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

Raymond D. Watts
USGS Fort Collins Science Center
Fort Collins, CO 80526-8118
phone 970-226-9378
e-mail: rwatts@usgs.gov

Vivian R. Queija
USGS Earth Resources Observation and Science
Seattle, WA 98104
phone 206-220-4565
e-mail: vqueija@usgs.gov

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. At a single site under way in Liberty Bay, Washington, we test the hypothesis that shoreline development near spawning grounds of Pacific herring, Clupea pallasii, associates with a suppression of herring spawn. Eastern Puget Sound is the only area of the Sound that has a substantial (approximately 30%) shoreline with developed shoreline parcels. Furthermore, Liberty Bay is the only area in the Sound, where the herring spawning group actually is the most urbanized. The proximity of the shorelines of Liberty Bay, Port Orchard, and Port Angeles, to the Naval Industrial Area, makes it likely that the herring spawning group near Liberty Bay might be experiencing some level of development impacts. The goal of our study is to test the null hypothesis that the observed suppression of spawn probability as a function of shoreline parcel density is due to chance alone.

Abstract
Although statistical methods are present in the literature on the assessment of herring spawning, many of the studies were conducted in the 1970s and 1980s, before the development of modern statistical analysis techniques. The present study is a reassessment of the relationship between herring spawn and shoreline development.

Onshore Urbanization Indicators
Shoreline Modification and Shoreline Parcel Density
We tested two types of development indicators: (1) fraction of shoreline physical modification (midwidths, riprap, piers, piers, etc.); (2) and (2) 200-m sample points on the shoreline. For each of our shoreline sample points, we associated the parcel modification value from the closest shoreline unit.

Shoreline Modification Indicator
The Washington State Shoreline inventory is the primary data source for shoreline modification. We used the parcel modification density by counting parcels that were partly or entirely in the circle with a search radius of 200 m. The count of shoreline parcels was then divided by the area of the circle, and the result was multiplied by 1,000 to obtain the number of shoreline parcels per square kilometer.

Statistical Association
Shoreline modification and shoreline parcel density
In Liberty Bay, the most effective indicator of herring spawning probability is the shoreline parcel density hypothesis. At each site, we estimated the probability of herring spawn using a multiple parameter logistic regression model that estimates the probability of herring spawn.

Discussion
The model was developed using a multiple parameter logistic regression model that estimates the probability of herring spawn.

Conclusion
The model was developed using a multiple parameter logistic regression model that estimates the probability of herring spawn.

Appendix
The model was developed using a multiple parameter logistic regression model that estimates the probability of herring spawn.

Table: Shoreline Parcel Density

<table>
<thead>
<tr>
<th>Search Radius (m)</th>
<th>Shoreline Parcel Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>59.1</td>
</tr>
<tr>
<td>200</td>
<td>58.3</td>
</tr>
<tr>
<td>500</td>
<td>59.4</td>
</tr>
<tr>
<td>1000</td>
<td>59.6</td>
</tr>
</tbody>
</table>

Figure: Probability of Herring Spawn

The probability of herring spawn is plotted against the shoreline parcel density hypothesis.

1. What is the importance of this study in understanding the effects of shoreline development on herring spawn?
2. What is the relationship between herring spawn and shoreline development?
3. How was the model developed and what are its limitations?
4. What are the implications of this study for conservation and management practices in Puget Sound?