ADVANCES IN MAPPING AND MODELING SALMON HABITAT USING PRISM, PALSAR, AND TERRASAR-X DATA

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1. INTRODUCTION

Freshwater habitat quality and quantity are key abiotic variables driving the abundance and distribution of anadromous salmonids. Knowledge is minimal about the condition of freshwater habitats and how habitat condition affects salmon over large, remote areas on both sides of the Arctic and northern Pacific Oceans [1]. This hampers abilities to predict effects of habitat change on salmon and to understand the relative importance of freshwater and marine influences on observed declines in salmon abundances. Such abilities are crucial to restoring and sustainably managing salmon, a commercially, culturally, and ecologically important resource. Modeling is a practical option for estimating habitat suitability and salmon abundances over broad areas with available high-resolution digital geospatial data (e.g., stream, terrain, and vegetation) [e.g., 2, 3, 4]. However, such data are lacking for many areas, particularly in Russia and northwestern Alaska. The recent advent of ALOS and TerraSAR-X products may enhance prospects for modeling freshwater habitats, ultimately contributing spatially extensive information needed by decision makers to conserve salmon. Our research objectives are to investigate the feasibility of 1) modeling high-resolution hydro-geomorphic attributes, as descriptors of freshwater habitats, using digital elevation models (DEM) produced from ALOS data, and 2) characterizing ice conditions on small streams (10 to 100 m wide) from TerraSAR-X data to indicate overwintering habitat suitability.

2. STUDY AREA

The study area is the Nome River basin in the 687,000 km^2 Arctic-Yukon-Kuskokwim (AYK) region of northwestern Alaska [5]. Basin topography varies from coastal lowlands to mountain peaks, but consists mostly of uplands with broad hills and flat divides [6]. Elevations range from sea level to 1420 m. The basin is in the arctic tundra biome, and thus, the vascular plant community is dominated by herbaceous and shrubby vegetation. The most conspicuous shrubs are *Salix* spp. with heights that rarely exceed 2 m. Riparian areas contain some deciduous trees (e.g., *Betula* spp.), but no stream reach has tree cover exceeding 10% [7]. The Nome River drains 441 km^2 and empties into Norton Sound (66.67º N, -165.33° W) about 5 km east of the city of Nome. It supports several species in the family Salmonidae and is a particularly important producer of coho salmon (*O. kisutch*) and arctic grayling (*Thymallus arcticus*) [7]. Over the extent of coho-salmon distribution in the Nome River, channel width varies from 10 to 100 m.

3. METHODS

3.1 Generating DEMs and hydro-geomorphic attributes

Hydro-geomorphic attributes useful for assessing salmon habitat suitability can be modeled using high-resolution DEMs, however, the spatial resolution and vertical accuracy of DEMs currently available for many areas are inadequate for this purpose. Thus, we produced high-resolution DEMs of the Nome River basin from remote-sensing data with both SAR interferometry (InSAR) and optical stereo processing methods. DEMs were produced from pairs of PALSAR data with GammaRS commercial software, using InSAR methods. The temporal baseline of selected pairs was one cycle or 46 days. The DSM and ORI Generation Software for ALOS-PRISM (DOGS-AP) [8] were used to produce stereo DEMs from six triplet images, providing coincident backward, nadir, and forward-viewing geometries. DOGS-AP fully supports the rigorous sensor models of PRISM, taking full advantage of the two equivalent, but separate stereo pair and CTF image pyramid methods to optimize DEM accuracies. The accuracies of DEMs from each processing method were evaluated using NASA ICESAT laser altimetry data. Resulting DEMs were combined into mosaic products using Multi-Mosaic software.

The final mosaics were used with established methods [9] to estimate a suite of hydro-geomorphic attributes (e.g., channel locations, channel gradients, channel size — based on drainage area, and floodplain extent) from which aquatic habitat suitability has been assessed in other locations [e.g., 4]. We developed methods to estimate additional hydro-geomorphic attributes describing channel sinuosity and degree of braiding or anastomosing from the DEMs. Derived values were compared to field-measured values to assess the accuracy of attributes. Field measurements of attributes and GPS locations were obtained at over 100 field sites during low-flow conditions in August of 2009.

