Skeena Historical Land Use Change and Ecological Function Project

FINAL REPORT

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Deliverable 3: Technical Report for Skeena Historical Orthophotographic Archive

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Executive Summary

The following report describes the final phase (Phase II) of the collaborative WWF-UBC Skeena Historical Land Use Change and Ecological Function Project. This project entailed collecting air photos at two study areas within the Skeena River watershed in northwestern B.C. in order to develop a historical timeline of environmental change in this important ecosystem. The Skeena River watershed is one of the only major river systems in B.C. that is un-dammed. Growing development pressures on this system create an interesting and timely study illustrative site for a conversation on the role of historical ecology in improving natural resource decision making.

Availability of aerial photography from 1937 through 1988 was assessed and then images were collected, scanned, and archived for two pilot study sites within the Skeena River watershed. The first study site consisted of the Lakelse sub-watershed southwest of Terrace, BC, whereas the second study site was selected along the main stem of the Skeena River and is notable for importance as eulachon habitat. A total of 1,012 historical aerial photos were scanned and archived in this database, 778 of which provide coverage of Lakelse watershed and 234 cover the main stem of the Skeena River. Of the photos scanned, 371 were further orthorectified (to correct for distortion and to geolocate the images) in two mosaicked chronosequence images of Lakelese watershed (circa 1937/1938 and 1988). At the Lakelse site, an initial photointerpretation of basic landscape disturbances was conducted as part of a feasibility analysis for additional research involving the archive.

As demonstrated in our literature review from the prior Phase I of this project, as well as from the example photointerpretations provided here (as part of Phase II), aerial photography provides a wide array of opportunities for rigorous ecological analysis and applications which can improve natural resource management and decision making. Creating an air photo time series provides insight into the patterns and processes of disturbance regimes as well as the response and recovery rate of ecosystems post-disturbances. The incorporation of historical information presents an opportunity for more robust decision making and is one step towards improved sustainable environmental management. The potential incorporation of chronosequence information into environmental assessments is another key application of the approaches outlined here. Project objectives, methods and preliminary outcomes of the historical orthophotographic database are described in more detail in the remainder of this report.

Introduction

The analysis of historical landscapes, often referred to as historical ecology, provides insight into the patterns and processes of a disturbance regime and empirically reveals the (often unexpected and complex) effects of decisions and past policy in shaping landscape condition (Higgs et al. 2014, Renard et al. 2015). The most prevalent source of spatially contiguous historical ecological data are air photos, typically providing coverage within the twentieth century. Historic air photos provide the longest, spatially accurate record of forest conditions, prior to the advent of many industrial forest harvest activities. Furthermore, aerial photos are high resolution, allowing for characterization of heterogeneous ecosystems, such as riparian forests (Gergel et al 2007), and identification of important landscape features. Aerial photos have been previously used in a wide variety of ecological applications. Examples include tracking natural landscape and riverine dynamics (Little et al. 2013), comparing landslide activity in logged and unlogged areas (Jacob 2000), and assessing historical changes in ecosystem services and their interactions (Tomscha & Gergel 2016).

Aerial photography is a cornerstone of forestry inventory. Trained photo-interpreters can map forest tree species distributions, structural stages and other canopy characteristics important for wildlife (Morgan and Gergel 2010). Recent advances and development of new techniques for air photo analysis and interpretation are improving a variety of conservation applications (Morgan et al. 2010; Morgan & Gergel, 2013; Tomlinson, Gergel, Beechie, & McClure, 2011). Contemporary aerial photography is already used as the basis for much of the ecological and forest mapping in British Columbia. When combined with historical aerial photography, it has the potential to provide important information regarding change over time for many habitats of concern. In addition, there is great opportunity for the outputs of aerial photograph interpretation to be used in collaboration with field measurements and remote sensing tools to extrapolate estimates of carbon storage, timber stocks, habitat suitability, etc. across heterogeneous landscapes, both terrestrial and aquatic.

