

Development and Application of a GIS-Based Proximity Analysis Tool for Use in Endangered Species Risk Assessments

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Abstract: Risk assessments of the potential for endangered species exposure to pesticides in aquatic environments often involve an analysis of the proximity of pesticide use-sites to surface waters. A geographic information system (GIS) based proximity analysis identifies the acreage of potential pesticide use-sites falling within a given buffer distance to these surface waters. The surface waters of concern can include both the water bodies that serve directly as critical habitat areas as well as water bodies that act as transport pathways for pesticides to enter these habitat areas. The results of a proximity analysis can be used to predict pesticide contributions to these surface waters at the watershed scale and also provide an indication of the acreage of land treated by pesticides that would be affected should pesticide use restrictions be required within surface water buffers as a mitigation to reduce risk to aquatic species. Watershed scale proximity analyses can become complicated and resource intensive when a critical buffer distance is uncertain or when evaluating the impacts of a range of buffer distances. To address these issues, a new approach was developed to simultaneously evaluate a broad range of surface water buffer distances as mitigation for pesticide exposure at the watershed scale. The method was applied to watersheds designated as salmonid evolutionary significant units (ESUs) in the Pacific Northwest and California. The GIS-based approach uses the latest NHDPlus hydrography data, remotely sensed land cover data, and county-level agricultural statistics datasets to generate cumulative distributions of pesticide use-site area as a function of proximity to surface waters. A flexible, reusable GIS tool was then created so that the method could be applied to other geographical areas and in additional watershed scale risk assessment contexts.

Introduction

Background

- Risk assessments of the potential for endangered species exposure to pesticides in aquatic environments often involve an analysis of the proximity of pesticide use-sites to surface waters.
- In November 2008 the National Marine Fisheries Service (NMFS) issued a biological opinion on the registration of pesticides containing chlorpyrifos, diazinon, and malathion. The opinion proposed the following to reduce the risk of salmonid exposure to these pesticides in the Pacific Northwest:

Element 1. Apply the following no-application buffers/setbacks (buffers):

- Where ground applications are permitted. Do not apply pesticide products within 500 ft (152.4 m) of salmonid habitats.
- Where aerial applications are permitted. Do not apply pesticide products within 1,000 ft (304.8 m) of salmonid habitats.

- Additionally, the 2008 opinion describes salmonid habitats as ...

"... freshwaters, estuarine habitats, and nearshore marine habitats including bays within the ESU/DPS ranges including migratory corridors. The freshwater habitats include intermittent streams and other temporally connected habitats to salmonid-bearing waters. Freshwater habitats also include all known types of off-channel habitats as well as drainages, ditches, and other manmade conveyances to salmonid habitats that lack salmonid exclusion devices."

- To better understand the impacts of the proposed surface water buffers on agriculture, and the reduction in pesticide exposure risk, a proximity analysis tool was developed to enable the assessment of the acreage of potential pesticide use sites within a range of distances to surface water bodies of various classifications.

Study Area

- Evolutionary significant units (ESUs) associated with five different salmon species (chinook, steelhead, sockeye, coho, and chum) in Washington, Oregon, Idaho, and California were considered.
- Thirty ESUs whose status was designated as either "endangered", "threatened", "proposed threatened", or "not determined" were chosen for assessment.



Figure 1. Pacific Northwest salmon ESUs.

Objectives

- Develop a methodology that uses nationally available, high resolution datasets.
- Design the methodology to be flexible regarding the land use classifications associated with potential pesticide use sites and the water body features that are of interest in the assessment.
- Enable the simultaneous evaluation of a broad range of surface water buffer distances from a single analysis output dataset.
- Incorporate the methodology into a flexible and reusable GIS tool that may be applied to other geographical areas and in additional proximity analysis contexts.

Methodology

Datasets

- Land Use:** The National Land Cover Dataset (NLCD) 2001 dataset was used to identify the areas of potential pesticide use. For this assessment, the NLCD "Cultivated Cropland" class was representative of the land cover where the pesticides of interest would be applied. The source of the NLCD dataset used in this assessment was the GeoSTAC database (<http://www.geostac.org>).
- Hydrography:** The NHDPlus dataset was used to identify the surface water features of interest that serve as or contribute to salmonid critical habitat areas. The NHDPlus hydrography layers include streams, rivers, canals, pipelines, lakes, ponds, reservoirs, wetlands, and coastlines. It is based on the 1:100,000 scale NHD medium resolution hydrography dataset and has received additional QA/QC and corrections (<http://www.horizon-systems.com/nhdplus/>).

