Introduction

• The population of the cougar (*puma concolor*) has reportedly increased over the past thirty years (Washington Department of Fish and Wildlife 2010).

• Additionally, the human population in Washington State has increased as well.

• Specifically, the population of counties in western Washington in which rural land is being developed is growing at a greater rate than the state average.

• The combination of increasing cougar populations and rising human populations in Wildland-Urban Interface (WUI) areas suggest that the number of human-cougar encounters will increase as well.
A human-cougar encounter may result in a range of possible outcomes. These outcomes span from a confirmed sighting of a cougar to an attack on livestock, pets, or in rare instances, humans. The number of human-cougar encounters in Washington has been increasing, (Beier 1991, Fitzhugh et al. 2003) as have the number of cougars taken in hunts (Dawn et al. 2003). The increase in human-cougar encounters creates potential issues in regards to public safety, public policy, and management of predators.
Wildland-Urban Interface

• The wildland-urban interface (WUI) is defined as the space in which housing units intersect with wildland areas which are undeveloped or unaltered by humans.

• Housing development in these areas are shown to cause the loss of wildlife habitat as well as fragmentation (Theobald et al. 1997).

• Furthermore, development can disrupt population dynamics of wildlife (Soule 1991), as well as decrease biodiversity in an ecosystem (McKinney 2002).
Over the past 25 years, the WUI of western Washington has increased in terms of area, as well as the number of housing units.

According to Stewart et al. (2007), from 1990 to 2000, the area of WUI land in Washington State increased 16.4%.

The number of housing units in the WUI increased 29.6% in the same time period.

According to Tully (2013), from 2000 to 2010, the area of WUI land in Washington State increased 8.2%. Furthermore, the number of housing units in the WUI increased 22.5% during the same time period.
Cougar Ecology, Spatial Use, and Interaction with Prey

• Even though there is a large body of research regarding cougars, there is much to be discovered regarding cougar behavior.

• The cougar is a solitary animal (Sunquist and Sunquist 2002), meaning they do not collaborate with other animals in order to feed or protect their young.

• Cougars are populated at low densities over large areas (Logan and Sweanor 2001), which makes observational research difficult.

• Cougars are nocturnal creatures, which adds to the difficulty of observation (Beier et al. 1995).
Human-Cougar Interactions, Hunting, and Population Dynamics

• Lambert et al. (2001) recognized the issue of increasing numbers of human-cougar conflicts in the Pacific Northwest.

• They used trapping and tracking methods to measure the relative density, fertility, survival, and growth rate of cougar populations in northeastern Washington, northern Idaho, and southern British Columbia.

• Their findings suggest the increase in human-cougar conflicts could be due to a young population of cougars caused by excessive hunting. They also suggest that more humans are interfering with cougar habitats.

• They conclude that negative social perceptions about cougars could promote excessive hunting. In order to preserve the cougar population, Lambert et al. recommend stricter hunting regulations, monitoring of cougars, and collaboration with resource managers to effectively manage the problem.
History of Cougar Management and Conservation

• Before the year 1960, cougars and other carnivores were managed through the process of extermination.

• Cougars were depicted as dangerous predators who prey upon livestock, game animals, and threaten human safety.

• Hunters were incentivized through the use of bounties from the late 1800s which remained in effect until the 1960s.

• Environmentalism and changing public perceptions towards predators during the 1960s multiple western states classified the cougar as a game animal, which offered more protections to the species.

• Recently, cougars have been considered an important indicator species, which emulates the ecological well-being of certain regions.

• This new protective ideology has created controversy regarding the hunting of cougars.
• It is widely held that current policies regarding cougar management fail to protect cougars from over-hunting, which is evident by the reported increase in cougar harvest rates.

• Western states have taken action in order to protect the cougar from over-hunting. For example, California has successfully banned the hunting of cougars.

