COMPARING AND MAPPING ECOSYSTEM SERVICE USE ACROSS INTEREST GROUPS IN THE UPPER PEACE RIVER WATERSHED

By

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We accept this thesis as conforming
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Abstract

The ecosystem service (ES) approach to conservation normally uses economic or biophysical assessments for valuating nature's services. In contrast, even though ES are required for human well-being, the actual uses of services by differing interest groups are rarely considered, nor are intangible cultural ES. The aim of this research was to quantify different uses for 15 cultural and provisioning ES indicators across seven groups on a regional scale, as well assess spatial differences in ES across eight groups using participatory GIS. Results demonstrate that different interest groups use ES differently; in terms of ES type, frequency of use, as well as spatial location of ES use. In particular, this work highlights the importance of considering cultural ES (e.g. aesthetic/scenic, sense-of-place) during decision making processes. Spatial locations of ES hotspots were also shown to correspond with established areas of high biodiversity, both required for effective and legitimate decisions regarding land use.

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Chapter 1: Introduction

Ecosystem Services

Ecosystem services (ES) have been broadly described as the activity, function, condition or process of natural ecosystems that benefit and sustain human life (Daily, 1997; Mace, Norris, & Fitter, 2011), and that have value for people (Chan et al., 2012a). Ecosystem services are derived from numerous complex natural cycles that operate on different scales; cycles that are driven by solar energy within the biosphere, which contains all known life (Daily, 1997). Ecosystem services maintain the production of market valued goods (e.g., timber, fiber, pharmaceuticals, and industrial products) (Daily, 1997); in addition to intangible non-market human benefits such as aesthetic views, recreational opportunities and landscapes with scientific or educational value (Chan et al., 2012a; Chan, Satterfield, & Goldstein, 2012b; Daily, 1997). Additionally, ES are the essential life support systems on Earth (e.g. primary production, nutrient cycling, soil formation), making ecosystem functioning and life on Earth possible (Daily, 2006; Millennium Ecosystem Assessment (MEA), 2005).

Ecosystem services are categorized as provisioning (e.g., food, water, shelter), regulating (e.g., climate mitigation, pollination), cultural (e.g. recreation, aesthetic) or supporting services (e.g., nutrient cycling, photosynthesis) (MEA, 2005). While it is acknowledged that slightly alternate typologies for ES categorization exist (Costanza et al., 1997; de Groot, Wilson, & Boumans, 2002), the MEA typology is the most widely recognized (Brown, Montag, & Lyon, 2012; Cimon-Morin, Darveau, & Poulin, 2013; Haines-Young & Potschin, 2010). Provisioning, regulating and cultural ES are sustained by supporting ES, and all are intricately linked to biodiversity, which describes the variability of life across all levels of biological organization: genes, species, ecosystems and their associated interactions.

Biodiversity Underpins Ecosystem Services

Biodiversity is defined by the United Nations (1992) in the Convention on Biological Diversity as “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.” The relationship between biodiversity and ES is complex, confusing, and poorly understood in many instances. Mace, Norris, & Fitter (2012) propose that confusion exists because biodiversity has three keys roles to play at different levels of ES, that is, it can be considered as a regulator of ecosystem processes underpinning all ES, as a final ES itself, or as a good produced by ES. Additionally, it is unclear how much biodiversity is needed in order to maintain ecosystem function required for delivering ES (Isbell et al., 2011), how alterations to biodiversity will effect ecosystem function and ES delivery (Nagendra, Reyers, & Lavorel, 2013), or how impacts to biodiversity will affect rates of declining ecosystem functions (e.g., oxygen production, uptake of carbon dioxide, decomposition) (Cardinale et al., 2011). However, there is a significant and growing body of evidence that provides links between biodiversity, ecosystem function and resulting ES.

Some experiments have shown that biodiversity underpins the delivery of services, and that ecosystem function and service capacity fluctuates with differing levels of biodiversity (e.g., Balvanera et al., 2006; Cardinale et al., 2012, Isbell et al., 2011, Maestre et al., 2013; Pasari, Levi, Zavaleta, & Tilman, 2013). For instance, experiments by Isbell et al. (2011) demonstrated that the loss or decrease of almost every studied plant species was shown to decrease ecosystem functioning and the delivery of supporting ES in some context, and almost every species was important to ecosystem function at least once. This study also suggests that in order to maintain ecosystem multifunctionality [when multiple functions and services of an ecosystem (e.g., biomass production, nutrient uptake) are considered simultaneously] in a changing world, many species are needed at multiple times and in many different spaces (Isbell et al., 2011; Maestre et al., 2012; Pasari et al., 2013). Even species shown to have little effect on ecosystem function and ES delivery in one context could be important when considering other scenarios or contexts, for example, if environmental conditions change or if ecosystem functions or services are considered in alternative contexts such as importance for aesthetic or ethical reasons (Isbell et al., 2011).

Additional experiments coming from decades of research using both terrestrial and aquatic habitats have shown that plant species richness makes significant contributions to ecosystem mulifunctionality, including carbon storage, nutrient pooling, and primary productivity (e.g., Balvanera et al., 2006; Cardinale, Bennett, Nelson, & Gross, 2009; Hector et al., 1999; Isbell et al., 2011). These demonstrated relationships suggest that a loss of plant species richness (i.e., biodiversity loss) may impair ecosystem functioning and decrease ES delivery in both number and quality (Isbell et al., 2011; Maestre et al., 2012). These experiments provided evidence that maintaining plant species richness in natural ecosystems can maintain ecosystem functions and ES such as those linked to carbon (e.g., carbon sequestration) and nitrogen (e.g., soil fertility) (Maestre et al., 2012), as well as maintain rates of oxygen production and carbon dioxide uptake from the atmosphere (Cardinale et al., 2011). A last example demonstrating links between biodiversity and ecosystem functions and services comes from experimental results demonstrating that tree species richness is positively correlated to multiple ES such as carbon storage, biomass production, berry production and potential for hunting game (Gamfield et al., 2013). Given these demonstrated relationships, in a broad sense biodiversity has been shown to have a key role in ecosystem function (and multifunctionality) and the resulting ES delivery that humans benefit from (Diaz, Fargione, Chaplin III, & Tilman, 2006).

However, given the complexity between biodiversity and ES functioning (Mace et al., 2012), we still know very little about the role of biodiversity when it comes to its importance for the functioning of ecosystems and ES provided (Daily, 1997; Pasari et al., 2013). This is not surprising given that this is a relatively recent field of interest; research from 2006 provides the first quantitative evidence for links between biodiversity, ecosystem functioning and ES (Balvanera et al., 2006). A considerable amount of research is still required in order to further understand the role of differing components of biodiversity (e.g., genetic, species, and landscape diversity), for the delivery of ES (Diaz et al., 2005), as well as to confirm linkages already established (Balvanera et al., 2006).

Declining Ecosystem Services

What is evident is that across all biological levels and processes, biodiversity is experiencing global declines at an alarming rate (Cardinale et al., 2012; Isbell et al., 2011; Hooper et al., 2012). At the global scale, the primary driver of biodiversity loss is land use change (Sala et al., 2000), for example, conversion to agriculture, urban and rural development, transportation, forestry, hydroelectric development, and oil and gas extraction/exploration (Austin, Buffet, Nicolson, Scudder, & Stevens, 2008; Lindenmayer & Fischer, 2006). In addition, the resulting habitat loss, habitat fragmentation and habitat degradation stemming from these anthropogenic environmental alterations are expected to act concurrently with accelerating changes in climate (MEA, 2005; Rands et al., 2010; Hui, 2013). Changing climatic factors can negatively affect multiple life stages of organisms, alter species habitat and resources, and lead to changes in phenology (Hui, 2013). Numerous scientific publications have attributed biodiversity loss to the Earth becoming increasingly dominated by humans, intensifying pressures on natural ecosystems; economic development and growth in human prosperity are associated with natural landscape conversion, posing series challenges for biodiversity (e.g., Austin et al., 2008; Balvenera et al., 2001; Cardinale et al., 2012: Daily, 1997; Diaz et al., 2006; Ehrlich & Mooney, 1983; Foley et al., 2005; Guo, Zhang, & Li, 2010; MEA, 2005; Nagendra et al., 2013; Rands et al., 2010; Sala et al., 2000; Wilson & Peter, 1998). The continued growth of the human population and the associated consumption of natural resources have resulted in the unsustainable exploitation of biodiversity and resulting ES (Cimon-Morin et al., 2013; Rands et al., 2010). The MEA (2005) suggests that we have lost more biodiversity in the past 50 years than in any other time in human history, resulting in many negative consequences including changes in ecosystem function and the resulting ES, which are deemed necessary for well-being. It is suggested that up to 60% of the global ES evaluated are being degraded, overused, or lost to unsustainable anthropogenic activities (MEA, 2005). If current threats to biodiversity loss are not alleviated, humans could find themselves in a mass extinction crisis within a few centuries (Barnosky et al., 2011).

Ecosystem Services and Human Well-Being

Human well-being has many dimensions (Chiesura & de Groot, 2003), but it can be described as the human experience with characteristics of a good quality of life, health, sense of self, freedom to have choices, good social relationships (Diaz et al., 2006), in addition to having life satisfaction, self-esteem and vitality (i.e., enthusiasm, energy) (Guerin, 2012). It is strongly believed that human well-being depends upon biodiversity and the resulting material and non-material ES (Daily, 1997; Haines-Young & Potschin, 2010; MEA, 2005) necessary for a satisfactory life (Diaz et al., 2006). Humans could not exist if certain ecosystem goods and services were no longer produced by nature (e.g., freshwater, food) (Rands et al., 2010), and human well-being could be significantly reduced if other non-material ES were eliminated or reduced (e.g., landscapes used for sense of place and recreational opportunities).

Ecosystem Service Approach

Ecosystem services are rarely considered in policy development or land-use decisions partly because the relationships between biodiversity and ES (and thus well-being) are not fully appreciated, valued, or understood (Thompson et al., 2011). However, major links between biodiversity, ES, and human well-being have been established. Therefore, based upon the precautionary principle ideally all species should be conserved since we cannot be certain what species provide ES (Isbell et al., 2011) necessary for human well-being. Given that adhering to the precautionary principle in this sense is unlikely in today's developing world, it is essential that land alterations operate conservatively to maintain ES and the biodiversity needed to provide them (Ehrlich & Mooney, 1983). To accomplish this, ES and biodiversity need to be accounted for in major land-use decisions given the severe consequences that humanity will face should we continue to disregard demonstrated links between biodiversity loss and declining ES.

The term 'ecosystem services' was first used in the early 1980's as a framework for understanding how changes to ecosystem processes and species (e.g., extinction) can affect the distribution of services to humans (Erhlich & Erhlich, 1981; Ehrlich & Mooney, 1983). The concept has been slow to catch on with the first major piece of ES literature published in 1997 (i.e., Daily, 1997) and with almost 60% of the journal articles mapping ES being published after 2007 (Schagner, Brander, Maes, & Hartje, 2013). Recently the ES approach has been rapidly developing in response to the recognition (made by over 1,360 global experts) that global ecosystem degradation is occurring and there is a need for maintaining ES benefits to humans (MEA, 2005).

Using the ES approach acknowledges that humans and ecosystems are interconnected and in order for human well-being to persist, we need healthy ecosystems (Daily, 1997, MEA; 2005; Menzel & Teng, 2010). The ES approach works to influence research and land management decisions according to what people care about or value most (Chan et al., 2012a). The ES approach is being used with the aim of achieving more environmentally sound land-use management decisions and to justify nature and biodiversity conservation (Martin-Lopez et al., 2012; Menzel & Teng, 2010; Schaich, Beiling, & Plieninger, 2010), and is gaining momentum globally due to the increased recognition and importance of ES. The ES approach does not replace reasons for conserving nature based upon intrinsic values, but it does complement the intrinsic approach by broadening logic for conservation by understanding how nature contributes to human well-being (Daily, Kareiva, Polasky, Ricketts, & Tallis, 2011, p.4).

To date, the ES approach has mainly focused on determining the market value of ES, primarily for provisioning and regulating services, using various economic valuation techniques such as hedonic pricing, willingness-to-pay and the travel cost method (Chan et al., 2012b; Hein, van Koppen, de Groot, & van Ierland, 2006; Lamarque et al., 2011). The economic valuation of ES is often used to make policy recommendations (Menzel & Teng, 2010) and as a means for informing and thus improving decision-making (Chan et al., 2012a). The economic ES approach is being used as a tool for making connections between ecology and economics. This is useful because assigned values for nature are conveyed to a broader audience, such as policymakers and resource land use managers, who would not normally be privy to ecosystem information (Chan et al., 2012b). Additionally, when humans learn of connections between how nature provides for their well-being and survival, it could instigate those people to appreciate nature they previously undervalued. The ES approach using monetary valuations can also be useful for looking at potential trade-offs or cost-benefit analysis' for land use options or policy decisions. An ES trade-off is a management decision that occurs when one ES is reduced and traded off, due to the consequences of using another (Rodriguez et al., 2006). For example, future land-use scenarios developed in Oregon showed that a "conservation" scenario produced the best results for ES, especially when considering carbon sequestration as a market commodity; however, other services such as land used for building houses and timber production would be traded off as a consequence of biodiversity conservation (Polasky et al., 2011, p. 254).

While economic valuations have been the focus, the ES approach to conservation also uses biophysical assessments aimed at understanding how changes in ecosystems might effect ES (Chan et al., 2012a; Martin-Lopez et al., 2012), for example, how changes in tree species richness affect ES (Gamfield et al., 2013), or how differences in plant diversity affect ES maintenance (Isbell et al., 2011). Although the ES approach to biodiversity conservation is useful for policy and decision-making, it has recently been recognized as a limited assessment since monetary assignment assumes all people value the same ES, and in the same way (Klain & Chan, 2012; Menzel & Teng, 2010), nor can all ES can be identified using biophysical assessments (e.g., sense of place, spiritual/religious). The current ES paradigm neglects important social perspectives such as moral and cultural values referred to as cultural ecosystem services (CES) (Chan et al., 2012a; Chan et al., 2012b; Schaich et al., 2012; Klain & Chan, 2012; Tengberg, Fredholm, Eliasson, Knez, Saltzman, & Wetterberg, 2010). However, a third ES approach has recently been used for non-economic valuations of ES, in order to enable the explicit inclusion of more intangible values associated with the socio-cultural domain and CES (e.g., Fagerholm, Kayhko, Ndumbara, & Khamis, 2012; Klain & Chan, 2012; Martin-Lopez et al., 2012), which is important for full and comprehensive accounting of services (Plieninger et al., 2013).

Cultural Ecosystem Services

There are many social values that fall outside of the economic or ecological domain, yet they can be crucial for well-being and the sustainability of societies (Chan et al., 2012a; Chiesura & de Groot, 2002; Klain & Chan, 2012). Cultural ES cover a broad range of services such as spiritual and religious values, inspiration, sense of place, cultural heritage values, educational values, recreation and ecotourism (MEA, 2005). In many cases cultural benefits can be considered as irreplaceable in a landscape (Plieninger et al., 2013), although cultural aspects of ecosystems and their contributions to human well-being are valued differently for each person (Menzel & Teng, 2010). For example, the use of natural systems, particularly from a cultural, sacred and spiritual interaction perspective, may not be deemed critical for someone who rarely spends time outdoors (Smith, Case, Smith, Harwell, & Summers, 2013).

In several cases it has been shown that intangible CES can be more important to people than material ES (Chan et al., 2012a). For example, in the Puget Sound of the United States, Iceland, Hanson, & Lewin (2008) found that two of the top four ES identified as being most important across multiple interest groups were in the CES category (i.e., recreation and ecotourism, ethical and existence values). Similarly, through interviews, Raymond et al. (2009) found that community members and decision-makers in Australia recognized the three most highly valued ES (across the four MEA ES categories) were also CES (recreation and tourism, bequest, intrinsic and existence); freshwater and water regulation from the provisioning ES (PES) categories were fourth and fifth in importance to people. Interestingly, another study looking at social preferences for ES from all four MEA categories, found that responses varied for ES importance according to a variety of complex factors including cultural traditions, access to ES (i.e., rural vs. urban living), household income, gender, educational level, and individual needs (Martin-Lopez et al., 2012). They found that rural people recognized a more diversified flow of ES because they were more closely connected to ecosystems (Martin-Lopez et al., 2012). However, across all 3379 participants surveyed, CES such as nature tourism, aesthetics, and existence values ranked high (Martin-Lopez et al., 2012). Given the demonstrated importance of CES to humans, it is important to assess cultural values across interest groups to see what is most highly valued for people with differing interests, within each unique region.

Despite the recognized importance of sometimes intangible CES (Chan et al., 2012a; Daily, 1997; de Groot et al., 2002; Plieninger et al., 2013), the incorporation of CES into the ES approach lags far behind other, more tangible ES with the exceptions of recreation and ecotourism (Chan et al., 2012a; Plieninger et al., 2013). This lack of CES inclusion is largely due to methodological challenges (Plieninger et al., 2013) and difficulty in assessment owing to their non-market value, incommensurability, and intangibility (Chan et al., 2012b; Klain & Chan, 2012; Menzel & Teng, 2010; Plienger et al., 2013). Further, cultural insensitivity comes as a result of ignoring CES and by not considering broad and diverse interest group perspectives; this has plagued biological conservation (Chan et al., 2012a). Neglecting CES is highly problematic for the ES approach since overlooking ES highly valued by people produces incomplete assessments, which could result in misled trade-off assessments and management plans (Schaich et al., 2010). By not including the human dimension the ES concept may produce unintended consequences, become irrelevant to policy, and ultimately fail (Chan et al., 2012a; Menzel &

Teng, 2010). Therefore, the ES approach needs to incorporate CES to improve decision-making and make ES assessments more valuable and complete.

Interest Groups

One way to incorporate the human dimension into the ES approach is by involving multiple interest groups and having them identify crucial values and local ecological knowledge using participatory methods (described below) (Klain & Chan, 2012; Fagerholm et al., 2012; Ruiz-Frau, Edwards-Jones, & Kaiser, 2011). This approach has been successful at acknowledging CES and incorporating non-economic valuation methodologies (e.g., Klain & Chan, 2012; Fagerholm et al., 2012), since trying to put a price on CES such as scenic beauty and historical culture is fraught with challenges due to incommensurability. For my research purposes, an ‘interest group’ is any group of individuals that share common interests and who may be affected by land-use decisions or outcomes. Few studies have used a multiple interest group approach for identifying or ranking the needs, perceptions, or uses of ES (Lamarque et al., 2011; Raymond et al., 2009) and even fewer studies have identified or researched more than a few ES in a single study. This oversight is problematic for the ES approach to accomplish what it strives to, that is effective and sustainable land-use management with full consideration given to the implications on human well-being. This conflicts with the very concept of ES, where human well-being is essentially the driving force of ES resource management (Menzel & Teng, 2010). Social preferences for specific ES have been found to vary according to several complex factors, such as income level, access and proximity to services, ethnicity and gender (Hartter, 2010). Therefore, uses and needs of ES differ and are not the same for people across interest groups. In order for the ES approach to be more effective, decision makers and scientists must stop assuming what the most important ES values are, but rather ask interest groups in communities what ES are needed for human well-being to persist according to their local value systems and local uses, and then account for this information during decision-making.

Using interest group participants in decision-making for land-use and for conservation initiatives can lead to more legitimate and higher quality decisions, and it can help avoid conflict by using a collaborative approach for making decisions (Jones-Walters & Cil, 2011). Using interest groups within the context of land management decisions can also lead to improved social outcomes between groups, it can improve learning across groups, and allow for a better understanding for what is being used and valued locally (Young et al., 2013). By involving local groups and incorporating their ideas and values into the implementation of conservation plans, it can lead to a greater willingness on the part of those involved to implement those plans (Young et al., 2013) and perhaps even become advocates for plans. Conservation initiatives may not be successful if governing bodies or conservationists continue to make land-use decisions when interest groups perceptions and needs for biodiversity or ES remain ignored or undervalued (Ferketic, Latimer, & Simander, 2010; Jones-Walters & Cil, 2011).

Mapping ES Using Public Participation GIS

In order to conserve ES it is essential to first map their locations so that priority locations for ES delivery can be identified (van Berkel & Vergurg, 2012) and subsequent conservation strategies can be developed in order to protect those locations (Martinez-Harms & Balvanera, 2012) in order to maintain human well-being over the long-term. It is important to know what ES are on the landscape, in addition to their locations, so that the delivery of those ES can be managed and monitored (Crossman, Burkhard & Nedkov, 2012). Mapping can also enable the identification of ES hotspots (i.e., priority locations for ES delivery with a high intensity, richness and diversity of ES), which should be maintained due to their high supply of ES

(Martinez-Harms & Balvanera, 2012). Mapping ES is a growing trend (Crossman et al., 2012). However, to date most ES mapping studies have used secondary (already available) data at broad scales (Martinez-Harms & Balvanera, 2012). Additionally, most ES mapping studies have focused on provisioning and regulating ES based upon biophysical assessments (van Berkel & Vergurg, 2012). Although it is difficult, mapping can be a way to incorporate the intangible and often neglected CES values (Klain & Chan, 2012). There has been a clear lack of formal research and ES mapping for CES such as aesthetic/scenic beauty, which are critical for the maintenance of human welfare (Martinez-Harms & Balvanera, 2012).

Public participation geographic information systems (PPGIS) uses easily understood tools (e.g., paper and digital maps) that strive to include public values into decision-making processes (Barnt, 1998). Public participation GIS typically uses participants to identify various landscape attributes on either paper maps or computer based GIS technologies; for instance, Brown et al. (2012) used a Google Map interface that allowed online users to mark on digital maps where they perceive ES to be located in New Zealand. PPGIS has been used in numerous applications worldwide, including planning in US national parks (Brown & Weber, 2011); identifying places with significant conservation value in New Zealand (Brown & Weber, 2012); and mapping community values and threats to natural capital and ES in Australia (Raymond et al., 2009). By being able to visually see where ES are located on maps, PPGIS methods allow differing interest groups to comprehend what and where ES are being utilized and valued on the landscape according to public input. It is a means for providing visuals to help people understand what values are most important to others, and therefore can help gain insight regarding what locations might be the most important (e.g., ES hotspots) to conserve for long-term human well-being. PPGIS is a bottom-up approach that aims to empower those interest groups involved in the process, by providing a visual tool that helps them understand threats and conservation priorities (Fagerholm et al., 2012) relevant in their region. However, because the identification of regulating and supporting services (the two remaining MEA 2005 categories) can require greater ecological knowledge, it remains doubtful whether public participatory methods are effective for identifying ES within these two categories (Brown et al., 2012).

Research Questions and Objectives

Despite the recognized importance of including CES and different interest groups into the decision-making process for land use management and conservation planning, few studies have used a multi-interest group approach to identify and map multiple values that include CES (for examples see Klain & Chan, 2012; Raymond et al., 2011). The following research questions guided this thesis:

- Do different interest groups use all ES indicators researched?
- Is there a difference between the frequencies of use for ES indicators among different groups?
- How do ES rank in importance across different interest groups?
- Where does ES utilization occur on the land base?
- Are there overlapping areas of ES usage across interest groups enabling the identification of ES 'hotspot' areas?
- In regards to land-use planning and policy, are there any conservation implications for priority ES locations according to differences/similarities of ES use across interest groups, in addition to any identified overlapping biodiversity values?