Incorporation of historical land use and land cover change over time is critical in order to learn from previous mistakes, to understand the response of ecosystems to natural and human disturbances, and to move towards more sustainable decision making in natural resource development. An example insight gained from historical air photo analysis is provided in Figure 1 below.

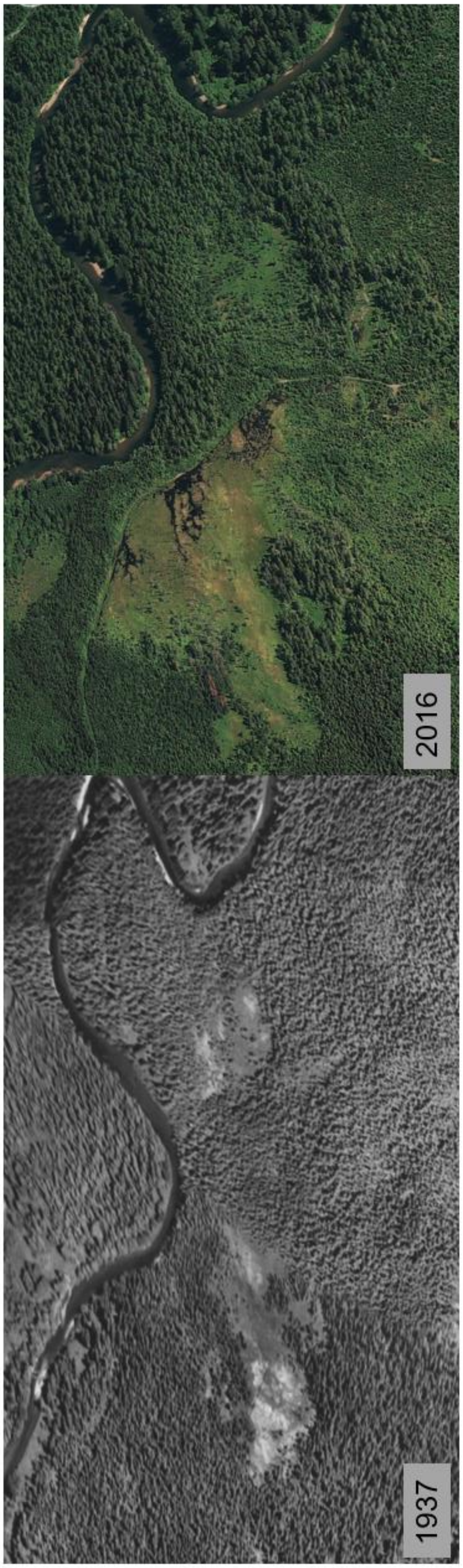

Figure 1: Lessons to be learned from historical aerial photographs. The image above represents the same area in 1937 (on the left) and in 2016 (on the right). The photos demonstrate how historical ecology can prevent environmental decision-makers from making similar mistakes in a contemporary setting. The photo comparison shows a forestry service road was built along this section of the Lakelse River after 1937 and was not built with proper cross drainage implements. As such, the road caused water to pond and created a large wetland feature in this area. This potentially impacted natural flow of runoff to the river, affected nutrient retention and release timing, and other biophysical processes.

The following report describes the methods and outcomes of the collaborative WWF-UBC Skeena Historical Land Use Change and Ecological Function Project. This project entailed collecting air photos at two study areas within the Skeena River watershed in northwestern B.C. in order to develop a historical timeline of environmental change in this important ecosystem. The Skeena River watershed is a highly biodiverse, mountainous and primarily forested region and is one of the only major river systems in B.C. that is not dammed. The effects of large-scale anthropogenic disturbance are of relatively recent concern compared to similar environments in southern areas of B.C. (Lewis 2008; Jones et al. 2010). Pressure from timber industry largely began in the 1970s and now the Skeena-Stikine region (which comprises the majority of land area in northwestern B.C.) is faced with highest number of major natural resource development proposals in the province (OAG BC 2015). The growing development pressure on highly biodiverse and productive ecosystems in the Skeena create an interesting and timely study site for a conversation on the role of historical ecology in natural resource decision making.

