Urban Metrics Correlated with Reduced Herring Spawn in Liberty Bay and Port Orchard, Washington

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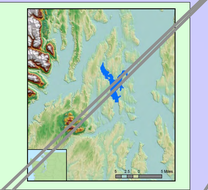
Abstract:

Through statistical correlation we present preliminary evidence that quantitatively links shoreline development to reduction of herring spawn (observed egg deposits) in the Liberty Bay – Port Orchard section of Puget Sound. Using data from Kitsap County and from the Washington State Departments of Natural Resources and Fish and Wildlife, we associated indicators of shoreline development with sample points every 100 m along the shoreline of the study area (N=577). We evaluated statistical relationships of these indicators to presence or absence of offshore herring spawn within 120 m of each sample point. Our null hypothesis was that shoreline development does not affect the probability of observed spawn; the alternative hypothesis was that spawn probability is significantly dependent on shoreline development. Our results support the rejection of the null hypothesis and the conclusion that there is observable suppression of spawn probability as shoreline parcel density increases.

Introduction:

The U.S. Geological Survey (USGS) has initiated a multi-disciplinary approach to study the impacts of urbanization on essential biological resources along the shorelines of Puget Sound. A pilot study is under way in Liberty Bay, Washington, to test the hypothesis that urbanization adversely affects spawning of Pacific herring, sand lance, and surf smelt in the Port Orchard/Madison area. These species are close to the base of the food chain and are an important nutrient source for higher trophic level species, such as salmon and orcas.

The study area of Liberty Bay is a located in western Puget Sound and the central Kitsap Peninsula. Liberty Bay contains the City of Poulsbo and is bounded on the west by Bangor Naval base and Hood Canal and on the east by Bainbridge Island on, as shown at right.



Onshore Urbanization Indicators

Shoreline Modification and Shoreline Parcel Density

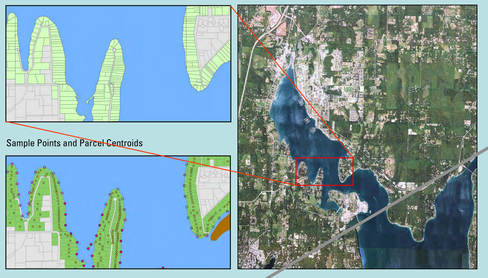
We tested two types of development indicators: (1) fraction of shoreline physical modification (bulkheads, riprap, piers, jetties, etc.), and (2) counts of shoreline ownership parcels in circles of various radii (50, 100, 200, 500, and 1000 m) centered on the sample points.

Shoreline Modification Indicator

The Washington State Shorezone Inventory previously mapped shoreline modification and aggregated various modification types into a summary total modification indicator (percent of shoreline modified) for each shorezone unit. For each of our shoreline sample points, we associated the percent modification value from the closest shorezone unit.

Indicator 1: Shoreline Physical Modifications

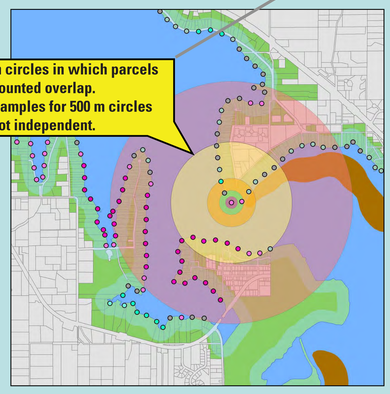
Indicator 2: Shoreline Parcels



Parcel Density Indicators

We estimated shoreline development density by counting parcels that were partly or entirely within 100 m of shore. This was done by generating a 100 m buffer from the shoreline inland, and then using this buffer to select shoreline parcels, thus eliminating parcels and parcel fragments that were either in water or more than 100 m inland. We consolidated remaining parcel fragments by tax account number (owner) and eliminated public parcels (parks, roads, etc.). The centroids of remaining parcels closely represent commercial and residential development because there are few undeveloped parcels in this part of Puget Sound.