The specific objectives of this research were to: 1) Collect quantitative non-spatial data on the ES being utilized by different interest groups in the study area; 2) Use PPGIS and map the spatial locations where stakeholders identify ES indicators; 3) Determine what ES uses overlap across stakeholder groups and assign ES 'hotspots'; 4) Rank ES importance quantitatively, according to stakeholder weighting, both as individual stakeholders and collectively across groups; 5) Determine if research outcomes provide implications for biodiversity conservation.

This thesis research used an online survey for collecting non-spatial information on the use, and frequency of use, for ES across seven interest groups using the Upper Peace River Watershed (UPRW) in Northern British Columbia as the study area. My research also documents primary spatial data on a regional scale for both cultural and provisioning ES use across eight differing interest groups in the UPRW using PPGIS methods. The differences and similarities of ES use across interest groups, and spatial knowledge of cultural and provisioning ES on the land base is crucial to help manage multiple land use challenges that are currently associated with the UPRW (see Methods), so that human well-being based on all important needs are incorporated, making decisions more effective, fair, and complete. Previous to this thesis research project, information on the use, rankings, and locations of ES across interest groups in the UPRW had not been quantitatively addressed or mapped. This study takes a non-economic quantitative ES approach for determining where ES are being used on the landscape, in addition to identifying who is using them (i.e., interest groups) and with what frequency the use is occurring. The aim of this research is to demonstrate the importance of CES and PES across all interest groups residing in the UPRW. It also aims to identify ES “hotspots” (priority locations for ES delivery) for cultural and provisioning ES within the UPRW. Hotspots will identify the most critical areas to conserve in order to maintain the most highly valued ES of the region, and thus help maintain region human well-being. Additionally, since it is possible to identify areas capable of protecting both ES and biodiversity for win-win scenarios (Naidoo et al., 2008), I briefly asses any spatial overlaps with biodiversity values.

Chapter 2: Methods

The mixed-methodological approach for this research project involved two separate data collection phases. First, an online survey was developed to assess people's use, and frequency of use, for 15 ecosystem service indicators within the study area. Second, a mapping component using PPGIS methodology during one-on-one interviews was used to assess people's spatial use of 16 ES indicators within the regional landscape.

Study Site

The study boundary is the Upper Peace River Watershed (UPRW) encompassing 581,994 hectares (Provincial Government of BC, 2007) with an 82 km stretch of riparian valley bottom following the Peace River between the town of Hudson's Hope (population: 1012) and Fort St. John (population: 19,000) in northeastern British Columbia (56º13'41".03N; 121º24'26".05W). The majority of the study area is crown land with a boreal-forested ecosystem that is used for oil and gas development due to significant oil and gas accumulations (Hunt & Ratcliffe, 2004), while the eastern half of the watershed has a high concentration of privately held land within the Agricultural Land Reserve. The Peace River/Boudreau is a proposed protected area under the Fort St. John Land and Resource Management Plan that is located on the southern portion of the Peace River within the study area (Provincial Government of BC, 1997), and there are two Provincial Parks (Butler Ridge and Moberly Lake) within the watershed.

The study area is within Treaty 8 First Nations territory and there are two First Nations reserves located within in the study area: West Moberly First Nations (population: 205) and Saulteau First Nations (population: 840). There are multiple recreation sites (fishing, camping, boating, sightseeing, bird watching) scattered throughout the study region, a cultural use area, along with archeological evidence such as tools, shell beds, flakes, projectile points and bones dating back 5830 ± 80 years (Valentine, Fladmark, & Spurling, 1980). Fieldwork done at Charlie Lake (an area with high levels of use just outside the study area boundary), found artifacts dating human occupation at this site back to 10 500 B.P. (Driver, Handly, Fladmark, Nelson, Sullivan, & Preston, 1996). A diversity of dinosaur footprints have also been discovered here (Currie & Sarjeant, 1979). The study area is used extensively for natural resource developments and is slated for multiple development expansions, such as oil and gas (i.e., liquid natural gas extraction, roads for access, pipelines, seismic lines, well pads) (BC Oil and Gas Commission, 2013), wind farm developments, coal mines (North Peace Economic Development Commission, 2011), and a third hydro dam on the Peace River (BC Hydro, 2013). Numerous at-risk or regionally important species reside in and have been identified within the study area, e.g., Northern Goshawk (*Accipiter gentilis*), Grizzly Bear (*Ursus arctos*), Fisher (*Martes pennant*), Wolverine (*Gulo luscus*), Arctic Grayling *(Thymallus arcticus)*, Mountain Goat (*Oreamnos americanus*), Northern Caribou (*Rangifer tarandus*) (Anderson & Scheck, 2004); close to 200 rare plants have been identified in the Peace River Valley portion of the study area alone (Hilton, Andrusiak, Krichbaum, Simpson, & Bjork, 2013). The study area is also considered an integral component of the proposed wildlife connectively corridor known as the Yellowstone to Yukon (Y2Y) corridor. Expanding resource development pressures coupled with at-risk species within a socio-ecological landscape make this an ideal location for an ecosystem service research project.

Developing Ecosystem Service Typology

Survey and interview questions were designed to receive responses regarding ES indicators that fit within two major ES categories, provisioning and cultural. The term ‘indicator’ represents human benefits (material or non-material) that are utilized within a landscape (Fagerholm et al., 2012). A slightly modified MEA (2005) typology was used for ES indicators most relevant to the regional social dynamics (Fagerholm et al., 2012; Raymond et al., 2009) of the UPRW. For instance, the MEA CES of 'social relations' or 'knowledge systems' were not used during this research project; it was presumed that these CES would not be adequately represented across all interest groups in the study area. Additionally, I added 'wildlife used for viewing' to the working ES typology, since wildlife is plentiful in the study area. In a similar study also targeting community members (i.e., interest groups) within British Columbia, wildlife was determined to be a prominent and highly valued feature of the landscape (Klain & Chan, 2012).

Online Survey

Sample population and data collection.

Since I was interested in human use of ES indicators, all users of the watershed were identified as being key participants. Survey participants were recruited using non-proportional quota sampling in addition to snowball sampling (Bernard, 2000). Invitations (259) were sent out using FluidSurveys® software version 4.0. The invitation encouraged people to distribute the online survey link to other interested participants. Additionally, to increase wide-spread regional knowledge of this research project, to gain survey participants, and to request participation for a follow-up PPGIS mapping component, 65 posters describing the research project were distributed throughout the watershed in the communities of Fort St. John, Hudson's Hope, Chetwynd and Moberly Lake, and an advertisement (1/4 page in size) was placed in a local newspaper for two subsequent Fridays. In order to describe the research project and request First Nations participants, a meeting was held at the Treaty 8 Land Office in Fort St. John with two Treaty 8 First Nations representatives; informal consent to involve First Nations was granted. Finally, presentations were offered to multiple interest groups and clubs residing within the study area, including: North Peace Rod and Gun Club, Peace Country River Rats Jet Boat Association, Peace Valley Environmental Association, Fort St. John Chamber of Commerce, Hudson's Hope Town Council, Hudson's Hope Historical Society, Fort St. John Town Council, Treaty 8 First Nations, Peace River Regional District, Moose ATV Club, Fort St. John Snowmobile Club, Fort St. John Hiking Club, Northern Dirt Riders Association, Blizzard Bike Club, Industry businesses. The resulting three presentations were given by the lead researcher within the study area during May and June 2013. In total, 138 respondents started the online survey with 101 participants self-identifying with an interest group, of which 93 participants gave responses that were useful for analysis. The 45 incomplete surveys, which were defined as those that did not answer anything more than the respondent characteristics, were not analyzed.

Online survey design and delivery.

The survey was delivered using an online survey program called FluidSurveys®, version 4.0. To test the suitability and effectiveness of the survey, preliminary sampling was completed with seven individuals who reside outside of the study area. The feedback, comments and suggestions were combined and resulting changes were made to the online survey before being delivered to potential respondents. The online survey was approved by the Royal Roads University Ethical Review Board prior to being launched and was made available from April 16, 2013 to June 30, 2013.

The survey began with an introduction to the research project, as well as a preamble stating how completion of the survey indicates research participation acceptance (Appendix A). This was followed by five sections of questions: 1) respondent characteristics (i.e., length of residency, community type, occupation, primary and secondary interest group association, age group, gender, ES concept familiarity); 2) provisioning ES indicators including frequency of use (e.g., fish used for food, wood used as a fuel source, natural materials used for ornamental purposes); 3) cultural ES indicators including frequency of use (e.g., landscapes used for spiritual, religious or aesthetic reasons); 4) listing ES indicators in order of highest to lowest use, and 5) self-perceived changes in the ES use using two likert-scale questions followed by options to explain responses in an open-ended format.

A map outlining the study area was provided on every page of the online survey for easy reference. Additionally, to facilitate a clear understanding across interest groups, a widely accepted definition for the term 'ecosystem services' was provided before any questions regarding ES were delivered: "*Ecosystem Services are the resources that come from nature and bring benefits to humans (Daily, 1997) and that contribute to making human life both possible and worth living (Diaz et al., 2006). They are necessary in order for human well-being to persist.*" Short descriptions for cultural and provisioning ES were also given prior to any questioning. In total, there were 36 closed-ended, 2 open-ended and 1 ranking question in the survey. However, it was unlikely that participants would be brought to all 39 questions due to variation in responses and corresponding branching options in the survey. The online survey can be found in Appendix B.

Final interest group categorization.

Participants selected and self-identified with 16 interest groups from the original list of 19 options (Table 1). Subsequently, in order to try and satisfy the assumptions of the chi-square test used for statistical analysis [i.e. interest groups should contain samples greater than 10 (Koehler & Larntz, 1980; expected cell frequencies greater than 5 in 80% or more of the cells

Table 1

Final Interest Group Categorization used for Survey Analysis.

Original groups provided (No. usable surveys analysed[a])	**Combined categories used in final analyses**	**No. Participants (% total)**
Local Government (10) Provincial Government (1) Federal Government (0) First Nations Government (2)	Government	13 (14%)
West Moberly First Nations (1) Saulteau First Nations (4) Halfway River First Nations (0) Prophet River First Nations (0) Doig River First Nations (1)	First Nations	6 (7%)
Agriculturalist/Farmer (14)	Agriculturalist	14 (15%)
Environmentalist/Conservationist (25)	Environmentalist	25 (27%)
Hunter (5) Fisher (3)	Hunter/Angler	8 (9%)
Motorized Recreationist (7) Non-motorized Recreationist (5)	Recreationist	12 (13%)
Business Owner (6) Industry (2) Community (3) Other (4)	Other	15 (16%)

[a]From a total of 100 participants, 93 surveys were deemed usable for final analysis. The seven omitted from analyses were deemed incomplete and unusable.

(Cochran, 1954)], similar groups were pooled together. This included combining the following groups: Local, Provincial, Federal and First Nations Government (Government); all five First Nations bands (First Nations); Hunters and Fishers (Hunter/Angler); and, Motorized and Non-Motorized Recreationists (Recreationists). To help equalize sample sizes across groups, Business Owners, Industry, Community and Other were lumped together into the 'Other' category. Here the chi-square restriction of expected frequencies of less than 5 was still not satisfied, however, based on an extensive analysis by Roscoe & Byars (1971) the test is robust to low group sample sizes (>10) when counts are relatively uniform across all groups. While First Nations participant numbers were low (n=6), this group was used in the analysis due to the large influence that indigenous peoples have in their traditional territories (Blomley, 1996; Klain & Chan, 2012).

Statistical analysis - survey data.

Chi-square tests of independence were performed to test the null hypothesis of no association between interest group affiliation and ecosystem service use for the 15 questions which solicited a binary (yes/no) or nominal response. Kruskal-Wallis tests were run to determine if there were differences in the frequency of use for specific ES indicators (i.e., fishing, hunting/trapping, wild edible collection, natural material collection used for ornamental purposes, using landscapes for scientific/educational purposes, aesthetic purposes, inspirational purposes, historical/cultural heritage purposes or for purposefully viewing wildlife) across interest groups. A Kruskal-Wallis test was also used to determine if there was an overall difference across interest groups when asked if they thought whether or not ecosystem services were important to consider when making major land-use decisions. Similarly, a Kruskal-Wallis test was used to determine if there was a significant difference across interest groups when asked how they would rate the local natural landscapes and/or local wildlife in terms of their importance to overall feeling of attachment or belonging to the UPRW. For significant results, pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Descriptive statistics were used to describe respondent characteristics and to analyze specific survey questions: types of food grown/raised, animal species hunted, reasons for fishing/hunting, wild plant uses, importance of the ES concept, rating the importance of sense of place, forms of recreational activities undertaken, wildlife species of self-importance, changes in ES indicators over time. Software used for all analysis was IBM SPSS Statistics, Version 21 (2012).

PPGIS- Mapping Interviews

Interview sample.

Non-proportional quota sampling was used to select participants for one-on-one, semi-structured interviews that were conducted in person. Quota sampling is similar to probability sampling with one significant difference, that is, rather than selecting participants at random, interviewers choose participants (Bernard, 2000). Additionally, snowball sampling was used in some circumstances. For example, when a key interviewee mentioned other individuals whom they felt would be pertinent to include in the research (i.e., individuals with high levels of regional CES and PES use), every attempt was made to include those candidates. The snowball method is useful in a research project such as this, where the study population is difficult to ascertain (Bernard, 2000).

To ensure unbiased sampling, multiple interest groups and individuals were contacted either by phone or email depending on whether cellular phone and/or internet service was available. Each time an interest group representative or individual was contacted, a script was followed to ensure consistency. Additionally, to increase wide-spread regional knowledge of this research project, to gain online survey participants, and to request participation for the PPGIS mapping component, 65 posters describing the research project were distributed throughout the watershed in the communities of Fort St. John, Hudson's Hope, Chetwynd, and Moberly Lake, and an advertisement (1/4 page in size) was placed in a local newspaper for two subsequent Fridays. A meeting with two Treaty 8 First Nations representatives was held in order to describe the research project and request their consent to involve First Nations in this research project; informal consent was granted. Finally, presentations were offered to multiple interest groups and clubs residing within the study area, as described above (see section 'Sample population and data collection').

In total, 32 people from 10 different interest groups participated in the mapping interviews. However, one interviewee chose to abstain from mapping their spatial use of ES indicators, but did complete a paper version of the online survey during the interview that was later entered into the FluidSurveys® 4.0 format for analysis. In order to reduce the number of groups and attempt to increase sample size within groups, we used the second choice for those participants who selected 'Business Owner' and 'Community' as their first self-identified interest group. This was because everyone is a part of the larger community and we wanted to better represent the type of land-use interests that participants represented. The final interest group categories used in the spatial and statistical analysis were: Environmentalist (8), Agriculturalist (6), First Nations (FN) representing two bands (Saulteau FN and Doig FN) (4), Motorized Recreationist (4), Non-motorized Recreationist (3), Hunter/Angler (3), Government (2), and Industry (2). Respondent characteristics were analyzed using descriptive statistics on the demographic variables.

Interview design.

Semi-structured, one-on-one interviews were conducted in-person by the principal researcher during May and June of 2013. An exception was with two First Nations members who preferred to be interviewed together rather than separately. However, their responses were independent and were kept separate for the analysis. Interview locations were chosen based upon participant's convenience. The majority of the interviews were conducted in people's homes, with the exception of 11 interviews that were conducted elsewhere: one at a coffee shop, two at places of business belonging to the participants, two interviews were held at public libraries, three at public schools where the participants worked, and three at First Nations reserve band offices. Each interviewee began with a preamble and the signing of a consent form (Appendix C). Interviews lasted between 20 to 150 minutes, taking an average of 76 minutes.

Part 1: A topographic map of the study area was designed using ArcGIS 10.0 software, with shapefiles obtained by request from Natural Resources Canada and Data BC. The map was printed and laminated at a scale of 1:500,000, measuring 44 X 54 inches in size. In order for participants to familiarize themselves with the study area, the map was provided to participants at the beginning of each interview. The study area was visually explained and any uncertainties in the study area boundary were clarified.

Part 2: Participants were asked if they had completed the online survey in advance of the interview. If they had not completed the survey, and although it was not mandatory, participants had the option to complete the survey in paper format during the interview with the interviewer reading aloud each question and recording responses. Surveys were transcribed post-interview by the interviewer into the FluidSurveys 4.0 online survey format. Eleven participants completed the survey in this way. If participants had completed the online survey prior to the interview, they began their interview by being asked questions regarding respondent characteristics (i.e., length of residency, community type, occupation, primary and secondary interest group association, age group, gender, ES concept familiarity). The same respondent characteristic questions were asked at the beginning of the online survey.

Part 3: To facilitate a clear understanding across interest groups, a definition for the term 'ecosystem services' was provided before any questions regarding use of ES were delivered: "*Ecosystem Services are the resources that come from nature and bring benefits to humans (Daily, 1997) and that contribute to making human life both possible and worth living (Diaz et al., 2006). They are necessary in order for human well-being to persist.*" A short definition for cultural and provisioning ES was also provided. Using the questions designed to gather spatial responses (see Appendix D), participants were asked to draw polygons around the areas that they used for specific ES indicators. Participants were told to circle only those areas of current use defined as use 'within the past 5 years'. A different color was used for each of the 16 ecosystem service indicators. Each time a person drew a polygon, notes were taken regarding how the participants used the ES indicator at each location.

Part 4: Post interview, the map was photographed using a Canon Rebel XTi EOS camera. The map was erased after a sufficient number of photographs were taken in order to capture the level of detail drawn. In total, 895 polygons were digitized using ArcGIS 10.0, along with eight shapefiles with each one representing an interest groups use of ES indicators. After digitization 10 polygons were removed in the cases where participants selected between 50%-100% of the study area. These were excluded from the analysis since they do little to identify areas of spatial significance (Brown & Pullar, 2012). For each of the remaining 885 polygons, respondent characteristics and ES indicator typology was entered into the attribute table in order to link participants to the corresponding ES features. Additionally, an Excel file was created to show the number of polygons drawn for each ES indicator.

Data analysis and spatial overlay of polygons.

There is no appropriate 'overlap' tool available for use on vector format polygons in ArcGIS 10, therefore to show areas of overlapping ES use across interest groups, we used an overlap tool developed by EMIKO, Christian Martinez, Conservation International Ecuador (2012). This tool was used to overlay polygons to depict areas of overlapping ES use across interest groups and to locate any ES hotspots (i.e., priority locations for ES delivery with have a high intensity, richness and diversity of ES). The overlapping was done to depict three scenarios: 1) spatial overlap for all combined ES indicators identified by all interest groups; 2) spatial overlap for all identified PES indicators across all interest groups, and 3) spatial overlap for all identified CES indicators across all interest groups. By altering the symbology of the layer properties, I assigned varying colors (green-yellow-red) to each of the three resulting overlap shape files to visually display ES hotspot locations for all interest groups within the study area. Additionally, in order to show hotspot locations for each individual interest group, all eight interest group polygons were merged and overlapped separately for purposes of comparison.

Ecosystem service hotspot locations.

For the map that assessed all identified polygons (PES and CES) across all groups, heuristic judgment was used to determine how many overlaps would constitute an ES 'hotspot' location. Ecosystem service hotspots were determined as those locations (i.e., resulting polygons from using overlap tool) with 80-102 overlapping polygons (10.5% of all polygons drawn). For the primary hotspot location, ES indicators that were either completely or partly within the major hotspot region were identified. The number of polygons selected for each ES indicator within the main hotspot was also determined, as well as the interest groups that selected that indicator, and the number of participants that selected the indicator. Four other locations to the northeastern end of the Peace River Valley were also identified as ES hotpot areas, but these were not analyzed due to their relatively small size. The two maps depicting CES and PES use separately were used as a means for comparing any differences or similarities in locations of use and land cover types between the two categories. Finally, in order to assess any spatial relationships between ES hotspot locations between interest groups, an ES hotspot map was developed for each interest group

Chapter 3: Results

Online Survey

Respondent characteristics.

Of the 93 survey participants whose online surveys were analyzed, 50 were male (55%) and 42 were female (45%). Seventy-three participants had lived in the region for more than 15 years (78%), and 28 of those were also born in the region (38%). Only two of the participants had lived in the region for less than 1 year (2%) who both belonged to the Government interest group. Thirty of the participants were in the age category of 55-64 years (32%), 16 were in the '65 or above' age group category (17%), and 21 participants were in the 45-54 age group (23%). Only two participants were in the youngest age category of 18-24 (2%) and 23 participants fell within the ages of 25-44 (23%). The majority of the participants lived in a rural community (54%), with 39 participants living in the city/urban or suburban environment (42%). Four participants lived on First Nations Reserves (4%). When participants were asked to state their occupation or livelihood, the most frequently given response was 'retired' (19%), second was 'Industry' (i.e., oil/gas, mines, forestry) (16%). It took participants an average of 27 minutes to complete the online survey.

Perceptions of ES across interest groups.

When participants were asked if they had heard of the 'ecosystem service' concept prior to participating in the research project, 66% responded with no, 27% said yes, and 8% were unsure. After a widely accepted definition for the term ES was provided, participants thought that the human use of ES was important to consider when making major land-use decisions; across interest groups, 69% of participants responded with the option of 'It's Essential'. When asked if participants thought that there had been a change in the ES that they used in the UPRW during the time that they had lived there, the majority (47%) said there had been a decrease in ES, 11% thought there had been an increase, 14% saw no change in ES, 17% were unsure and 10% did not respond. When asked whether participants thought there would be a change in ES that they use in the UPRW over the next 10 years, 67% though that there would be a decrease in ES, 9% thought there would be an increase in ES, 5% envisioned no change, 12% were unsure and 11% did not respond. The most frequently mentioned reasons for a future decrease in ES was perceived to be due to increased industrial developments (oil/gas, coal mines) and/or the currently proposed third large hydro dam (Site C) on the Peace River. When one interviewee (a trapper) was asked if specific natural landscapes and/or specific habitats for local wildlife were important to their overall feeling of belonging to the Peace Region, they responded by saying, "The wildlife is the big thing here and its being hit hard with oil and gas developments. Oil and gas have crowded the wild animals really badly." In response to ES heritage values, the same trapper said:

> "Most of our historical heritage values have been flooded. We lost an old homestead last year because of a pipeline that goes through it now. The company paid money for use of the land, but it doesn't give you back what you had, the heritage".

For the minority of participants that did not perceive any past or future loss of the ES they receive in the UPRW, in some cases this was perceived to be due to the increased access opening further recreational opportunities, which had become available due to new logging roads being built into areas previously inaccessible. For instance, one interviewee from the Motorized Recreation interest group said:

> "[A]esthetics is one of the main reasons we go out to ride [ATV]. Around here there are no restrictions on what kind of recreation you can do in certain areas, except for the

provincial parks. You can do everything everywhere. I don't think that other places are really like that".

Additionally, another representative from the Motorized Recreationist group perceived that the aesthetic and sense of place that he valued along the Peace River would not be impacted if the Site C dam were developed. He said that he does not see much of an aesthetic difference between the Williston Reservoir and the lower Peace River that is less impacted by current upstream dams.

Relationships between use of ES indicators and interest groups.

