the seasonal dynamics of juvenile Coho, which is why we added presentations on recent work in this area. However, we anticipate that the topics for the afternoon discussion will emerge during the morning session and may include representing the dynamics at a given life stage, relating habitat variables to survival rates, and developing metrics to summarize model outputs.

Workshop Agenda

9:00	Overview of workshop
9:15	Brief description of this Coho Modeling Project
9:30	Description of the Dynamic Landscape Model
10:00	Description of the Nickelson / Lawson Coho life-cycle model
10:30	Break
11:00	Jeff Rodgers (ODFW): Seasonal habitat monitoring and estimating carrying capacity of juvenile Coho
11:30	Joe Ebersole (EPA): Seasonal movement and survival of juvenile Coho
12:00	LUNCH (not provided)
1:00	Open Discussion: Modifying the Coho life-cycle model to utilize the dynamic landscape framework
4:30	Summary of open discussion

Day 1: 1 pm to 5 pm

---

[1] Nickelson, T.E. and P. W. Lawson 1998. Population viability of Coho salmon, *Oncorhynchus kisutch*, in Oregon coastal basins: application of a habitat-based life cycle model. Can. J. Fish. Aquat. Sci. **55**:2383-92.

Goal: Clarify Current Model Capabilities and Limitations and Prioritize Model Refinements

Participants: Core Team and Tom Nickelson

Agenda

1. Pete and Dan bring the team up to date of where the Dynamic Landscape and Coho life-cycle models are.
    Provide sample runs to outline current capabilities.
    Any proposed modifications to the latest versions?
2. Identify and prioritize areas targeted for refinement (with simulation examples if possible to illustrate why a given component is a candidate for refinement – for example, juvenile over-dispersion).
3. Core Team brainstorming: prioritize potential refinements: how best to take advantage of the dynamic landscape framework.
4. How to best take advantage of tomorrow's workshop.

Additional topics:

5. Define data needs required for refinement (calibration /validation)
6. Define / revisit how model results will be summarized / presented (e.g., use probability of extinction, PVA etc.)
7. Define hypotheses to be tested with model
8. Develop outline for first manuscript
9. Define / revisit how model results will be summarized / presented (e.g., use probability of extinction, PVA etc. at the basin scale?)
10. Use of ForClim (Richard Busing) for long-term simulations
11. Synchronized weather
12. Initial wood load

Appendix B: Abstract to Coho Escapement Workshop

Estimating Coho Habitat Capacity Using GIS-based Variables
Mark Meleason, Pete Lawson, Dan Miller, Kelly Burnett, and Gordie Reeves

We are linking a dynamic landscape model with a habitat-based life cycle model for Oregon coastal Coho to explore scenarios of natural disturbance and forest management. The landscape model simulates both wood and sediment inputs to the stream. The Coastal Landscape Analysis and Modeling Study provides inputs to the landscape model of initial forest conditions and simulated responses to a variety of land management scenarios. Modeled wood inputs to the stream are from riparian and upslope processes (e.g., tree mortality and debris flows) and modeled sediment sources are landslides and debris flows. In-channel wood and sediment budgets are simulated for each reach. The Coho life-cycle model is based on the approach used in Nickelson and Lawson (1998). They estimated production of egg, summer parr, smolts, adults, and spawners for each modeled stream reach. Smolt capacity, which reflects habitat quality, was estimated from stream survey data using Oregon Department of Fisheries and Wildlife's Habitat Limiting Factors Model (HLFM). In their published model application, habitat quality was either held constant or varied uniformly over the landscape. There was no explicit spatial component of either habitat quality or salmon distribution among reaches.

The research presented here describes how we are linking outputs from the dynamic landscape model to estimate habitat capacity spatially in the landscape, which is then used in the Coho life cycle model. Specifically, we are developing a method that estimates habitat capacities at various stages of the life cycle based on simulated estimates of sediment and wood loads, and physical characteristics of the channel from a 10-m digital elevation model. We are using HLFM v 7.1 to calibrate our estimates of habitat capacities for a given life stage. Once this model is complete we will be able to explore the implications of spawner distribution within a basin, and the implications of changing habitat patterns as the landscape evolves.