The bottom left illustration shows how we used concentric sampling circles constructed at each shoreline sample point (these had radii of 50, 100, 200, 500, and 1000 m) to characterize shoreline parcel density by counting parcel centroids within each circle. We did not know beforehand how large an area would be most effective in representing parcel density in statistical analysis. Parcel densities within 100-meter circles are color coded for each sample point.



Statistical Association

Does Shoreline modification matter?

The table below shows one-parameter logistic regression models of the probability of herring spawn. Shoreline physical modification, as expressed by the total modification percentage indicator *modpct*, does not significantly improve predictability compared to a constant probability model.

Table 1. Residual deviances and deviance reductions in single-variable logistic regression models of spawn probability using all data

	Variable	Residual Deviance	Deviance Reduction
1	null	799.4	0.0
2	pd50	761.6	37.8
3	pd100	772.4	27.0
4	pd200	714.2	85.2
5	pd500	602.9	196.5
6	pd1000	620.2	179.2
7	eelgrass	627.8	171.6
8	modpct	797.4	2.0
9	in_lb	419.8	379.6

Parcel density in 500 m circle: max predictive explanatory value

Shoreline modification: no predictive value

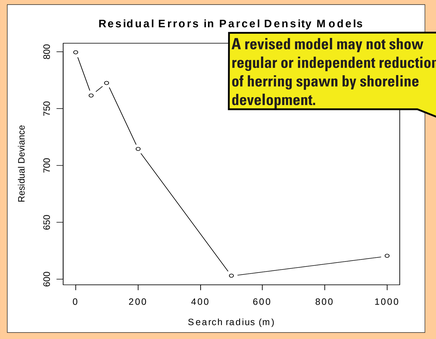
In Liberty Bay: max predictive non-explanatory value

Location in or out of Liberty Bay is the most effective indicator. But what is it about Liberty Bay that makes it so?

Single predictor

The best single predictor of spawn presence is the location of a sample point outside of Liberty Bay, but this variable tells us nothing about the causes of spawn suppression in Liberty Bay.

The shoreline development (parcel density) indicators have varying degrees of predictive value as shown in the graph below; the best of these is the 500 m radius indicator. The 500m result suggests herring may react to conditions along approximately 1 km of the nearshore environment.



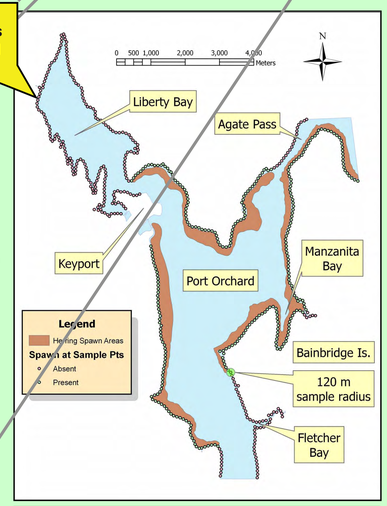
A revised model may not show regular or independent reduction of herring spawn by shoreline development.

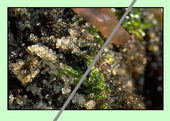
Offshore Herring Spawn

Observed egg deposits

Liberty Bay may have atypical features such as frequent spills of raw sewage and constricted connection to open water.

We generated sample points every 100 m along the shoreline, then winnowed the sample points to eliminate oversampling in sinuous shoreline areas. We also deleted sample points around Keyport , which is a naval industrial facility that did not fit well with our parcel density hypothesis. At each sample point we searched within a 120-meter radius circle and set an indicator for the presence or absence of previously observed egg deposits within that circle.