Methods

Study Site Selection

Members of the Landscape Ecology Lab (LEL) at the University of British Columbia Vancouver Campus, under the direction of Dr. Sarah Gergel, have compiled an air photo database for two study areas within the Skeena River Watershed. The air photo database contains photos from two different study areas from different time periods dating back to 1937. The coverage of the photos differs between years and areas. In consultation with James Casey (WWF), these two study sites were chosen because they represent habitat for two ecologically and culturally important fish species. The first study site is the Lakelse watershed (Figure 2) on the southwest side of Terrace provides important spawning habitat for Chinook salmon, as well as other terrestrial and aquatic wildlife. The second study site along the lower part of the main stem of the Skeena River (Figure 3), contains habitat for eulachon. Eulachon is an important cultural and subsistence species for First Nations people who have long-lived along the main stem of the Skeena River. The population has been declining in recent years and it is designated as threatened by COSEWIC in Canada (Department of Fisheries and Oceans Canada 2014). The second study site is separated into two parts (as seen below in Figure 3) and includes an area of known eulachon habitat and an area of unconfirmed, but suspected, habitat for eulachon.

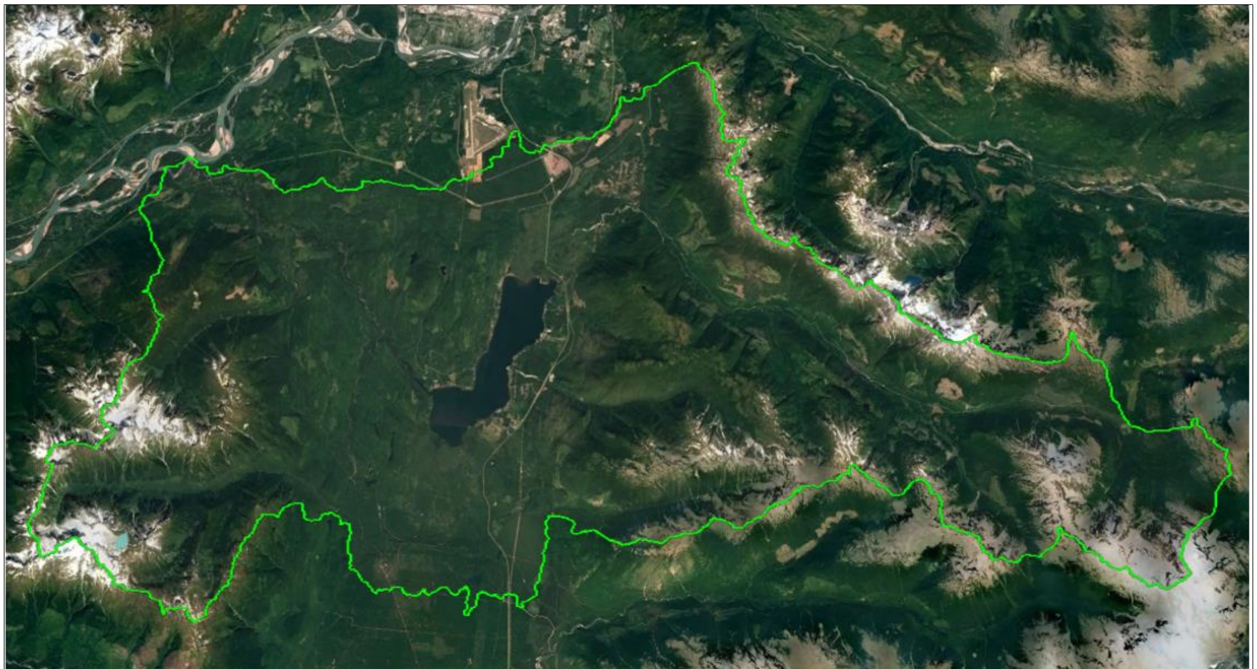

***Figure 2**: Study Site # 1: the green polygon outlines the Lakelse watershed on the south side of Terrace, B.C. Images from this area were collected from 1937-1938, 1947-1949, 1960, 1963, 1975 and 1988. Imagery (retrieved from Google Earth): 2016 SPOT Image*

