DISSERTATION

LINKING CULTURE, ECOLOGY AND POLICY: THE INVASION OF RUSSIAN-OLIVE (*ELAEAGNUS ANGUSTIFOLIA* L.) ON THE CROW INDIAN RESERVATION, SOUTH-CENTRAL MONTANA, USA

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In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Spring 2013

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ABSTRACT

LINKING CULTURE, ECOLOGY AND POLICY: THE INVASION OF RUSSIAN-OLIVE (*ELAEAGNUS ANGUSTIFOLIA* L.) ON THE CROW INDIAN RESERVATION, SOUTH-CENTRAL MONTANA, USA

Native plant diversity in riparian systems is currently threatened by the invasive Russian olive (*Elaeagnus angustifolia* L.) replacing woody riparian species, including plains cottonwood (*Populus deltoides* Marsh), used for centuries by the Apsáalooke or Crow Tribe of south-central Montana. The Dawes Act of 1887, also known as the Allotment Act, created a land tenure system that restricted ownership rights and forced an unfamiliar agro-economy on the Crow people. Land cessations, illegal land sales and/or leases over the last century resulted in a mosaic of private non-Indian land ownership parcels interspersed within Crow tribal and individual allotment lands. Crow Tribe and individual land allotments are held in trust by the federal government and managed by the federal trust agent, U.S Department of Interior-Bureau of Indian Affairs (BIA). *Elaeagnus angustifolia* was intentionally planted in the early 20th century along the floodplains of the Little Bighorn and Bighorn Rivers to support a largely non-Indian owned agro-economy. Mapped presence points of *E. angustifolia* trees within land use type and land ownership status were used as an indirect measure of policy induced invasion. Stem density of *E. angustifolia* (stem/km^2) varied significantly by land use type (13 predictor variables) ($p < 0.001$), and densities were significantly higher in wetlands, crop/pasture, mixed rangeland, residential and transportation ($p < 0.001$), and grass rangeland ($p < 0.01$), and mean stem density was highest in wetlands than other land use types. Fee patent (private non-Indian) land had marginally higher stem numbers than tribal and Reservation trust lands combined, although not significant. The Bighorn and Little Bighorn Rivers of Montana are highly regulated with

diversion dams, irrigation canals and ditches heavily dominated by *E. angustifolia*. The Crow people use cottonwoods for socio-cultural and ritual purposes; however they have witnessed a decline in availability to harvest specific size classes of cottonwood. Further, given predicted climate changes of warmer mean annual temperatures and increased precipitation for Montana, I used Maximum Entropy Modeling (MaxEnt) to predict suitable habitat and future spread of *E. angustifolia* along riparian corridors of the Little Bighorn and Bighorn Rivers. Climate variables ($n = 22$) used in the model contributed significantly to the model (AUC > 1.0) suggesting that near-term climate changes may influence the spread of *E. angustifolia* , particularly downstream from diversion dams used for irrigation purposes.

Personal interviews of Crow Elders overwhelmingly agreed (~80%) that sub-adult cottonwood trees were the most difficult to find now compared to 25 years ago. Maximum distances to travel to obtain sub-adult size classes used exclusively in ceremony increased in present-day by 30 km compared to recent history. Plot data comparing near and far from ceremonial and Crow Fair campground sites indicated that cottonwood stem heights (from 7.32 m plots where $n=10$) were significantly shorter near ceremony sites (< 150 m near) compared to sites farther away (> 2.4 km away; $p < 0.01$). There were more cottonwood trees with diameter at breast height (dbh) < 5 cm in plots located far from ceremony sites than near ($p < 0.05$). Near-term (10 years) climate change predictions, coupled with reduced cottonwood availability to harvest indicated that mid-sized cottonwoods will continue to decline, while *E. angustifolia* populations will spread.

Personal interviews with Elders and Crow community surveys reported 23 uses of cottonwood with the branch as the most often used plant part. Elders also mentioned Pine (*Pinus* sp.) and buffaloberry (*Shepherdia canadensis* (L.) Nutt. *argentea*) woody species are equally important to Crow culture. Traditional food sources such as chokecherry (*Prunus virginiana* L.) are also mentioned as becoming more difficult to find for traditional harvest. *Elaeagnus angustifolia* is not used by the Crow people who consider this species to be problematic, changing the visual landscape and making it difficult to find historical home sites and sacred places. Gender differences in knowledge of *E. angustifolia* were significant, as males had more knowledge than females, and the oldest age groups (> 55 years) had higher knowledge than younger age groups.

Taken in total, I conclude that *E. angustifolia* is displacing culturally important native biota harvested by the Crow people, and has heavily invaded private or fee-patent lands. Density of this species in allotted lands, however, is not managed by the Crow, as approximately two thirds are leased to non-Indians for farming or ranching operations. Lack of access and management oversight by the Crow Tribe for all lands within the reservation boundaries resulted in drastic changes in vegetation from the once dominant plains cottonwood to an almost mono-culture of *E. angustifolia.* Growth of this thorny shrub severely restricts the ability to harvest important woody species used in the expression of Crow culture through ceremony. Traditional Crow knowledge related to harvesting practices of culturally important native biota may be in the initial stages of erosion. Future land policy should reflect the ability of the Crow Tribe to manage invasive species within reservation boundaries, regardless of ownership class. To preserve traditional knowledge of native biota, *E. angustifolia* removal projects coupled with re-vegetation of culturally important species closer to Crow communities will allow access by Elders, and hence preserve their rich cultural knowledge for generations to come.

ACKNOWLEDGEMENTS

I would first like to thank my committee for their unwavering support and encouragement to complete this research. This would not have been possible without the enthusiasm for the project and willingness of Dr. George Beck to take me as his graduate student, and for Dr. Tom Stohlgren who agreed to co-chair the committee. Dr. Beck also provided financial support during this past year, helping in ways that otherwise, I would not have been able to continue as a graduate student. Dr. Beck graciously provided me with the use of a laptop, and access to software after the one provided by Little Big Horn College had crashed and burned. In short, Dr. Beck has mentored me during troubling times, both professional and personal, and given constant support. I'm fortunate and grateful to the female scientists on my committee, Dr. Kathleen Sherman and Dr. Cini Brown who cheered me on to the finish line, and provided suggestions to strengthen the quality of my writing. To Dr. Tom, for his patience with me in becoming a better writer, and to discuss and assist with the statistical analysis; in so doing he has made me a better scientist. I'm grateful that he also supported my work through attending the AICF workshop. In total, through the near heroic efforts of my committee and Janet Dill, deserve awards for their unwavering support in accomplishing a life-long dream of completing my doctoral studies. In short, they have all helped me to see this project through to completion, and I hope I have in some way made each of them proud.

The breadth of this project was daunting, given the volumes written on American Indian land policies, which is difficult to summarize, yet a critical aspect when linking ecology with Crow culture. I'm extremely thankful to Cris Stainbrook, President of the Indian Land Tenure Foundation (ILTF) for dialogue and comments on a previous paper written on the subject of American Indian land policy. I am indebted to Dr. Paul Evangelista for his assistance and support, despite what seemed to be an exasperating and frustrating experience with a student physically removed from the CSU campus. Without his guidance and help, I would not have been able to incorporate spatial modeling techniques into my work. He is also appreciated for coming to Crow Agency, and I'm fairly certain that his presence during his short stay remains in the minds of those he met, for he was gracious and kind to all at our tribal college. Dr. Tom also visited our campus and spoke with our President, Dr. David Yarlott, Jr., as this was appreciated by all for his desire to know more about our Tribe and visit the reservation while on vacation with his family. Thanks especially to Alicia Waters-Crall and Thomas J. Medicine Horse, for fieldwork and assistance with data uploads to the NIISS system. To those in the CSU Natural Resource Ecology Lab, especially Dr. Greg Newman, thank you for the assistance in navigating the MaxEnt model, and issues with NIISS data uploads.

I'm so honored and grateful to have had Little Big Horn College students, both current and former to assist me in the field. If not for the valiant efforts of Garrett Costa, Laura Tyler, and Bryan Singer, assisted by the Crow Tribe game warden Timothy Pease, accessing some populations of *E. angustifolia* in the field would not have been possible. Former students Kurrie J. Small, Annetta Passes and Namoie LaFriance, and Robin Stewart who worked with me as interns, and shared my vision of empowering the Crow Tribe to have a seat at the table, and a voice in natural resource management within the reservation. To Dr. Tim McCleary, a colleague and friend here at LBHC, I'm forever grateful for your advice, guidance, encouragement and willingness to share insights into my work.

To Dr. David Yarlott, Jr., for heroic measures in providing his unwavering faith and support of my work, providing an office in which I could escape and focus on my writing; for sharing your wisdom and constant encouragement in reminding me that I'm the expert in this work…. I will be forever in your debt, Aho! To my Crow family and friends, I'm honored for your encouragement and support, and thank the following families: Old Elk, Yarlott, Medicine Horse, Yellowtail, Bends, Scott, Dawes, Hill, Old Horn, Yapuncich, Costa, House, Old Coyote, Stewart, Medicine Crow, Pretty On Top, Yarlott, Moccasin, Bear Don't Walk, Big Man, Hugs, Fritzler, Not Afraid, Spotted Horse, and Howe. A special thanks to E.T. Springfield for his heroic efforts in locating materials in the LBHC library or archives. To my clan auntie Lana Moccasin, the late Deborah Yarlott, and Dorothy Anderson for their prayers and mentoring…I'm so honored. To Gwen Schneekloth and her husband Bob, for making sure I had food and giving me support during the lean times. Thank you so much, Dr. Diana Doan-Crider for your unwavering support and financial help when our situation looked bleak. Thanks to Myron aka Jo Jo Shields for tutoring me in ArcGIS when I was stuck and no amount of reading or help discussions would resolve my problem. I'm thankful to Dr. Nina Wampler, and Lynne Foster for reading drafts and providing insight into improving the clarity of the writing and cheering me up during moments of sheer panic. Dr. Nina Wampler for help in providing me the support I needed to get through these last few months, you are truly a beautiful soul. To friends and science sisters, Dr. Jill D. Pruetz, Dr. Diana Doan-Crider, Lisa H. Lone Fight, Jodi Rave, Marsha Small and Dr. Paige Mettler-Cherry for constant moral support and mentoring—I'm so honored to know each of you.

This research would not have been possible, if not for the funding and partial support from the USDA (formerly CSREES) NIFA grants from the Equity program at LBHC and moral support provided by Tim Grosser, the Director of said program to complete my project. Funding from USDA Tribal College Research Grant Program likewise provided financial support allowing me time away from fulltime employment at the tribal college (LBHC) to complete the fieldwork—I could not have finished my degree without this support. I was likewise honored with funding and constant moral support from the American Indian College Fund, in selecting me as the first Alfred P. Sloan, STEM Foundation Fellow. Thank you to Dennis Carder, former program coordinator for support, and to Hepsi Barnett for providing me with funding to purchase supplies and who has continued to provide emotional and moral support to get me to the finish line! To Roy Stewart at LBHC for seeking my support, guidance and insight into the AIHEC/NASA short-term project on *E. angustifolia* and allowing me to work with his hard working and dedicated interns, Annetta Passes and Bryan Singer. To Dr. Penny Kukuk for providing a workshop at SKC, and especially Rachel Smith and her husband Eric Rowell for helping me with my GIS processing questions while attending the Students to Academic Professoriate for American Indians (SAPAI).

