The Riverscape Analysis Project: A Typology of North Pacific Salmon Rivers.

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Abstract

To assist salmon conservation efforts around the North Pacific Rim, we developed and analyzed a geospatial database of riverine landscape features in the North Pacific. The system architecture and database design optimize parameter extraction, streamline data maintenance, standardize processing workflow and provides users with access via the Internet. We quantified and classified physical complexity by watershed for all rivers draining into the Pacific Ocean in the contiguous United States, British Columbia, Alaska and the Kamchatka Peninsula in Russia. Landsat remote sensing data assist in routing drainages across Digital Elevation Model (DEM) data to extract floodplain, network, and catchment features; large rivers in relatively flat terrain may be more accurately quantified with this novel approach. Overall physical complexity of each watershed was quantified and used to rank all watersheds based on hydrogeomphology and human influence. The resulting database is a systematic ranking of physical habitat potential as a tool to address questions about landscape structure and biological productivity at regional to continental extents. Preliminary results are showing strong relationships between metrics derived from Landsat and other remote sensing platforms such as Quickbird. These relationships may then be used to “scale-up” electro-fishing based estimates of juvenile densities to a watershed.

Introduction

Salmon are a declining keystone species of Pacific river ecosystems. Pacific salmon inhabit a large variety of geographical landscapes in North America. Landscape features in watersheds are important in determining salmonid productivity; however, a systematic top-down survey of landscape characteristics of salmon watersheds over the entire region has not yet been performed. The North Pacific Rim Typology Project, funded by the Gordon and Betty Moore Foundation, is a remote-sensing based classification of salmon producing rivers across the north Pacific Rim. The goal of this work is to produce a web-accessible decision support database that will assist salmon conservation around the Pacific Rim, based on a robust, hierarchically nested classification (typology) of rivers and river habitats and aimed at conserving the existing and potential production of salmon in the context of the ocean domains influencing the rivers and salmon that spawn and rear in them. The database and ranking provides a systematic classification of potential capacity to support salmon.

Database design: input, storage, and output

The processing workflows developed for the Typology Project are a complex combination of automated algorithms and user interaction: landscape features were managed in an ESRI ArcSDE Enterprise Geodatabase. The data are accessible via multiple outputs including: SDE/SQL connection, Globe Service, and web browser (Fig. 1). Processes are all reproducible and scale independent. The only limiting factor is the resolution of input data. Therefore, if high resolution data is acquired at target locations it can be processed similar to the coarser resolution data.