Chi-square tests for association were conducted between interest group affiliation and use of 15 ES indicators; there were five statistically significant relationships found (Table 2). An association between interest group and landscapes used for historical/cultural heritage (ES indicator) was found, [χ^2 (d.f.=6, N=93) = 17.069, p=.01]. Examination of the cell frequencies showed that 100% of First Nations participants used landscapes for historical/cultural heritage purposes, and 25% of participants from the Recreationist interest group used landscapes for this purpose. The percentage of landscape users for historical/cultural heritage purposes was between 61.5% - 85.7% for all other interest groups.

There was also a significant relationship found between interest groups and purposeful wildlife viewing [χ^2 (d.f.=6, N=93) = 17.408, p=.01]; 100% of First Nations participants used landscapes for wildlife viewing purposes, while only 25% of participants from Government used landscapes for this purpose. Similarly, there was a significant relationship found between interest groups and hunting/trapping, [χ^2(d.f.=6, N=93) = 16.021, p=.01], with 100% of First Nations participants used landscapes for hunting/fishing purposes, and only 23.1% of participants from Government hunting/trapping. Other statistically significant relationships were

Table 2.

Results of the Chi-Square Test of Independence Used to Identify Relationships between Ecosystem Service use and Interest Groups.

				Interest Group							
ES Indicator	**ES Category**	**x^2**	**p-value**	**Agriculturalist**	**Environmentalist**	**First Nations**	**Government**	**Hunter/Angler**	**Recreationist**	**Other**	**Total**
Aesthetic/Scenic	Cultural	5.990	.42	100.0%	100.0%	100.0%	92.3%*	100.0%	100.0%	100.0%	98.9%
				14	25	5	12	7	12	14	89
Sense of place	Cultural	6.573	.36	100.0%	100.0%	100.0%	100.0%	100.0%	91.7%*	100.0%	98.9%
				14	25	5	13	7	11	14	89
Recreation	Cultural	2.053	.92	92.9%	88.0%	100.0%	92.3%	100.0%	91.7%	85.7%	91.1%
				13	22	5	12	7	11	12	82
Ornamental resources	Provisioning	11.125	.09	64.3%	76.0%	100.0%	92.3%	37.5%*	66.7%	57.1%	70.3%
				9	19	5	12	3	8	8	64
Historical/Cultural heritage	Cultural	17.069	.01	85.7%	76.0%	100.0%	61.5%	85.7%	**25.0%**	71.4%	70.0%
				12	19	5	8	6	3	10	63
Wood	Provisioning	10.326	.11	85.7%	60.0%	100.0%	61.5%	87.5%	66.7%	46.7%	67.7%
				12	15	6	8	7	8	7	63
Wildlife viewing	Cultural	17.408	.01	85.7%	76.0%	100.0%	**25.0%**	85.7%	58.3%	57.1%	67.4%
				12	19	5	3	6	7	8	60
Freshwater	Provisioning	11.451	.08	92.9%*	60.0%	80.0%	38.5%*	75.0%	58.3%	78.6%	67.0%
				13	15	4	5	6	7	11	61
Scientific/Educational	Cultural	7.437	.28	78.6%	80.0%	60.0%	53.8%	71.4%	41.7%*	64.3%	66.7%
				11	20	3	7	5	5	9	60
Wild edible plants	Provisioning	15.335	.02	**92.9%**	48.0%	100.0%	46.2%	87.5%	50.0%	64.3%	63.7%
				13	12	5	6	7	6	9	58
Fish	Provisioning	8.805	.19	71.4%	52.0%	83.3%	53.8%	100%*	50.0%	60.0%	62.4%
				10	13	5	7	8	6	9	58
Hunting/Trapping	Provisioning	16.021	.01	71.4%	44.0%	**100.0%**	**23.1%**	75.0%	33.0%	53.3%	51.6%
				10	11	6	3	6	4	8	48
Spiritual/Religious	Cultural	8.723	.19	71.4%	72.0%	100.0%	61.5%	42.9%	41.7%	50.0%	62.2%
				10	18	5	8	3	5	7	56
Inspiration	Cultural	17.219	.01	78.6%	64.0%	**100.0%**	46.2%	71.4%	**16.7%**	42.9%	56.7%
				11	16	5	6	5	2	6	51
Food (fruit/veg/livestock)	Provisioning	8.687	.19	85.7%*	52.0%	50.0%	38.5%	37.5%	41.7%	46.7%	51.6%
				12	13	3	5	3	5	7	48

Note. ES indicators are listed in order of highest to lowest use across groups based on total overall use across all groups. Numbers contributing to overall significant Chi-square tests (p-value < .05) are highlighted in bold. Numbers with an asterisk represent interest groups with the furthest deviation of the observed count from the expected count according to adjusted residual values of ±1.96, which is added value to the Chi-square test, but were not considered significant according to the Chi-square test.

found between interest group affiliation and wild edible plants used for food and/or medicinal use [χ^2 (d.f.=6, N=93) = 15.335, p=.02], with 100% of First Nations participants using wild edible plants. However, looking at the adjusted residuals for wild edible plant use shows that Agriculturalists have a larger residual value (2.5) than First Nations (1.5), suggesting that Agriculturalists use wild edible plants more than any other interest group. A significant value is also seen for use of inspirational landscapes [χ^2(d.f.=6, N=93) = 17.219, p=.01], with 100% of First Nations, but only 16.7% of Recreationists using landscapes for inspirational purposes (e.g. art, song, story-telling, dance, etc.).

According to the Chi-square statistic, there was no significant relationship found between interest group affiliation and the 10 remaining ES indicators [i.e., aesthetics, sense of place, recreation, ornamental resources, wood, freshwater, scientific/educational, fish, spiritual/religious, food (fruit, vegetables, livestock]. However, clear overall trends were seen that are supported by the adjusted residual values (see Table 2). For instance, Agriculturalists had an adjusted residual value >1.96 suggesting they use land for food more than other groups (85.7%). Similarly, Hunters/Anglers had a residual value >1.96 for fishing, suggesting that they fish more than other interest groups (100%). For freshwater collection from any source (other than from a municipal water system), the residual values suggest that Agriculturalists use freshwater (92.9%) more than any other group, and that Government uses freshwater the least (38.5%). Residual values suggest that Hunter/Anglers use ornamental resources less (37.5%) than other groups, as all other interest groups ornamental resource use is greater than 57.1%. According to residual values, Recreationists use landscapes for scientific/educational purposes less (41.7%); Government uses landscapes for aesthetic/scenic purposes the least (yet still high at 92.3%); and Recreationists used landscapes for sense of place less than all other groups (yet also still high at 91.7%). When looking at the Chi-square statistic and the residual values combined, only recreation and spiritual/religious landscapes show no significance between interest group affiliation and ES indicator. When looking at the overall use of ES indicators across groups, the top three in order of highest to lowest use are all within the CES category and are landscapes used for aesthetic/scenic beauty, sense of place and recreation respectively (Table 2).

Differences for frequency of ES indicator use.

The Kruskal-Wallis test used to determine if there were differences in the frequency of use for specific ES indicators across interest groups produced six significant results (Table 3). Frequency of hunting/trapping was statistically different between the different interest groups, [χ^2(d.f.=6, N=93)= 16.390, p= .012], as was the frequency of collecting wild edible plants for food or medicinal purposes [χ^2(d.f=6, N=91)=17.737, p=.01], frequency of using landscapes for spiritual/religious purposes [χ^2(d.f.=6, N=90)= 15.406, p=.02], frequency of using landscapes for inspirational purposes [χ^2(d.f.=6, N=90)=14.695, p=.02], frequency of using landscapes for their cultural/historical heritage [χ^2(d.f=6, N=90)=16.429, p=.01] and frequency of using landscapes to purposefully observe wildlife [χx^2(d.f=6, N=88)=15.792. p=.02]. Post-hoc analysis revealed significant differences in frequency of wild edible plant collection between the First Nations (Mdn=5.0) and Environmentalists (Mdn=2.0)(p=.01), between First Nations and Recreationists (Mdn=1.5)(p=.03), and between First Nations and Government (Mdn=1.0)(p=.04), but could not find significance between remaining groups, or with other combinations of groups. Additionally, post-hoc analysis revealed significant differences between interest groups for the frequency of using landscapes for religious or spiritual purposes, for using landscapes for their cultural/historical heritage, and for using landscapes to purposefully observe wildlife. However, post-hoc tests failed to differentiate between the groups for the ES indicators of: frequency of

Table 3.

Results of the Kruskal-Wallis Test Showing Frequency of Use for Ecosystem Service Indicators

				Interest Group							
Ecosystem Service Indicator	**ES Category**	**x^2**	**p-value**	**Agriculturalist**	**Environmentalist**	**First Nations**	**Government**	**Hunter/Angler**	**Recreationist**	**Other**	**Total**
Aesthetic/Scenic	Cultural	4.149	.66	5.0	4.0	5.0	4.0	4.0	4.5	3.0	4.0
Recreation	Cultural	6.290	.39	3.0	4.0	4.0	3.5	5.0	4.5	4.0	4.0
Wildlife viewing	Cultural	15.792	**.02**	4.0^{a}	3.0^{ab}	5.0^{ab}	1.0^{b}	4.0^{ab}	2.5^{ab}	2.5^{ab}	3.0
Fishing	Provisioning	12.067	.06	2.0	2.0	3.0	2.0	3.0	1.5	2.0	2.0
Hunting/Trapping	Provisioning	16.390	**.01***	2.0	1.0	2.5	1.0	3.0	1.0	2.0	2.0
Wild edible plants	Provisioning	17.737	**.01**	3.5^{ab}	2.0^{b}	5.0^{a}	1.0^{b}	3.0^{ab}	1.5^{b}	2.5^{b}	2.0
Ornamental resources	Cultural	11.138	.08	2.0	2.0	3.0	2.0	1.0	2.0	2.0	2.0
Spritual/Religious	Cultural	15.406	**.02**	2.0^{ab}	3.0^{ab}	6.0^{a}	2.0^{ab}	1.0^{b}	1.0^{b}	1.5^{b}	2.0
Scientific/Educational	Cultural	8.633	.20	2.0	3.0	4.0	2.0	2.0	1.0	2.0	2.0
Inspiration	Cultural	14.695	**.02***	2.0	2.0	3.0	1.0	3.0	1.0	1.0	2.0
Cultural/Historical heritage	Cultural	16.429	**.01**	2.0^{a}	2.0^{ab}	2.0^{ab}	2.0^{ab}	2.0^{ab}	1.0^{b}	2.0^{ab}	2.0

Note. ES indicators are listed in order of highest to lowest frequency of use across all groups (based on total values). Values given are median values based on the average monthly use over a 12 month period. Numeric values given correspond to the following: 1.0= Never, 2.0= Less than once/month, 3.0=1-2 days/month, 4.0=3-4 days/month, 5.0=5-10 days/month, 6.0=Greater than 10 days/month.
[a]Highest median value. [b]Lowest median value. [ab]Intermediate median value. Values followed by both subscripts (a and b) are not significantly different based on post-hoc tests.
*Significant overall Chi-Square test ($p<0.05$), but where the post hoc test failed to differentiate between groups.

hunting/trapping and for landscapes used for inspirational purposes (Table 3). There were no significant differences across interest groups for frequency of use for fishing, ornamental resources, landscapes used for scientific/educational purposes, landscapes used for aesthetic/scenic beauty, or landscapes used for recreation.

The Kruskal-Wallis test was also used to determine that there was no overall difference across interest groups when asked if they thought human use of ecosystem services was important to consider when making major land-use decisions, [χ^2(d.f=6) = 6.658, p= .354], with 69% of participants selecting “It’s Essential,” 19% selecting “It’s Important,” 3% selecting “Somewhat Important,” and 9% were “Unsure” of ES importance. No participants from any interest group felt that that ecosystem services were “Not Important” to consider. The Kruskal-Wallis test used to determine if there was a significant difference across interest groups when asked how they would rate local natural landscapes and/or local wildlife in terms of their importance to overall feeling of attachment or belonging (sense of place) to the Peace Region was statistically significant [χ^2(6) =17.623, p=.007]. Post-hoc analysis revealed significant differences for sense of place between the Government (Mdn=3.0) and Environmentalists (Mdn=4.0) (p=.021), but could not find significance with other combinations of groups.

Participants’ self-ratings for frequency of using ES indicators.

Table 4 shows ES indicators in order of highest to lowest use across interest groups for frequency of use totaled across all participants. According to participants, the top three ES indicators that were used most frequently across all interest groups are: 1) aesthetic/scenic landscapes, 2) landscapes used for non-motorized recreation, and 3) landscapes used for sense of place. The results of the Chi-Square test of Independence shows similar results in that ES

Table 4

Participants Self-Ordering of Ecosystem Service Indicators for Frequency of Use

ES Indicator	**ES Category**	**#1**	**#2**	**#3**	**Total No. of Times Selected**
Aesthetic/Scenic	Cultural	10	17	7	47
Recreation (Non-motorized)	Cultural	12	10	9	41
Sense of place	Cultural	8	5	8	37
Food (Fruit/Veg)	Provisioning	6	3	6	31
Wildlife for viewing	Cultural	8	5	4	31
Freshwater	Provisioning	14	5	5	29
Wildlife for food	Provisioning	7	5	5	27
Recreation (motorized)	Cultural	8	5	6	25
Wood (for fuel/building)	Provisioning	1	5	5	24
Educational/Scientific	Cultural	0	7	2	21
Fish	Provisioning	3	1	3	18
Inspiration	Cultural	3	3	0	17
Wild edible plants	Provisioning	1	2	6	16
Cultural/Historic heritage	Cultural	0	2	2	15
Livestock	Provisioning	1	5	0	14
Spiritual/Religious	Cultural	2	1	3	11
Ornamental resources	Provisioning	0	0	1	10
Natural medicines	Provisioning	0	1	0	6

Note. ES Indicators are listed in order of highest to lowest use.

indicators being used the most are, 1) aesthetic/scenic landscapes, 2) landscapes used for sense of place, and 3) landscapes used for recreational purposes (motorized and non-motorized).

Mapping Interview

Respondent characteristics.

Of the 31 people who were interviewed and gave spatial data on the locations of use for ES indicators, 13 were female (42%) and 18 were male (58%). Fifteen participants had lived in the region for more than 15 years, but were born elsewhere (48%), while 12 participants had lived in the region for more than 15 years and were born there (39%). The number of participants living in the region for 11-15 years was two (7%), with two participants living in the region for 6-10 years (7%). No one had been living in the region for less than six years. The majority of participants lived within the UPRW (77%), but 23% of participants resided just outside the UPRW boundary (e.g., Chetwynd, Doig, portion of Fort St. John outside study boundary) although they still use the UPRW for its ES. Most participants were in the age group category of 55-64 years (32%), eight were 65 years of age or older (26%), seven were 45-54 (23%), three participants were 35-44 (10%) and three were 25-34 (10%). No participants were younger than 25. The majority of participants lived in rural areas (71%), with 23% residing in urban areas and 7% living on First Nations reserves. When participants were asked if they had heard of the 'ecosystem service' concept prior to participating in the research project, 74% responded with no, 23% said yes, and only one participant was unsure (3%). Most of the participants completed the survey online (68%), whereas 10 participants chose to complete the survey in person with the interviewer (32%), which was later entered into the online survey format via the lead researcher.

Ecosystem service indicators.

In total, 895 polygons were drawn by the 31 mapping participants in order to represent their locations of ES indicator use in the UPRW. During mapping interviews, the average number of polygons mapped per participant was 29, the lowest number was five polygons (motorized recreationist), second lowest was six polygons (Industry); the highest number of polygons drawn was 79 (Environmentalist), second highest was First Nations (77 polygons). Across all interest groups the majority of participants drew the highest number of polygons for areas that were used for recreational purposes (motorized and non-motorized) (114), the second highest number of polygons were depicted for local places that participants used for aesthetic, scenic or, awe-inspiring beauty (110), the third highest number of polygons were drawn for places used for wild edible plant collection (70) (Table 5). All 31 participants drew spatial use polygons for both recreation and aesthetic/scenic landscapes, and at least one participant from each interest group drew use polygons within the UPRW for the following ES indicators: fish (food), wood, freshwater, spiritual/religious, sense of place, historical/cultural heritage, recreation, and aesthetic/scenic landscapes. Across interest groups, the fewest number of polygons were drawn for PES; wood (39), freshwater (37), natural medicines (26), and food (vegetables, fruit, livestock) (25) (Table 5).

On average, participants drew the largest sized polygons for ES belonging to the CES category (Table 5). The largest average area drawn was for landscapes used for inspiration at 243 km^2; second in size were sense of place landscapes at 226 km^2 on average, whereas the largest PES polygons (on average) were areas used for hunting/trapping, which were nearly half the size of the largest CES at 135km^2. The second largest polygon (on average) for PES was an

Table 5

The 885 Polygons Depicted During Mapping Interviews.

Ecosystem service indicator	ES category	Total no. polygons drawn	Average area/polygon (km²)	No. of participants
Recreation (motorized/non-motorized)	Cultural	114	121	31
Aesthetic/scenic landscapes	Cultural	110	129	31
Wild edible plants (for food)	Provisioning	70	20	22
Scientific/Educational landscapes	Cultural	64	35	19
Spiritual/Religious landscapes	Cultural	60	159	21
Ornamental resources	Provisioning	60	20	17
Hunt/Trapping wildlife	Provisioning	53	135	16
Fish (food)	Provisioning	46	15	18
Historical/Cultural heritage	Cultural	46	6	22
Wildlife (used for viewing)	Cultural	46	53	21
Sense of place landscapes	Cultural	45	226	29
Inspirational landscapes	Cultural	44	243	20
Wood	Provisioning	39	42	23
Freshwater	Provisioning	37	6	25
Natural medicines	Provisioning	26	7	6
Food (vegetables/fruit/livestock)	Provisioning	25	4	20

Note. ES Indicators are listed in order of highest to lowest total number of polygons drawn across all interest groups.

area used for collecting wood from forests, which was substantially smaller at 42km². All other averages for PES polygons were between 20km² and 4km², where the smallest average sized polygons were for food (4km²) (vegetables, fruit, livestock).

Given that this research focused on a regional watershed scale it did not account for additional areas located just outside of the study area boundary, which were mentioned multiple times as being important for specific ES across different interest groups: Charlie Lake (e.g., for fishing, aesthetics, recreation), Pine River (e.g., recreation), Halfway River (e.g., spiritual/religious, aesthetics), Carbon Lake Area (e.g., aesthetics, ornamental resources, spiritual/religious), Klin-se-za Provincial Park (also known as Twin Sisters or Beattie Peaks) (e.g., recreation), and the Williston Reservoir (e.g., fishing, aesthetics). Most of these areas are associated with freshwater bodies.

High use of cultural ES indicators.

During mapping interviews, across all interest groups participants drew the most polygons for CES (521 polygons or 58%) (Table 5). The highest number of polygons were drawn for areas used 1) for recreational purposes (motorized and non-motorized) (114 polygons), and 2) for local places that they used for their aesthetic, scenic or, awe-inspiring beauty (110 polygons) (Table 5). As mentioned previously, participants drew the largest sized polygons for ES belonging to the CES category. Lastly, the highest numbers of polygons drawn within the main ES hotspot (described below) were also for CES: 1) aesthetic/scenic (28 polygons identified by 24 participants), recreation (28 polygons by 23 participants), and 3) spiritual/religious (15 polygons by 14 participants). Individuals from each interest group drew at least one polygon for each of these three CES within the primary ES hotspot location.

Overlapping ES polygons and resulting hotspots.

There were eight maps developed by merging and subsequently overlapping polygons drawn to represent ES indicator use; each map represents a particular interest groups use of ES within the UPRW and each map depicts ES hotspot locations also specific to each interest group (Figure 1). Seven of the eight interest groups (First Nations, Environmentalists, Agriculturalists, Government, Hunters/Anglers, Industry, and Motorized Recreationists) had all or part of their respective ES hotspot located within the Peace River and the corresponding riparian areas, although all groups used the Peace River to some degree for its ES. However, First Nations most heavily used ES hotspots were located near Moberly Lake and Moberly River, but mainly in mountainous areas used for wild edible collections (for food and medicinal purposes), collecting wood (mainly used for heat fuel), aesthetic/scenic value, sense of place, recreation, scientific/educational purposes, ornamental resource collection, and hunting game. Additionally, Non-motorized Recreationist participants locations for highest ES use was located primarily at the Moberly Lake area, which was used for the following ES indicators: food (personal gardens), wood collection, ornamental resources, spiritual/religious, aesthetic/scenic values, recreation, fish (for food), wild edible plants, freshwater, scientific/educational, sense of place, purposefully viewing wildlife, historical/cultural heritage, inspiration; in other words, all ES indicators other than game. Ecosystem service coldspots were different for each interest group, but are especially prevalent in the northeastern portion of the watershed (Figure 1).

The shapefile developed by merging and then overlapping all 895 ES use polygons drawn to represent all interest groups combined spatial ES use, produced 39528 polygons and shows areas of overlapping ES indicator use across all interest groups (Figure 2). The highest intensity of ES use (i.e., for all combined ES indicators) was usually observed either on, or close to fresh

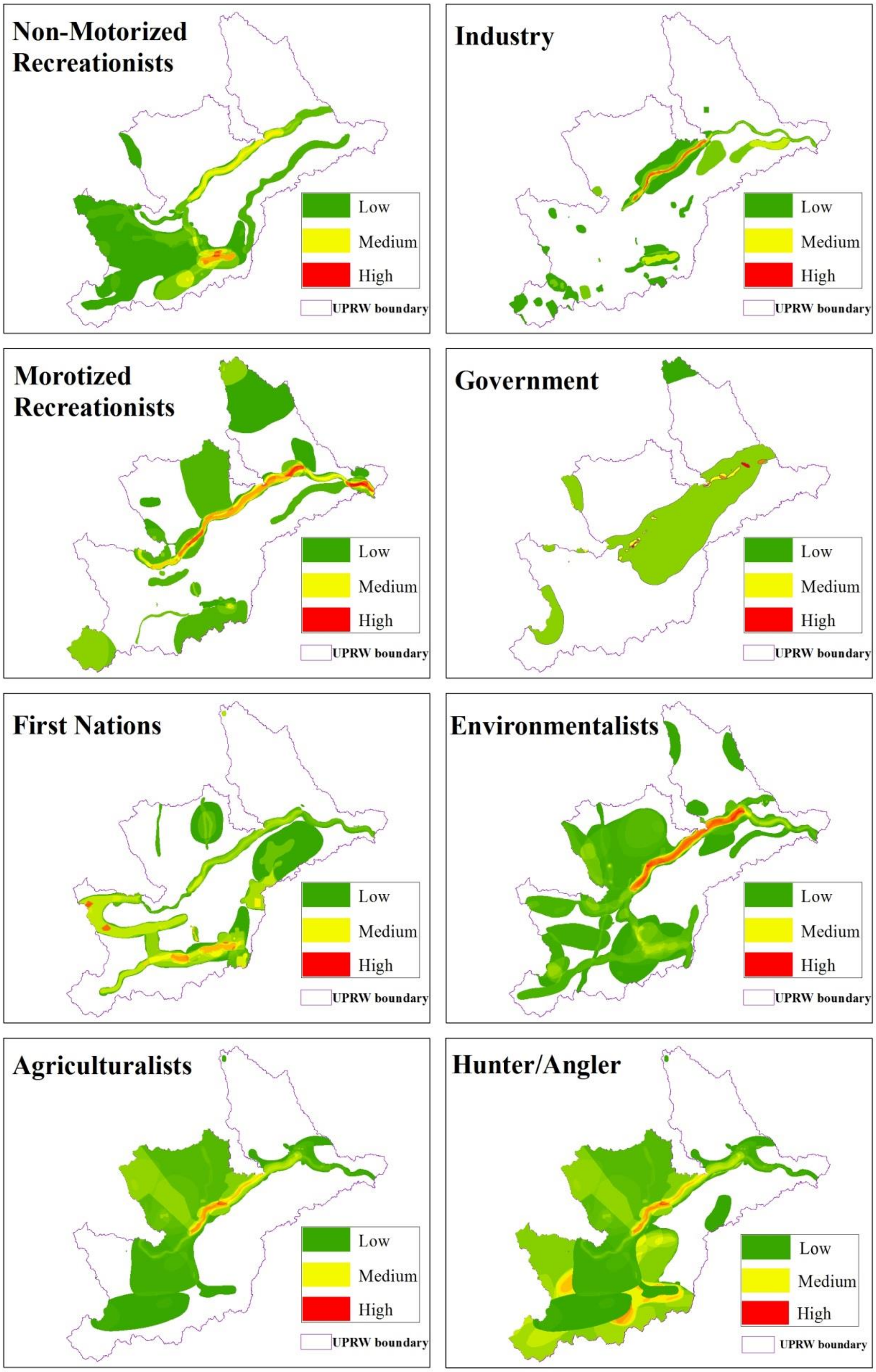

Figure 1. Ecosystem service hotspot locations for each individual interest group.