Certainly not least, to my husband, David Small who has helped me in so many ways, it is difficult to account in such short verse. Thank you for your love and for standing by my side. I'm so grateful that you endured this process with me. Thank you for providing insight into my work, constant encouragement, and support and believing in me, during my moments of doubt and fear. To my children, Cody, Kenny and Kelly, who sacrificed the most in time away from their mom....my love to you all! To the aids for my son with autism, Kenny G., Mrs. Laurie Billings and Mrs. Thomas, for watching over my son at school during my long absences. To my mother-in-law Connie Jackson Yellowtail, I sincerely thank you for moral support and willingness to help. To my auntie-mom Donna Scott-McCurdy who took me in years ago, and has always helped me; I will always love you and am so honored to know you. To my dear mother, Wanda, with much love, I truly appreciate you for helping me pay the electric bills, food, etc., and especially in taking care of Kenny G. so I could complete my bachelors and

masters degrees. To my dear sister/friend, Ms. Jane Radunzel, whom I lost 2 years ago; thank you for reminding me to "dance in the rain", and for the many conversations about my research and the trials of being a graduate student...I will cherish and miss you always. To my Crow family members who have passed to the "other side camp"; Sonny Scott, Cloyce Little Light, Frances Scott, Duwayne McCurdy, my late grandfather, Wilbur (Buster) Scott, and my maternal grandmothers, Amy Shane, Goes Hunting, and Pretty Woman….I hope I have honored each of you. Last, it is in honor of my family and Crow ancestors that I dedicate this work to the Apsáalooke people. It is my sincerest hope that this project will result in meaningful invasive species control and management (especially *E. angustifolia* and *Tamarix* sp.), and to influence real policy changes that will allow our Tribe to have land management control for ALL land within reservation boundaries, regardless of ownership. For through this empowerment, we strengthen sovereignty and save our culturally important native plants and the traditional knowledge inherent in the land itself. In saving our natural floodplain species, we secure our rights to continue to practice sacredly held ceremonies and harvest traditional foods, passing this knowledge from our community Elders to future generations.

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CHAPTER 1. AMERICAN INDIAN LAND POLICY: LAND USE, OWNERSHIP STATUS AND THE DENSITY OF THE INVASIVE RUSSIAN OLIVE (*ELAEAGNUS ANGUSTIFOLIA* L.) ON THE CROW INDIAN RESERVATION, MONTANA, USA

1.0 Summary

American Indian Land policy for the Apsáalooke or Crow Tribe of South Central Montana differs vastly from that of their non-Indian land owners; a legacy of the Dawes Act. Invasive species such as *Elaeagnus angustifolia* L. also known as, Russian olive) were intentionally planted in the mid and late 20th century along the floodplains of the Little Bighorn and Bighorn Rivers to support a largely non-Indian owned agro-economy. We ask: Which land use type has a higher density of *E. angustifolia*? Further, we ask whether the occurrence of *Elaeagnus angustifolia* is equally distributed within the different ownership statuses and discuss this as an indirect measure of how American Indian land policy drives vegetation change. *Elaeagnus angustifolia* stem density (stem/km^2) varied significantly by land use type (13 predictor variables; $p < 0.001$). *Elaeagnus angustifolia* stem densities were much greater in wetlands ($p < 0.001$) than in crop/pasture land use type. Fee patent land had higher *Elaeagnus angustifolia* stem numbers than tribal and Reservation trust lands combined, albeit marginally so ($p<0.08$). We conclude that the Tribe should manage invasive species on the Reservation, regardless of ownership status.

1.1 Introduction

Human disturbance continues to be the driving force in changing natural and historic dynamics of riparian ecosystems (Busch and Smith 1995, et al. 1999, Corbacho et al. 2003). During the early part of the 20th century, federal land policy promoted economic growth without effective management plans to sustain natural resources (Platt 2004). Approximately 85% of the nation's floodplains have been converted to croplands and grazing lands, and rivers have been diverted for power and municipal supply projects (Fleischner 1994, Scott et al. 1997). Permanent alteration of landscapes caused pollution of waterways, loss of productive land due to erosion, and ultimately the loss of native flora and fauna (Rood and Mahoney 1990, Rood and Mahoney 1995, Scott et al. 1997). This is particularly problematic for Western riparian areas and their adjacent floodplains since these are among the most productive ecosystems in the semi-arid northwest (Johnson 1994). Loss of native flora in riparian systems has been hastened by the introduction of non-native invasive plant species and present day attempts to reverse the influence of past land development have been met with mixed results (Johnstone 1986, Olson and Knopf 1986 a,b, Hobbs and Huenneke 1992, Lesica and Miles 1999, 2001). Land use changes along river systems are among the most problematic of these human disturbances (Ligon et al. 1995, Middleton 1999). Practices such as river diversion, damming and the draining of adjacent floodplains for development of crop agriculture create windows of opportunity for invasive species to outcompete native woody vegetation (Ligon et al. 1995, Lesica and Miles 2001, Middleton 1999). For instance, *Elaeagnus angustifolia*, a non-native woody species, has effectively displaced the dominant native plains cottonwoods (*Populus deltoides* L.W. Bartram ex Marshall ssp. *monilifera* (Aiton) Eckenwalder) in many western riparian systems (Tilman 1985, Olson and Knopf 1986 a,b, Scott et al. 1997, Richardson et al. 2000). This invasive species tends to be less sensitive to anthropogenic disturbances, and proliferates under a wide variety of environmental and ecological conditions (Pearce and Smith 2001, Katz and Shafroth 2003). Human influenced perturbations of the seasonal timing of high water flows from diversion dams and *Elaeagnus angustifolia*'*s* propensity to escape cultivation, continue to plague land owners along riparian and wetland systems throughout the west, including on the Crow Indian Reservation in South-central Montana (Akashi 1988, Pearce and Smith 2001, Jarnevich and Reynolds 2011). Previous studies have suggested that *Elaeagnus angustifolia* occurs in upper terraces as well as along irrigation ditches and canals, yet few have evaluated whether this species is associated with a particular land use type (Shafroth et al. 1995, Lesica and Miles 2001, Pearce and Smith 2001).

The rapid spread of *Elaeagnus angustifolia* within the Apsáalooke or Crow Indian Reservation was due in large part to the initial plantings by non-Indian farmers for use as field windbreaks and bank stabilization along rivers and streams during the 1940s and again in the 1970s (Olson and Knopf 1986 a,b). Additionally, nurseries and USDA-Natural Resource Conservation Service (NRCS) offices in the state of Montana continued to promote planting *Elaeagnus angustifolia* for wildlife and bank stabilization projects until 2009 (Katz and Shafroth 2003) further exacerbating the problem. Plant species themselves, however, do not become invasive within Reservations without a complicated network of land ownership changes due to socially charged policies passed by those with the power and resources to secure such changes (Robbins 2004). Thus, it is important to examine biological invasion of *Elaeagnus angustifolia* within the context of land tenure and policy of American Indian land use, property ownership, and colonization processes.

Land use and ownership rights for non-Indian US citizens, differ vastly from those granted to the Native Americans (Belue 1991, Hoxie 1995, Churchill 1999, Anderson 2001, Hoxie et al. 2001). Fee patent ownership or private land allows the owner to essentially develop their land without the need to consult with the federal government regarding land use, i.e. crop agriculture, grazing, etc. Conversely, initial allotments assigned to individual Crow Tribal members through the Dawes Act (1887), however were restricted in land use or development, without express permission from the Department of Interior's trust agent, the Bureau of Indian Affairs (BIA). This was specifically assigned to individuals who met a specific blood quantum (i.e. more than half Crow Indian). Those individuals falling within this group were considered unable to manage their land allotments, as ownership title is held in trust status by the Department of Interior's agency, the Bureau of Indian Affairs (BIA). Tribal land (held communally by the Crow Tribe) is also held in trust status, and agricultural development, sale or leasing of said land first requires approval from the BIA. In essence, the federal government has retained ownership title for the benefit of the Crow Tribe and its individual members, and in so doing restricted land use options (Jaimes 1992, Deloria 1997, Churchill 1999, Anderson 2001). This trust responsibility has determined the history of land use, ownership, and landscape vegetation changes in general within the Crow Reservation boundaries (Trosper 1978, Belue 1991, Heiser 1999, Anderson 2001). Although most land use texts address the history of federal policy on public and federal lands, few address how Native American land policy has affected the ecological integrity of local landscapes upon post-settlement and development.

Land use rights for Native American Tribes, such as the Apsáalooke or Crow Tribe, differ drastically from those of their non-Indian counterparts (Belue 1991). For indigenous Tribes of the western US plains, the idea of land ownership was unfamiliar. The idea that land must be improved upon, when in the eyes of the Crow it already gave all that was necessary for life, was not easily embraced. In the spring of 1890, out of desperation because his people were starving, the last of the great Crow chiefs, Plenty Coups, adopted this new economy of farming and ranching (Bradley 1977, Heiser 1999). However, many found this new sedentary way of life not only unfamiliar, but furthermore undesired (Medicine Crow 1966). Early land use policies were tied to a European construct of "productive" land use (Belue 1989, 1991, Churchill 1999, Clow 2001), and a three-state territory occupied by the Crow was viewed as wasted land because it was non-cultivated. This perception of wasted land was used as a justification for the exploitation of land for cattle ranching and crop agriculture (Anderson 2001, Clary 2002). Treaties between the Crow Tribe and the federal government granted limited basic rights of land ownership to the Crow, formalized in the General Allotment Act of 1887, also known as the Dawes Act. The Allotment Act served to eliminate tribally-held communal land holdings to promote individual property ownership.

Crow elders speak of their association with the land in the telling of their origin story relative to their Montana and Wyoming ancestral lands. As Dr. Joseph Medicine Crow states, "It, (land) was to the Indian, life itself" (Medicine Crow 1966). In Rodney Frey's (1987) publication on the Crow Indians, he writes about their association with land, and that the rivers are as "their own children." Crow-identity and their ties to the land are further exemplified within their religious beliefs that land is a living and even spiritual being, given to the Crow by the "Creator of all things" (Belue 1991). Therefore, one cannot separate the land and rivers from culture, as for the Crow they are viewed as being inseparable from themselves. Land use, however, is determined by federal policies that grant ownership rights within a specific land tenure system. Policy drives these human disturbances that ultimately influence vegetation change.