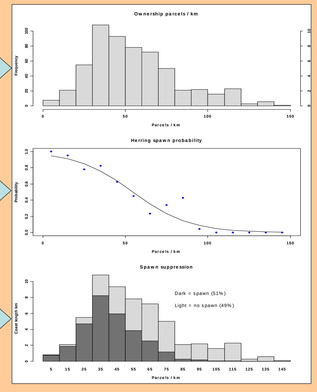




Distribution of parcel densities measured with 500m search radius. The greatest parcel densities is in the range 30 to 60 parcels / km

The regression model of probability variation indicates that herring spawning is most sensitive when parcel density is around 50 parcels / km

Application of the model to current distribution of parcel density; the distribution of expected spawn nearly divides the shoreline between areas of spawn and no spawn



Discussion

Our study area was intentionally selected to have a strong urban gradient, but it represents a small fraction of Puget Sound and is therefore not a representative sample. A qualitative examination of parcel data indicated that density in the Liberty Bay area is greater along the shore than inland, and we selectively examined the influence of this zone of maximal density, which is also closest to the observed response variable (herring spawning). Continuing this focus on shoreline conditions, we looked for evidence of influence of bulkheads and other shore modifications—and did not find any. Stronger predictive models may include such factors as inland development density, impervious surface area, fractional disturbed surface within watersheds, etc. Our single parameter model has sufficient predictive power, however, that we believe it should be tested over broader areas; if it holds up to such challenges, then it is important to do process research to identify the factors of shoreline development (impervious surface area, septic system discharge, etc.) that produce the observed influence.

2006 Analysis of Statistical Association of Shoreline Development with Suppression of Herring Spawn

Questions, Corrections, and Extensions for 2008

1. **Parcel counts associated with shoreline sample points were not independent in the 2006 analysis.** We laid out shoreline samples at 100 m intervals, and for each point we counted parcels within a 500 m radius. Approximately four sample points on each side of a given sample "saw" some of the same shoreline parcels, and in areas of sinuous shoreline there was even more overlap.

   We might winnow sample points to eliminate overlap, but this would reduce the number of samples from N = 577 to roughly N = 50, which is judged as a marginal sample size. Therefore in 2008 we will enlarge the study area as well as eliminate sample overlap.

2. **Is Liberty Bay a representative area?** Many places around Puget Sound can likely be judged, for one reason or another, as atypical. Liberty Bay could be one of these for several reasons, e.g. frequent raw sewage discharges, limited connection to more open waters, etc. Again, the strategy for 2008 is to enlarge the study area so that it is not so singularly responsive to Liberty Bay's unique conditions. As indicated in the blue box at center, a location in Liberty Bay is the strongest single predictor of spawn presence or absence—a result that does not answer any questions about why Liberty Bay associates with spawn suppression. If similar natural and urban factors occur elsewhere, then analysis of a larger area will, in principle, determine whether predictions in the area around Liberty Bay area are skewed by its particular characteristics or derivable from more general underlying responses.

3. **What if the predictive power of shoreline development density does not hold up?** It is well known that large volumes of contaminants are introduced into Puget Sound from its urbanized watersheds. Liberty Bay is not highly urbanized at any distance from the shoreline, so watershed condition is likely to be more important—perhaps even dominant—in a larger study than it was in Liberty Bay. Thus, part of our 2008 strategy is to incorporate indicators with broader spatial reach than the shoreline development indicator.

4. **How will data be analyzed in 2008?** The general strategy is to (a) develop a model using roughly 50% of a Sound-wide dataset for training and (b) to test the resulting model on the remaining portion of the Sound. This strategy is particularly helpful for assessing whether the training area and model are representative of the entire Sound. The model will again be a multiple parameter logistic regression model that estimates the probability that herring spawn offshore, given spatial descriptors for a particular shoreline point.

5. **One potential variable that will be unrepresented** is the timescale of urbanization. In order to test how quickly urbanization affects forage fish, both urban status and fish response must be described temporally as well as spatially.

6. **What did we do in 2007?** We acquired precision GPS locations in support of field studies and we assembled datasets for the 2008 analysis. Funding and FTE limits precluded greater progress.