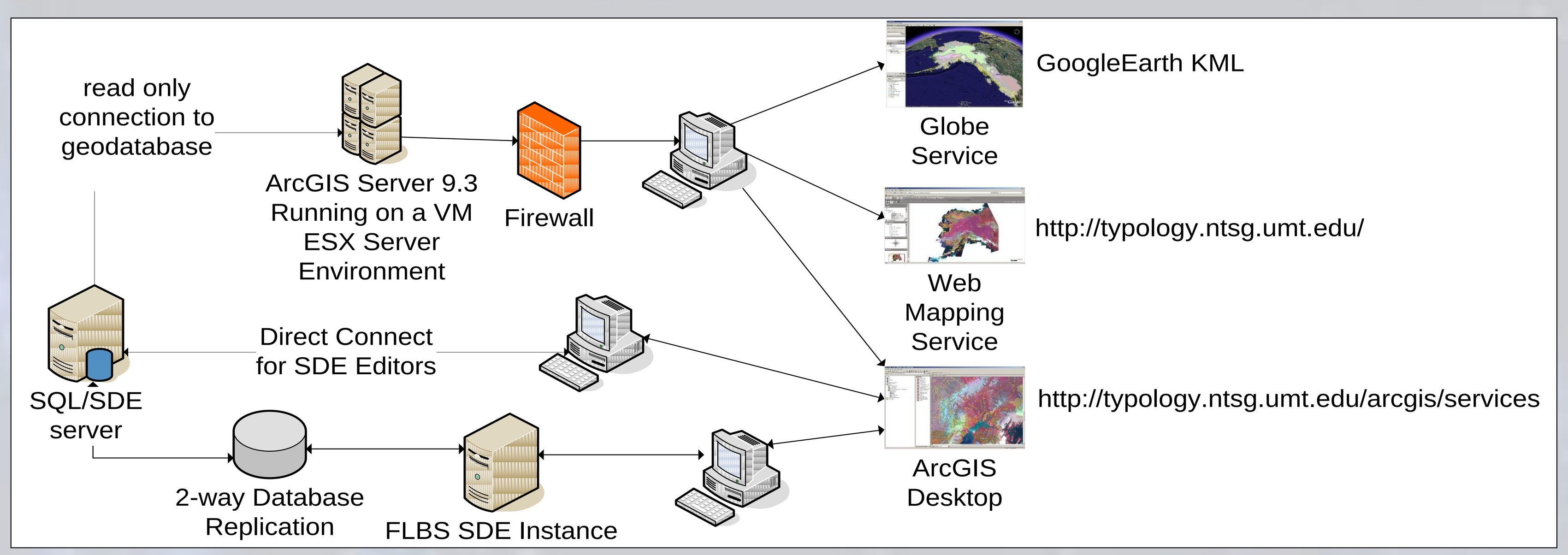

Figure 1. Diagram of database and output connections

GIS processing/model

We used an combination of data, including digital elevation model (DEM) and multi-band Landsat satellite images to delineate landscape features. Landsat was used to identify regions of water and vegetation, and DEMs were used to define watershed boundaries. A combination of Landsat and DEM data were used to extract drainage channels and floodplains.

Methods

We made a distinction between extrinsic (absolute) and intrinsic (relative) variables; intrinsic variables (in bold type in Table 1, below) were selected with the intention of being independent of watershed area. Each variable was relatively ranked by watershed on a scale of 0 to 1. Composite rankings of intrinsic variables were summarized as the mean of each feature class and by principal component analysis (PCA). An overall ranking was computed as the mean of the meta-group rankings combined with the Human Footprint Index. Correlations were computed by Kendall’s rank-correlation test (τ).

Table 1. List of physical complexity metrics organized by meta-group.

Floodplain	Waterbody	Node	Watershed
Number; total length; total area; floodplain area standard deviation **Mean** area **Density in watershed** (number/watershed area) **Floodplain area/watershed area** **Mean elevation** **Sinuosity**	Number; total length; total area; waterbody area standard deviation **Mean** area **Density in watershed** (number/watershed area) **Waterbody area/watershed area** **Mean elevation**	Number **Density in floodplain** (number/floodplain area) **Linear density** (number/river length in the floodplain)	Total area, perimeter/area Change **coefficient of variation** in elevation **Floodplain** (meta-group, rescaled mean) **Node** (meta-group, rescaled mean) **Waterbody** (meta-group, rescaled mean)

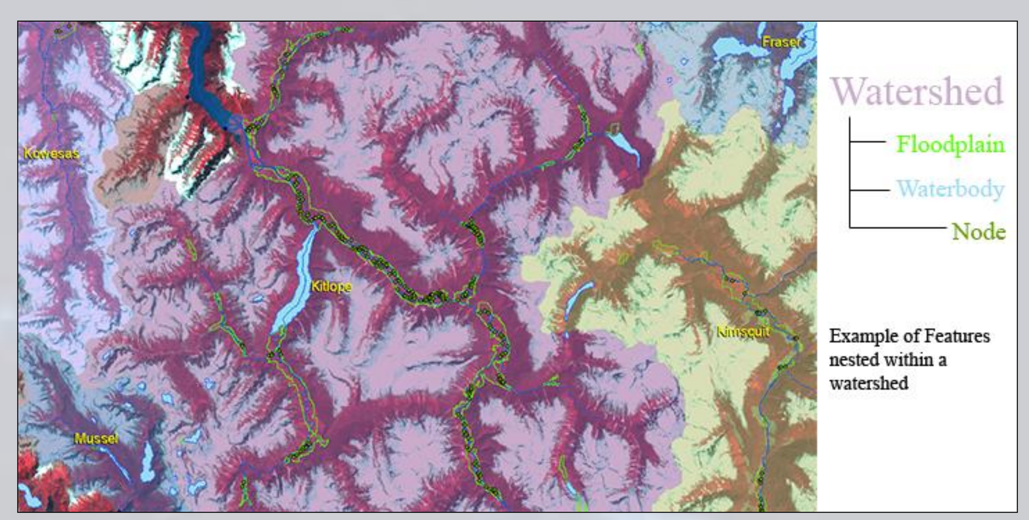

Figure 3. An example of node, water body, floodplain, and watershed features.