Land use is ultimately determined by ownership, and as such, is an important factor that influences plant community vegetation and will likewise play an integral role in the preparation of a comprehensive land management plan (Lundgren et al. 2004). Plains cottonwood is a woody riparian species that is essential for maintaining the ecological health of riparian ecosystems in the semi-arid west (Karr 1978, Junk et al. 1989, Segelquist et al. 1993, Gurnell 1995, Shafroth et al. 1995, Cordes et al. 1997, Suagee 1999). Woody species, such as plains cottonwood, filters water flowing from agricultural watersheds to rivers and its value has been well documented (Karr 1978, Peterjohn and Correll 1984, Cooper et al. 1999). Native woody vegetation limits infiltration of surface water into the hyporheic (below root level) zone during drought periods and traps fine sediments during heavy spring seasonal snowmelt and high storm flows (Segelquist et al. 1993, Naiman 1997, Scott et al. 1997, Middleton 1999). Native plant species, such as plains cottonwood, have adapted to correspond with natural seasonal high and low flows of rivers linked by their adjacent floodplains (Junk et al. 1989, Howe and Knopf 1991, Andersen et al. 2007). Diversion dams constructed for irrigation projects along the Little Bighorn and Bighorn Rivers, initiated in the late 19th and early 20th centuries, reduced the natural seasonal flood pulse that creates bare mineral substrates for plains cottonwoods' short-lived, wind-dispersed seeds (Junk et al. 1989, Scott et al. 1997, Katz and Shafroth 2003, Northcott et al. 2007).

Plains cottonwoods have been harvested for centuries along these river systems and floodplains by the Crow to use in ceremony as thatch for shade structures during the Crow Fair (Figure 1.1), which has been held annually since its inception in 1903 (Graetz and Graetz 2000, Mellis 2003, Murphy 2004). Recently, Crow Elders mentioned that specific size classes, primarily saplings (3 to 4 m stem height) that are used exclusively for ceremonies, have become difficult to locate, and that *Elaeagnus angustifolia* within the floodplains is difficult to control (C. Howe 2002). *Elaeagnus angustifolia* escaped cultivation and became naturalized within the last half of the 20th century due to federal agency sponsored programs that promoted this species for use as shelterbelt and bank stabilization along earthen irrigation canals and ditches (Read

1958, Olson and Knopf 1986b). This species has since become ubiquitous within pastures and along the upper and lower terraces of Little Bighorn and Bighorn River systems on the Crow Reservation.

Figure 1.1. Shade structures constructed with plains cottonwood saplings and branches used as thatch during the annual Crow Fair celebration. Photo by V. Small, August 2012.

Floodplains invasion by *E. angustifolia,* however, cannot be examined strictly from an ecological perspective, but rather must be viewed within the context of the reigning land use policy during the time of its estimated introduction. These complex networks of policy and culture are key factors in which land and riverine disturbance regimes were drastically changed and through this process created conditions that favored plant invasion within ecosystems (Robbins 2004). Our objective was to connect land tenure history caused by American Indian land use policy and ownership with the invasion of *Elaeagnus angustifolia* on the Crow Indian Reservation. We ask the following questions: Is *Elaeagnus angustifolia* equally distributed within land ownership status? Are there differences in stem density within land use type categories? To test our hypotheses, we collected presence points of *Elaeagnus angustifolia* trees and mapped these utilizing geospatial land cover dataset layers within the Little Bighorn and Bighorn Valleys of the Crow Indian Reservation in south-central Montana, USA. Finally, we examine the political ecology of agricultural resource access and use and discuss this as a possible factor contributing to accelerated rates of *Elaeagnus angustifolia* invasion.

1.2 Study site

We conducted our study within the current boundaries of the Crow Indian Reservation in south-central Montana, USA (Figure 1.2). The major portion of the present-day Reservation boundary lies completely within Bighorn County and in small portions of Yellowstone County to the northwest and contains 9,291 km^2 (Statewide FINAL Oil and Gas EIS, p. 3-37). Surface acre ownership includes the Crow Tribe (1,844 km^2; 20%), individually allotted trust (4,191 km^2; 45%), and private fee acreage (3,255 km^2; 35%). The pattern of surface ownership is a "checkerboard" of tribal, trust and fee lands (EIS 2008) (Figure 1.3).

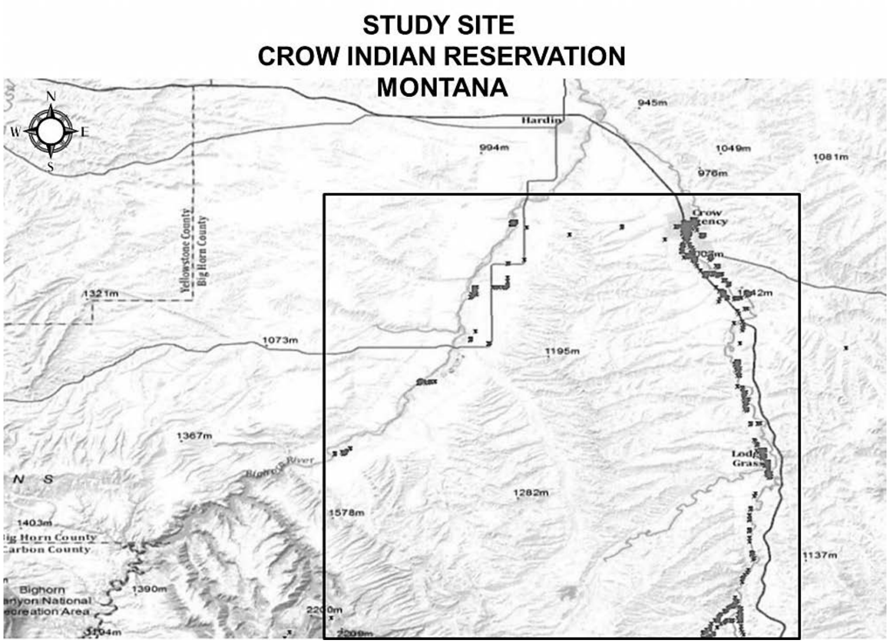

Figure 1.2. Study Site with *E.angustifolia* L. mapped presence points, Montana USA.

Land use on the Crow Indian Reservation includes rangeland for livestock grazing, irrigated and dryland crop production, forestland, and developed areas (community/municipal). Of the approximately 6,070,284 surface hectares in tribal and individual allotted trust ownership, approximately 68% is grazing rangeland, 12% dry cropland, 3% irrigated cropland, 15% forestland, 1% wildland, and 1% developed areas (Crow 1997). Most agricultural land on the Reservation is leased to non-Indian interests; in 1996, leases included approximately 4,856,227 hectares of grazing lands, 60,702 hectares of dryland farmland, and 121,405 hectares of irrigated farmland (EDA 1996, EIS 2008). In the 2000 Census, the Reservation's population density was 1.19 persons/km^2 compared to 2.5 and 6.0 persons/km^2 for Big Horn County and Montana, respectively (US Census 2000).

The Bighorn River and its tributary, the Little Bighorn, run south to north through the Crow Indian Reservation. These rivers create three major watersheds divided by three mountain ranges; the Pryors to the northwest, the Bighorn to the southwest, and the Wolf Mountains to the southeast. The Little Bighorn River drains approximately 3,367 km^2 of mountains, foothills and valleys (US Geological Survey 2003). The majority of this drainage area (~2,849 km^2) runs through the Crow Indian Reservation in southeastern Montana. The Little Bighorn River flows north for approximately 129 km from the Bighorn Mountains of Wyoming through an alluvial valley. The main river channel is approximately 193 km long. Perennial tributaries to the Little Bighorn River include Lodge Grass and Pass Creeks, and large ephemeral tributaries consisting of Owl and Reno Creeks (US Geological Survey 2003). The climate is semi-arid with 304 mm mean annual precipitation and 7.5 ^{o} Celsius average annual temperature (Western Regional Climate Center 2008).

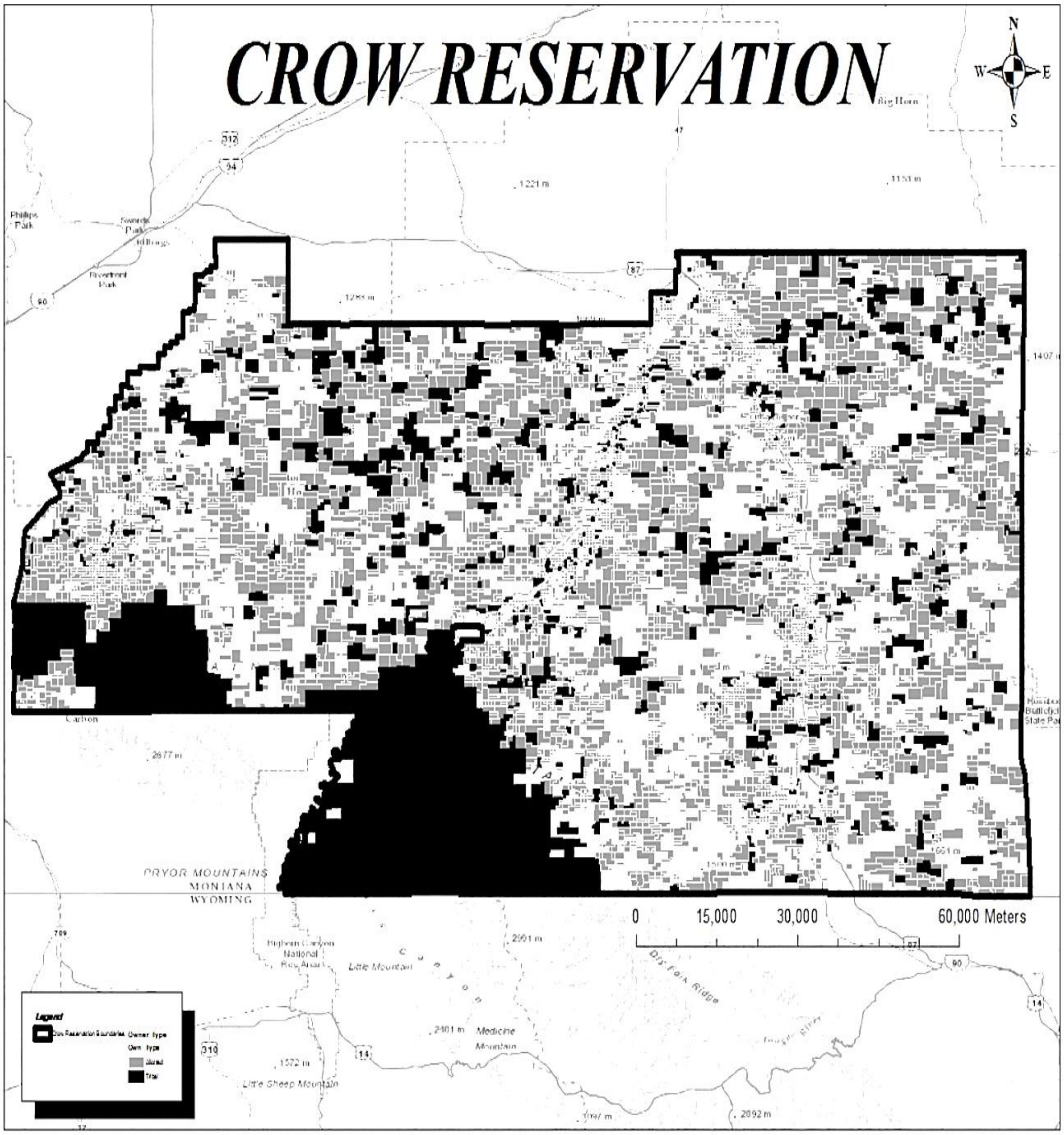

Figure 1.3. Crow Indian Reservation map of land ownership "checkerboard" effect comparing Tribal Trust (dark squares) and allotted land (lighter squares). White squares represent privately held land (non-Crow). Approximately 2/3 of allotted land is leased to non-Indians for cattle grazing, and dryland and irrigated crop agriculture (USDA 2004).