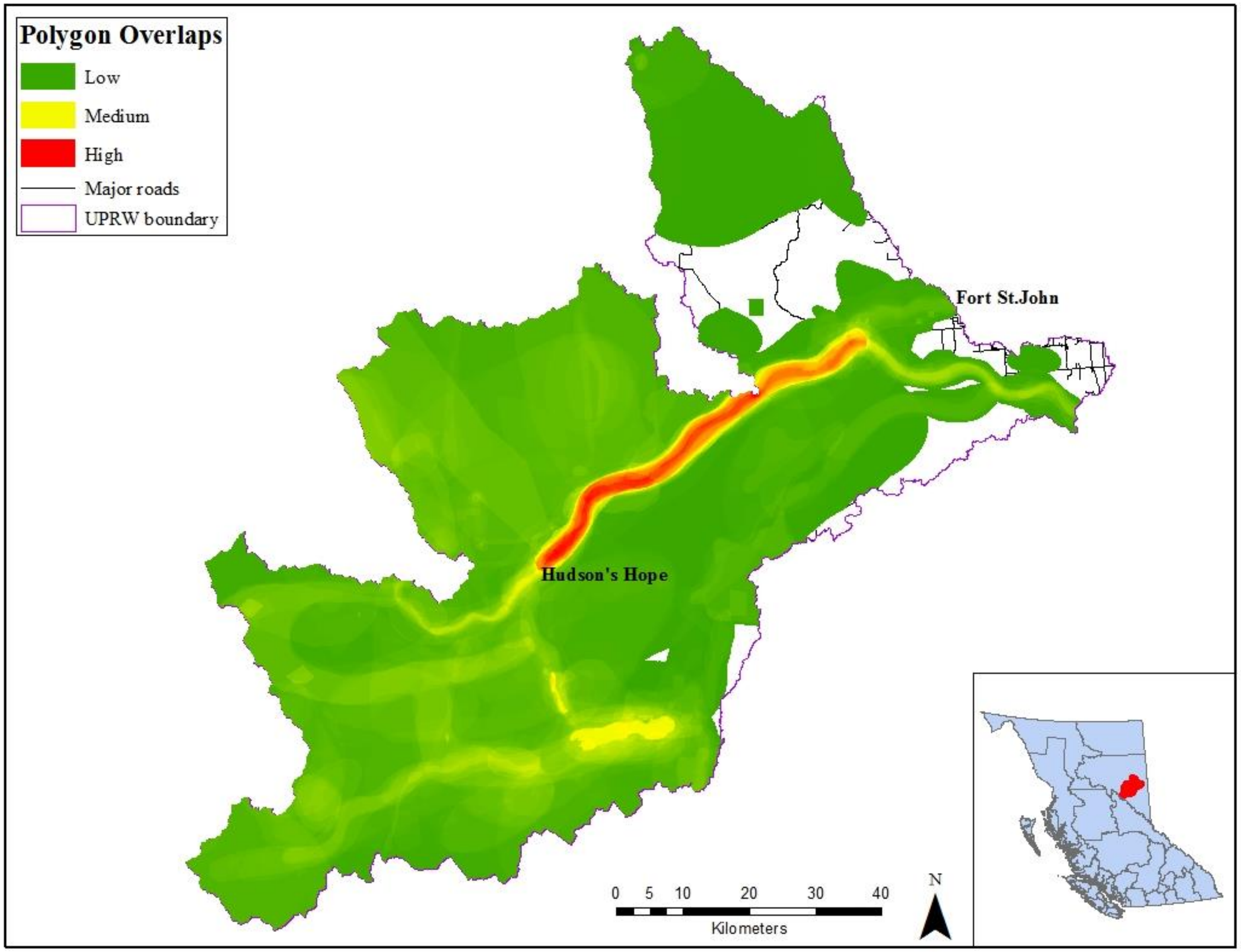

Figure 2. Overlapping polygons for all cultural and provisioning ecosystem services depicted across eight interest groups within the Upper Peace River Watershed. Areas in red indicate those locations most highly used in the ecosystem for its services.

water, specifically the Peace River and Moberly Lake. Additionally, the majority of ES use was also observed to occur in close proximity to roads. Whereas according to geospatial data depicting land use, roads, and oil/gas activity, ES coldspots across all groups normally occurred in areas that are either urbanized (i.e., Fort St. John) or are located on agricultural land or on land with young forest, but that have seen impacts from the oil and gas industry.

The largest ES hotspot identified in the study area for all ES indicators across all interest groups (Figure 3) is located on the Upper Peace River between Hudson's Hope and the confluence of the Halfway River measuring approximately $52km^2$, with a perimeter of 82km, length of 38kms, and about 1.9km across as the largest width. This ES hotspot includes the water within the river (identified for ES indicator uses such as recreational motor boating, fishing, and canoeing, in addition to aesthetic, spiritual/religious, inspiration, and sense of place values), as well as the riparian area that includes privately held land in the Agricultural Land Reserve (ALR) (Figure 4), along with the view-scapes of the valley along the southern extent of the terrestrial landscape. There were 193 ES indicator polygons (out of 885 total) located within the main ES hotspot location, which were either contained completely or partly within this ES hotspot (Table 6). Within this main ES hotspot, participating interest groups used 15 of the 16 ES indicators researched: aesthetics/scenic landscapes, recreation, spiritual/religious landscapes, inspirational landscapes, fish (for food), sense of place, scientific/educational landscapes, ornamental resources, wildlife (used for viewing), hunting/trapping, historical/cultural heritage, wood, wild edible plants (for food), freshwater collection for domestic use, land used to grow or raise food (vegetables/livestock) (Table 6). All eight interest groups drew ES indicators for recreation, spiritual/religious landscapes, and fish (for food) within this hotspot. Additionally, all eight interest groups also drew polygons for aesthetic values, although the Government polygon

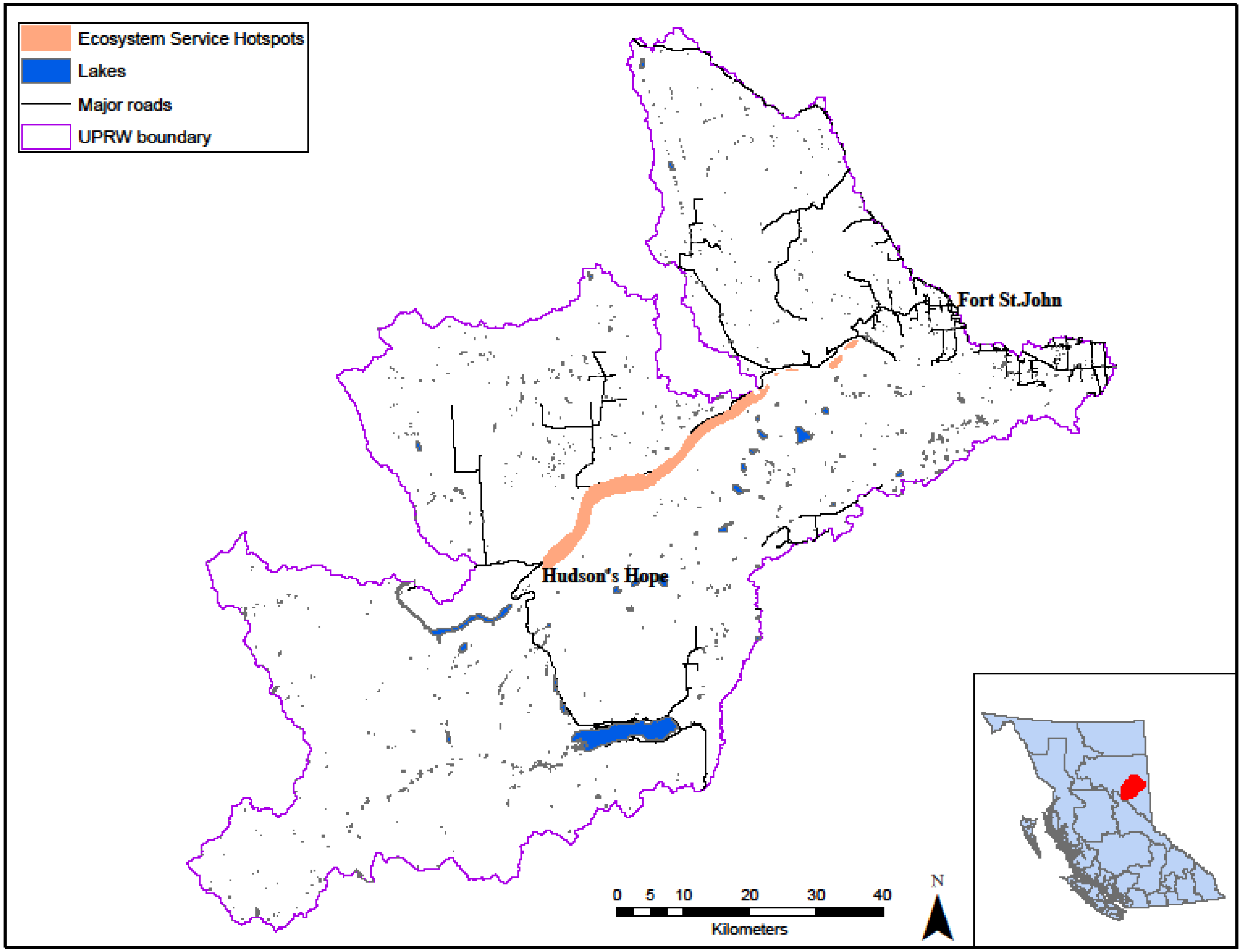

Figure 3. Hotspot locations for cultural and provisioning ecosystem services for eight interest groups within the Upper Peace River Watershed, as designated by 80-102 overlapping polygons (10.5% of all polygons drawn).

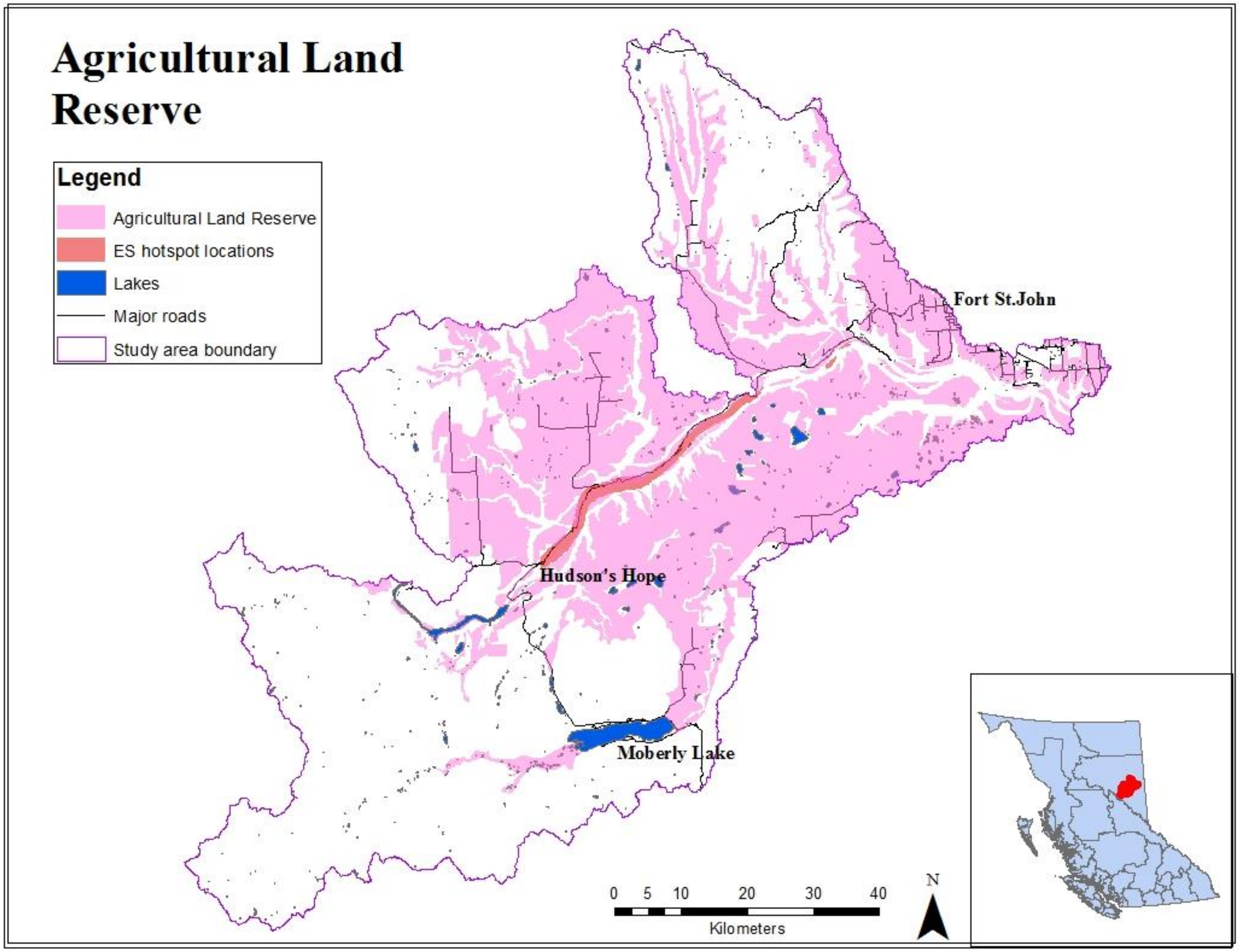

Figure 4. Agricultural Land Reserve within the Upper Peace River Watershed. The Ecosystem Service hotspot locations are also shown to display areas of overlap between land used for agricultural use and for regional ecosystem service use across interest groups.

Table 6

Summary Showing Ecosystem Services Found in the Primary ES Hotspot Location of the Upper Peace River Watershed.

Ecosystem service indicator	ES category	No.of particpants (n=31)	No. of polygons	Interest groups (n=8)
Aesthetics/scenic landscapes	**Cultural**	**24**	**28**	**A, E, FN, H, I, M, NM**
Recreation (motorized/nonmotorized)	**Cultural**	**23**	**28**	**A, E, FN, G, H, I, M, NM**
Spiritual/Religious landscapes	**Cultural**	**14**	**15**	**A, E, FN, G, H, I, M, NM**
Inspirational landscapes	Cultural	13	14	A, E, FN, G, H, M, NM
Fish (food)	Provisioning	12	18	A, E, FN, G, H, I, M, NM
Sense of place landscapes	Cultural	11	11	A, E, H, M, N
Scientific/educational landscapes	Cultural	9	15	A, E, G, NM
Ornamental resources	Provisioning	7	12	A, E, FN, H
Wildlife (used for viewing)	Cultural	7	11	A, E, FN, M
Hunt/Trapping wildlife	Provisioning	7	10	A, E, FN, I
Historical/Cultural heritage	Cultural	5	8	A, E, FN
Wood	Provisioning	5	6	A, E, H, M
Wild edible plants (for food)	Provisioning	4	7	A, E
Freshwater	Provisioning	3	5	A, E
Food (veg/fruit/livestock)	Provisioning	3	5	A, E
Natural medicines	Provisioning	0	0	

Note. Interest Group categories are as follows: A= Agriculturalist, E=Environmentalist, FN=First Nations, G=Government, H=Hunter/Angler, I=Industry, M=Motorized Recreationist, NM=Non-motorized Recreationist indicating aesthetic use was excluded from analysis because it encompassed the entire watershed (see ‘Interview Design’ in the Methods section describing reasons for polygon exclusion). The number of participants that selected each ES indicator within the hotspot is shown in Table 6. There were four smaller hotspot locations identified within the northeastern portion of Upper Peace River for all interest groups although these were not analyzed further (i.e., not analyzed for what ES indicators were identified within them, or what groups identified ES within them), due to their relative small size (i.e., the largest of four measured 1km^2), yet their locations are still depicted in Figure 2.

Across interest groups, respondents assigned 364 polygons to locations representing areas of use for PES and 521 polygons to locations representing areas of use for CES. These polygons were merged and overlapped separately according to their respective ES categories in order to depict CES and PES hotspot locations separately, enabling identification for any major differences between CES and PES hotspot locations (Figure 5). The resulting CES and PES hotspot locations overlap to some extent in the Peace River corridor, but the CES hotspot is much more extensive in the Peace River corridor, whereas the PES hotspot is comparatively more extensive within Moberly Lake, the Moberly River, and around a mountain area near Carbon Lake. Areas of polygons overlap with medium intensity (medium ES use levels) were more widely distributed in the PES map, whereas the CES map produced medium levels of ES use mainly near water bodies (e.g., Moberly Lake, Moberly River, Cameron Lake, eastern extent of the Peace River in the UPRW) (Figure 5).

Chapter 4: Discussions

Perceptions of Ecosystem Service Benefits

The ecosystem service concept is not widely disseminated among the general population as demonstrated by the majority of participants surveyed and interviewed in this study as not being familiar with the term. However, when given the definition or engaged in a discussion of the ES concept, there was an overwhelming understanding for the importance of ES. This perceived importance of the ES concept may be linked to the majority of participants belief of decreasing availability in the ES they use within the UPRW, both during the time that they had lived in the region; in addition to predicted declines of ES in the future, which were described as unfavorable for various reasons. For instance, the past decrease in available ES was reported by participants to be largely due to natural resources developments (with oil and gas activities mentioned most frequently), leading to perceived habitat fragmentation, reduced opportunities for other land uses, decreased wildlife populations, and lower water quality (See Potential Impacts to ES). There was a clear sense of ES loss (past and future) reported by many of the participants across differing interest groups; loss of habitat due to industrialization (and specifically the potential development of the Site C dam) was cited as the main reason for potential loss in ES use in future years. However, there was also a minority of participants perceiving that the ES that they utilize have increased in the past, and/or will increase in the future. The differences observed for how and where people perceive ES can be due to differences in individual background (e.g., different culture, gender, level of education, proximity to ES, and/or upbringings), which builds upon previous insight gained by Plieninger et al. (2013), van Berkel & Verburg (2012), Fagerholm et al. (2012), and Martin-Lopez et al.

(2012). These findings confirm that different people perceive different changes in ES delivery; some will feel impacts, whereas others may benefit from landscape changes.

Ecosystem Service Use Differs across Interest Groups

To the best of my knowledge, this is the first empirical study to show differences in ES use, along with differences in frequency of ES use, across multiple interest groups for multiple ES indicators. Recognizing differences in ES use across interest groups is important not only for understanding what ES are most important to people (and hence to consider during land use decisions), but also as a means for pin-pointing potential conflicts before they occur, and that might arise from land-use decisions (de Chazal, Quetier, Lavorel, & Van Doorn, 2008) or from different needs of ES (Martin-Lopez et al., 2012). Avoiding conflict between interest groups is an important part of environmental decision and policy making (de Chazal et al., 2008).

This study demonstrates that different interest groups use ES differently, both in terms of which ES indicators, as well as the frequency of use for ES. Therefore, those involved with policy making or land use decision-making may be able to resolve conflict early on by recognizing and working with these types of differences in ES use. Consideration for these differences can enhance the success of conservation strategies (Bryan, Raymond, Crossman, & King, 2010) or land-use plans. Recognizing differences and similarities between ES preferences or ES uses can be a tool to identify ES hotspot areas worthy of conservation, or for recognizing ES worth considering during trade-off decisions (Martin-Lopez et al., 2012), making decisions more comprehensive.

The Role of Different Interest Groups

The role that interest groups play in ES use, frequency of use, and spatial location of ES use, are important considerations as different interest groups use ES differently as described above. A clear example of this is with First Nations. While the number of First Nations participants was relatively small for this study, it is clear that First Nations involvement and high use of ES highlighted the importance of including First Nations in discussions regarding land management and land use planning. For instance, First Nations used two ES indicators more frequently than any other interest group (wild edible plants and landscapes used for spiritual/religious purposes), and 100% of First Nations participants said that they used 11 of the 15 ES indicators researched. First Nations high use of landscapes for specific ES indicators is not surprising given First Nations long-standing occupancy on the land, their environmental guardianship, strong relationships with the land, and how they pass on traditional ecological knowledge and wisdom (TEKW) from generation to generation (Turner, Ignace, & Ignace, 2000). First Nations utilize many long-standing strategies for sustainability using natural resources; strategies that come from multiple generations of practice and experimentation leading to a deep understanding for Earths ecological and physical systems (Turner et al., 2000). Given Treaty 8 First Nations land claims, deep TEKW and tight knit connections to the land, it is entirely appropriate that provincial legislation requires First Nations be consulted regarding all land use applications on Crown land (Province Government of BC, 2011).

Other interest groups were shown to use the landscape as much as, if not more than First Nations in some cases. For example, but perhaps not surprisingly, compared to any other group analyzed growing food within the UPRW was practiced by more Agriculturalist participants who also used the greatest amount of freshwater from non-municipal sources. Many of the results highlighted the importance of considering Agriculturalists and Hunter/Anglers land uses, as both of these groups also played a strong role in ES use and both identified strongly with CES and PES. It is recognized that a large amount of time and money resources may be required to engage in multi-interest group dialogue, which can be a major challenge with limited resources. However, my results indicate that all participating interest groups are closely connected to the land for specific ES benefits and therefore all groups are reliant upon specific ES bundles for their well-being. Therefore, during consultation processes for land use decisions it is recommended that legislation be adapted to require decision-makers refer to other interest groups whom also have a high demonstrated use of ES, and strongly consider their uses and values of the land giving them considerable weight in order to maintain all human well-being regardless of interest group affiliation.