Results

We processed 1556 watersheds ranging from 1 to 850,000 km^2. Feature classes included watersheds, floodplains, and nodes (junctions of separation and return loops in the floodplain) . Our analysis consists of all the watersheds in the database (Table 2). Floodplain sinuosity and waterbody density in the watershed were the greatest loading factors in the PCA (Table 3). Mean feature class rank was correlated with the PCA ranking (τ =0.40, p<0.01). Physical complexity of rivers showed a general trend of increasing in relation to decreasing human impact (τ =0.30, p<0.01) but not with latitude (τ =0.14, p=0.07) (Fig. 4).

Table 2. Selected metrics for the four largest watersheds.

	WATERSHED		FLOODPLAIN		NODES		HFP
name	area (km^2)	coef. of var. elevation	density (#/m^2)	floodplain area/ watershed area	floodplain/ area density	nodes/river (#/m)	Human Footprint Mean
Yukon	858220	0.741352	$3.5\ 10^{-09}$	0.058020	$4.4\ 10^{-07}$	$6.9\ 10^{-04}$	3.9615
Columbia	669608	0.460457	$2.7\ 10^{-09}$	0.009283	$8.6\ 10^{-07}$	$6.8\ 10^{-04}$	17.1506
Fraser	233156	0.373931	$5.5\ 10^{-10}$	0.004655	$7.7\ 10^{-07}$	$8.3\ 10^{-04}$	9.7892
Kuskokwim	118019	1.061402	$3.8\ 10^{-09}$	0.072369	$5.6\ 10^{-07}$	$8.5\ 10^{-04}$	2.8217

Table 3. Results of principal component analysis.

principal component	greatest loading factor	variance explained
1	floodplain sinuosity	0.20
2	waterbody density in watershed	0.12
3	floodplain area / watershed area ratio	0.09
4	floodplain area mean	0.08