1.3 Methods

1.3.1 Study Species

Elaeagnus angustifolia, a member of the Oleaster family, is a small tree or deciduous shrub measuring between 4 to 9 m in height (USDA Plant Database 2005). The bark has a distinctive deep red color and its branches appear black and often display large thorns. Leaves are alternate, lanceolate, and are 5 to 7cm long with small scales creating a greenish-gray appearance on the upper portion and a silvery reflectance color on the lower leaf surface. Fragrant, yellowish bell-shaped flowers bloom in June and are insect-pollinated producing large one-seeded fruits in late fall and winter. Large oval seeded fruits are dispersed by birds and mammals (Van-Dersal 1939, Borell 1962, Olson and Knopf 1986b, Kindschy 1998, Pearce and Smith 2009). Seeds, however, are also viable and able to float for about 3 days; thus, water is also a likely important dispersal agent for this species (Brock 1998, Pearce and Smith 2001, 2009). *Elaeagnus angustifolia* is also capable of fixing nitrogen, having formed a symbiotic relationship with acctinomyecetes (*Frankia*) (Johnson 1995). However, results from a recent study on soil nitrogen levels under subcanopy of *Elaeagnus angustifolia* shrubs growing beneath plains cottonwood showed that despite increased nitrogen, enriched soils were not likely to promote exotic weed invasions (DeCant 2008). Reproduction by this species is primarily through seed, although it also is capable of re-sprouting from roots and stumps (Olson and Knopf 1986a). This particular aspect of asexual reproduction is what makes this species so difficult to eradicate (Reynolds and Cooper 2010). Pathogens and herbivores that normally prey on *Elaeagnus angustifolia* in their native range are absent from their invaded systems, unlike their native counterparts (Mack et al. 2000), supporting the enemy-release invasion theory (Keane and Crawley 2002).

1.3.2 Field sampling

In July 2010, we used an opportunistic field data collection method to obtain presence points of *Elaeagnus angustifolia* within the Bighorn and Little Bighorn River watershed systems in south-central Montana within the present-day boundaries of the Crow Indian Reservation (n = 1180). We mapped coordinates of all accessible *Elaeagnus angustifolia* trees within the riparian zones of these two river systems, where access was allowed, although in some cases we were able to gain access by boat or all-terrain vehicles. This study was limited to the floodplain and riparian areas of the Bighorn River beginning on the north side of Yellowtail Dam after bay to the confluence of the Little Bighorn River (~ 61 km), just south of Hardin, Montana. Riparian and floodplain areas were roughly delineated from ArcGIS using a 1.61-2.0 km buffer zone from the center of each river to focus collection points. Data collected included northing, easting, datum, zone, species, and distance to surface water. These data were uploaded to ArcGIS for analysis (ESRI 2009).

1.3.3 Geospatial Analysis

To determine differences in density (stems/km^2) of *Elaeagnus angustifolia* within land use type categories (n=13), and ownership statuses (n=4), we uploaded presence points collected during the 2010 field season. We obtained shapefiles from the Bureau of Indian Affairs (BIA), Irrigation and Natural Resources Department and converted them to raster. We applied a zonal statistics tool to calculate a summary statistic using grids of integer types (i.e. feature statuses of ownership and land use type). Through the raster calculator, we employed the zonalstats tool to compute a statistic using values for the zones defined within the zonegrid (i.e. land use type and land ownership type) with statistic resulting in a sum of values from the feature status containing presence points of *Elaeagnus angustifolia*. We obtained dependent variables (stems/km^2) within independent variables of ownership status from the attribute tables for statistical analysis. A spatial join between point files (*Elaeagnus angustifolia* stems) and 13 variables within the feature status for land use type were also performed to obtain database files for further analysis. We used one-way analysis of variance (ANOVA) to examine the role of ownership and land use type as predictor variables for the dependent variable (stem count) using SYSTAT 9.0 (Wilkinson 2010). We employed a post-hoc Tukey's multiple comparison of means to test significant ANOVA results and we set $\alpha = 0.05$.

1.4 Results

1.4.1 Land use type and ownership status

Elaeagnus angustifolia density varied within land use type ($n = 13$) ($p < 0.01$) (Table 1.1). *Elaeagnus angustifolia* density was higher in crop/pasture compared to wetland ($p < 0.001$) and lower in mixed rangeland compared to wetland ($p < 0.001$) (Figure 1.4). *Elaeagnus angustifolia* stem density was less in grass rangeland than wetlands ($p < 0.01$), and wetlands had a higher density compared to transportation ($p < 0.001$) and residential ($p < 0.001$) land use type categories. Number of *Elaeagnus angustifolia* stems within ownership status was marginally significant ($p < 0.08$) where fee patent and allotted ownership statuses had more stems than tribal trust or tribal reserved combined (Figure 1.5). *Elaeagnus angustifolia* densities across grouped ownership and land use type categories did not differ.

Table 1.1: *Elaeagnus angustifolia* density (trees/km^2) differed among 13 land use type categories.

Analysis of Variance			Land use type		
Source	DF	Sum of squares	Mean squares	F	Pr > F
Model	12	18.45	1.54	6.25	0.0001
Error	39	9.59	0.246		
Corrected Total	51	28.04			

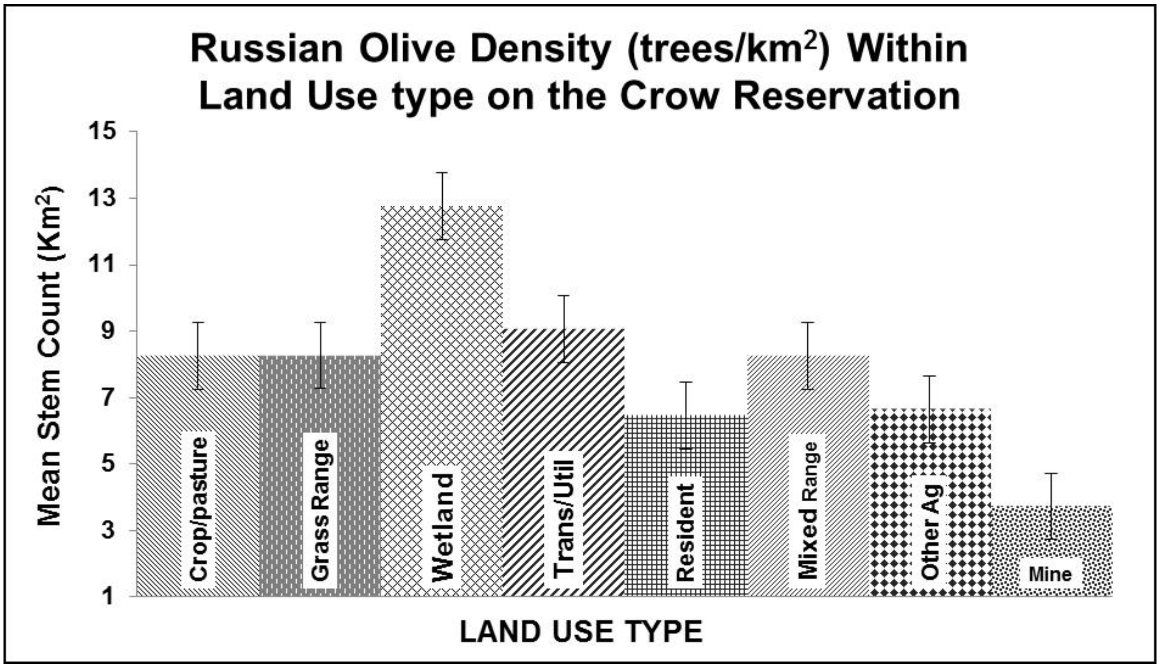

Figure 1.4 Mean *Elaeagnus angustifolia* stem density (trees/km^2) with standard error of the mean for land use type categories. Stem data were transformed before conducting one-way Analysis of Variance, using $\log_{10} (N_i + 1)$. Wetlands are significantly different (higher stem density) from crop/pasture, mixed rangeland, transportation and residential ($p < 0.001$), and grass rangeland ($p < 0.01$) based on Tukey's multiple comparison of means test.

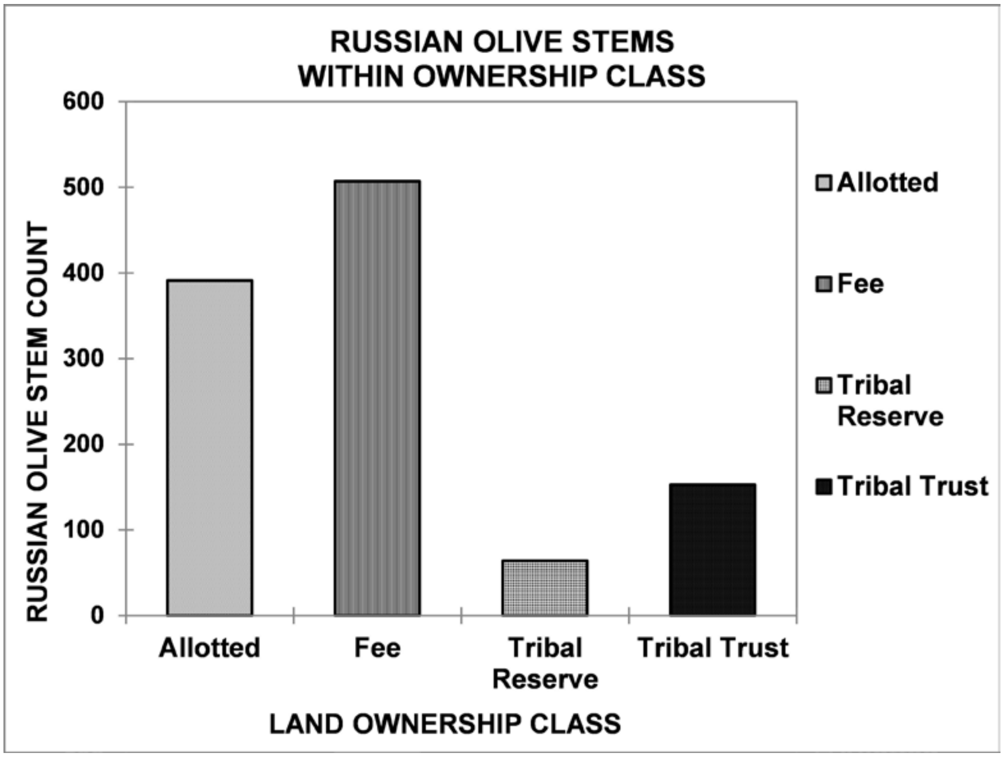

Figure 1.5. *Elaeagnus angustifolia* stems within land ownership status. Differences were marginally significant ($p < 0.08$), and fee patent (private) ownership status had a higher numbers of stems than other ownership classes combined.