• However, in Washington State politics became influential in cougar management when voters passed Initiative 655 in 1996. This initiative placed a ban on hunting with dogs, and has become a catalyst for debate regarding the management of cougars.
• Following the initiative, the WDFW expected a drastic reduction in the number of cougar harvested.

• In response, the WDFW:
  • Removed the requirement of permits
  • Increased the length of the season from 7.5 weeks to 7.5 months.
  • Bag limits were increased from 1 to 2 cougar per year.
  • The price of tags was reduced from $24 to $5.

• As a result, the number of tags sold increased from an average of 1,000 per year to 59,000. Furthermore, harvest figures increased from 121 to approximately 160.

• Additionally, the spatial distribution of harvests were clustered in areas where cougars were not socially accepted, and the density of hunters was high.
• While there was growing concern about the survival of the cougar species, there was also concern about cougar-human interactions and human safety.

• After Initiative 655 passed, reported human/cougar conflicts increased from 247 in 1995, to 495 in 1996, to 927 in 1998.

• In 2002, legislators in Okanogan, Ferry, and Stevens counties persuaded the WDFW to increase the allocation of hunting permits in those counties, citing the increased number of complaints involving cougars.

• The WDFW accepted their request despite the research that indicated that the complaints in these three counties were exaggerated and fabricated by local media sources. Furthermore, the cougar population in this region was declining due to the increased number of “problematic” cougars taken.
Hedonic Property Model

• Based on the influential work of Rosen (1974), hedonic property models attempt to estimate non-market values by observing the willingness to pay for a home given its physical and neighborhood properties.

• The price of a market good is comprised and valued on its characteristics.

• Therefore, it is possible to value individual characteristics of a good by estimating the willingness to pay of consumers if this characteristic changes.

• This is used to estimate the value for environmental services that affect housing prices.

• Hedonic studies have been utilized to estimate the value of non-market goods (or bads).

• Some examples include air pollution, aircraft noise, road traffic, water quality, as well as distance to landfills.
The main objective of this research is to measure the impacts of cougar sightings on housing prices in twelve western Washington counties.

In order to do so, I employ the use of a hedonic real estate price model.

Based on the results, I make recommendations for changes in policy in regards to management of cougars, as well as land use management.
Study Area, Data Sources, and Validity

• My study area includes the western Washington counties of Clallam, Cowlitz, Grays Harbor, Jefferson, Lewis, Mason, Pacific, Skagit, Thurston, Wahkiakum, Whatcom

• This study area contains 19,097 square miles, a population of 1,322,715 people, and has 3,541,617 housing units (US Census 2014).

• This study consists of two sources of data: housing data, and cougar incident reports.
Housing Data

- First dataset contains housing sales data from the twelve counties within my study area.
- The dataset was acquired from Real Market Data, a company that processes data regarding houses and property.
- The dataset contains variables such as property value, bathrooms, bedrooms, floor area, acreage, age, home state of buyer, as well as addresses from 1986-2012.
- There are 297,480 home sales in this dataset.
- The average home is 43 years old, has 1600 square feet, has a sale price of $200,480, and has 2.9 bedrooms and 1.7 bathrooms.
In order to be used for spatial analysis, the housing data must be geocoded.

This process was completed by Logan Blair in his thesis “The Economic Impacts of Forest Pathogens in Washington State: A Hedonic Approach.”

Blair (2015) used the geocoder function in ESRI ArcGIS 10 in order to create physical points of the addresses provided in the housing sales dataset.
Cougar Incident Reports

• Second dataset contains Cougar Incidents Reports, which were obtained from the Washington Department of Fish and Wildlife (WDFW).

• WDFW compiles information about each incident, such as a report narrative, report information (report year, report number, incident date), reporting party, species, and location of the encounter.

• To extract the incident report data I used Outwit Hub, which “scrapes” the desired information from the website, and exports the data to an Excel spreadsheet.

• The data regarding the location of each sighting is reported in Township, Range, and Section (TRS) format.

• In order to input the location data into ArcGIS, it was necessary to convert the data form TRS format to latitude and longitude coordinates.