Cultural Ecosystem Services in Land Use Decisions

For all interest groups, some cultural ES were consistently ranked at the top of all ES uses (e.g., for Chi-square results, Kruskal Wallis results, spatial mapping) and cited as important for many groups. Several results of this research indicate participants use specific CES more than any PES in the UPRW, indicating a higher level of importance of CES (compared to PES) to people and their well-being. In particular, aesthetic/scenic use ranked the highest amongst all interest groups in terms of number of participants using this ES, and also in terms of highest frequency of use. Similarly, aesthetic/scenic use was selected most often by participants who self-ordered their use of ES indicators, and scored the greatest number of polygons drawn in the primary ES hotspot area located in the Peace River Valley. At least one participant from each interest group drew at least one polygon for each of the top three CES identified (within the main ES hotspot), which also signifies the high importance of CES within the UPRW and specifically within the ES hotspot located in the Peace River Valley. Cultural ES such as aesthetic landscapes and outdoor recreation are essential for human well-being (MEA, 2005; Tobias, 2013). The large polygons drawn for CES indicate that people need vast areas for their well-being and health; for example, they need expansive view-scapes that provide aesthetic/scenic values, provide inspiration, spiritual/religious values, and give them a sense of belonging to the Peace region.

Cultural ES are often neglected and overlooked by conventional land-use decisions and ES valuations (Chan et al, 2012a; Schaich et al., 2010). They are undervalued and underappreciated compared to the more tangible values used for decision making (Plieninger et al., 2013), which does not allow for full cost accounting of ES enabling an ill-informed decision-making process (Chan et al., 2012a). Therefore, in order to better incorporate the regionally important CES identified through this research, the uses for CES across all interest groups must be recognized and accounted for in decision-making. Exposure to nature has a direct role on human health and well-being; it promotes human health by improving social and emotional functioning, improves concentration, reduces stress, and it can offer protection against disease and mortality (Kuo, 2013). A recent review synthesizing the literature regarding the impacts that nature has on human well-being when using non-material benefits (i.e., CES) states that, experiencing nature generally makes us healthier and happier, and intangible benefits are "at least as important" as the incorporation of the tangible benefits into decision-making (Russell et al., 2013, p 474). Empirical results shown here indicating the high importance of CES, compliments other studies with similar results in terms of CES ranking highest for what matters most across differing interest groups (e.g., Bryan et al., 2010; Iceland et al., 2008; Raymond et al., 2009). This demonstrated high importance of CES to participants suggests that neglecting CES during decision-making may result in decisions that exclude the uses and values that matter most to many people (Chan et al., 2012a) in the UPRW.

Again First Nations, Agriculturalists and Hunter/Anglers played a strong role in ranking several CES use values high, and all groups used aesthetic scenery to a large extent (100% of participants across 6 of 7 participating interest groups). However, many groups also had high use of ecosystems for sense of place, recreational opportunities, historical/cultural heritage, and for viewing wildlife frequently. Participants overwhelmingly appeared attached and connected to the UPRW landscapes and associated wildlife. The most surprising result when looking at frequency of use was perhaps the fact that Agriculturalist participants had the highest mean frequency for ‘purposeful wildlife viewing’, whereas Governments’ reported mean monthly frequency of use was ‘never.’ Reasons for this could be that Government participants do not feel that they ‘purposefully’ view wildlife at any specific location, but rather they use non-specific locations for opportunistic viewing and observing of wildlife when they come into contact with them. For instance, during an interview, one retired government employee reported that the drive from Hudson’s Hope to Bear Flat (along Peace River Valley) was very significant for wildlife, especially for ungulates during winter, and that he opportunistically used the Peace River corridor to observe wildlife every time he saw an animal. Another reason for this low level of ‘purposeful wildlife viewing’ could be that Government employees tended to live in urban settings (perhaps owing to job proximity as the government office is in Fort St John), so they would need to seek out more rural or wild locations for viewing wildlife, compared to Agriculturalists who mainly lived rurally. This was shown during mapping interviews, when some Agriculturalists drew polygons around their property as an area used specifically for ‘purposeful wildlife viewing’. Lastly, there were two mapping participants that had low ES use depicted during interviews.

This variance of ES use between different interest groups is likely related to a combination of complex factors such as age, household income, individual needs, access to ES (i.e., rural vs. urban living), and time spent living in the region (Martin-Lopez et al., 2012). In a study examining differing preferences for ES bundles, rural people seem to be more connected to the land and reliant upon ES (Martin-Lopez et al., 2012). This could mean that well-being of Agriculturalists' (and for others living rurally) for example, is more closely connected to the landscape and to ES provided in the UPRW. People living on the land for longer periods may also have closer connections to local ecosystems and be more reliant upon them for delivery of different ES.

For the majority of participants, CES had a higher importance than PES, which may be because people in this area may not be as heavily reliant upon PES. The MEA (2005) suggested that effects of ES loss on human well-being vary across communities, and that the more serious consequences will be felt by those living in developing nations. For instance, conversion of natural landscapes to agricultural lands, massive water withdrawals (accompanied by untreated wastewater discharges), and deforestation occurs more rapidly in developing countries (MEA, 2005). Even within developing countries, there is an economic divide among socioeconomic classes with respect to who will most feel the impact of ES loss, because poorer people are typically more directly dependent upon ES, whereas people who are better off financially can purchase substitutes for local ES (e.g., water, wood products, pollinators) in many cases (MEA, 2005). This may be the scenario of the UPRW, that is, people are currently able to purchase substitutes for PES (e.g., food grown elsewhere or bottled water). However, the costs of relocating ES will become unbearable at some point in the future (Ehrlich & Mooney, 1983). Additionally, CES are considered as irreplaceable in a landscape (Plieninger et al., 2013) and cannot be relocated or substituted with technological advancements or bioengineering. Decision-makers should therefore act now to protect the long-term maintenance and resiliency of biodiversity and ecosystem functions that provide regional ES that enable human well-being and happiness across multiple interest groups.

Provisioning Ecosystem Services in Land Use Decisions

Provisioning ES were also heavily used across all groups, as mentioned previously, especially by First Nations, Agriculturalists and Hunters/Anglers. Again, the high utilization of ES within these groups could be due to complex factors such as age and proximity to ES. For instance, results shows that the highest percentage of people living rurally, in addition to the highest number of participants belonging to the 65 and above age category, belonged to the Agriculturalists interest group (with high ES use). Similarly, a previous study showed that elderly people living rurally had a greater awareness of provisioning ES since they were seen as more likely to have been dependent on ES related to traditional farming practices throughout their lifetime (Martin-Lopez et al., 2012).

Frequency of use among interest groups differed for the PES indicators surveyed (fish, hunting/trapping/wild edible plants). All were often cited as high priorities, but mapping interviews shows that fishing for food and wild edible plant collection occurred at small local scales, whereas hunting required larger landscapes. According to participants use of ES, landscapes are being used the least to grow/raise food such as fruit, vegetables and livestock. However, people may be using food grown within the UPRW with a greater frequency than many of the other ES indicators. This indicates that participants aren’t necessarily growing food or raising livestock to a large extent within the UPRW, but that food coming from local sources is important to them. This corresponds with results showing that 84% of those not growing food in the UPRW, said that it was important to them to be able to purchase locally grown food or livestock.

It is worthy to note that during mapping interviews it was mentioned by several interest groups, that wild edible collection was only possible for 3-5 weeks during the year and that in general many ES indicators were used less in winter. Additionally, for PES used more opportunistically, it may not be as important to protect specific locations for long-term maintenance of that service, for example for opportunistic ornamental resources locations (e.g., used to collect antlers, rocks, feathers, etc.) and wood gathering areas that change according to current logging roads access and forestry operations that people often depend on for wood gathering opportunities.

Ecosystem Service Hotspots: Importance of Proximity to Freshwater Bodies

The primary ES hotspot location identified extends along the riparian corridor of the Peace River from Hudson's Hope to the mouth of the Halfway River, suggesting that areas with the highest amount of ES delivery were not scattered randomly throughout the landscape (also shown in Plieninger et al., 2013), but rather near large water bodies such as the Peace and Moberly Rivers, and Moberly and Cameron Lakes. These freshwater bodies were identified as delivering a multitude of PES and CES to regional participants across interest groups. Both plant and animal species present in aquatic ecosystems are involved in several complex ecosystem processes and functions (e.g., filtration, decomposition, nutrient cycles, etc.), that in turn provide humans with many benefits (Gutierrez & Alonso, 2013), such as clean water, habitat provision, flood control and fish. Many of these benefits are invisible and often taken for granted (Postel & Carpenter, 1997; Gutierrez & Alonso, 2013). The primary ES hotspot location has been shown to have high value for local communities and has high levels of multiple ES use, especially for the non-tangible, non-market CES of aesthetic/scenic landscapes, recreation (motorized/non-motorized), and spiritual/religious uses. Activities and ES use in the primary ES hotspot were varied across groups, but also included other ES often unaccounted for: sense of place, spiritual renewal, inspirational landscapes, freshwater use, hunting and trapping wildlife, and purposefully viewing wildlife.

The close link of particularity CES to freshwater bodies builds upon findings by Plieninger et al. (2013), where water bodies were shown to be extremely important for recreation, aesthetics and heritage sites. Additionally, a study from Australia showed that there were multiple high ES values clustered around the entire river bank that they investigated (Zhu, Pfueller, Whitelaw, & Winter, 2010), as was found with this study for the Peace River Valley in particularly. Similar to Plieninger et al (2013), this study also found that specific locations delivering ES bundles (i.e., ES hotspots) are clearly more important than other areas for their delivery of ES; however, people also used ES in their everyday surroundings such as their backyards and gardens.

Synergistic Biodiversity Values within an ES Hotspot

Biodiversity – the variability of life on Earth from genes to ecosystems – is a pre-requisite underpinning the delivery of ES. Biodiversity supports the delivery of services, and ES capacity declines with a reduction in biodiversity (Balvanera et al., 2006; Cardinale et al., 2007; Isbell et al., 2011; Maestre et al., 2013; Pasari et al., 2013), since declining levels of biodiversity decrease ecosystem functions such as oxygen production and soil development (Cardinale et al., 2007), which underpin and maintain ES. Therefore, sustainable development means including and managing for both ES and biodiversity, since human welfare is linked to both (Naidoo, et al., 2007). Protecting areas most important for ES delivery (i.e., ES hotspots), as well as those areas most important for biodiversity (i.e., biodiversity hotspots) are of critical importance for maintaining human well-being (Anderson et al., 2009; Diaz et al., 2006; Daily, 1997). The ultimate objective of conservation is when synergies between areas highly valued for its ES production capacity in addition to high biodiversity values can be fostered (Cimon-Morin et al., 2013); having more than one reason for protecting an area can be more persuasive and resilient than single shot approaches to conservation (Redford & Adams, 2009). Additionally, the long-term financial benefits of conserving important nature areas capable of delivering high levels of ES can greatly exceed the short-term cost of nature protection (Cimon-Morin et al., 2013).

However, even though biodiversity has been linked to the production of ES and biodiversity has been shown to be well-captured by aesthetic values accompanied with high plant diversity (Gos & Lavorel, 2012), protecting the main ES hotspot area identified in the Peace River Valley (shown to have high aesthetic and other ES use values) does not necessarily mean that biodiversity will be protected or vice versa; that is, protecting an area with significant biodiversity values does not mean that areas important for ES delivery will be conserved (Balvanera et al., 2001; Chan et al., 2006; Cimon-Morin et al., 2013; Mace et al., 2013; Naidoo et al., 2008). It has been shown that ES hotspots can be poor to medium predictors of biodiversity (Gos & Lavorel, 2012). However, it is possible to identify areas capable of protecting both ES and biodiversity for win-win scenarios (Naidoo et al., 2008).

Natural riparian corridors can harbor the most biological diverse, dynamic and complex habitats within the Earth's terrestrial landscape (Naiman et al., 1992), although it is important to mention that freshwater ecosystems may also be the most endangered ecosystem in the world (Dudgeon et al., 2005). Given that the Peace River is a large river, presumably the large riparian corridor of the Peace River Valley, which harbors the main ES hotspot identified in this study, is one of the most biological diverse and complex natural systems within the UPRW. Analyzing land cover geospatial data obtained from GeoBase shows that the southern extent of the ES hotspot located along the Peace River is a relatively equal mix of coniferous and broadleaf open forests, with small patches of mixed-wood open forest and low lying shrubs. This relatively undeveloped and inaccessible intact forest with multiple streams along the southern extent of the main ES hotspot is an area that has already been proposed as a protected area (Boudreau Protected Area) due to many unique features such as, being representative of a specific ecosection (minor macroclimatic and physiographic variations at a small scale), having important cultural/historic sites and critical swan nesting sites, and being part of important winter ungulate range (Provincial Government of BC, 1997). As landscapes undisturbed by humans provide a maximum amount of supporting and regulating ES (Cimon-Morin et al., 2013), Boudreau, part of which has been identified as an ES hotspot, likely also has high levels of supporting (e.g., primary production, production of atmospheric oxygen, nutrient cycling) and regulating (e.g., carbon sequestration, water regulation) ecosystem services.

It is acknowledged that the Peace River corridor within the UPRW is not in its natural state, as it has already faced some impacts due to previous upstream dam projects and the river level fluctuates due to the upstream dam operations. However, it appears that this main ES hotspot has retained a large amount of biodiversity across many species levels. For example, despite some impacts from human use, extensive aquatic and terrestrial inventories recently completed for the proposed Site C dam have provided interesting and significant findings regarding biodiversity values.

Listed below is a summarization of species identified within the Peace River Valley through baseline surveys. Species are referred to under the BC provincial conservation framework, where red means ‘endangered or threatened’, and blue means ‘species of special concern’. Additionally, the BC Conservation Data Centre defines and ranks at-risk ecological communities (natural plant community and its associations) according to the BC provincial framework (Provincial Government of BC, n.d.). There are two red-listed and 15 blue-listed ecological communities, and several sensitive ecosystems (e.g., 3965 ha of wetlands, 7 tufa seeps, 1 marl fen, 2667 ha grasslands, 1135 ha old growth forests) within the Peace River Valley (Hilton, Andrusiak, Krichbaum, Simpson, & Bjork, 2013). A sensitive ecological community is described as a particularly ecologically fragile system, which may not be provincially listed but that has fragile ecosystem processes, sensitive habitat values, and is susceptible to changes such as hydrological and invasive plants (Resource Information Standards Committee, 2006).

Rare plants were defined as vascular plants, mosses and lichens that were: federally listed under the Canadian Species at Risk Act (SARA) on Schedule 1 (SARA, 2002); species with assigned at-risk status according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); and/or provincially listed (red or blue) species in BC (as described above). In a summary of rare plants surveyed, 781 vascular plants, 107 mosses and 217 lichens were recorded, including 11 red-listed, 28 blue-listed and 119 rare vascular plants, 44 rare mosses, and 42 rare lichens (Hilton et al., 2013).

For animal species 14 of 65 butterfly taxa are recorded from the Peace River Valley as red or blue listed (Hilton, Simpson, & Guppy, 2013); two of the eight bat species are provincially listed at-risk; the Valley also has blue-listed Fishers, since the specific tree type and tree size required for reproductive dens and for resting are found in the Peace River Valley (Simpson et al., 2013). The Peace River Valley has significant habitat for several at-risk migratory bird species (Hilton, Simpson, Andrusiak, & Albrecht, 2013), non-migratory birds (Hilton &

Simpson, 2013) and raptors (Hilton, Simpson, & Andrusiak, 2013). The Peace River Valley contains healthy populations of carnivores (gray wolf, black bear, cougar, occasionally grizzly bears) (Simpson et al., 2013), five amphibian species, and two reptile species (Hilton, Andrusiak, Simpson, & Sarell, 2013), in addition to 19 ungulate birthing sites identified, as well as high ungulate densities (i.e. moose, elk, white-tailed and mule deer) due to high quality habitat. Maintaining populations of large carnivores is important since they are keystone species; they contribute to ecosystem processes, species diversity and to the maintenance of ecological health (Miller et al., 2001). Carnivores are at the top of the food chain, therefore through grazer-predator interactions carnivores help control the populations of ungulates, which would overgraze vegetation if predators were removed (Fretwell, 1977). There are also 32 fish populations in the Peace River, one population is red-listed and two are blue-listed under provincial framework (Mainstream Aquatics Ltd, 2012). No information was found for invertebrates (other than butterflies/dragonflies) or microbes.

According to species richness maps produced for Biodiversity BC, nearly the entire UPRW in addition to the main ES hotspot contain a large amount of species richness (211-266 species based upon equal interval classification across the province) compared to many other parts of BC (Austin et al., 2008). Considering the above biodiversity data in addition to research data presented here indicating overlap of ES hotspots with this high amount of biodiversity, leads to the presumption that a win-win decision could be made by conserving the main ES hotspot location. In other words, by protecting high levels of biodiversity in addition to protecting an area shown to deliver a high diversity and richness of ES, global conservation priorities for species and ecosystems are achieved, as well as the maintenance of human well-being in the region.

Payment for ES Approach to Increase Biodiversity Levels

The northern portion of the primary ES hotspot identified is interspersed with annual cropland, perennial cropland and pasture, with small patches of herb and coniferous open forest. Since humans are an integral part of the northern extent of the ES hotspot and there is a significant amount of land used for agricultural purposes, the northern portion along the Peace River could be a good place to implement a payment for ES mechanism to attempt to boost biodiversity levels. The payment for ES approach is one where ES users provide an incentive (usually financial) to compensate those who own or ultimately manage and provide the desired ES (Cimon-Morin et al., 2013; Tallis et al., 2011). This approach may be appropriate for implementation in part because due to a growing human population, global food shortage is leading to rapid agricultural expansion, which is an increasing concern as impacts from expansion (e.g., habitat destruction, eutrophication) are predicted to lead to "unprecedented ecosystem simplification," meaning that there would be a significant loss of biodiversity, species extinctions, changes in species composition, eutrophication of surface waters, groundwater pollution, increasing greenhouse gases, acidification of soils and freshwater, and large changes to the functions of ecosystems leading to further ES loss (Tilman et al., 2001). Agricultural areas, while important for provisioning ES (i.e., food production), typically have low levels of biodiversity due to farming practices such as pesticide and fertilizer use, and physical manipulations of the land (McLaughlin & Mineau, 1995). Given growing demands for food, these highly disturbed and managed ecosystems are important to conservation; agri-biodiversity is necessary for conservation as is wild biodiversity (Phillips, 1998).

Using the payment for ES approach could be one way to ensure the long-term maintenance of diverse ES identified within the ES hotspot location, as well as biodiversity within the hotspot. To try and increase biodiversity levels in agricultural areas of the Peace River corridor, Agriculturalists could receive incentives that would reduce and/or restrict land-use practices (Cimon-Morin et al., 2013); for instance, rather than conventional methods, famers could use organic methods that would enhance soil fertility and increase levels of biodiversity (Mäder, Fliessback, Dubois, Gunst, Fried, & Niggli, 2002). Win-win areas for biodiversity and ES conservation can be one of the best places to use payment for ES approaches in order to achieve biodiversity conservation objectives (Naidoo et al., 2008). When compared to natural systems there is a greater potential for cultural landscapes (e.g., agricultural) to expand ES supply through economic incentives (Schaich et al., 2010). Conserving the identified ES hotspot for the multitude of identified ES (including objectives considered to meet a growing demand for food), as well as for its regional biodiversity could be a crucial opportunity.

Road Networks and Connectivity to Ecosystem Service Hotspots

Perhaps somewhat surprisingly, none of the identified ES hotspot locations were found in either of the protected areas located within the study area (i.e., Butler Ridge and Moberly Lake Provincial Parks). However, there is limited road access into one of these parks; Butler Ridge Provincial Park can only be accessed by a 40km gravel road or by boat. Whereas, there are roads accessing all areas identified as being highly valued for their ES. For instance, a highway (Hwy 29) runs alongside the northern extent of the entire main ES hotspot along the Peace River. Given these results, roads appear to be necessary for ES provisioning in the UPRW. During mapping interviews, this highway was mentioned multiple times as being important for the aesthetic drive, the sense of place that it gives to residence, and for wildlife viewing opportunities.

The importance of ES proximity to roads is supported by Chan et al. (2006), where recreation values were estimated partly based upon their accessibility due to road proximity, indicating that roads are necessary for high levels of ES use. Additionally, in another study that assessed the location of landscape service indicators on an island in Tanzania, small villages located on main roads provided the highest intensity (i.e., richness and diversity) landscape service indicators (Fagerholm et al., 2012). My research builds upon this and suggests that use of CES and PES are more intense when proximity to roads is closer. However, it can be highly problematic when trying to achieve a high level of both biodiversity and ES in the same area, since roads are also known to negatively impact biodiversity, and many of the biological processes and functions that virtually all ES depend upon (e.g., soil, plant, hydraulic and animal processes) (Duniway & Herrick, 2013). The ecological effects of roads can have many negative impacts on biodiversity such as wildlife mortality from road construction and vehicle collisions; animal behavior modifications due to shifting home ranges and habitat fragmentation (e.g., altered movement patterns, altered escape response mechanisms, and altered physiological state), edge effect leading to changes in physical characteristics in the environment (e.g., temperature changes, soil density, dust, sedimentation, changes in light, etc.); and alteration of the chemical environment due to road maintenance (e.g., adding heavy metals, salt, organics, nutrients, etc.) (Trombulak, & Frissell, 2000).

A literature review by Mitchell, Bennett & Gonzalez (2013) revealed that there is little known regarding how connectivity and road access affect ES delivery (especially for CES and PES), and that links between CES and connectivity have never been tested. However, road networks in a biodiversity hotspot located in China resulted in decreased ecosystem function and structure, which led to extensive loss in ecosystem service value (Wang, Cui, Liu, Dong, Wei, &

Liu, 2007). These studies demonstrate that the potential implications of road construction and road access and proximity to natural landscapes deserve more attention within an ES framework.

Potential Impacts to ES in the Upper Peace River Watershed

The concept of ES is based on the ability of humans to interact with natural surroundings and gain health and well-being directly or indirectly from ecosystems. In this study I explored the uses of PES and CES, which are typically derived directly from nature. Therefore, any impacts to the geographic location would be expected to have direct consequences for the well-being of the resident human populations. In particular, freshwater bodies play an important role for the delivery of both CES and PES in this region. Therefore, the ecological integrity of major freshwater bodies in the UPRW is important to maintain for regional well-being. The main ES hotspot identified extends along the riparian corridor of the Peace River from Hudson's Hope to the mouth of the Halfway River, and is located in a portion of the region slated to be flooded by the creation of the proposed Site C dam. This proposal involves a 60m high dam above the Peace River bed, which will create a reservoir projected to flood 5550 hectares of river valley bottom 83kms long, and 2-3 times the current width of the Peace River (BC Hydro, 2013).