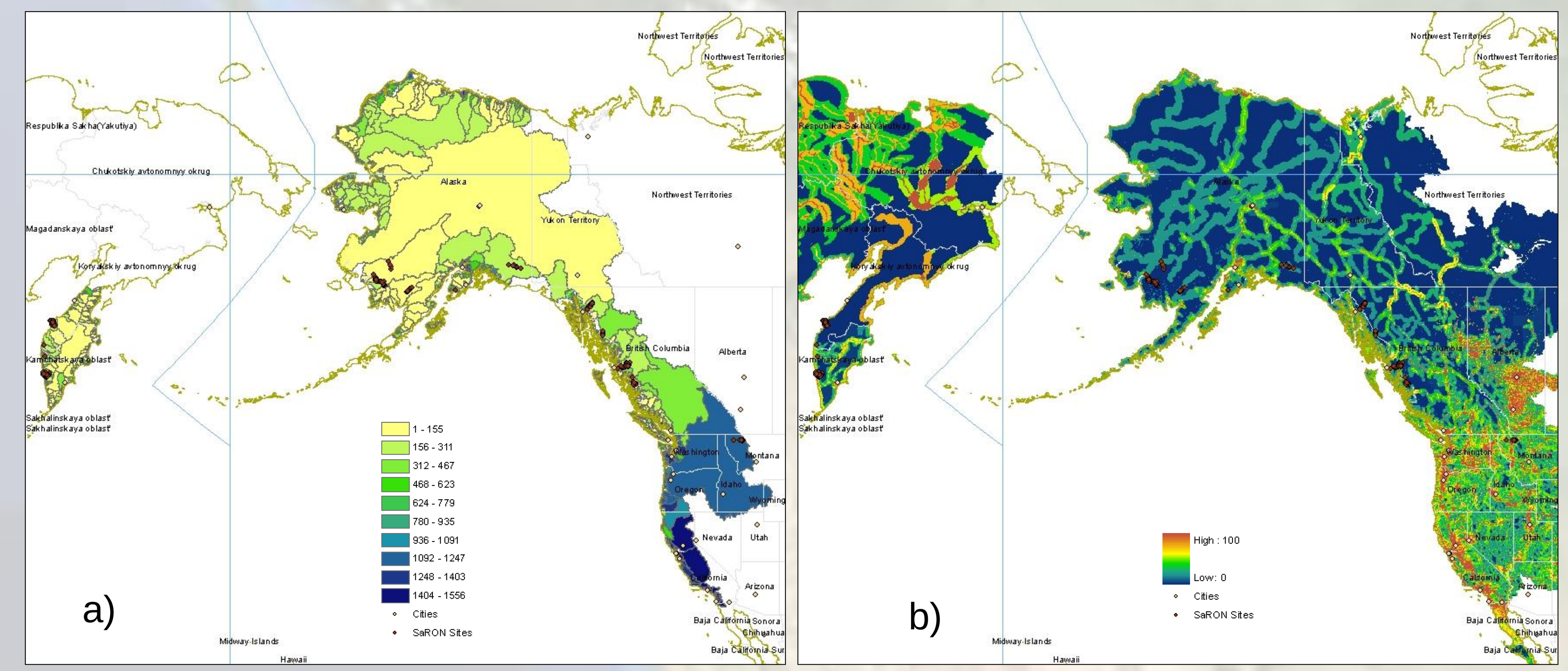

Figure 4. a) Overall ranking, which combines the b) Human Footprint Index normalized by WWF Freshwater Ecoregions with all RAP variables.

Future work

To asses potential salmon productivity, Quickbird data is classified into riverine habitats. Juvenile density estimates are populated from in stream electro-fishing samples within the footprint of the Quickbird scene. Statistically significant relationships between features extracted from the remote sensing data are used to extrapolate population estimates to the floodplain or watershed scale(Fig 5).

In addition, we are incorporating outputs from the Variable Infiltration Capacity (VIC) Hydrologic Model into the RAP database to asses the future impact of Global Warming on Pacific salmon. These analyses will help to make informed management decisions.

Finally, we are integrating our watershed ranking with Wild Salmon Center efforts to develop multi-scale tools that will help direct the allocation of resources for salmon conservation.

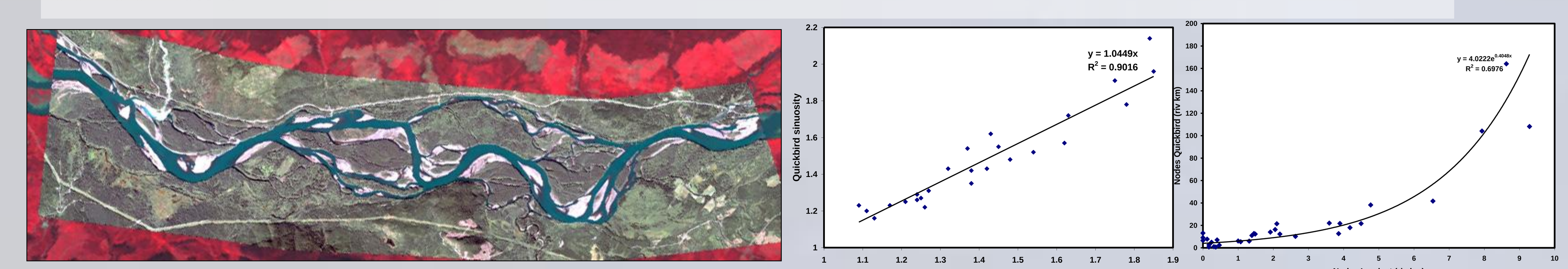

Figure 5. An example of Quickbird imagery overlaid on Landsat data.