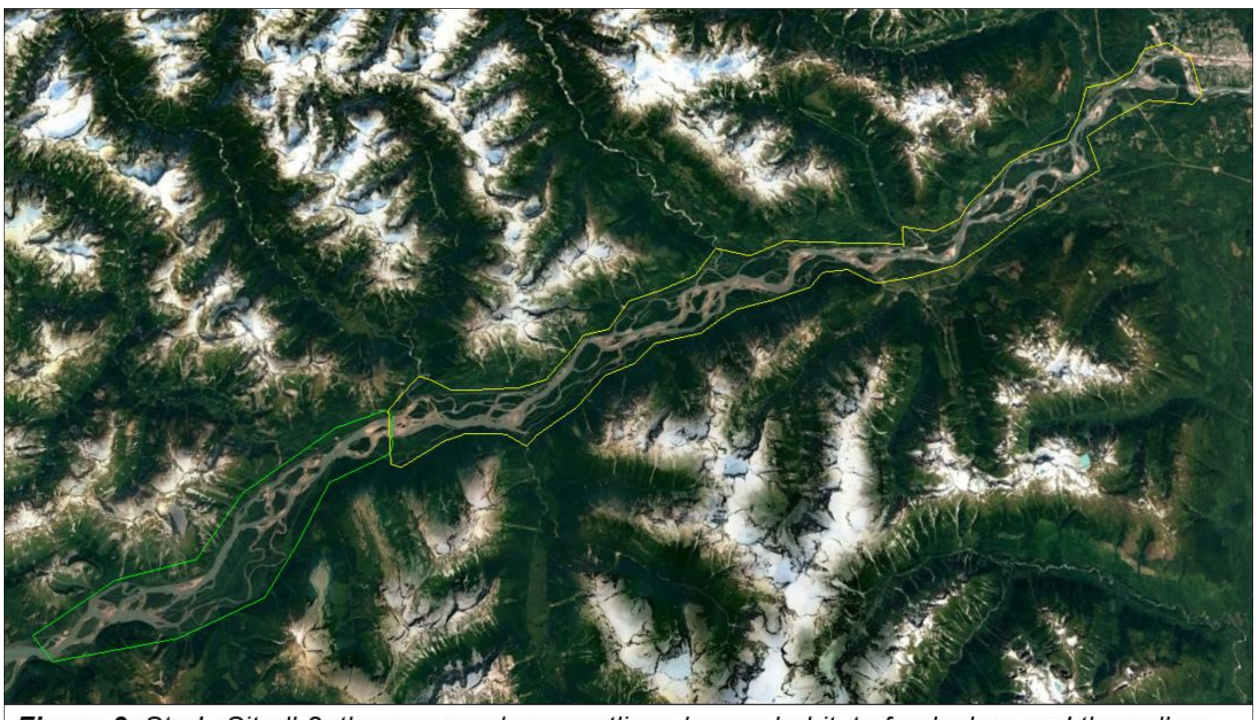

***Figure 3**: Study Site # 2: the green polygon outlines known habitat of eulachon and the yellow polygon indicates potential habitat area. Images from both of these areas were collected from 1937-1938, 1975 and 1980. Imagery (retrieved from Google Earth): 2016 SPOT Image*

Air Photo Database

Hard copy air photos were retrieved from the GeoBC air photo database, now held at the Geographic Information Centre at UBC-Vancouver The photos were scanned according to the UBC Scanning Protocol (see project metadata). The scanning of photographs converts analog files into digital files that are represented as pixels. Scanning was completed by two LEL personnel using an Epson Expression 1640 XL scanner at a resolution of 1200 dots per inch (dpi). Each photo was scanned in chronological flightline sequence and archived by flight number. All photos were scanned with a northern orientation and saved in TIFF (.tif) format. . Additional information, including flightline maps, are included with the project metadata, housed online by UBC.