Throughout BC, valley bottoms are threatened (Resource Information Standards Committee, 2006). If the proposal is approved, the potential outcomes are expected to impact the area in ways similar to what has been shown in other large dam construction projects. For example, Bunn & Arthington's (2002) literature review found that terrestrial plant communities within river habitat affected by dam systems were less diverse, contain more exotic species, and lack rare shoreline herbs compared to ecosystems with natural flow regimes. Additionally, specific to the Site C dam, potential effects for wildlife are listed include habitat loss, habitat fragmentation and habitat alterations due to activities such as clearing and preparing for the dam, generating station and spillways, from reservoir creation (including road construction), from building the transmission line, realigning the main highway, constructing new roads, and from excavating materials. It is widely acknowledged that habitat loss is the largest reason for global biodiversity decline (Sala et al., 2000). Research in Japan has shown that one of the most serious effects of dams is the "barrier effect" that leads to habitat fragmentation and prevents species (e.g., fish, invertebrates) from being able to migrate, leaving upstream habitats and species populations isolated. It is well established that fragmentation jointly affects population and community structure through creating smaller local habitats as well as from isolating effects (Gonzalez et al., 1998). Small local habitat patches in conjunction with isolation is shown to increase extinction risk through reduced population size and reduced genetic diversity, combined with environmental factors. Morita & Yamamoto (2001) demonstrated that fish populations of Charr isolated from dam construction were extirpated more quickly than in larger, connected stream habitats. Morita & Yamamoto (2001) also found that habitat connectivity was important for the persistence of Charr, both due to fish population size and lower genetic diversity in dammed populations.

In addition to the riverine system itself, wetlands and associated riparian zones in the Peace River provide many ES that would be lost if flooded from dam construction, such as water quality improvement, flood control, carbon sequestration and biodiversity services (e.g., habitat, biological control, food) (Zedler & Kercher, 2005). Changes in hydrology caused by dams synergistically interact with other threats to biodiversity (e.g., pollution discharge may increase downstream from reduced flows, hence concentrating pollutants) to produce complex and often unpredictable negative effects (Dudgeon, 2000). For instance, in a report prepared for the International Union for Conservation of Nature, the United Nations (2001) and the World

Commission on Dams suggests that dams and their associated reservoirs have many additional negative impacts on freshwater biodiversity including: changing turbidity levels that species are adapted to; trapping silt in reservoirs depriving downstream habitats of nutrients/mineral; removing woody debris that creates habitat downstream; fostering of exotic species that replace native species; cessation of normal river flooding impacting biodiversity; impacts of multiple dams leads to cumulative effects such as further contributions to habitat fragmentation leading to of further separation of populations in a shrinking habitat lost to growing reservoirs (McAllister, Craig, Davidson, Delany, & Seddon, 2001).

Turning a section of river into a reservoir leads to the irreversible consequence of habitat loss, which is especially problematic in northern areas where river valley habitats are often the most productive ecosystems (Nilsson & Berggren, 2000). Reservoirs can also contribute to climate change through the release of GHGs (Louis, Kelly, Duchemin, Rudd, & Rosenberg, 2000). Preventing future development on the Peace River will help ensure that these or other negative impacts do not affect biodiversity values, nor the delivery of ES that biodiversity underpins. Diverse plants and animals are required and are involved in complex ecosystem processes and functions, providing humans with many ES benefits (Gutierrez & Alanso, 2013). The ES hotspot has been identified to contain numerous at-risk ecosystems, plants and animal species. Losing species in the at-risk categories could propel us further towards the sixth mass extinction crisis within a few centuries (Barnosky et al., 2011); therefore biodiversity values within the hotspot are in need of critical protection. This study has also shown that freshwater bodies (especially the Peace River Valley) are particularly important for delivering multiple ES for regional inhabitants of the UPRW. Therefore removing habitat and significantly altering habitat within the ES hotspot will reduce human well-being of regional inhabitants.

Chapter 5: Recommendations and Conclusions

Policy Recommendations

The full economic and non-market costs of losing habitat (e.g., river habitat and wetlands due to dam construction as described above) has been largely underestimated because the resulting loss of ES has not been accounted for (Postel & Carpenter, 1997, p. 210). Additionally, the cumulative impacts of other land use activities, such as expanding coal mines, oil and gas exploration and development, agriculture and forestry can have negative consequences for biodiversity found in the UPRW (Ministry of Water, Lands & Air Protection, 2004), which can lead to a further decrease in ES supply. In order to support sustainable management and conservation decisions in the UPRW, short-term interests (e.g., electricity generation, oil/gas extraction) need to be accurately weighed and measured according to the long-term impact that they will have for future human generations and their well-being. This includes full cost accounting of all ES (material and non-material benefits) using interest groups during decision-making processes as demonstrated here.

In regards to conservation planning and policy development, my research results indicate that protecting the main ES hotspot will be critical in order to maintain the well-being of humans across regional interest groups as it has been found to provide numerous ES to eight different interest groups in the region. Conserving this location could be a win-win situation where both biodiversity and ES values are protected for the long-term resiliency of inhabitants. The ES hotspot outlined has been surveyed and contains numerous at-risk ecosystems, plant and animal species. The probable loss of at-risk species in the near future in this area will contribute to the ongoing sixth mass extinction crisis currently documented (Barnosky et al., 2011); therefore biodiversity values, along with ES values, within the hotspot are in need of critical protection.

Recommendations for Future Research on ES

Obtaining equal sample sizes among different interest groups was difficult due to the unknown outcome of the self-identification process for interest group association in this study. For instance, with the online survey there was a high percentage of Environmentalist participants (27%) compared to only two Industry participants (2%). There are two plausible explanations for the higher participation rate of Environmentalists compared to other groups. First, this type of research may be of most interest to people that most closely associate with the Environmentalists group, or secondly, several people feel that they most closely identify with Environmentalists due to the large amount of natural resource development occurring in the region, in addition to the large number of participants that perceive the ES they use are declining. People's perceptions of declining ES availability were evident through survey analysis and through comments made during mapping interviews; the majority of participants were personally concerned with the environmental degradation they perceive is occurring. Survey data using self-identification will always suffer from unequal participation among groups.

With unbalanced interest groups (specifically the higher participation rate of Environmentalists) coupled with merged interest groups, there can be limitations to the research data; some significance to the p-values may have been lost. However, all groups did identify with the concept of ES and all groups used all ES indicators researched. While merging groups, which was necessary to satisfy Chi-square assumptions may have reduced the ability to obtain significant p-values in a particular ES category, there were clear differences that emerged; many significant results were found and only the most significant results would have been identified through statistical analysis. While the Chi-square and Kruskal-Wallis tests are robust methods to accommodate the unbalanced nature for this type of data (Koehler & Larntz, 1980; Roscoe &

Bryars, 1971), I recommend that using a smaller subset of interest groups for participants to identify with, may reduce some of the unbalanced contributions in future survey designs. Additionally, I acknowledge that there are likely some differences between members of merged groups, for example motorized and non-motorized recreationists tend to have different recreational uses of trails and have different concerns for litter and trash on trails (Andereck, Vogt, Larkin, & Freye, 2001), yet they were merged into one group for analytical purposes. However, since all significant p-values were $p \leq .02$, the p-values are likely to remain significant given these limitations.

With future research working to elicit sociocultural ES values from interest groups, it has recently been recommended to use a framework that starts with participation numbers that seem immediately feasible, and after that researchers can determine if further participants are required, and what the appetite of local interest groups is like for participation (Chan et al., 2012a). Obtaining further participants across with differing interests may require the involvement of someone (or a research team) that actually lives within the community in order to help communicate the importance of the research. Additionally, in order to pre-determine what interest group people would identify with prior to interviews, it may be useful to confirm what group they will choose prior to meeting, so that specific interest groups can be targeted if needed to achieve equalization of numbers across interest groups.

In this study some individuals were unable to rank the top five ES indicators, or to quantify their ES use, particularly CES such as inspirational landscapes, aesthetics and sense of place. Some mapping participants believed that certain CES were all the same thing, and that they used them at the same time and in the same area, e.g. landscapes used for aesthetics, spiritual/religious value, inspiration, and sense of belonging. This further resulted in some participants having difficulty quantifying ES indicators. These issues may be, in part, because definitions for CES are vague (Plieninger et al., 2013). Therefore, it might be useful to have more robust and descriptive definitions for ES indicators. However, it is also completely plausible that people are in fact experiencing several ES at the same time in the same place, since benefits coming from non-material interactions with nature can be obtained through different ways: through knowing, perceiving, interacting and living within nature (Russell et al., 2013). There is an additional challenge in mapping CES, because people often want to map entire expansive view-scapes for CES indicators of aesthetics, sense of place and landscapes used for inspiration. As demonstrated by other researchers, CES are intangible and inherently difficult to map (as was seen with Brown & Raymond, 2007; Klain & Chan, 2012). Ultimately CES boundaries are not well delimitated in real life, for instance, the boundaries we have for CES such as sense of place and aesthetic views are not well delineated when we go outside. Therefore, it is debated whether exact boundaries are needed during participatory GIS methods in order to produce robust or accurate scientific results (Fagerholm et al., 2012; McCall, 2006).

Part of the difficulty with mapping ES, is that some participants were unable to identify the appropriate scale of ES use when presented with a map, and/or did not understand how the spatial information would be processed and analysed. It could be useful at the onset of interviews to verbally articulate a limit for polygon size and describe how smaller areas will give more value or weighting to the area chosen as valued in the analyses. It could have been useful to have more fine-scaled detail (e.g., dirt roads, major pipelines) on the paper map during interviews, so that people were more clearly able to orient themselves and pin-point locations more precisely. However, it could be a fine balance as too much detail would require a very large map given the large spatial extent of the watershed, making it impractical and cumbersome for interviews. Further, web-based mapping methods such as PPGIS using a google map interface (e.g., Brown & Weber, 2012) may help alleviate these problems because participants can work at multiple spatial scales to more precisely draw the area of ES use (Zhu et al., 2010). Ideally a multi-media approach might work best because it could accommodate for most participants comfort levels associated with identifying spatial information – some people are comfortable with maps, others with interactive online media.

Future Challenges

Interest groups were seen to have differing levels of use for specific ES indicators as described above, whereas different scales of stakeholder (e.g., provincial, national, global) uses were not considered, which may be dependent upon additionally complex factors such as cultural backgrounds, and the impact of the ES to their income or living conditions (Hein et al., 2006). For instance, people living in the UPRW may be interested in conserving fishing uses in the Peace River, whereas global interests may be more interested in ES uses such as protecting forests for carbon sequestration. Creating ideal management plans can be challenging as it should involve all scales of stakeholders; assessing and basing management plans based upon one spatial stakeholder scale alone may results in plans that are unacceptable for stakeholders at other scales (Hein et al., 2006). Therefore a future research challenge is to extend our knowledge of ES use in the UPRW that is needed across different scales of interest groups.

Despite limiting indicators to the cultural and provisioning categories in this study, it in no way negates the importance of regulating and supporting ES. It is the authors belief that this research project using interest groups and PPGIS methods to identify and map CES and PES may be complimented by an additional ES assessment, one that uses expert assessment and valuation methods to build models to predict the supporting and regulating ES provided by the watershed land cover, ecosystem attributes, land use, etc. (Daily et al, 2011). Using both this thesis research data in combination with data coming from expert assessments may help achieve more full cost (i.e., monetary and non-monetary ES values using interest groups) accounting for all ES identified as most important in the region. Additionally, a complete biophysical assessment of the UPRW would provide valuable information beyond the preliminary biodiversity assessment used here.

Lastly, a practical challenge of the research data includes making sure that information stemming from this research makes it to decision-makers and thus becomes useful and practical. Being able to clearly communicate discovered relationships to decision makers and the public is perhaps one of the most important contributions a scientist could make towards conservation (Thompson et al., 2011), as illustrating linkages will best inform policy and ecosystem management decisions. This can require interested or dedicated decision-makers or non-governmental organizations that have commitments to long-term planning and campaigning (Chan et al., 2012a). All attempts to disseminate the goals of this research, as well as the results were made and are ongoing. For instance, multiple presentations were offered to numerous interest groups, and municipal and regional governments were made aware of this research through letters, conversations and presentations. Additionally, the lead researcher also plans to disseminate results to the Joint Review Panel at hearings during the decision-making process for the proposed Site C dam. Dissemination of results to the academic and scientific community will be made through submission of peer-reviewed publications, and future presentations at conferences.

Conclusion

In this thesis, I have demonstrated a successful and useful method for quantifying and mapping multiple ES indicators at a regional scale using data collected from multiple interest groups. Given the difficulties involved with mapping intangible CES, and given that relatively few studies that have attempted to do so, there is no standard methodological approach for mapping CES. However, this study successfully applied PPGIS methods and an online survey for eliciting responses regarding CES (and PES) indicator use, frequency of ES indicator use, and location of ES indicator use across multiple interest groups. Research findings confirm that all interest groups are using all ES indicators to some extent. People use specific locations for ES and thus, specific locations are more important than others for regional human well-being in the UPRW. Overlapping spatial ES indicators used across interest groups enabled for the identification of a main spatial hotspot location, which extends along the Peace River from Hudson's Hope to the mouth of the Halfway River. This ES hotspot appears to also have a synergistic relationship with high biodiversity levels, making the protection of the main ES hotspot area identified of the utmost conservation importance.

References

Andereck, K. L., Vogt, C. A., Larkin, K., & Freye, K. (2001). Differences between motorized and nonmotorized trail users. *Journal of Park and Recreation Administration*, *19*(3), 62-77.

Anderson, B. J., Armsworth, P. R., Eigenbrod, F., Thomas, C. D., Gillings, S., Heinemeyer, A., & Gaston, K. J. (2009). Spatial covariance between biodiversity and other ecosystem service priorities. *Journal of Applied Ecology*, *46*(4), 888-896. doi: 10.1111/j.1365-2664.2009.01666.x

Anderson, J., & Scheck, J. (2004). *Peace region aerial surveys march 2004.* Retrieved from British Columbia Ministry of Environment: http://www.env.gov.bc.ca/esd/distdata/ecosystems/frpa/Approved_FRPR_sec7_WLPPR_sec9_Notices_and_Supporting_Info/UWR/Timber_Supply_Areas/Dawson_Creek_TSA/Supporting_Info/Docs/UWR_2004_AERIAL_SURVEY_final_April04.pdf

Austin, M.A., Buffet, D.A., Nicolson, D.J., Scudder, G.G.E., & Stevens, V. (Eds). (2008). *Taking nature's pulse: The status of biodiversity in British Columbia.* Victoria, Canada: Biodiversity BC.

Balvanera, P., Daily, G.C., Ehrlich, P.R., Ricketts, T.H., Bailey, S., Kark, S., Kremen, C., & Pereira, H. (2001). Conserving biodiversity and ecosystem services. *Science, 291*(5511), 2047.

Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology Letters, 9*(10), 1146-1156. doi:10.1111/j.1461-0248.2006.00963.x

Barndt, M. (1998). Public participation GIS—Barriers to implementation. *Cartography and Geographic Information Systems*, *25*(2), 105-112.doi: 10.1559/152304098782594607

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O., Swartz, B., Quental, T. B., Marshall, C., McGuire, J.L., Lindsey, E.L., Maguire, C., Mersey., B., & Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, *471*(7336), 51-57. doi: 10.1038/nature09678

BC Hydro. (2013). *Environmental impact statement executive summary*. Retrieved from Canadian Environmental Assessment Agency website: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Executive_Summary.pdf

BC Oil and Gas Commission. (2013). *Oil and gas land use in the Fort Nelson LRMP area of British Columbia.*
Retrieved from http://www.bcogc.ca/node/8233/download.

Bernard, H.R. (2000). *Social research methods: Qualitative and quantitative approaches* (1st ed.). Thousand Oaks, California: Sage Publications.

Blomley, N. (1996). "Shut the province down": First Nations blockades in British Columbia, 1984-1995. *BC Studies: The British Columbian Quarterly*, (111), 5-35.

Brown, G., Montag, J.M. & Lyon, K. (2012). Public participation GIS: A method for identifying ecosystem services. *Society and Natural Resources*, *25*(7), 633-651. doi: 10.1080/08941920.2011.621511

Brown, G. G., & Pullar, D. V. (2012). An evaluation of the use of points versus polygons in public participation geographic information systems using quasi-experimental design and Monte Carlo simulation. *International Journal of Geographical Information Science*, *26*(2), 231-246.

Brown, G., & Raymond, C. (2007). The relationship between place attachment and landscape values: Toward mapping place attachment. *Applied Geography*, *27*(2), 89-111.doi: 10.1016/j.apgeog.2006.11.002

Brown, G., & Weber, D. (2011). Public participation GIS: A new method for use in national park planning. *Landscape Urban Planning*, *102*(1), 1-15.

Brown, G., & Weber, D. (2012). A place-based approach to conservation management using public participation GIS (PPGIS). *Journal of Environmental Planning and Management, 56*(4), 455-473. doi: 10.1080/09640568.2012.685628

Bryan, B. A., Raymond, C. M., Crossman, N. D., & Macdonald, D. H. (2010). Targeting the management of ecosystem services based on social values: Where, what, and how? *Landscape and Urban Planning*, *97*(2), 111-122. doi: 10.1016/j.landurbplan.2010.05.002

Bunn, S. E., & Arthington, A. H. (2002). Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management*, *30*(4), 492-507.doi: 10.1007/s00267-002-2737-0

Cardinale, B. J., Bennett, D. M., Nelson, C. E., & Gross, K. (2009). Does productivity drive diversity or vice versa? A test of the multivariate productivity-diversity hypothesis in streams. *Ecology*, *90*(5), 1227-1241. doi: 10.1890/08-1038.1

Cardinale, B.J., Duffy, J.E., Gonzales, A., Hooper, D.D., Perrings, C., Venali, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D.A., Kinzig, A.P., Daily, G.C., Loreau, M., Grace, J.B., Larigauderie, A., Srivastava, D.S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature, 7401(486),* 59-67. doi: 10.1038/nature11148

Cardinale, B. J., Matulich, K. L., Hooper, D. U., Byrnes, J. E., Duffy, E., Gamfeldt, L., Balvanera, P., O'Connor, M.I. & Gonzalez, A. (2011). The functional role of producer diversity in ecosystems. *American Journal of Botany*, *98*(3), 572-592. doi: 10.3732/ajb.1000364

Cardinale, B.J., Wright, J.P., Cadotte, M.W., Carroll, I.T., Hector, A., Srivastava, D.S., Loreau, M., & Wels, J. (2007). Impacts of plant diversity on biomass production increase through time because of species complementarily. *Proceedings of the National Academy of Sciences, 104*(46), 18123-18128. doi: 10.1073/pnas.0709069104

Chan, K.M.A., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Benjamin, S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J., & Woodside, U. (2012a). Where are cultural and social in ecosystem services? A framework for constructive engagement. *BioScience, 62*(8), 744-756. doi: 10.1525/bio.2012.62.8.7

Chan, K.M.A., Shaw, M.R., Cameron, D.R., Underwood, E.C., & Daily, G.C. (2006). Conservation planning for ecosystem services. 4(11): e379. Doi:10.1371/journal.pbio.0040379

Chan, K.M.A., Satterfield, T., & Goldstein, J. (2012b). Rethinking ecosystem services to better address and navigate cultural values. *Ecological Economics, 74*, 8-18. doi: 10.1016/j.ecolecon.2011.11.011

Chiesura, A., & de Groot, R. (2003). Critical natural capital: a socio-cultural perspective. *Ecological Economics, 44*, 219-231. doi: 10.1016/S0921-8009(02)00275-6

Cimon-Morin, J., Darveau, M., & Poulin, M. (2013). Fostering synergies between ecosystem services and biodiversity in conservation planning: A review. *Biological Conservation*, *166*, 144-154. Doi: 10.1016/j.biocon.2013.06.023

Cochran, W. G. (1954). Some methods for strengthening the common χ 2 tests. *Biometrics*, *10*(4), 417-451.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neil, R.V., Paruelo, J., Raskin, R.G., Sutton, P., & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253-260. doi: 10.1038/387253a0

Crossman, N.D., Burkhard, B., & Nedkov, S. (2012). Quantifying and mapping ecosystem services. *International Journal of Biodiversity Science, Ecosystem Services & Management, 8*(1-2), 1-4. doi: 10.1080/21513732.2012.695229

Currie, P.J., & Sarjeant, W.A.S. (1979). Lower cretaceous dinosaur footprints from the Peace River canyon, British Columbia, Canada. *Palaeogeography, Palaeoclimatology, Palaeoecology, 28:* 103-115.

Daily, G.C. (1997). *Nature's services: Societal dependence on natural ecosystems.* Washington, DC: Island Press.

Daily, G.C., Kareiva, P.M., Polasky, S., Ricketts, T.R., & Tallis, H. (2011). Mainsteaming natural capital into decisions. In Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C., & Polasky, S. (Eds.), *Natural Capital: Theory and practice of mapping ecosystem services* (pp.3-14). New York, US: Oxford University Press.

de Chazal, J., Quétier, F., Lavorel, S., & Van Doorn, A. (2008). Including multiple differing stakeholder values into vulnerability assessments of socio-ecological systems. *Global Environmental Change, 18*(3), 508-520. doi: 10.1016/j.gloenvcha.2008.04.005

de Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics, 41*(3), 393-408. doi: 10.1016/S0921-8009(02)00089-7

Diaz, S., Fargione, J., Chaplin III, F.S., & Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology, 4*(8), 1300-1305. doi: 10.1371/journal.pbio.0040277.

Díaz, S., Tilman, D., Fargione, J., Chapin III, F. S., Dirzo, R., Kitzberger, T., Gemmill, B., Zobel, M., Vila, M., Mitchell, C., Wilby, A., Daily, G.C., Galetti, M., Laurence, J.P., Rosamond, N., Power, A., & Harvell, D. (2005). Biodiversity regulation of ecosystem services. *Ecosystems and Human Well-Being: Current State and Trends*, *1*, 297-329.

Driver, J.C., Handly, M., Fladmark, K.R., Nelson, D.E., Sullivan, G.M., & Preston, R. (1996). Stratigraphy, radiocarbon dating, and culture history of Charlie Lake Cave, British Columbia. *Arctic, 49*(3), 265-277.

Dudgeon, D. (2000). Large-scale hydrological changes in tropical Asia: Prospects for riverine biodiversity. *BioScience, 50*(9), 793-806. doi: 10.1641/0006-3568(2000)050[0793:LSHCIT]2.0.CO;2

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., Naiman, R.J., Prieur-Richard, A., Soto, D., Stiassny, M.L.J., & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews, 81*(2), 163-182. doi: 10.1017/S1464793105006950

Duniway, M.C., & Herrick, J.E. (2013). Assessing impacts of roads**:** Application of a standard assessment protocol. *Rangeland Ecology & Management, 66*(3), 367-375. doi: 10.2111/REM-D-11-00130.1

Dunn, O.J. (1964). Multiple comparisons using rank sums. *Technometrics, 6*(3): 241-252.

EMKIO, Christian Martínez. Conservation International Ecuador. Quito, 2012. Cited in: Ramírez-Gómez, S.O.I., & Martínez, C. (2013). Participatory GIS, indigenous communities in Suriname identify key local sites. *ArcNews, (35)*1.

Ehrlich, P. R., & Ehrlich, A. H. (1982). *Extinction: The causes and consequences of the disappearance of species*. London: Gollancz.