• This process was done by using a Township Geocoder provided by the Bureau of Land Management.

• Once the data was converted to latitude and longitude, I was able to plot the cougar sightings in ArcGIS.
Methods

• GIS is used to create buffers in order to intersect the locations of houses sold near a cougar sighting.

• For the purpose of this research, I chose buffers of .5km, 1km, 3km, and 5km.

• In order to extract the data within the previously mentioned buffers, I use the “Intersect” tool in ArcGIS 10.4.

• The output feature class contains the intersections of home sales within the buffers surrounding the cougar sighting.
Example of Buffers and Intersected Homes near Beaver, WA
Hedonic Fixed Effects Model

• A hedonic pricing model includes housing and environmental characteristics as variables in a regression model.

• While holding variables constant during regression analysis, I am able to calculate the impact of a specific variable.

• Specifically, I measure the effect of the independent variable: the presence of a cougar, on the dependent variable: the sale price of a house.

• Fixed-effects are used to control for spatial autocorrelation through the use of geographical indicator variables (Parameter and Pope 2012).

• I utilize census blocks as an indicator variable to control for disparity in the value of homes within the specific group or area. Additionally, I create a dummy interaction between sale quarter and year with census block in order to control for altering characteristics over time.
## Results

Dependent Variable = ln(Sale Price)

<table>
<thead>
<tr>
<th></th>
<th>0.5km</th>
<th>1km</th>
<th>3km</th>
<th>5km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 0 to 30</td>
<td>-0.0808***</td>
<td>-0.113***</td>
<td>-0.108***</td>
<td>-0.0256***</td>
</tr>
<tr>
<td></td>
<td>(0.0148)</td>
<td>(0.00919)</td>
<td>(0.00695)</td>
<td>(0.00429)</td>
</tr>
<tr>
<td>Day 30 to 90</td>
<td>-0.0522</td>
<td>-0.0678</td>
<td>0.00294</td>
<td>-0.0260***</td>
</tr>
<tr>
<td></td>
<td>(0.0440)</td>
<td>(0.0333)</td>
<td>(0.00968)</td>
<td>(0.00468)</td>
</tr>
<tr>
<td>Day 90 to 180</td>
<td>-0.0505</td>
<td>-0.0846**</td>
<td>0.00357</td>
<td>-0.0330***</td>
</tr>
<tr>
<td></td>
<td>(0.0365)</td>
<td>(0.0247)</td>
<td>(0.00544)</td>
<td>(0.00585)</td>
</tr>
</tbody>
</table>

|                  | Observations| 120,289    | 120,289    | 120,289    | 120,289    |
|------------------|-------------|------------|------------|------------|
| Adjusted R       | 0.4709      | 0.4737     | 0.4779     | 0.4715     |
| Quarter x Census Block FE | Yes     | Yes        | Yes        | Yes        |
| Quarter and Year FE | Yes     | Yes        | Yes        | Yes        |