1.5 Discussion

1.5.1 Land use

The invasion of *E. angustifolia* on the Crow Indian Reservation mimics the history of restricted ownership and land use management (Fig. 1.3). We found *E. angustifolia* occurring in high densities in wetlands, crop, and pasture land use type categories. *Elaeagnus angustifolia* is apparently able to invade systems outside predicted moist wet habitats, as we found stems growing in 11 of the 13 land use types: Roadsides (transportation), mixed rangeland, grass rangelands, residential, other agriculture (dryland crops), mixed urban areas and land listed as mine/quarry. *Elaeagnus angustifolia density* within residential land use type category and mixed urban areas may be the result of intentional planting for horticulture reasons. The occurrence of *E. angustifolia* within land use type categories that consist of xeric and moist soils provides further evidence that this species is able to successfully establish and invade beyond riparian forest habitats.

The largest human impact upon floodplains within the last 150 years has been the onset and development of agriculture in this semi-arid region of south central Montana (Dynesius and Nilsson 1994, Middleton 1999, Junk et al. 1989, Tockner and Stanford 2002). During the late 19th century and throughout the 20th century, approximately 70% of the natural floodplains along North American rivers were drained to allow for expansion of crop agriculture and grazing lands (Junk 1989). The ecological effects caused by these agricultural practices on river systems and associated native plant communities were devastating. Plant life history traits of native species, such as growth rate, flood tolerance and seed deposition, were and remain negatively affected by a constant, rather than seasonal fluctuation in river and stream flow rate (Junk 1989, Mahoney and Rood 1990, Johnson 1994, Rood and Mahoney 1995, Scott et. al. 1997). Artificial impoundments, especially diversion dams used for flood irrigation, decreased populations of native plant species and promoted the invasion of *E. angustifolia* (Currier 1982, Mahoney and Rood 1990, Rood and Mahoney 1995, Lesica and Miles 2001, Pearce and Smith 2001).

Extremely dense populations of *E. angustifolia* are easily observed via windshield view by simply driving along I-90 north from just south of Lodge Grass, Montana to its confluence with the Bighorn River. *Elaeagnus angustifolia* density increases within the woody landscape as one approaches the town of Crow Agency (see Figure 1.2). Along the Bighorn River, southeast of Hardin, *E. angustifolia* appears to have been intentionally planted, as sub-adult stems visibly line irrigation ditches, and this is particularly noticeable just north of Crow Agency at the confluence of the Bighorn and Little Bighorn Rivers. Plains cottonwood trees growing in the uplands are most likely remnants of the last 100-year flood, which occurred in 1978 in the Little Bighorn River Valley (J. Friedman pers. comm. April 2008). Most irrigated crops, primarily sugarbeet crops, are located on the near northern edges, and extreme southwestern portions of both river systems. *Elaeagnus angustifolia* is said to have arrived here as early as the 1930s. During the depression, the Indian Emergency Conservation Work, IECW, or CCC-I, a sub-unit of the Civilian Conservation Corps (CCC) planted *E. angustifolia* as a windbreak or shelterbelt (Gower 1972, B. Old Coyote, Jr. February 2011). *Elaeagnus angustifolia* escaped initial cultivation and now grows well in the uplands beneath large stands of adult cottonwoods (Figure 1.6).

Figure 1.6. *Elaeagnus angustifolia* trees observed lining the Bighorn River just south of Lodge Grass, Montana. Light trees in foreground adjacent to river are *E. angustifolia*, with adult plains

cottonwood trees (darker canopy) behind them in the central portion of the gravel bar. Photo by V. Small, July 2012.

Elaeagnus angustifolia populations have become an overwhelming problem for farmers and land owners, who endure loss of productive land, both in crops and grazing land along these watershed systems (M. Eggers October 2001 pers. comm.). *Elaeagnus angustifolia* commonly invades the banks of irrigation ditches and sub-irrigated pastures in south-central Montana (V. Small pers. observ.). Local and state agencies have encountered difficulties when attempting to contain *E. angustifolia* spread along riparian systems throughout the reservation (Brock 1998, J. Not Afraid pers. comm., NRCS Crow Agency, 2002). *Elaeagnus angustifolia* has adverse effects on agriculture in Montana. Retired BIA irrigation employees (B. House July 2006) noticed when earthen ditches are dredged, *E. angustifolia* sprout quickly along the banks, often blocking the flow of irrigation. Large *E. angustifolia* infestations create serious problems for ranchers because thorns cause physical damage to eyes of cattle and create land barriers when moving cattle to neighboring pastures. Dense *E. angustifolia* stands within pasture lands on the Reservation decreased livestock forage due to its ability to shade understory plants and native grasses. De-commissioned irrigation ditches where flooding rarely occurs also provide effective invasion habitat (V. Small pers. observ.). We found patches of *E. angustifolia* growing along small dry ditches; similar results were reported along the Marias and Milk Rivers (Lesica and Miles 2001, Pearce and Smith 2001). As plains cottonwoods decline with age and die, *E. angustifolia* replaces them, leading to the disappearance of ecologically important plains cottonwoods from riparian systems of the northwest (Lesica and Miles 2001, Katz and Shafroth 2003).

Naturalized *E. angustifolia* trees have been reported to be growing successfully in riparian and moist wet meadows in Colorado, Utah, and Idaho (Knopf and Olson 1984); in the understory of riparian forests as well as in pastures in Utah (Christensen 1963); and along the North Platte River in Nebraska (Bovey 1965). Lesica and Miles (2001) found *E. angustifolia* growing on high river terraces and along the lower terraces of the Marias River in northern Montana. The only known ecological study conducted on the Bighorn River in Montana, showed *E. angustifolia* growing in upper terraces within middle-aged stands of plains cottonwoods as well as in dense thickets away from intact plains cottonwood stands in lower terraces (Akashi 1988). Jarnevich and Reynolds (2011) employed a coarse-scale model using distance to water to predict suitable habitat based upon previously collected presence points of *E. angustifolia* trees throughout the western US, including Montana. Distance to water was the most significant predictor for *E. angustifolia* occurrence when using coarse-scale modeling. However, when they employed fine-scale modeling, distance to water ranked as the fifth most important factor influencing suitable *E. angustifolia* habitat. Mean diurnal temperature, precipitation, elevation, and humidity were more important environmental factors than distance to water. This study supports Jarnevich and Reynolds (2011) recent findings that increase in precipitation and mean temperature are important variables in determining near-future suitable habitat for *E. angustifolia*.

We found *E. angustifolia* occurring in high densities within wetlands, crop, and pasture land use type categories. *Elaeagnus angustifolia* is apparently able to invade systems outside predicted moist wet habitats, as we found stems growing in 11 of the 13 land use types: Roadsides (transportation), mixed rangeland, grass rangelands, residential, other agriculture (dryland crops), mixed urban areas, and land listed as mine/quarry. *Elaeagnus angustifolia* density within residential land use type category and mixed urban areas likely was caused by intentional planting for horticulture reasons. The occurrence of *E. angustifolia* within land use type categories that consist of xeric and moist soils provides further evidence that this species is able to successfully establish and invade beyond riparian forest habitats.

1.5.2 Land ownership

Perhaps to no greater extent has a culture been marginalized with regard to land ownership rights via legislation than with the passing of the Allotment Act of 1887. This policy was enacted to force the Crow to adopt an individual land ownership paradigm, rather than a communal form they had embraced before their forced relocation to the Reservation. The Act was also designed to assimilate the Crow toward a more "productive" use of the land, as the federal government culled the Crow's large horse herds (1921-1930) to make way for the land to be used as pasture for non-Indian cattle barons (Heiser 1999). Land tenure for the Crow was divided into three distinctively different property ownership rights: (1) fee simple title, which refers to property rights that allow the owners to determine the use and disposition of the land, whether Indian or non-Indian; (2) individual trust, where land is allotted to an individual Indian, but remains under federal trust, with the Bureau of Indian Affairs (BIA) as the agent controlling any property use decisions by the owner; and (3) tribal trust, where land is owned by the Tribe as a whole while held in trust with the BIA, from whom all land use decisions must be approved (Belue 1991, Churchill 1999, Anderson 2001). *Elaeagnus angustifolia* stem densities were markedly higher, (marginally significant) in fee patent and allotted ownership status compared to the number present within Tribal trust and reserve lands. The unequal distribution of this invasive species relates to land ownership status, and in particular to allotted land that was leased, after being obtained illegally in some cases, beginning in the late 19th century. Approximately two-thirds of all allotted land is currently leased by non-Indians for agricultural use, either for grazing or crop production.

Employing the methods of the Homestead Act of 1862, the Dawes Act allotted land to Native American individuals into 65 ha (160-acre) sections. Allotments were awarded according to the following formula: To each Crow member's head-of-household a 65 ha plot; to their spouse's 32 ha (80 acres); and to dependent children (under the age of 18) a 16 ha (40-acre) plot. This allotment process resulted in land originally under Crow ownership being transferred to non-Indian settlers in the Montana territory. Hence, the Dawes Act provided the federal government's solution to the "Indian problem" by promoting assimilation, disbanding communal land holdings, promoting individual land ownership, and granting deed of Indian lands originally given under the Fort Laramie Treaty of 1858, to non-Indian settlers.

Heirship is a central reason that Crow tribal members cannot economically benefit from their own land and resources (Churchill 1999, Anderson 2001). In keeping with provisions of the Allotment Act, land that was permanently frozen into the tenure category of individual trust must pass to the owner's heirs. Heirship provisions were followed, subject to the laws of the particular state in which a tribe resided, and Crow Indians who exceeded a specific blood quantum were declared incompetent to handle their affairs and did not have valid wills in which to pass their land allotments to a specific family member (Anderson 2001). Instead, entire families were granted ownership of a specific allotment. Thus, as generations passed, the number of heirs owning a parcel of land grew exponentially.

Multiple allotted land ownership due to heirship provisions of the Dawes Act (1887) resulted in land fractionation, which encumbers the process of making land use decisions. Consensus of a majority of land owners within a specific parcel of land is required, in some cases from as many as 55 individual owners, before any changes could be authorized by the BIA (Anderson 2001). This example is problematic given that to benefit economically from their land; a consensus of multiple owners is required. In cases where ownership included minors, or those whom the BIA Realty office could not locate, the BIA approves land leases without majority consent. Furthermore, without the ability to encumber their land as collateral, because the actual title was held by the federal government, they were unable to obtain the necessary capital for infrastructure to establish a farming or agricultural economy (Anderson 2001). In essence, the Crow people are essentially barred from claiming any reasonable market share by making use of their own land. Had the government's efforts to promote private land ownership been left to a single tenure category, the Crow would have encountered a less encumbered process in their ability to control land use management and development within the Reservation today.