Ehrlich, P.R., & Mooney, H.A. (1983). Extinction, substitution, and ecosystem services. *BioScience*, *33*(4), 248-254. doi:10.2307/1309037

Fagerholm, N., Kayhko, N., Ndumbara, F., Khamis, M. (2012). Community stakeholders' knowledge in landscape assessments- mapping indicators for landscape services. *Ecological Indicators*, *18*, 421-433. doi: 10.1016/j.ecolind.2011.12.004

Ferketic, J.S., Latimer, A.M., & Simander Jr., J.A. (2010). Conservation justice in metropolitan Cape Town: A study at the Macassar Dunes Conservation Area. *Biological Conservation, 143*(5), 1168-1174. doi: 10.1016/j.biocon.2010.02.024

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chaplin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, J.A., Patz, I., Prentice, C., Ramankutty, N., & Snyder, P.K. (2005). Global consequences of land use. *Science, 309*(5734), 570-574. doi: 10.1126/science.1111772

Fretwell, S. D. (1977). The regulation of plant communities by food chains exploiting them. *Perspectives in Biology and Medicine*, *20*(169), 85.

Gamfeldt, L., Snail, T., Bagchi, R., Jonsson, M., Gustafsson, L., Kjellander, P., Ruiz-Jaen, M.C., Fröberg, M., Stendahl, J., Philipson, C.D., Mikusiński, G., Andersson, E., Westerlund, B., Andrén, H., Moberg, F., Moen, J., & Bengtsson, J. (2013). Higher levels of multiple ecosystem services are found in forests with more tree species. *Nature Communications*, *4*(1340), 1-8. doi: 10.1038/ncomms2328

Gos, P., & Lavorel, S. (2012). Stakeholders' expectations on ecosystem services affect the assessment of ecosystem services hotspots and their congruence with biodiversity. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *8*(1-2), 93-106. doi: 10.1080/21513732.2011.646303

Guerin, E. (2012). Disentangling vitality, well-being and quality of life: A conceptual examination emphasizing their similarities and differences with special application in the physical activity domain. *Journal of Physical Activity and Health*, *9*(6), 896-908.

Guo, Z., Zhang, L., & Li, Y. (2010). Increased dependence of humans on ecosystem services and biodiversity. *PLoS ONE 5*(10):1-9. doi:10.1371/journal.pone.0013113

Gutiérrez, M. R. V. A., & Alonso, M. L. S. (2013). Which are, what is their status and what can we expect from ecosystem services provided by Spanish rivers and riparian areas? *Biodiversity and Conservation*, *22*(11), 2469-2503. doi: 10.1007/s10531-013-0532-2

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In Raffaelli, D.G., & Frid, C.L.J. (Eds.), *Ecosystem ecology: a new synthesis* (pp. 111-139). New York, US: Cambridge University Press.

Hartter, J. (2010). Resource use and ecosystem services in a forest park landscape. *Society and Natural Resources*, *23*(3), 207-223.

Hector, A., Schmid, B., Beierkuhnlein, C., Caldeira, M. C., Diemer, M., Dimitrakopoulos, P., Finn, J.A., Freitas, H., Giller, P.A., Good, J., Harris, R., Hogberg, P., Huss-Danell, K., Joshi, J., Jumpponen, A., Korner, C., Leadley, P.W., Loreau, M., Minns, A., Mulder, C.P.H., O'Donovan, G., Otway, S.J., Pereira, J.S., Prinz, A., Read, D.J., Scherer-

Lorenzen, M., Schulze, E.D., Siamantziouras, S.D., Spehn, E.M., Terry, A.C., Troumbis, A.Y., Woodward, F.I., Yachi, S., & Lawton, J. H. (1999). Plant diversity and productivity experiments in European grasslands. *Science*, *286*(5442), 1123-1127. doi: 10.1126/science.286.5442.1123

Hein, L., van Koppen K., de Groot, R.S., & van Ierland, E.C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. *Ecological Economics, 57*(2), 209-228. doi: 10.1016/j.ecolecon.2005.04.005

Hilton, S., Andrusiak, L., Krichbaum, R., Simpson, L., & Bjork, C. (2013). *Part 1 vegetation and ecological communities: Terrestrial vegetation and wildlife report. Site C clean energy project.* Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-1-Vegetation.pdf

Hilton, S., Andrusiak, L., Simpson, L., & Sarell, M. (2013). *Part 3 amphibians and reptiles: Terrestrial vegetation and wildlife report.* Site C clean energy project. Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-3-Amphibians.pdf

Hilton, S., & Simpson, L. (2013*). Part 5 non-migratory birds: Terrestrial vegetation and wildlife report. Site C clean energy project*. Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-5-NonMigratory_Birds.pdf

Hilton, S., Simpson, L., & Andrusiak, L. (2013*). Part 6 raptors: Terrestrial vegetation and wildlife report. Site C clean energy project.* Retrieved from Canadian Environmental

Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-6-Raptors.pdf

Hilton, S., Simpson, L., Andrusiak, L., & Albrecht, C. (2013). *Part 4 migratory bird: Terrestrial vegetation and wildlife report. Site C clean energy project*. Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-4-Migratory_Birds.pdf

Hilton, S., Simpson, L., & Guppy, L. (2013). *Part 2 butterflies and dragonflies: Terrestrial vegetation and wildlife report. Site C clean energy project.* Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-2-Butterflies.pdf

Hooper, D. U., Adair, E. C., Cardinale, B. J., Byrnes, J. E., Hungate, B. A., Matulich, K. L., Gonzalez, A., Duffy, J.E., Gamfeldt, L. & O'Connor, M. I. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature*, *486*(7401), 105-108. doi:10.1038/nature11118

Hunt, A. D., & Ratcliffe, J. D. (2004). Triassic stratigraphy, Peace River area, Alberta and British Columbia, Canada. *AAPG Bulletin*, *43*(3), 563-589.

Hui, D. (2013). Global climate change and biodiversity: Issues and future research. *Journal of Biodiversity and Endangered Species, 1*(1), 1-2. doi: 10.4172/jbes.1000e105

Iceland, C., Hanson, C., & Lewis, C. (2008). Identifying important ecosystem goods and services in Puget Sound. *World Resources Institute*.

Integrated Land Management Bureau (1997) Fort St. John Land and resource management plan: Section 4.0 protected areas. Retrieved from http://archive.ilmb.gov.bc.ca/slrp/lrmp/fortstjohn/fort_stjohn/plan/4.htm

Isbell, F., Calgagno, V., Hector, A., Connolly, J., Harpole, W.S., Reich, P.B., Scherer-Lorenzen, M., Schmid, B., Tilman, D., van Ruijven, J., Weigelt, A., Wilsey, B.J., Zaveleta, E.S, & Loreau, M. (2011). High plant diversity is needed to maintain ecosystem services. *Nature*, *477*(7363), 199-203. doi: 10.1038/nature10282

Jones-Walters, L., & Cil, A. (2011). Biodiversity and stakeholder participation. *Journal for Nature Conservation*, *19*(6), 327-329. doi: 10.1016/j.jnc.2011.09.001

Klain, S.C., & Chan, K.M.A. (2012). Navigating coastal values: participatory mapping of ecosystem services for spatial planning. *Ecological Economics, 82*, 104. doi: 10.1016/j.ecolecon.2012.07.008

Koehler, K. J., & Larntz, K. (1980). An empirical investigation of goodness-of-fit statistics for sparse multinomials. *Journal of the American Statistical Association*, *75*(370), 336-344.

Kuo, F.E. (2013). Nature-deficit disorder: evidence, dosage, and treatment. *Journal of Policy Research in Tourism, Leisure and Events*, *5*(2), 172-186. doi: 10.1080/19407963.2013.793520

Lamarque, P., Tappeiner, U., Turner, C., Steinbacher, M., Bardgett, R.D., Szukics, M., & Lavorel, S. (2011). Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. *Regional Environmental Change*, *11*(4), 791-804. doi: 10.1007/s10113-011-0214-0

Lindenmayer, D.B., & Fischer, J. (2006). *Habitat fragmentation and landscape change: An ecological and conservation synthesis.* Washington, DC: Island Press.

Louis, V. L. S., Kelly, C. A., Duchemin, É., Rudd, J. W., & Rosenberg, D. M. (2000). Reservoir surfaces as sources of greenhouse gases to the atmosphere: A global estimate. *BioScience*, *50*(9), 766-775.

Mace, G.M., Norris, K., & Fitter, A.H. (2011). Biodiversity and ecosystem services: a multilayered relationship. *Trends in Ecology and Evolution, 27*(1), 19-26. Doi: 10.1016/j.tree.2011.08.006

Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., & Niggli, U. (2002). Soil fertility and biodiversity in organic farming. *Science*, *296*(5573), 1694-1697.

Maestre, F.T., Quero,J.L., Gotelli, N.J., Escudero, A., Ochoa, V., Delgado-Baquerizo, M., García-Gómez, M., Bowker, M.A., Soliveres,S., Escolar, C., García-Palacios, P., Berdugo, M., Valencia, E., Gozalo, B., Gallardo, A., Aguilera, L., Arredondo, T., Blones, J., Boeken, B.,Bran, D., Conceição, A.A., Cabrera, O., Chaieb, M., Derak, M., Eldridge, D.J., Espinosa, C.I., Florentino, A., Gaitán, J., Gatica, M.G., Ghiloufi,W., Gómez-González, S., Gutiérrez, J.R., Hernández, R.M., Huang, X., Huber-Sannwald, E., Jankju, M., Miriti, M., Monerris, J., Mau, R.L., Morici, E., Naseri, K., Ospina, A., Polo, V., Prina, A., Pucheta, E., Ramírez-Collantes, D.A., Romão, R., Tighe, M., Torres-Díaz, C., Val, J., Veiga, J.P., Wang, D., & Zaady, E. (2012). Plant species richness and ecosystem multifunctionality in global drylands. *Science, 335*(6065), 214-218. doi: 10.1126/science.1215442

Mainstream Aquatics Ltd. (2012). Site C Clean Energy Project: Fish and Fish Habitat Technical Data Report. Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_O.pdf

Martin-Lopez, B., Iniesta-Arandia, I., Garcia-Llorente, M., Palomo, I., Casado-Arzuaga, I., Amo, D.G.D., Gomez-Baggethun, E., Oteros-Rozas, E., Palacios-Agundez, I., Willaarts, B., Gonzalez, J.A., Santos-Martin, F., Onaindia, M., Lopez-Santiago, C., & Montes, C. (2012). Uncovering ecosystems service bundles through social preferences. PLoS one, 7(6), e38970. doi: 10.1371/journal.pone.0038970

Martínez-Harms, M.J., & and Balvanera, P. (2012). Methods for mapping ecosystem service supply: a review. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *8*(1-2), 17-25. http://dx.doi.org/10.1080/21513732.2012.663792

McCall, M. K. (2006). Precision for whom? Mapping ambiguity and certainty in (participatory) GIS. *Participatory Learning and Action*, *54*(1), 114-119.

McLaughlin, A., & Mineau, P. (1995). The impact of agricultural practices on biodiversity. *Agriculture, Ecosystems & Environment*, *55*(3), 201-212. doi: 10.1016/0167-8809(95)00609-V

Menzel, S., & Teng, J. (2010). Ecosystem services as a stakeholder-driven concept for conservation science. *Conservation Biology*, *24*(3), 907-909. doi: 10.1111/j.1523-1739.2009.01347.x

Millennium Ecosystem Assessment (MEA). (2005). *Ecosystems and human well-being: Biodiversity synthesis.* Retrieved from http://www.maweb.org/en/Reports.aspx

Miller, B., Dugelby, B., Foreman, D., del Rio, C. M., Noss, R., Phillips, M., Reading, R., Soule, M.E., Terborgh, & Willcox, L. (2001). The importance of large carnivores to healthy ecosystems. *Endangered Species Update*, *18*(5), 202-210.

Mitchell, M. G., Bennett, E. M., & Gonzalez, A. (2013). Linking landscape connectivity and ecosystem service provision: Current knowledge and research gaps. *Ecosystems*, 1-15. doi: 10.1007/s10021-013-9647-2

Morita, K., & Yamamoto, S. (2002). Effects of habitat fragmentation by damming on the persistence of stream- dwelling charr populations. *Conservation Biology*, *16*(5), 1318-1323. Doi: 10.1046/j.1523-1739.2002.01476.x

Naidoo, R., & Iwamura, T. (2007). Global-scale mapping of economic benefits from agricultural lands: implications for conservation priorities. *Biological Conservation*, *140*(1), 40-49.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R. E., Lehner, B., Malcolm, T.R., & Ricketts, T. H. (2008). Global mapping of ecosystem services and conservation priorities. *Proceedings of the National Academy of Sciences*, *105*(28), 9495-9500. doi: 10.1073/pnas.0707823105

Naiman, R.J., Decamps, H., & Pollock, M. (1992). The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications*, *3*(2), 209-212.

Nagendra, H., Reyers, B., & Lavorel, S. (2013). Impacts of land change on biodiversity: making the link to ecosystem services. *Current Opinion in Environmental Sustainability*, *5*, 1-6. Doi: http://dx.doi.org/10.1016/j.cosust.2013.05.010

Nilsson, C., & Berggren, K. (2000). Alterations of riparian ecosystems caused by river regulation. *BioScience*, *50*(9), 783-792. doi: 10.1641/0006-3568(2000)050[0783:AORECB]2.0.CO;2

North Peace Economic Development Commission. (2011). *Spatial export analysis: Assessing the contribution of the northeast and peace river regions to British Columbia's* *exports*. Retrieved from http://npedc.ca/sites/npedc.ca/files/document/106/northeast-peace-river-exports-final-urban-futures-4-october-2011.pdf

Pasari, J. R., Levi, T., Zavaleta, E. S., & Tilman, D. (2013). Several scales of biodiversity affect ecosystem multifunctionality. *Proceedings of the National Academy of Sciences*, *110*(25), 10219-10222. doi: 10.1073/pnas.1220333110

Phillips, A. (1998). The nature of cultural landscapes—a nature conservation perspective. *Landscape Research*, *23*(1), 21-38. doi: 10.1080/01426399808706523

Plieninger, T., Dijks, S., Oteros-Rozas, E., & Bieling, C. (2013). Assessing, mapping, and quantifying cultural ecosystem services at community level. *Land Use Policy*, *33*, 118-129. doi: 10.1016/j.landusepol.2012.12.013

Polasky, S., Caldarone, T., Duarte, Ka'eo Duarte, T., Goldstein, J., Hannahs, N., Ricketts, T., & Tallis, H. (2011). In Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C., & Polasky, S. (Eds.), *Natural Capital: Theory and practice of mapping ecosystem services* (pp.249-263). New York, US: Oxford University Press.

Postel, S., & Carpenter, S. (1997). Freshwater ecosystem services. In Daily, G. (Ed.) Nature's services: Societal dependence on natural ecosystems (pp. 195-214). Washington, DC: Island Press.

Provincial Government of British Columbia. (n.d.). *B.C. conservation data centre home.* Retrieved from http://www.env.gov.bc.ca/cdc/

Provincial Government of British Columbia. (1997). Fort St. John land and resource management plan. Retrieved from Integrated Land Management Bureau http://archive.ilmb.gov.bc.ca/slrp/lrmp/fortstjohn/fort_stjohn/plan/toc.htm

Provincial Government of British Columbia, Refractions Research Inc. (2007). *Freshwater atlas: Watershed boundary generation process flow.* Retrieved from ftp://ftp.geobc.gov.bc.ca/pub/outgoing/FreshWaterAtlasDocuments/FWA1.2.WatershedBoundaryProcess.rev2.pdf

Provincial Government of British Columbia (2011). *Land use operational policy: Communication sites.* Retrieved from http://www.for.gov.bc.ca/land_tenures/documents/policies/communication_sites.pdf

Raymond, C.M., Bryan, B.A., MacDonald, D.H., Cast, A., Strathearn, S., Grandgirard, A., & Kalivas, T. (2009). Mapping community services for natural capital and ecosystem services. *Ecological Economics, 68*(5), 1301-1315. doi: 10.1016/j.ecolecon.2008.12.006

Redford, K. H., & Adams, W. M. (2009). Payment for ecosystem services and the challenge of saving nature. *Conservation Biology*, *23*(4), 785-787. doi: 10.1111/j.1523-1739.2009.01271.x

Resource Information Standards Committee. (2006). *Standards for mapping ecosystems at risk in British Columbia: An approach to mapping ecosystems at risk and other sensitive ecosystems. Version 1.0.* Retrieved from BC Ministry of Environment, Ecosystems Branch.: http://www.env.gov.bc.ca/fia/documents/standards_for_mapping_ear_version1.pdf

Rodríguez, J. P., Beard, T.D., Bennett, E.M., Cumming, G.S., Cork, S., Agard, J., Dobson, A.P., & Peterson, G.D. (2006). Trade-offs across space, time, and ecosystem services. *Ecology and Society, 11*(1): 28-42.

Roscoe, J. T., & Byars, J. A. (1971). An investigation of the restraints with respect to sample size commonly imposed on the use of the chi-square statistic. *Journal of the American Statistical Association*, *66*(336), 755-759.

Ruiz-Frau, A., Edwards-Jones, G., & Kaiser, M. J. (2011). Mapping stakeholder values for coastal zone management. *Marine Ecology Progress Series*, *434*, 239-249. doi: 10.3354/meps09136

Russell, R., Guerry, A.D., Balvanera, P., Gould, R.K., Basurto, X., Chan, K.M.A., Klain, S., Levine, J., & Tam, J. (2013). Humans and nature: How knowing and experiencing nature affect well-being. *Annual Review of Environment and Resources*, *38*, 473-502. doi: 10.1146/annurev-environ-012312-110838.

Sala, O.E., Chapin III, F., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H.A., Oesterheld, M., LeRoy, P.N., Sykes, M.T., Walker, B.H., Walker, M., & Wall, D.H. (2000). Global biodiversity scenarios for the year 2100. *Science*, *287*(5459), 1770-1774, doi: 10.1126/science.287.5459.1770

Schagner, J.P., Brander, L., Maes, J., & Hartje, V. (2013). Mapping ecosystem services' values: Current practice and future prospects. *Ecosystem Services*, *4*, 33-46. doi: 10.1016/j.ecoser.2013.02.003

Species at Risk Act (2002). Subsection 2(1), 42(2) and 68(2). (2003). Retrieved from http://www.sararegistry.gc.ca/approach/act/sara_e.pdf

Schaich, H., Bieling, C., & Plieninger, T. (2010). Linking ecosystem services with cultural landscape research, *Gaia*, *19*(4), 269-277.

Smith, L.M., Case, J.L., Smith, H.M., Harwell, L.C., & Summers, J.K. (2013). Relating ecosystem services to domains of human well-being: Foundation for a U.S. index. *Ecological Indicators*, *28*, p.79-90. doi: 10.1016/j.ecolind.2012.02.032

Simpson, K., Simpson, T.K., Simpson, L., Andrusiak, L., Hilton, S., Kellner, M., Klafki, K, Mattson, I., & Creagh, A. (2013). Part 7 mammals: Terrestrial vegetation and wildlife report. Site c clean energy project. Retrieved from Canadian Environmental Assessment Agency: http://www.ceaa-acee.gc.ca/050/documents_staticpost/63919/85328/Vol2_Appendix_R-7-Mammals.pdf

Tallis, H., Pagiola, S., Zhang, W., Shaikh, S., Nelson, E., Stanton, C., & Shyamsundar, P. (2011). Poverty and the distribution of ecosystem services. In Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C., & Polasky, S. (Eds.), *Natural Capital: Theory and practice of mapping ecosystem services* (pp.3-14). New York, US: Oxford University Press.

Tengberg, A., Fredholm, S., Eliasson, I., Knez, I., Saltzman, K. & Wetterberg, O. (2012). Cultural ecosystem services provided by landscapes: Assessment of heritage values and identity. *Ecosystem Services, 2*, 14-26. doi: 10.1016/j.ecoser.2012.07.006

Thompson, I.D., Okabe, K., Tylianakis, J.M., Kumar, P., Brockerhoff, E.G., Schellhorn, N.A., Parrotta, J.A. & Nasi, R. (2011). Forest biodiversity and the delivery of ecosystem goods and services: Translating science into policy. *BioScience, 61*(12), 972-981. doi: 10.1525/bio.2011.61.12.7

Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., Schindler, D., Schlesinger, W.H., Simberloff, D., & Swackhamer, D. (2001). Forecasting agriculturally driven global environmental change. *Science*, *292*(5515), 281-284.

Tobias, S. (2013). Preserving ecosystem services in urban regions: Challenges for planning and best practice examples from Switzerland. *Integrated Environmental Assessment and Management, 9*(3), 243-251.

Trombulak, S. C., & Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*, *14*(1), 18-30.

Turner, N.J., Ignace, M.B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications, 10*(5), 1275-1287. doi: 10.1890/1051-0761(2000)010[1275:TEKAWO]2.0.CO;2

United Nations. (1992). *Convention on biological diversity.* Available: http://www.cbd.int/doc/legal/cbd-en.pdf

McAllister, D., Craig, J. F., Davidson, N., Delany, S., & Seddon, M. (2001). Biodiversity impacts of large dams. *Background paper, 1*.

Valentine, K.W.G., Fladmark, K.R., & Spurling, B.E. (1980). The description, chronology and correlation of buried soils and cultural layers in a terrace section, Peace River Valley, British Columbia. *Canadian Journal of Soil Science, 60*: 185-197.

van Berkel, D.B., & Verburg, P.H. (2012). Spatial quantification and valuation of cultural ecosystem services in an agricultural landscape. *Ecological Indicators, 27*(5), 641-658. doi: 10.1007/s10980-012-9730-7

Wang, J., Cui, B., Liu, S., Dong, S., Wei, G., & Liu, J. (2007). Effects of road networks on ecosystem service value in the longitudinal range-gorge region. *Chinese Science Bulletin, 52*(II), 180-191. doi: 10.1007/s11434-007-7022-4

Wilson, E.O. & Peter, F.M. (Eds.) (1998). Biodiversity. Washington, DC: National Academy Press.

Young, J. C., Jordan, A., Searle, K. R., Butler, A., Chapman, D.S., Simmons, P., & Watt, A. D. (2013). Does stakeholder involvement really benefit biodiversity conservation? *Biological Conservation*, *158*, 359-370. doi: 10.1016/j.biocon.2012.08.018

Zedler, J. B., & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. *Annual Reviews of Environment and Resources*, *30*, 39-74. doi: 10.1146/annurev.energy.30.050504.144248

Zhu, X., Pfueller, S., Whitelaw, P., & Winter, C. (2010). Spatial differentiation of landscape values in the Murray River Region of Victoria, Australia. *Environmental Management*, *45*(5), 896-911. doi: 10.1007/s00267-010-9462-x

Appendix A- Online Survey Consent Form

Your Use of Nature's Services
My name is Rachel Darvill and this research project, 'Comparing the Use of Ecosystem Services across Interest Groups', is part of the requirement for a Master of Science degree in Environment and Management at Royal Roads University. Dr. Chris Ling, associate professor with the School of Environment and Sustainability at Royal Roads University, can establish my credentials. He can be reached at [redacted] or by calling [redacted]

Data collection for this research project consists of the online survey to follow, in addition to follow-up Geographic information System (or GIS) mapping sessions that will use a smaller subset of participants. The survey questions ask participants about their use of nature and its services, or the benefits nature provides, within the Upper Peace River watershed. In addition to submitting my final report to Royal Roads University in partial fulfillment for a Master of Science in Environment and Management degree, I will also be sharing my research findings with Wildsight Golden, my sponsor organization.

The data will also be used to publish articles in peer-reviewed research journals, and to share the results to any other interested parties within or outside of the study area. A copy of the final report will be published and archived in the Royal Roads University Library, or I can be contacted for a copy. This study's outcomes will be useful to interest groups by empowering them with knowledge related to regional ecosystem service use. It will provide recommendations for future conservation priorities necessary to maintain critical ecosystem services, and thus regional human well-being.