Note: *p<0.1** p<0.05***p<0.01
- Coefficients regarding housing and environmental characteristics produce expected values.
- Houses with a view significantly increase its value.
- Each additional acre on the property significantly increases its value.
- The coefficient for house age is negative and significant, suggesting that people have a preference for newer homes.
- Square footage is also significant and positive.
- Number of bedrooms producing a significant and negative effect seems counterintuitive; however, they are found to produce a negative result in hedonic studies (Sirmans et al. 2005).
- Floor area is controlled for in this model, suggesting an increase in the number of bedrooms would mean smaller bedrooms.
- Additionally, more bedrooms could take away from other desirable characteristics not included.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient 1</th>
<th>Coefficient 2</th>
<th>Coefficient 3</th>
<th>Coefficient 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>View</td>
<td>0.165***</td>
<td>0.165***</td>
<td>0.167***</td>
<td>0.164***</td>
</tr>
<tr>
<td></td>
<td>(0.00620)</td>
<td>(0.00619)</td>
<td>(0.00636)</td>
<td>(0.00619)</td>
</tr>
<tr>
<td>Acres</td>
<td>0.0146***</td>
<td>0.0146***</td>
<td>0.0147***</td>
<td>0.0147***</td>
</tr>
<tr>
<td></td>
<td>(0.000691)</td>
<td>(0.000695)</td>
<td>(0.000699)</td>
<td>(0.000694)</td>
</tr>
<tr>
<td>House Age</td>
<td>-0.000938***</td>
<td>-0.000920***</td>
<td>-0.000919***</td>
<td>-0.000988***</td>
</tr>
<tr>
<td></td>
<td>(0.0000810)</td>
<td>(0.0000816)</td>
<td>(0.0000805)</td>
<td>(0.0000815)</td>
</tr>
<tr>
<td>Square Feet</td>
<td>0.000373***</td>
<td>0.000374***</td>
<td>0.000372***</td>
<td>0.000373***</td>
</tr>
<tr>
<td></td>
<td>(0.00000867)</td>
<td>(0.00000868)</td>
<td>(0.00000861)</td>
<td>(0.00000866)</td>
</tr>
<tr>
<td>Bedrooms</td>
<td>-0.0269***</td>
<td>-0.0267***</td>
<td>-0.0257***</td>
<td>-0.0264***</td>
</tr>
<tr>
<td></td>
<td>(0.00402)</td>
<td>(0.00401)</td>
<td>(0.00397)</td>
<td>(0.00399)</td>
</tr>
<tr>
<td>City</td>
<td>0.00354*</td>
<td>0.00607***</td>
<td>0.0105***</td>
<td>-0.00248***</td>
</tr>
<tr>
<td></td>
<td>(0.00669)</td>
<td>(0.00661)</td>
<td>(0.00664)</td>
<td>(0.00677)</td>
</tr>
</tbody>
</table>
Discussion, and Conclusion

• This regression model serves as a revealed preference valuation method in order to elicit an individual’s willingness to pay for avoiding the negative effects an additional cougar sighting.

• Impacts of cougar sightings on housing values in western Washington have mixed effects over distance and time.
  
  • Within 30 days of a cougar sighting, houses at each distance experience a significant negative effect.
  
  • At 1km, there is significant negative effect within 30 days, and after 90 day of a sighting.
  
  • At 3km, there is a positive effect after 30 days, although it is not significant.
  
  • At 5km, there is a significant negative effect that increases over time.
  
  • In order to interpret these results, the coefficients were applied to the average sale price of a home.
Effects of an Additional Cougar Sighting on Housing Values within .5km

- $144,100.10 (0 Days)
- $132,907.86 (30 Days)
- $136,768.43 (90 Days)
- $137,002.74 (180 Days)
Effects of an Additional Cougar Sighting on Housing Values within 1km

- 0 Days: $144,100.10
- 30 Days: $128,698.20
- 90 Days: $134,649.14
- 180 Days: $132,405.27
Effects of an Additional Cougar Sighting on Housing Values within 3km

- 0 Days: $144,100.10
- 30 Days: $129,393.16
- 90 Days: $144,523.71
- 180 Days: $144,615.55

Housing values fluctuate over time following the sighting, with a significant decrease and then a recovery over 180 days.
Effects of an Additional Cougar Sighting on Housing Values within 5km
Policy Recommendations

• Results reflect on a willingness to avoid the negative impacts of cougars in these areas, therefore local officials would benefit from investing in education regarding cougars as well as management programs.

• Investing in education programs which focus on cougar behavior could help reduce human-cougar interactions.

• Management programs which emphasize sustainable hunting practices will preserve the age structure and density of cougar populations.

• Additionally, the impacts of 1-655 should be researched in order to determine whether policy changes should be made.

• Furthermore, the results could help shape policy in regards to land management, ensuring that future homes created in WUI areas are safe for both humans and cougars alike.