Huge losses in Tribal and individual Crow land to non-Indian owners prompted the US Congress to pass the 1920 Crow Act (H.R. 2381, H.R. 7255, and S.B. 332). The 1920 Crow Act was summarily ignored by the Bureau of Indian Affairs, the federal agency within the Department of the Interior tasked with overseeing Indian lands (Belue 1991). Under the Crow Act, non-Indian land owners were given extended leases on allotted Crow land. The Act restricted the amount of acreage that a single non-Indian land owner could lease or purchase. Section II of the Act stipulates allowable limits on land sales and leases within Reservation boundaries. Land sales listed as a fee simple, or trust patent, could not exceed 259 ha (640 acres) of agricultural land, or 518 ha (1280 acres) of grazing land. The Act further stipulated that individuals, corporations or companies are barred from the purchase of any amount of land that, in sum, would result in ownership that exceeded the allowable limit. Violators of Section II were to be found guilty of a misdemeanor, punishable by fine and/or imprisonment. As an agent of the federal trust, the BIA has been responsible for the enforcement of Section II and was required to notify all potential buyers of the acreage limits.

Unfortunately, beginning in 1940, the BIA failed to post public land sale notices that warned all bidders of the acreage limitations. In 1951, when the BIA was notified of the error, the agency instituted a policy that effectively halted approval of all Crow land sales and leases (Belue 1991). The economic impact on the local community can often be the major determinant of whether policy can reasonably be enforced. When threatened with repatriation of illegally sold tracts of land, non-Indian ranchers and farmers who had been leasing Crow lands banded together with the local land barons and threatened to terminate their leases, should the BIA decide to enforce Section II of the Act (Belue 1991).

The policies established in the era of the 1920 Crow Act resulted in the loss of large tracts of land to private, non-Indian ownership within Reservation boundaries. As a result, non-Indian land ownership parcels increased and became interspersed with land held under trust status within the Reservation, creating a mosaic of land owners consisting of federal, state, private, and Tribal owned land jurisdictions. This complexity has inhibited the Tribe's ability to manage and monitor the ecological integrity of land since large portions are no longer held under trust by the federal government yet fall within the original boundaries granted to the Crow by the Fort Laramie Treaty of 1868. Finally, although the Tribe ostensibly holds the decision-making rights with regard to trust lands use, final approval power remains with the BIA and the US Department of Interior. Without the ability to make decisions regarding land use, the Crow Tribe is effectively powerless to manage the ecological integrity of riparian systems, much less improve their economic future.

1.6 Conclusions

Crow Tribal government was denied access to the process of resource management and, as a result, large parcels of land were leased to non-Indians for agricultural purposes along the river systems within Reservation boundaries. Land parcels allotted to individual Crow owners, (held in Trust status) were too small to support successful and profitable gain in farming or ranching (Trosper 1978). Most parcels of Tribal and individual land allotments within families were often kilometers apart, thus limiting a family's ability to combine parcels to increase their land base. As a result of the severe economic hardships of the Great Depression, many Crow land owners either sold or leased their allotments to non-Indian farmers and ranchers simply to survive.

Multiple intentional plantings of *E. angustifolia* were actively promoted and supplied by federal agencies, i.e. the NRCS, during the peak of agricultural development in the late 19th and early 20th centuries along both the Bighorn and Little Bighorn Rivers. Negative ecological impacts caused by *E. angustifolia* invasion now extend well beyond the floodplain, where this invasive species can be found growing in multiple land use types. Ownership restrictions led to many Indian individuals selling their allotments to non-Indians or to a fee patent status. These restrictions applied to allotments that continue to be unmanaged within floodplains and have led to problems in stemming the further spread of this species into crop and pasture lands, in particular. Forced agriculture led to large-scale irrigation projects during the early part of the 20th century in which the invasive *E. angustifolia* was actively introduced and continually promoted by state and local nurseries until 2009. Despite the passing of recent legislation designed to overcome the heirship rule issues and allow the Tribe and it's individual members to have land returned or leases taken back from non-Indian owners, the American Indian Probate

Reform Act (AIPRA 2008), the problems associated with invasive *E. angustifolia* and its impact on the riparian systems on the Crow Reservation will continue to evade land management and cultural input from the Crow Tribe. Thus, the political ecology of access to agricultural use of the land and restricted ownership policies have led to accelerated rates of invasion. Federal policies must prioritize cultural values to be incorporated into ecological land management along these river systems, which are so intimately tied to Crow cultural identity. Finally, said policies must work to enforce coordination between local and federal agencies in developing invasive species management plans throughout the reservation, regardless of ownership status.

1.7 References Cited

Akashi Y (1988) Riparian vegetation dynamics along the Bighorn River. Ph.D. Dissertation, University of Wyoming, Laramie, WY.

American Indian Probate Reform Act (2004) Amended (2008) 25 U.S.C.§ 2206(b)(1)(A) 47 25 U.S.C.§ 2206(b)(2)(A)(ii) 48 25 U.S.C.§ 2206(b)(2)(B) and 25 USC § 464 One Hundred Eighth Congress of the United States of America Second Session the twentieth day of January, two thousand and four: An Act To amend the Indian Land Consolidation Act to improve provisions relating to probate of trust and restricted land, and for other purposes.

Andersen DC, Cooper DJ, Northcott K (2007) Dams, floodplain land use, and riparian forest conservation in the semiarid upper Colorado River Basin, USA. Environmental Management, 40:453-475.

Anderson TL (2001) Land tenure and Agricultural Productivity in Indian Country (pp 35-54). In: Clow RL, Sutton I (ed). Trusteeship in Change. University Press of Colorado, Boulder, CO, 354 pp.

Belue CT (1991) White Oppression and Enduring Red Tears: Indian Law and Real rules for White Control of Crow lands. University of Wisconsin Law School, Madison, WI, 107 pp.

Belue CT (1989) Oppressors, Power and Tears. University of Wisconsin Law School, Madison, WI, 101pp.

Borell AE (1962) Russian olive for wildlife and other conservation uses. USDA Leaflet No. 517, Washington D.C.

Bovey RW (1965) Control of Russian olive by aerial application of herbicides. University of Nebraska Agricultural Research Station No. 1605.

Busch DE, Smith SD (1995) Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern U.S. Ecological Monographs 65:347-370.

Bradley CC (1977) After The Buffalo Days: An Account of the First Years of Reservation Life for Crow Indians Based On Official Government Documents from 1880 To 1904 A.D. Crow Central Education Commission, Crow Agency, MT, 183 pp.

Brock J. H. (1998) Invasion, Ecology and Management of *Elaeagnus angustifolia* (Russian olive) in the Southwestern U.S.A. (p 25-36). In: Starfinger U, Edwards K, Kowarik I, Williamson E(ed). Plant Invasions: Ecological Mechanisms and Human Responses. Backhuys Publishers, pp. 372.

Christiansen EM (1963) Naturalization of Russian olive (*Elaeagnus angustifolia* L.) in Utah. American Midland Naturalist 70:133-137.

Churchill W (1999) The Tragedy and the Travesty: The Subversion of Indigenous Sovereignty in North America. (p 17-71). In: Johnson TR, (ed). Contemporary Native American Political Issues. Altamira Press Sage Publications, Inc., Walnut Creek.

Clary WP, Kinney JW (2002) Streambank and vegetation response to simulated cattle grazing. Wetlands 22:139-148.

Clow RL, Sutton I (ed) (2001) Trusteeship in change: toward tribal autonomy in resource management. University Press of Colorado, Boulder (355 pp).

Cooper DJ, Merritt DM, Andersen DC, Chimner RA (1999) Factors controlling the establishment of Fremont cottonwood seedlings on the upper Green River, USA. Regulated Rivers-Research and Management 15:419-440.

Corbacho C, Sanchez JM, and Costillo E (2003) Patterns of structural complexity and human disturbance of riparian vegetation in agricultural landscapes of a Mediterranean area. Agriculture Ecosystems and Environment 95:495-507.

Cordes LD, Hughes FMR, Getty M (1997) Factors affecting the regeneration and distribution of riparian woodlands along a northern prairie river: the Red Deer River, Alberta Canada.

Currier P.J. (1982) The floodplain vegetation of the Platte River: phytosociology, forest development, and seedling establishment Ph.D. Thesis. Iowa State University. Ames, IA.

Crow Act (1920) June 4, 1920. [S. 2890.] 41 Stat., 751 Crow Act Amendments May (1926) Chapter 403 | [H. R. 8185.] 44 Stat., 658. Approved, May 26, 1926.

Crow (1997) Crow Tribe and Big Horn County Resource Assessment, December 1997. Report from Crow Conservation District and Big Horn Conservation District, assisted by the US Department of Agriculture, Natural Resources Conservation Service.

D'Antonio CM, Dudley TL, Mack M (1999) Disturbance and biological invasions: direct effects and feedbacks. p. 413–452. In: Walker LR (ed) Ecosystems of Disturbed Ground. Elsevier, pp. 900.

DeCant JP (2008) Russian olive, *Elaeagnus angustifolia*, alters patterns in soil nitrogen pools along the Rio Grande River, New Mexico, USA. Wetlands 28:896-904.

Deloria JV (1997) Red earth, white lies. Fulcrum Publishing, Golden CO, 288 pp.

Dynesius M, and Nilsson C (1994) Fragmentation and flow regulation of river systems in the northern third of the world. Science 266:753-762.

EDA /Economic Development Administration (1996) Profiles of Reservations: Crow Indian Reservation in American Indian Reservations and Trust Areas, US Department of Commerce, Washington, DC.

Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans Final (2008) Crow Indian Reservation: Natural, Socio-Economic, and Cultural Resources Assessment and Conditions Report (Crow Report). Prepared by LAO Environmental, Inc., Billings, MT. http://www.blm.gov/mt/st/en/fo/miles_city_field_office/seis.html (Accessed 15 September 2012)

ESRI 2009. ArcGIS Desktop: Release 9.3.1. Redlands, CA: Environmental Systems Research Institute.

Fitzgerald MO (2007) Native Spirit: The Sun Dance Way. Bloomington, Indiana: World Wisdom, Inc., 78pp.

Fleischner TL (1994) Ecological costs of livestock grazing in Western North America. Conservation Biology 8(3): 629-644.Friedman JM, Auble GT, Shafroth PB, Scott ML, Merigliano MF, Preehling MD, Griffin EK (2005) Dominance of non-native riparian trees in western USA. Biological Invasions 7:747–751.

Frey Rodney (1987) The World of the Crow Indians: As Driftwood Lodges. University of Oklahoma Press, Norman, OK, 193 pp.

General Allottment Act (or Dawes Act), Act of Feb 8, 1887 (24 Stat. 388ch, 119, 25 USCA 331) Acts of Forty-ninth Congress-Second Session, 1887 Retrieved July 25, 2007.

Gower CW (1972) The CCC Indian Division: Aid for Depressed Americans, 1933-1942. Minnesota History 43(1): 3–13.

Gurnell AM (1995) Vegetation Along River Corridors: Hydrogeomorphological Interactions. (p 237-260). In Gurnell, AM, Petts GE, (ed). Changing River Channels. Wiley pp.1-23.

Graetz R, and Gaetz S (2000) Crow Country: Montana's Crow Tribe of Indians. Northern Rockies Publishing Company pp. 68.

Gurnell AM (1997) The hydrological and geomorphological significance of forested floodplains. Global Ecology and Biogeography Letters 6:219-229.