The information you provide will be summarized in anonymous format in the body of the final report. At no time will any specific comments be attributed to any individual unless a specific agreement has been obtained beforehand. All documentation will be kept strictly confidential. Raw data will be kept indefinitely for research purposes only. You are not obligated to participate in this research project. If you choose to withdraw or abstain from participation, your refusal will be maintained in confidence. In addition, the data collected will not be retained pertaining to an individual who has withdrawn at any time.

This survey should take you about 15-25 minutes to complete and it will be open until June 30, 2013. Completing this survey will indicate your acceptance for your involvement in this survey.

Please feel free to circulate this survey. If you do, please use this link:http://fluidsurveys.com/s/youruseofnaturesservices/

Thank-you for your participation!
Sincerely, Rachel Darvill, BSc Biology, MSc Environment and Management candidate

Appendix B- Online Survey

How long have you lived in (or adjacent to) the Upper Peace River Watershed? Please refer to the map below, which outlines the Upper Peace River Watershed boundaries in the color orange/salmon.

○ Less than 1 year

○ 1-5 years

○ 6-10 years

○ 11-15 years

○ More than 15 years (born elsewhere)

○ More than 15 years (I was born here)

In what type of community do you live?

○ City or urban community

○ Suburban community

○ Rural Community

○ First Nations reserve

What is the name of the rural area, community or reserve where you live?

[ ]

What is your occupation/livelihood?

[ ]

What interest group do you most closely identify/associate with ?

○ Local Government

○ Provincial Government

- ○ Federal Government
- ○ First Nations Government
- ○ West Moberly First Nations
- ○ Saulteau First Nations
- ○ Halfway River First Nations
- ○ Prophet River First Nations
- ○ Doig River First Nations
- ○ Industry
- ○ Agriculturalist/Farmer
- ○ Environmentalist/Conservationist
- ○ Hunter
- ○ Fisher
- ○ Motorized recreationist
- ○ Non-motorized recreationist
- ○ Business Owner
- ○ Community (e.g. Chamber of Commerce, Artist, Rotary Club)
- ○ Other

If applicable, what other interest group do you most closely identify/associate yourself with, second only to your choice in the previous question ?

- ○ Local Government
- ○ Provincial Government
- ○ Federal Government
- ○ First Nations Government

- West Moberly First Nations
- Saulteau First Nations
- Halfway River First Nations
- Prophet River First Nations
- Doig River First Nations
- Industry
- Agriculturalist/Farmer
- Environmentalist/Conservationist
- Hunter
- Fisher
- Motorized recreationist
- Non-motorized recreationist
- Business Owner
- Community (e.g. Chamber of Commerce, Artist, Rotary Club)
- Other

Please select the age group that you belong to.

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 or Above

○ Prefer Not to Answer

What is your gender?

○ Male

○ Female

○ I Prefer Not to Answer

Have you heard of the ‘Ecosystem Services’ concept prior to participating in this research?

○ Yes

○ No

○ Unsure

Before we move forward, I would like to provide you with a widely accepted definition for the term ‘ecosystem services.’ Ecosystem services are the resources that come from nature and bring benefits to humans (Daily, 1997), and that contribute to making human life both possible and worth living (Diaz et al., 2006). They are necessary for human well-being to persist. In this survey, you will be asked questions regarding your use of ecosystem services within two main categories: 1) Provisioning Services. These are material products (human benefits) that come from nature, such as food, timber and freshwater. 2) Cultural Services. These are the non-material benefits that you receive from nature, such as aesthetic beauty, recreational opportunities, spiritual enrichment, cultural or historical heritage. Please consider the services that you use within the Upper Peace River Watershed boundary ONY; the area within the orange colored boundary line.

Given this definition, do you think that human use of ‘ecosystem services’ is important to consider when making major land-use decisions?

○ Not Important

○ Somewhat Important

○ Very Important

○ It's Essential

○ Unsure, please explain... ________________________

Do you use the land within the Upper Peace River Watershed to grow or raise local food for personal consumption or profit? For example, do you have a garden, agricultural crops, or raise livestock?

○ Yes

○ No

○ Unsure, please explain... ________________________

What kind(s) of local food do you grow/raise in the Upper Peace River Watershed? Please select all that apply and consider local sources such as agricultural crops, livestock and backyard gardens.

□ Vegetables

□ Fruit

□ Mushrooms

□ Wheat

□ Barley

□ Oats

□ Canola

□ Honey from beehives

□ Birds

□ Livestock

☐ Aquaculture

☐ Other, please list: ______________________

Although you do not use the local landscapes to raise or grow food, is it important to you to be able to purchase food that was grown locallly?

○ Yes

○ No

○ Unsure, please explain... ______________________

On average over a 12 month period, how often do you fish recreationally, for personal consumption, or for your livelihood within the Upper Peace River Watershed?

○ I never fish

○ Less than once per month on average

○ 1-2 day(s) per month

○ 3-4 days per month

○ 5-10 days per month

○ Greater than 10 days per month

Please select all of the reasons you fish.

☐ Recreation/pleasure

☐ Personal consumption

☐ For my livelihood/occupation

☐ Other, please list ______________________

On average, over a 12 month period, do you use the local area (Upper Peace River Watershed) to hunt or trap wild mammals and/or birds? If you do, please include the days that you go out to hunt/trap, but are unsuccessful at harvesting.

○ I never hunt/trap

○ Less than once per month on average

○ 1-2 day(s) per month on average

○ 3-4 days per month on average

○ 5-10 days per month on average

○ Greater than 10 days per month on average

Please select all of the reasons you hunt or trap wild mammals and/or birds.

□ Recreation/pleasure

□ Personal consumption

□ For my livelihood/occupation

□ Other, please list ______________________

What kind of mammal/bird species do you typically hunt/trap on an annual basis? Please select all that apply. Additionally, in the space located next to the species you select, please indicate how many of each species you typically harvest in one year.

□ Mule Deer ______________________

□ Elk ______________________

□ Plains Bison ______________________

□ Stone's Sheep ______________________

□ Mountain Goat ______________________

□ Caribou ______________________

□ Beaver ______________________

□ Moose ______________________

□ Grizzly Bear ______________________

- ☐ Black Bear ______________________
- ☐ Wolf ______________________
- ☐ Other, please list species ______________________
- ☐ I will abstain from this question

Do you use wood that is harvested from local forest stands within the Upper Peace River Watershed? If you do, please select all that apply.

- ☐ No
- ☐ Unsure where the wood comes from that I use
- ☐ Yes, as a fuel source for heat
- ☐ Yes, as a fuel source for cooking
- ☐ Yes, for lumber/building
- ☐ Yes, but for other reasons. Please list them. ______________________

Do you collect freshwater for domestic purposes (i.e. drinking, washing dishes, watering your garden, etc.) from any other source other than from your municipal water system? If so, please select all sources that apply.

- ☐ No, I use the municipal water system as my only water source
- ☐ Groundwater well
- ☐ I collect surface water from my roof (i.e. rain barrels, etc.)
- ☐ I collect surface water on my property (creek, river)
- ☐ I collect surface water off my property (creek, river)
- ☐ I collect water from a spring
- ☐ Other, please specify...

When in season, do you use specific places to collect wild plants, berries or mushrooms that you then use for tea, herbs, edibles and/or medicinal purposes? If yes, please select all your wild edible uses.

- ☐ No, I do not collect wild edibles
- ☐ Food (including herbs)
- ☐ Medicinal Purposes
- ☐ Tea
- ☐ Other, please list ______________________

On average, how often do you collect wild edibles when they are in season?

- ○ Less than once per month on average
- ○ 1-2 day(s) per month on average
- ○ 3-4 days per month on average
- ○ 5-10 days per month on average
- ○ Greater than 10 days per month on average

Do you use locations within the Upper Peace River Watershed to collect natural materials (i.e. flowers, rocks, animals skins, feathers, shells, etc.), which you then use for crafts, ornamental or decorative purposes?

- ○ Yes
- ○ No

On average, over a 12 month period how often do you use locations within the Upper Peace River Watershed to collect natural materials (i.e. flowers, rocks, animals skins, feathers, shells, etc.), which you then use for crafts, ornamental or decorative purposes?

- ○ Less than once per month on average

- ○ 1-2 day(s) per month on average
- ○ 3-4 days per month on average
- ○ 5-10 days per month on average
- ○ Greater than 10 days per month on average

On average, over a 12 month period, do you use local landscapes or places of nature for spiritual or religious reasons? Examples may include using landscapes for meditation, self-rejuvenation, ceremonies, etc.

- ○ Never
- ○ Less than once per month
- ○ 1-2 times per month
- ○ 3-4 days per month
- ○ 5-10 days per month
- ○ Greater than 10 days per month

On average over a 12 month period, do you use local landscapes, or place of nature, for scientific or educational reasons?

- ○ Never
- ○ Less than once per month
- ○ 1-2 times per month
- ○ 3-4 days per month
- ○ 5-10 days per month
- ○ Greater than 10 days per month

On average over a 12 month period, do you use local places of nature solely for their aesthetic, scenic or awe-inspiring beauty?

- ○ Never
- ○ Less than once per month
- ○ 1-2 times per month
- ○ 3-4 days per month
- ○ 5-10 days per month
- ○ Greater than 10 days per month

On average over a 12 month period, do you use specific places for the inspiration they give to you for art, song, stories, dance, etc.?

- ○ Never
- ○ Less than once per month
- ○ 1-2 times per month
- ○ 3-4 days per month
- ○ 5-10 days per month
- ○ Greater than 10 days per month

How would you rate the local natural landscapes and/or local wildlife in terms of their importance to your overall feeling of attachment or belonging to the Peace region?

- ○ Not Important
- ○ Somewhat Important
- ○ Very Important
- ○ Essential
- ○ Unsure, please explain... ________________________

On average, over a 12 month period, do you use or visit specific local areas for their cultural and/or historical heritage (i.e. historical homestead, historical middens, birth sites, burial sites, etc.)?

- ○ Never
- ○ Less than once per month
- ○ 1-2 times per month
- ○ 3-4 days per month
- ○ 5-10 days per month
- ○ Greater than 10 days per month
- ○ Unsure, please explain... ______________________

Do you use specific locations in the Upper Peace River Valley for recreational purposes (non motorized or motorized)?

- ○ Yes
- ○ No

What kinds of nature-based recreational activities do you take part in, within the Upper Peace River Watershed? Please select all that apply.

- ☐ Hiking
- ☐ Motorized boating
- ☐ Canoeing
- ☐ Kayaking
- ☐ Biking
- ☐ Swimming
- ☐ ATVing (quading, dirtbiking, etc.)

- ☐ Bird watching
- ☐ Camping
- ☐ Picnicking
- ☐ Photography
- ☐ Catch and release fishing (i.e. not for food)
- ☐ Cross-country skiing
- ☐ Snowshoeing
- ☐ Snowmobiling
- ☐ Other, please specify... ________________________

On average over a 12-month period, how often do you take part in nature-based recreational activities, which you selected in the previous question?

- ☐ Less than once per month
- ☐ 1-2 times per month
- ☐ 3-4 days per month
- ☐ 5-10 days per month
- ☐ Greater than 10 days per month

Do you use specific locations for observing the local wildlife (including mammals, birds and fish)?

- ○ Yes
- ○ No

How often do you purposefully use the local landscape to observe, or try to observe, the local wildlife (i.e. mammals, birds and/fish)?

- ○ Less than once per month

- ○ 1-2 times per month
- ○ 3-4 days per month
- ○ 5-10 days per month
- ○ Greater than 10 days per month

What species (excluding humans) living in the Upper Peace River Watershed are the most important to you, for either personal or professional reasons?

- ☐ Deer
- ☐ Elk
- ☐ Plains Bison
- ☐ Stone's Sheep
- ☐ Mountain Goat
- ☐ Caribou
- ☐ Beaver
- ☐ Moose
- ☐ Grizzly Bear
- ☐ Black Bear
- ☐ Wolf
- ☐ Cougar
- ☐ Lynx
- ☐ Bobcat
- ☐ Fish, please specify which species... ______________________
- ☐ Birds , please specify which species... ______________________
- ☐ Other, please specify which species ______________________

☐ All species are equally important to me

Below is a list for some of the 'ecosystem services' that you might use in the Upper Peace River Watershed. Please choose the top five 'ecosystem services' THAT YOU USE THE MOST in the Upper Peace River Watershed. Rank in order, with #1 given to the service that you USE the most.

	#1	#2	#3	#4	#5
Fruits/Vegetables	○	○	○	○	○
Fish (for food and/or recreational use)	○	○	○	○	○
Livestock	○	○	○	○	○
Wood (for fuel and/or for building)	○	○	○	○	○
Natural medicines	○	○	○	○	○
Wild edible plants (used for food and/or natural medicines)	○	○	○	○	○
Wildlife used for food	○	○	○	○	○
Wildlife used for viewing	○	○	○	○	○
Ornamental resources for decorative use (e.g. flowers, plants, shells, animal skins, bark)	○	○	○	○	○
Freshwater for personal use	○	○	○	○	○
Outdoor recreation (motorized)	○	○	○	○	○
Outdoor recreation (non-motorized)	○	○	○	○	○
Landscapes used for their aesthetic/scenic value	○	○	○	○	○
Landscapes used for their spiritual or religious value	○	○	○	○	○
Landscapes used for educational/scientific purposes	○	○	○	○	○
Landscapes used for thier cultural or historical heritage	○	○	○	○	○

Landscapes that give me a sense of belonging	○	○	○	○	○
Landscapes used for inspiration	○	○	○	○	○

During the time that you have lived in the area, do you think there has been a change in the 'ecosystem services' (i.e. benefits that you receive from nature), which you use within the Upper Peace River watershed? You can optionally explain why you think this change has, or has not occured.

There has been a:

- ○ Significant increase in ecosystem services ______________________
- ○ Slight increase in ecosystem services ______________________
- ○ No change in ecosystem services ______________________
- ○ Slight decrease in ecosystem services ______________________
- ○ Significant decrease in ecosystem services ______________________
- ○ Unsure ______________________

Over the next 10 years, do you think that there will be a change in the 'ecosystem services' (i.e. benefits that you get from nature), which you use within the Upper Peace River watershed?You can optionally explain your response.

Over the next 10 years, I think there will be a:

- ○ Significant increase in ecosystem services, please explain... ______________________
- ○ Slight increase in ecosystem services, please explain... ______________________
- ○ No change in ecosystem services, please explain... ______________________
- ○ Slight decrease in ecosystem services, please explain... ______________________
- ○ Significant decrease in ecosystem services, please explain... ______________________
- ○ Unsure, please explain... ______________________

Thank you for your participation in this survey! Are you interested in learning more about how you could participate further with this Masters level research project, regarding your use of ecosystem services in the Upper Peace River Watershed?

- ○ Yes
- ○ No

Masters student Rachel Darvill will be holding in-person meetings in May/June 2013 in the Peace River Region with participants who are willing to share the locations on a map, of where they personally use specific ecosystem services (i.e. where they recreate, where they view wild animals, where they use inspirational landscapes, etc.). If you or your interest group participates in a mapping session, a presentation will be given beforehand so that you can learn more about the research, and also be given simple instructions for how you can map the locations where you use ecosystem service within the Upper Peace River Watershed.

If you are interested or want to know more, please contact Rachel at [redacted] or email her your contact info at [redacted]

If you don't email or phone me, I have no way to contact you. Please circulate this survey using this link...http://fluidsurveys.com/s/youruseofnaturesservices/

Thanks again for your participation!

Appendix C- Mapping Ecosystem Service Use Consent Form

My name is Rachel Darvill and this research project, 'Comparing the Use of Ecosystem Services across Interest Groups', is part of the requirement for a Master's of Science degree in Environment and Management at Royal Roads University. Dr. Chris Ling, associate professor with the School of Environment and Sustainability at Royal Roads University, can establish my credentials. He can be reached at [redacted] or by calling [redacted]

This document constitutes an agreement to participate in my research project, the objective of which is to compare the use of ecosystem services across interest groups. Ecosystem services are those benefits that humans acquire from nature. Data collection during this interview will consist of closed-ended questions that will ask you things such as: where you live, your age, gender, occupation, and what interest group you associate with. Additionally, you will be asked if you use specific ecosystem services within the Upper Peace River watershed and if you do, you will be asked to draw polygons around the areas where you use them within the landscape.

In addition to submitting my final report to Royal Roads University in partial fulfillment for a Master's of Science in Environment and Management degree, I will also be sharing my research findings with Wildsight Golden, my sponsor organization. The data will also be used to publish articles in peer-reviewed research journals, and to share the results to any other interested parties within or outside of the study area. A copy of the final report will be published and archived in the Royal Roads University Library, or I can be contacted for a copy.

The information you provide will be summarized in anonymous format in the body of the final report. Spatial information will be digitized using ArcGIS 10, to produce a map showing ecosystem service use locations. At no time will any specific comments be attributed to any individual unless a specific agreement has been obtained beforehand. All documentation will be kept strictly confidential. Raw data will be kept indefinitely for research purposes only. You are not obligated to participate in this research project. If you choose to withdraw or abstain from participation, your refusal will be maintained in confidence. In addition, the data collected will not be retained pertaining to an individual who has withdrawn at any time.

By signing this letter, you give free and informed consent to participate in this project.

Name: (Please Print): ____

Signed: ____

Sincerely,
Rachel Darvill, BSc, MSc Environment and Management candidate

Appendix D- Mapping Interview Questionnaire

Name: ___________________________________ Date: _________________________

For the following questions, please circle the appropriate response.

1. How long have you lived in (or adjacent to) the Upper Peace River Watershed?
   Less than 1 year
   1-5 years
   6-10 years
   11-15 years
   More than 15 years (born elsewhere)
   More than 15 years (I was born here)

2. In what type of community do you live?
   City or urban community
   Suburban community
   Rural Community
   First Nations reserve

2. What is the name of the rural area, community or reserve where you live?
   ____

3. What is your occupation/livelihood?
   ____

4. What interest group do you most closely identify/associate with?
   Local Government
   Provincial Government
   Federal Government
   First Nations Government
   West Moberly First Nations
   Saulteau First Nations
   Halfway River First Nations
   Prophet River First Nations
   Doig River First Nations
   Industry
   Agriculturalist/Farmer
   Environmentalist/Conservationist
   Hunter
   Fisher
   Motorized recreationist
   Non-motorized recreationist
   Business Owner
   Community (e.g. Chamber of Commerce, Artist, Rotary Club)

Other

5. If applicable, what other interest group do you most closely identify/associate yourself with, second only to your choice in the previous question?

Local Government
Provincial Government
Federal Government
First Nations Government
West Moberly First Nations
Saulteau First Nations
Halfway River First Nations
Prophet River First Nations
Doig River First Nations
Industry
Agriculturalist/Farmer
Environmentalist/Conservationist
Hunter
Fisher
Motorized recreationist
Non-motorized recreationist
Business Owner
Community (e.g. Chamber of Commerce, Artist, Rotary Club)
Other

6. Please select the age group that you belong to.

Under 18
18-24
25-34
35-44
45-54
55-64
65 or Above

7. What is your gender?

Male
Female

8. Have you heard of the 'Ecosystem Services' concept prior to participating in this research?

Yes
No
Unsure

Before we move forward, I would like to provide you with a widely accepted definition for the term 'ecosystem services.' Ecosystem services are the resources that come from nature and bring benefits to humans (Daily, 1997), and that contribute to making human life both possible and worth living (Diaz et al., 2006). They are necessary for human well-being to persist.

During this interview, you will be asked questions regarding your use of ecosystem services within two main categories:
1) Provisioning Services. These are material products (human benefits) that come from nature, such as food, timber and freshwater.
2) Cultural Services. These are the non-material benefits that you receive from nature, such as aesthetic beauty, recreational opportunities, spiritual enrichment, cultural or historical heritage.

Please show me the locations of where you use specific services that you use within the Upper Peace River Watershed boundary only!

(Codes for indicating ES use on map polygons are listed in parentheses)

1. FOOD – PLANTS (F)
Do you use the land within the Peace River Watershed to grow and/or harvest **local** food (i.e. domestic or wild plants, oats, berries, mushrooms, fruit and vegetables) for personal consumption or for profit?
YES or NO
If yes, where do you do this? Please indicate this area on the map.

2. FOOD – GAME (G)
Do you hunt, trap or harvest wild animals and/or birds for food?
YES or NO
If yes, where do you trap or harvest wild animals/birds.

3. FOOD – FISH (Fish-R or Fish-F)
Do you fish for food or for recreational purposes?
YES or NO
If so where do you fish?

4. WOOD/FUEL (W)
Do you use specific forest stands to collect or harvest wood for uses such as heating, cooking and /or building or constructing?
YES or NO
If you do, where are these forests located?

5. FRESHWATER (FW)
Do you collect freshwater for domestic purposes (i.e. drinking water, washing dished, watering your garden, etc.) from any other source other than from your municipal water system?
YES or NO
If you do, where do you collect this freshwater?

6. NATURAL MEDICINES (NM)

When in season, do you use specific places to collect wild plants, berries or mushrooms that you then use for tea and/or medicinal purposes?

YES or NO

If you do, where do you collect them?

7. ORNAMENTAL RESOURCES (OR)

Do you use locations to collect natural materials (i.e. flowers, rocks, animals skins, feathers, shells, etc.), which you then use for crafts, ornamental or decorative purposes?

YES or NO

If you do, where do you collect them?

8. SPIRITUAL/RELIGIOUS (S/R)

Do you use local landscapes or places of nature, for spiritual or religious reasons? Examples may include using landscapes used for meditation, self-rejuvenation, ceremonies or spiritual renewal/awakening, etc.

YES or NO

If you do, where are these locations?

9. SCIENTIFIC/EDUCATIONAL (S/E)

Do you use local landscapes, or place of natures, for scientific or educational reasons?

YES or NO

If so, where are these landscapes located?

10. AESTHETIC/SCENIC (A)

Do you use local places of nature solely for their aesthetic, scenic, or awe-inspiring beauty?

YES or NO

If you do, where are these places located?

11. INSPIRATION (I)

Do you use specific places for the inspiration that they give to you for art, song, stories, dance, etc.?

YES or NO

If so, where are these places of inspiration located?

12. SENSE OF PLACE (P)

Are specific local natural landscapes and/or specific habitats for local wildlife important to your overall feeling of belonging to the Peace region?

YES or NO

If there are, where are these landscapes/wildlife habitats?

13. CULTURAL/HISTORICAL HERITAGE (H)

Do you use or visit specific local areas for their cultural and/or historical heritage (i.e. historical homestead, dinosaur bones, historical middens, birth sites, burial sites, etc.)?

YES or NO

If so, where are these places of heritage?

14. RECREATION (R)
Do you use certain places for recreational purposes (non-motorized or motorized)? Examples of recreation include: hiking, motorized boating, canoeing, kayaking, biking, ATVing, swimming, fishing (catch and release), camping, snowmobiling, etc.

YES or NO

If so, where are they?

15. WILDLIFE (W)
Do you use specific locations for observing the local wildlife (including mammals, birds and fish)?

YES or NO

If so, where are these places? AND what are the species?