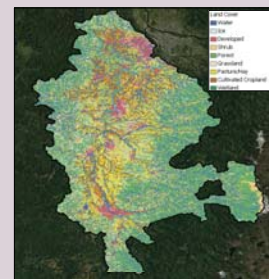


Figure 2. NLCD for Upper Willamette Chinook ESU.

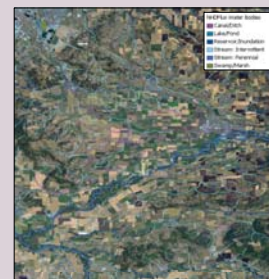


Figure 3. NHDPlus hydrography within Chinook ESU.

- Evolutionary Significant Unit Boundaries:** the NMFS maintains salmon ESU boundaries which depict watershed boundaries by which distinct populations are tracked and managed (<http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Maps/>). To provide consistency with the hydrography data used in this assessment, the NWFS ESU boundaries were re-delineated with the higher resolution NHDPlus catchments. The NHDPlus catchment boundaries represent the most detailed nationally available catchment boundary dataset.

Analysis Approach

- For each agricultural landscape location within an ESU determine the closest distance to a surface water body of interest using a Euclidean distance calculation.
- Perform the proximity calculation for each ESU independently so that the proximity of an agricultural area is relative only to water bodies within the watershed of interest.
- Provide flexibility to use any land cover dataset and allow the selection of different water body classes in the analysis based on a modified NHDPlus classification.
- Generate cumulative distribution functions of cultivated cropland area as a function of distance, enabling an assessment of any possible buffer distance.

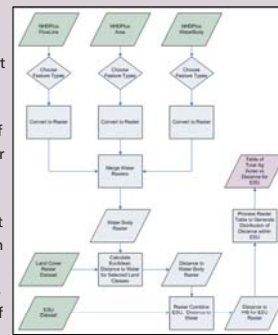


Figure 4. Proximity analysis processing flow chart.

Results and Discussion

Spatial Analysis Results

- The proximity analysis was conducted for all 30 salmon ESUs.
- The analysis resolution was set to 30 meters, the same cell size as the NLCD land cover input.
- GIS raster datasets of input water body features and the proximity to water for all cultivated cropland areas were generated as output.

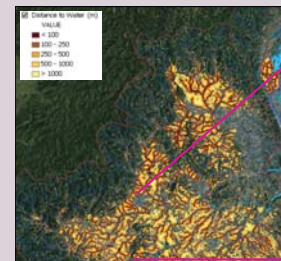


Figure 5. Agricultural proximity to water, Upper Willamette Chinook ESU.

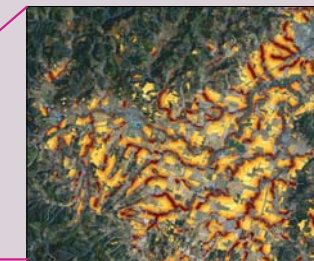


Figure 6. Close up of agricultural proximity to water.

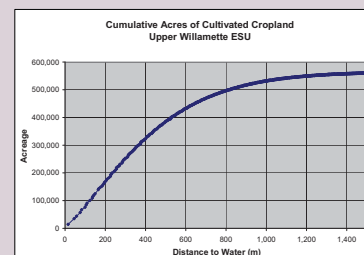


Figure 7. CDF of agriculture proximity to water, Upper Willamette ESU.

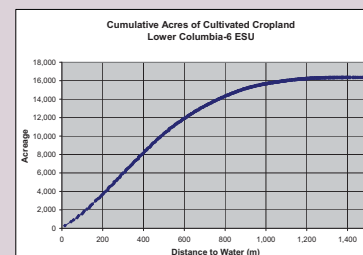


Figure 8. CDF of agriculture proximity to water, Lower Willamette ESU.