Heiser SA (1999) Chief Plenty Coups' use of farming and allotting in relation to land cessions on the Crow Reservation, 1880-1920. American Indian Studies Interdepartmental Program. UCLA, Los Angeles, CA. Master of Arts Degree pp. 152.

Hobbs RJ, Huenneke LF (1992) Disturbance, diversity, and invasion: implications for conservation. Conservation Biology 6:324-337.

Howe WH, Knopf FL (1991) On the Imminent Decline of Rio Grande Cottonwoods in Central New Mexico. The Southwestern Naturalist, 36:218-224.

Hoxie F (1995) Parading Through History: The Making Of The Crow Nation In America, 1805-1935. Cambridge University Press, Cambridge, 408 pp.

Hoxie F, Mancall PC, Merrell JH, (eds) (2001) American Nations: Encounters In Indian Country, 1850 to the present. Routledge, New York, 400 pp.

Jaimes MA (1992) Federal Indian Identification Policy: A Usurpation of Indigenous Sovereignty in North America (p123-138). In Jaimes MA (ed), The State of Native America: Genocide, Colonization and Resistance. South End Press, Boston, MA, 468 pp.

Jarnevich CS, Reynolds LV (2011) Challenges of predicting the potential distribution of a slow-spreading invader: a habitat suitability map for an invasive riparian tree. Biological Invasions, 13:153–163.

Johnson WC (1994) Woodland expansion in the Platte River, Nebraska: patterns and causes. Ecological Monographs 64:45-84.

Johnson GV (1995) Nitrogen fixation by Russian olive (*Elaeagnus angustifolia*): field and laboratory studies (abstract). 10th International Conference on *Frankia* and Actinhorizal Plants. Davis, CA.

Johnstone IM (1986) Plant invasion windows: a time-based classification of invasion potential. Biological Review 61:369-394.

Junk WJ, Bayley PB, Sparks RE (1989) The Flood Pulse Concept In River-Floodplain Systems (p 110-127). In: Proceedings of the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences 106, Department of Fisheries and Oceans, Honey Harbour, Ontario, Canada.

Karr JR, Schlosser IJ (1978) Water resources and the land-water interface. Science 201:229-234.

Katz GL, Shafroth PB (2003) Biology, ecology and management of *Elaeagnus angustifolia* L. (Russian olive) in Western North America. Wetlands 23:763.

Keane R M, Crawley MJ (2002) Exotic plant invasions and the enemy release hypothesis. Trends in Ecology and Evolution 17:164–170.

Kindschy RR (1998) European starlings disseminate viable Russian olive seeds. Northwestern Naturalist 79:119-120.

Lesica P, Miles S (1999) Russian olive invasion into cottonwood forests along a regulated river in north-central Montana. Canadian Journal of Botany 77:1077-1083.

Lesica P, Miles S (2001) Natural history and invasion of Russian olive along eastern Montana rivers. Western North American Naturalist 61:1-10.

Ligon FK, Dietrich WE, Trush WJ (1995) Downstream ecological effects of dams. BioScience 45:183-192.

Lundgren M R, Small CJ, Dreyer GD (2004) Influence of land use and site characteristics on invasive plant abundance in the Quinebaug highlands of southern New England. Northeastern Naturalist 11(3): 313-332.

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M, Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications 10:689–710.

Mack RN (1996) Predicting the identity and fate of plant invaders: emergent and emerging approaches. Biological Conservation 78:107-121.

Mahoney JM, Rood SM (1990) Collapse of riparian popular forests downstream from dams in western prairies: probable causes and prospects for mitigation. Environmental Management 14:451-464.

Medicine Crow J, Press DS (1966) A Handbook of Crow Indian Laws and Treaties. Crow Tribal Council, Crow Agency, MT 57 pp.

Mellis FA (2003) Riding Buffaloes and Broncos: Rodeo and Native Traditions in the Northern Great Plains. Norman:University of Oklahoma Press, 266 pp.

Middleton BA (1999) Disturbances in Wetlands (pp 5-59) Wetland Restoration, Flood Pulsing, And Disturbance Dynamics. John Wiley & Sons, Inc., New York, 223 pp.

Murphy M, (2004) Romancing the West. Frontiers: A Journal of Women Studies, 25:165-171.

Naiman RJ, Decamps H (1997) The ecology of interfaces: riparian zones. Annual Review of Ecological Systematics 28:621-658.

National Oceanic and Atmospheric Administration. (2008) Western Regional Climate Center Climatological data—Montana. Local Climate Data Summaries, Billings, Montana, USA.

Northcott KD, Anderson C, Cooper DJ (2007) The influence of river regulation and land use on floodplain forest regeneration in the semi-arid upper Colorado river basin, USA. River Research and Applications 23:565-577.

Olson TE, Knopf FL (1986a) Naturalization of Russian olive in the western United States. Western Journal of Applied Forestry 1:65-69.

Olson TE, Knopf FL (1986b) Agency subsidization of rapidly spreading exotic. Wildland Society Bulletin 14:492-493.

Pearce CM, Smith DG (2009) Rivers as conduits for long-distance dispersal of introduced weeds: example of Russian olive (*Elaeagnus angustifolia*) in the northern Great Plains of North America. In: Van Devender T, Espinosa-García, FJ, Harper-Lore BL and Hubbard, T (eds.) Invasive Plants on the Move. Controlling them in North America. Arizona-Sonora Desert Museum Press, 424 pp.

Pearce CM, Smith DG (2001) Plains cottonwood's last stand: Can it survive invasion of Russian olive onto the Milk River, Montana floodplain? Environmental Management 28:623-637.

Peterjohn WT, Correll DL (1984) Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. Ecology 65:1466-1475.

Platt RH, (ed) (2004) Land Use And Society: Geography, Law, and Public Policy. Island Press, Washington, DC, 488 pp.

Read RA (1958) The Great Plains shelterbelt in 1954. Great Plains Agricultural Council. University of Nebraska Experiment Station, Lincoln, NE, Pub 16.

Reynolds LV, Cooper DJ (2010) Environmental tolerance of an invasive riparian tree and its potential for continued spread in the Southwestern US. Journal of Vegetative Science. doi:10.1111/j.1654-1103.2010.01179.x

Richardson DM, Pysek P, Rejmanek M, Barbour MG, Panetta FD, West CJ (2000) Naturalization and invasion of alien plants: Concepts and definitions. Diversity and Distributions 6:93-107.

Robbins P (2004) Comparing invasive networks: cultural and political biographies of invasive species. Geographical Review 94(2):139-156.

Rood SB, Mahoney JM (1995) River damming and riparian cottonwoods along the Marias River, Montana. Rivers 5:195-207.

Rood SB, Mahoney JM (1990) Collapse of riparian popular forests downstream from dams in western parairies: probable causes and prospects for mitigation. Environmental Management 14:451-464.

Scott ML, Auble GT, Friedman JM (1997) Flood dependency of cottonwood establishment along the Missouri River, Montana. Ecological Applications 7:677-690.

Segelquist CA, Scott ML, Auble GT (1993) Establishment of Populus deltoides under simulated alluvial groundwater declines. American Midland Naturalist 130:274-285.

Shafroth PB, Auble GT, Scott ML (1995) Germination and establishment of the native plains cottonwood (*Populus deltoides* Marshall subsp. *monilifera*) and the exotic Russian-olive (*Elaeagnus angustifolia* L.). Conservation Biology 9:1169-1175.

Suagee DB (1999) The cultural heritage of American Indian tribes and the preservation of biological diversity. Arizona State Law Journal 31(483):82.

Tabacchi E, Lambs L, Guilloy H, Planty-Tabacchi AM, Muller E, Decamps H (2000) Impacts of riparian vegetation on hydrological processes. Hydrological Processes 14:2959-2976.

Tilman D (1985) The resource-ratio hypothesis of plant succession. American Naturalist 125(6):827-852.

Tockner K, Stanford JA (2002) Riverine flood plains: present state and future trends. Environmental Conservation 29:308-330.

Trosper RL (1978) American Indian relative ranching efficiency. American Economic Review 68:503-516.

US Census Bureau (2000) Census 2000 Summary File 2, Matrix PCT1 for Montana. Available: www.ceic.mt.gov/C2000/urban_rural_indian.xls (Accessed 15 September 2012)

U.S. Department of Agriculture, Natural Resources Conservation Service (2005) PLANTS database [Online]. Available: http://plants.usda.gov/ (Accessed 15 October).

United States Department of Agriculture/ Plant Database (2004) American Indian Reservations - Montana, North Dakota, and South Dakota, 2002 Census of Agriculture, Pilot Project, Specialty Products, Part 1 AC-02-SP-1, National Agricultural Statistics Service. Available: http://www.agcensus.usda.gov/Publications/2002/American_Indian_Reservations/amindian.pdf (Accessed 15 September).

United State Geological Survey (2003) Ground-water Resources along the Little Bighorn River, Crow Indian Reservation, Montana. US Department of the Interior Helena Water-Resources Investigations Report 03-4052.

Van-Dersal WK (1939) Birds that feed on Russian olive. Auk:483-484

Weber WA, Wittman RC (2001) Colorado Flora: Eastern Slope. University Press of Colorado, Niwot, CO 610 pp.

Wilkinson, L. 2010, SYSTAT. WIREs Comp Stat, 2:256–257. doi: 10.1002/wics.66

CHAPTER 2. CLIMATE CHANGE AND INVASION: DOES A LOSS OF ECOLOGICAL INTEGRITY AFFECT THE CULTURAL EXPRESSION OF AN INDIGENOUS CULTURE?

2.0 Summary

The invasive woody species, *Elaeagnus angustifolia* L., was promoted in the early 20th century to serve as field wind-breaks and for bank stabilization, but quickly became naturalized within riparian systems throughout the semi-arid northwest. The Bighorn and Little Bighorn Rivers of Montana are heavily regulated, and are now greatly dominated by the invasive *E. angustifolia* , which is slowly replacing native plains cottonwood (*Populus deltoides* L.). Historically to present day, the Crow Tribe in south-central Montana use cottonwoods of all size classes for socio-cultural and ritual purposes, yet Tribal Elders have expressed concern over a decline in specific size classes of cottonwood and a continued spread of *E. angustifolia* . Predicted climate changes, such as increases in mean temperature and precipitation in the upper northwest, may serve to exacerbate the spread of this invasive species. We used Maximum Entropy Modeling (MaxEnt) to predict suitable habitat and future spread of *E. angustifolia* along riparian corridors of the Little Bighorn and Bighorn Rivers within Crow Reservation boundaries. To determine cottonwoods available for harvest to and from ceremonial sites, we established riparian forest plots and used semi-structured open interviews with respected Elders in the Crow community between November 2010 and April 2011. Climate variables (n = 22) contributed significantly to the model, suggesting that climate change may contribute to the spread of *E. angustifolia* , particularly downstream from dams. Perceptions of cottonwood availability by the Elders matched the field plot data. Elders overwhelmingly agreed (~80%) that sub-adult trees were the most difficult to find now compared to 25 years ago. Maximum distances to travel to

obtain sub-adult size classes used exclusively in ceremony, increased in present-day by 30 km as opposed to recent history. Cottonwood stem heights (from 7.32 m plots where n=10) were significantly shorter near ceremony sites (< 150 m near) compared to sites farther away (> 2.4 km away; $p < 0.01$). There were more cottonwood trees with diameter at breast height (dbh) < 5 cm in plots located far from ceremony sites than near ($p < 0.05$). Near-term (10 years) climate change predictions, based upon the MaxEnt model, suggest that *E. angustifolia* will continue to spread. Coupled with local perceptions of reduced cottonwood availability, we suggest that mid-sized cottonwoods may become increasingly difficult to locate for ceremonies. Containment of *E. angustifolia* and management plans to increase cottonwood availability will improve the cultural as well as the ecological integrity of these important riparian systems.