3.2 Ice classification

Salmon production in arctic streams is often constrained by the availability of suitable overwintering habitat, which is determined largely by ice conditions. River ice can be classified to predict potential flooding hazards in large arctic rivers using SAR polarimetry [10]. We evaluated dual-polarization (HH-HV) TerraSAR-X data obtained from November 2008 through March 2009 to discriminate river ice into three classes important to fish survival: 1) open water, 2) ice over water, and 3) frozen to the bottom. To constrain the polarimetric analysis to backscatter variations from the stream channel, a water mask was produced from summer 2009 TerraSAR-X data and applied to winter scenes prior to classification. Using PolSARPro, we performed Polarimetric analysis on several TerraSAR-X images followed by supervised ice classification, adapting methods for large rivers [10]. These results were compared to coincident winter field measurements to confirm and quantify classification accuracy. Field data on ice depth were collected in late February and early March 2009, using an auger at 75 randomly selected transects for which GPS locations were obtained.

4. RESULTS AND DISCUSSION

Our initial results from analysis of ALOS and TerraSAR-X data demonstrate feasibility for modeling hydro-geomorphic attributes and classifying ice conditions that are relevant to salmon. We collaborated with the developer to modify the JAXA DOGS-AP software, enabling DEM vertical outputs from ALOS PRISM data in integer decimeters rather then integer meters. This improved DEMs for characterizing streams (<7% gradient) that are key salmon habitats. The PRISM-derived DEMs are more highly resolved and accurate than publicly available DEMs for the area; comparisons with NASA ICESAT laser altimetry data indicate accuracies of the PRISM DEMs on the order of 5-meters RMSE. Modeling of hydro-geomorphic attributes from these DEMs is yielding high-quality information as illustrated in Figure 1. Hydro-geomorphic attributes modeled from the PRISM data were better suited for describing salmon habitats than those modeled from PALSAR data, due largely to the higher resolution of the PRISM DEMs. Given the low cost and growing availability of ALOS PRISM data, our initial results suggest these data have great value for assessing the quality and quantity of freshwater habitats in tundra biomes of the AYK and other regions. Similarly, our initial results suggest the utility of ice-classification using TerraSAR-X, dual-polarized strip-mode data for channels as small as the Nome River, but further work remains. We intend to present new results of this research, quantifying accuracies of the hydro-geomorphic attributes and ice classification with field data, and relating summer fish abundances to habitat conditions inferred from these data.

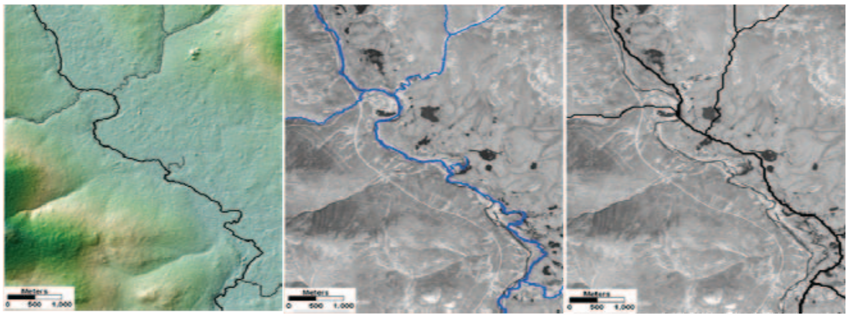

Figure 1. The left panel shows a shaded relief image from a 2.5-m DEM derived from PRISM optical imagery. Dark lines show channel locations traced from DEM-inferred flow directions. In the center panel, these channels are overlain on the ortho-rectified PRISM optical imagery to allow comparison with channels visible in the image. The right panel shows channels traced from the highest resolution publicly available DEM (USGS 60 m) overlain on the same PRISM image.

5. REFERENCES

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