Orthorectification Procedures

A subset of the scanned air photos from the Lakelse watershed area (Study Site # 1) were orthorectified and mosaicked together to provide a contiguous landscape view of the region from 1937/1938 as well as from 1988. There are inherent geometric (positional) errors in air photos due to the high relief displacement seen in mountainous areas and due to tilt displacement from the camera, which is more common in older aerial photos (Morgan & Gergel 2010). Orthorectification is the process of correcting these errors and removing distortion from the photos. The orthorectification process is comprised of three different steps. The first step is internal orientation performed to adjust for distortions within the camera due to any tilt or angulation of the camera used in the overflight or movements in the aircraft. The second step, external orientation, serves to correct imagery for terrain and elevation related distortions through the use of ground control points (GCPs) and a digital elevation model (DEM) derived from the BC Terrain Resource Information Management (TRIM) data, which are used to relate the raw original aerial photograph to modern orthoimagery (Wang & Ellis 2005). These processes were both completed in ENVI, a geospatial image analysis software, which transforms the raw image pixels into map coordinates using a least-squares regression model with a certain root mean square error (RMSE). After the image is orientated in space and geometric distortions are corrected, the boundaries of the photo are modified and transformed. The third step in the process is to mosaic all of the individual orthophotos into a single composite image, which was accomplished using ArcGIS.

Necessary technical information for the orthorectification process is provided by the camera operators and is referred to as a camera calibration report. These reports are typically only available in BC for photos taken after 1965. As such, parameters for the 1937 photos were manually derived and are not as precise. The RMSE error of the 1937 photos is therefore higher and the geometric corrections are not as accurate leading to slight differences between it and contemporary orthoimagery.

Air Photo Interpretation

Air photo interpretation can be conducted in many different ways to different outcomes. The basis for aerial photo interpretation is the delineation of polygons based upon observable characteristics (Morgan et al 2010). An overview of different observable characteristics used to delineate polygon boundaries is provided below in Table 1. Polygons can be digitized on raw images or digitally. Original raw images (with 60% overlap) can be viewed manually as stereo-pairs to visualize an area in 3-dimensions.

Characteristics	Ecological Features Depicted
Tone/Color	Identifies changes in vegetation type (polygon boundaries)
Size	Indicates tree age by size (old growth vs. second growth), size of anthropogenic features (i.e. roads)
Shape	Identifies obvious geometric edges caused by anthropogenic disturbance (i.e. pipeline right-of-ways) compared to natural disturbances, crown shape to identify species and successional stage of vegetation
Texture	Forest structural characteristics (high variability may indicate natural disturbance), tree species (deciduous vs. coniferous tree crowns)
Pattern	Identifies distinct anthropogenic disturbance patterns
Shadow	Assists with tree identification
Landscape Features	The topographic, high-elevation features that dictates landscape heterogeneity
Landscape Context	Location of a feature or patch within a landscape, surrounding areas

Table 1: A description of the air photo characteristics that can be used to delineate boundaries of polygons. Information was adapted from Morgan et al 2010; Morgan & Gergel, 2010.

Preliminary Results

There are several different projects and objectives that are currently utilizing the air photo database. Information about the different types of ongoing analysis is provided below. The existence of the air photo archive now provides a wide range of future opportunities for different analyses.

Delineation of Disturbance Regimes

One of the objectives for these air photos is to provide insight into the disturbance regime seen at the two study sites. Natural and anthropogenic disturbances create landscape-scale patterns and impact ecological processes at various spatial and temporal scales. Investigation into the differences observed in disturbance size, shape and effects of single-event natural and anthropogenic disturbances has been previously documented (Pickell et al. 2013; Narumalani et al. 2014; Shroeder et al. 2011), however much less is known about the effects of multiple disturbances, or combinations of natural and/or anthropogenic disturbances, occurring in the same spatial location. Empirical studies conducted in various ecosystems have demonstrated that interactions between multiple impacts can cause additive (as is typically expected), synergistic or antagonistic responses (Crain et al. 2008). The air photos collected for the study sites are being analyzed to determine how the size and shape complexity of forest patches differ in areas where single-event disturbances and multiple-event disturbances have occurred. The size and the complexity of shape of disturbed forest patches have direct implications on the amount of wildlife habitat available and the overall habitat connectivity, as well as carbon storage potential and disturbance recovery processes (Shroeder et al. 2011). This is interesting due to the increasing amount of natural (i.e. insects, climate/weather events, fire) and anthropogenic disturbances (i.e. forestry harvest, oil and gas development, encroaching residential populations) likely to occur with expanding natural resource development and predicted under future climate conditions. An example of air photo interpretation conducted to achieve this objective are provided below in Figure 4.