Acreage Impacted by Proposed Buffers

- For each ESU, the acreage of cultivated cropland within the proposed 500 ft and 1000 ft no application buffers was extracted.
- Within the Chinook salmon ESUs assessed, the Sacramento Winter/Central Valley ESU had the greatest impacted acreage (500 ft buffer: 477,000 ac, 1000 ft buffer: 801,000 ac)
- The total cultivated cropland within the Chinook salmon ESUs impacted by the 500 ft and 1000 ft buffers is 983,000 and 1,849,000 acres respectively.



Figure 9. Acreage within 500 ft buffer by ESU.

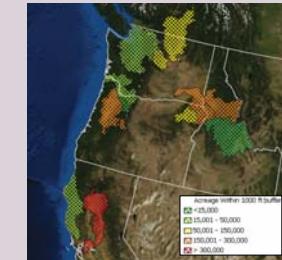


Figure 10. Acreage within 1000 ft buffer by ESU.

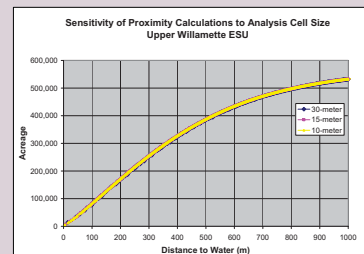


Figure 11. Proximity sensitivity to analysis cell size, Upper Willamette ESU.

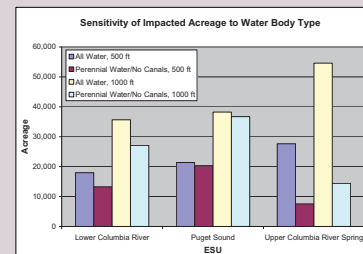


Figure 12. Sensitivity to water body types selected for analysis.

Sensitivity to Analysis Cell Size and Water Body Types

- The proximity analysis was re-run varying the raster analysis cell size from 10 to 30 meters. At the ESU scale, the results were extremely insensitive to cell size.
- The proximity analysis was rerun after removing intermittent streams/ponds and canals from the set of evaluated water body features. As expected, the results are very sensitive to which water body classifications are included.

Proximity Analysis Tool

- The proximity analysis tool is split into a hydrography pre-processing component and a proximity analysis component, both of which are compatible with ArcGIS 9.3.
- The tools are built within the ArcGIS Toolbox framework using python scripting.

Hydrography Processing

- The hydrography processing component integrates directly with an NHDplus database.
- Users can select which classes of water body feature types will be included in the analysis, including filtering out features with undefined flow direction.
- The analysis extent may be defined by a feature class representative of the areas over which the proximity to water body features will be summarized.

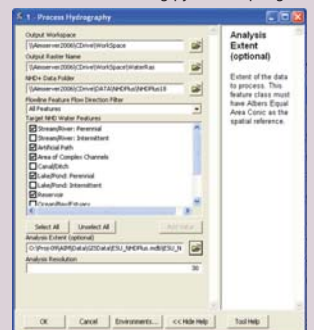


Figure 13. Hydrography pre-processing tool interface.

Proximity Analysis

- The proximity analysis component takes the pre-processed water body raster dataset, or any other water body raster dataset.
- Any land cover dataset can be provided as input, including NLCD and NASS Cropland Data Layer.
- The analysis cell size can be set by the user depending upon the resolution of the input datasets provided.



Figure 14. Proximity analysis tool interface.

Summary

- An ArcGIS tool was developed to enable efficient proximity analyses required for watershed scale endangered species risk assessments, as well as other assessments requiring estimation and summary of land cover proximity to water features.
- The methodology was applied to 30 ESUs representing 5 salmon species in the Pacific Northwest to determine the acreage of potential pesticide use sites that would be impacted by proposed no-application buffers.
- The results showed that the impacted acreage will be heavily dependent upon which classifications of water bodies are subject to the buffer requirements.
- The results were not sensitive to the raster analysis cell size, suggesting that the conversion of vector-based hydrography to a raster representation does not result in any loss of information at the watershed scale; however, analysis results will be sensitive to the land cover dataset's native resolution and accuracy.

Acknowledgements

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- Ben Koziol of Stone Environmental joined this project midway and was responsible for implementation of the tool.
- For additional information: Michael Winchell, Stone Environmental, 802-229-1882, mwinchell@stone-env.com.