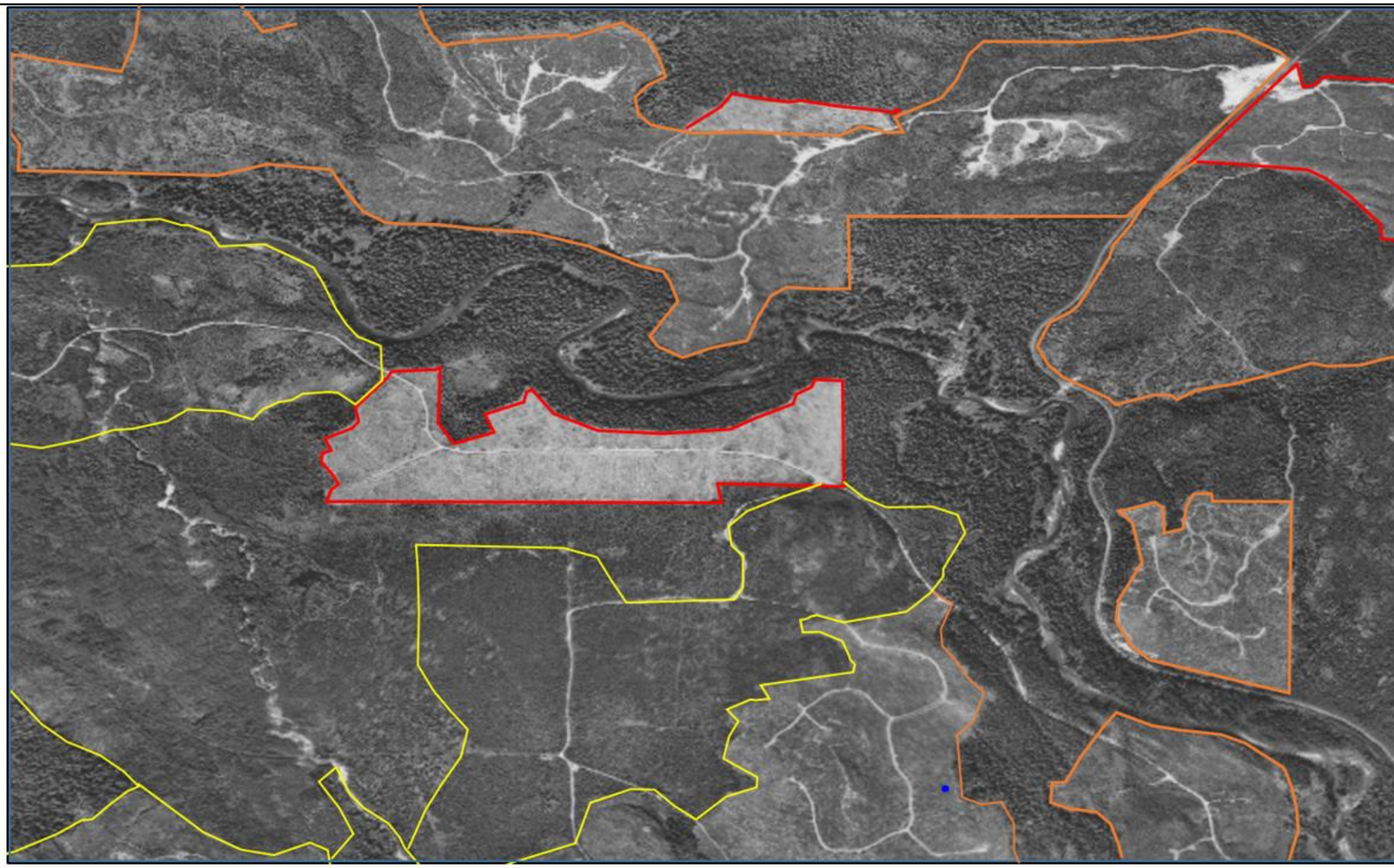

Figure 4: Demonstrates the delineation of areas of anthropogenic disturbance caused by forest harvest on either side of Lakelse River. This image was derived from the 1988 Lakelse watershed orthomosaic. The different color polygons represent three different time periods of anthropogenic disturbance and provides insight into the patterns of forest succession following disturbances. The yellow polygons indicate oldest areas of disturbance, orange polygons represent an intermediate age of disturbance and the red polygons indicate areas of more recent disturbance in 1988. In future work with the air photo library, it will be possible to delineate time periods for each of these disturbances and identify areas where multiple impacts have occurred.

Identification of Cumulative Impacts

Another objective which will benefit from aerial photo interpretation is the identification of areas where cumulative impacts have occurred. Cumulative environmental impacts occur in areas where multiple activities/stressors overlap and/or interact temporally and spatially (Terra and Santos 2012). Monitoring cumulative impacts over time is crucial to understanding ecosystem dynamics and thresholds and characterizing the response to and recovery from disturbances (as detailed in our literature review from Phase I of this project). Delineation of areas where multiple disturbances have occurred is one proposed method of accounting for cumulative impacts on forested land cover (Terra and Santos 2012). Historical aerial photo analysis provides an opportunity to create a temporal record of disturbance and highlight areas where cumulative impacts have occurred. This project has the potential to highlight areas where historical cumulative impacts have occurred within the Lakelse landscape in order to identify preferred areas for future conservation and development.

Further Opportunities

There are many additional opportunities for ecological analysis that can be conducted using the historical orthophotographic archive including measuring stream channel and morphology change over time, vegetation composition changes over time, identifying suitable habitat for organisms, and others. Of particular interest is the relation of land-based disturbances to aquatic systems. Proposed uses of the Lakelse watershed air photos are briefly outlined below as examples of future work in this area. Also of interest is mapping riparian habitat and longterm channel changes, especially in regards to the Study Site #2, of importance to eulachon.

Land-based disturbances are known to have impacts on terrestrial biodiversity (Newbold et al. 2016), but often less appreciated are the effects of land-based disturbances on aquatic ecosystems (Rosenau and Angelo 2009). In the case of forested watersheds, land-based natural and anthropogenic disturbances often involve (or are the result of) tree removal. The effects of tree removal in the riparian areas of river ecosystems can include increased water temperature due to loss of shade from trees, sedimentation due to increased erosion and run-off from the surrounding landscape, changes in the amount of organic inputs such as woody debris and leaf litter, increased nutrient inputs from the soil, destruction of aquatic and riparian area habitat, and other impacts (Rosenau and Angelo 2009; Olson et al. 2007).

To explore the potential interactions between riparian disturbances and aquatic ecosystems, LEL personnel are interested in quantifying the magnitude of disturbances over time in the riparian zone of the Lakelse River and relating this to historical spawning records of Chinook salmon abundance. Chinook salmon are an anadromous fish species that depend on freshwater river systems as a migration channel to spawn and complete their life cycle. The migration of adult salmon to spawning habitat can be interrupted by a multitude of aquatic disturbances including temperature, sedimentation and lack of food and therefore the abundance of salmon is theoretically an effective indicator of the effects of land-based disturbances on aquatic ecosystems. Future work will relate the area and type of disturbance to fish population change over time and while controlling for confounding factors (e.g., climatic teleconnections) which also impact salmon over time.

In summary, aerial photographs provide a wide array of opportunity for ecological analysis and application in natural resource decision making. Creating an air photo time series provides insight into the patterns and processes of a disturbance regime and the response and recovery rate of particular disturbances (Swetnam et al., 1999). The incorporation of historical information presents an opportunity for more robust decision making and is a step towards sustainable environmental management.

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