2.1 Introduction

Invasive plant species continue to threaten biodiversity and ecosystem function, particularly in riparian zones (Stohlgren et al. 1998). Throughout North America, in regions inhabited by Native people, invasive plants may threaten indigenous practices by outcompeting native plant species harvested for cultural use. This may be the case for the Crow (Apsáalooke) Indians of south-central Montana. Their present Reservation, carved from their original, historic territory, experienced an overwhelming spread of the invasive shrub or tree, *Elaeagnus angustifolia* L. in riparian zones during the last half of the 20th century (B. House May 5, 2008 pers. comm.). Personal observation from other Tribal members indicated that *E. angustifolia* seems to have invaded the upper and lower terraces along the historically significant Little Bighorn and Bighorn Rivers (Lesica and Miles 2001). Since its escape from cultivation in the early 20th century, *E. angustifolia* has slowly replaced large populations of plains cottonwoods (*Populus deltoides*, L. Marsh,) along regulated rivers in Montana. Plains cottonwood is one of the few hardwoods that grow in mid-elevations in this semi-arid region of the northwest (Rood and Mahoney 1995, Lesica and Miles 1999, 2001, Pearce and Smith 2001, Katz and Shafroth 2003). Riparian systems in the lower Yellowstone of the Great Plains were historically dominated by the family Salicaceae, primarily by the genera *Salix* (willow) and *Populus* (cottonwood) (Mahoney and Rood 1990, Scott and Auble 1997, Pearce and Smith 2001, Katz and Shafroth 2003). Genera of Salicaceae, such as plains cottonwood are obligate wetland species (Reed 1988), or phreatophytes, with establishment and survival restricted to streams, rivers, and floodplains in south central Montana (Howe and Knopf 1991). Riparian forests, such as those that grow along the Bighorn (Akashi 1988) and Little Bighorn Rivers provide important habitat for bird and mammal species (Gregory et al. 1991) and aid in the distribution of organic matter. (Andersen 2007). However, as with most navigable water systems in the U.S., river systems within the Crow Indian Reservation were diverted and drained in the early part of the 20th century for agriculture, grazing, and municipal water use (Rood and Mahoney 1995, Lesica and Miles 2001, Rood, et al. 2005, Andersen et al. 2007).

Harvesting plants for ritual and ceremonial purposes is an important expression of the cultural identity of the Great Plains indigenous peoples, including the Apsáalooke (Crow) Nation (Fitzgerald 2007). Perhaps the most significant woody species to the expression of Crow culture is the plains cottonwood used in the practice of the annual Sundance (*Ashkisshe*) (Fitzgerald 1991, 2007, Crummett 1993). Sundance ceremonies, several of which are held each summer throughout the Reservation (Crummett 1993, Fitzgerald 2007), require the harvest of an entire cottonwood tree, which is placed in the center of an arbor (Crummett 1993). Young sub-adult cottonwood trees are also used for the construction of the arbor in preparation for the Sundance. Historically, whole large saplings (1.7-3.5 m height) were placed along the outer rim of the arbor to be used for shade and windbreak for the dancers (Crummett 1993, Fitzgerald 2007). Cottonwoods are also used for construction of shade structures during the annual Crow Fair, held every August since 1921. Recently, the Elders expressed concern that certain sizes, specifically sub-adult size classes (3.6-8.5 m height) and large saplings of cottonwood were becoming more difficult to locate (T. Medicine Horse February 7, 2006 pers. comm.).

Construction of diversion dams in the last century affected the timing and intensity of water flow along northern reaches of the Little Bighorn and Bighorn Rivers (Akashi 1988). Regeneration of cottonwood requires a seasonal flood pulse in the spring to provide moist substrates. Wet banks, sand and gravel bars formed from natural scouring during spring flooding are essential for shade intolerant cottonwood seeds to successfully germinate (Katz and Shafroth 2003, Northcott et al. 2007). Cottonwood seeds are extremely small (400-1260 seeds per gram) and are wind dispersed over several weeks in June. Germination success of cottonwood, however, is extremely low, even on favorable sites such as those found along point and sand bars (Shafroth et al. 1995). Mortality rates for seedlings are higher on average than their *E. angustifolia* counterparts, and desiccation often occurs for seedlings that are not well supplied with capillary moisture following germination (Moss 1938). Cottonwoods require seasonal hydrological disturbance as with spring snowmelt, rather than sudden or abrupt changes such as reservoir release or heavy rainfall events (Shafroth et al. 1995).

Conversely, *E. angustifolia* seeds are much larger (11.4 seeds/gram) and have higher rates of success due to a protective endocarp that remains dormant for up to 3 years, germinating when environmental conditions are optimum. Seeds of *E. angustifolia* are also dispersed by mammals, birds and water, increasing their success of germination post-dormancy. Seedlings of *E. angustifolia* have greater survival rates than plains cottonwood due to their high tolerance of drought, floods, and a variety of soil conditions (Reynolds and Cooper 2010, Jarnevich and Reynolds 2011). Seedlings often establish as dense thickets under cottonwood canopy, grow slowly until the cottonwood die-back, then increase growth and spread (Shafroth et al. 1995). Invasion is also common within areas that are unsuitable for cottonwoods such as pastures (Figure 2.1), thus increasing their ability to continue to spread beyond riparian areas (Reynolds and Cooper 2010, Jarnevich and Reynolds 2011). Finally, in its introduced range, *E. angustifolia* is released from the suppressive effects of its native herbivores, pathogens, and co-evolved plant competitors (Mitchell and Power 2003), which keep it in check in its native Eurasia (Katz and Shafroth 2003).

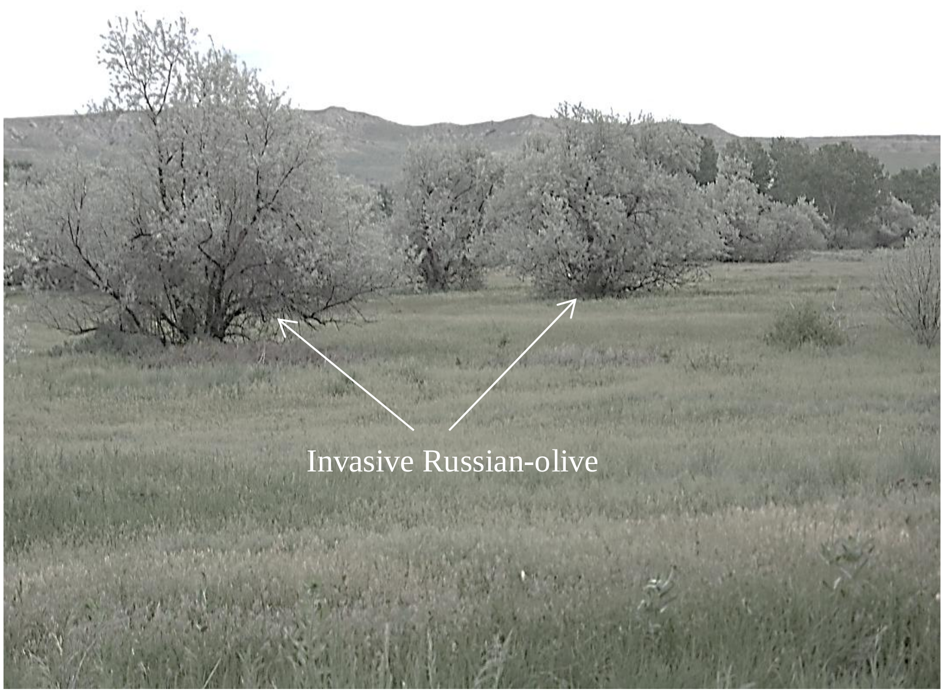

Figure 2.1: Invasion of pastures by *E. angustifolia* along Little Bighorn River system, north of Crow Agency, Montana. Photo by V. Small, July, 2008.

Combined effects of river diversion and continued spread of the invasive *E. angustifolia* has created significant challenges for Tribal, federal and state natural resource managers. Furthermore, land management within the Reservation can be problematic because the Crow Tribe does not own all land within Reservation boundaries, despite common assumptions to the contrary. The need to coordinate planning with multiple agencies and entities (federal, state, Tribal, private) and the growing concerns of the Crow Tribal community about the decline of plains cottonwoods suggests the need for in-depth study of this invasive shrub/tree in this system.

Species distribution maps are an important tool for land managers to identify specific areas to focus the limited personnel and funding for invasive plant species management. We focused on identifying specific climate characteristics, and modeled these with current *E. angustifolia* presence points to map and predict near-future suitable habitat. We hypothesize that short-term climate change will promote the continued spread of *E. angustifolia* and, as with other regulated river systems, eventually replace the dominant plains cottonwood within these riparian systems. To test this, we created baseline species distribution maps by using presence points of *E. angustifolia* trees collected along both river systems to identify near-term suitable habitat in tandem with predicted future climate environmental variables along the Little Bighorn and Bighorn Rivers within Reservation boundaries. We also hypothesize that the Crow people may be negatively affected by the invasive *E. angustifolia* due to a possible reduction in plains cottonwood available to harvest for socio-cultural purposes. We test this by conducting open semi-structured interviews with knowledge holders (Elders) between November 2010 and April 2011. Interview questions focused on local perceptions of stems available to harvest and distance to travel for harvest of specific size classes of cottonwoods present-day versus 25 years before present (ybp). Further, we established field plots located near and far from ceremonial sites to examine population size structure of cottonwoods and compare these (harvested vs. unharvest) at different distances.

2.2 METHODS

2.2.1 Study site

This study was conducted along the Bighorn and Little Bighorn Rivers and floodplains in south central Montana within present-day boundaries of the Crow Indian Reservation (Figure 2.2). The Bighorn River is a tributary of the Yellowstone River, which flows through the northern portion of the Bighorn Mountains in Wyoming where it flows into Montana, eventually forming the Bighorn Lake Reservoir and Bighorn Canyon Recreation Area, since the completion of the Yellowtail Dam in 1967 in Fort Smith, Montana (Bearss 1970, U.S. Department of the Interior 2001). This study includes the floodplain and riparian areas of the Bighorn River beginning on the North side of Yellowtail Dam afterbay to the confluence of the Little Bighorn River (~ 61 km), just south of Hardin, Montana, and the Little Bighorn River beginning at the Wyoming/Montana boundary, north to its confluence with the Bighorn River, just north of Crow Agency, Montana. The climate is semi-arid with mean annual precipitation of 304 mm and average annual temperature of 7.5 °C (NOAA Western Regional Climate Center 2008).

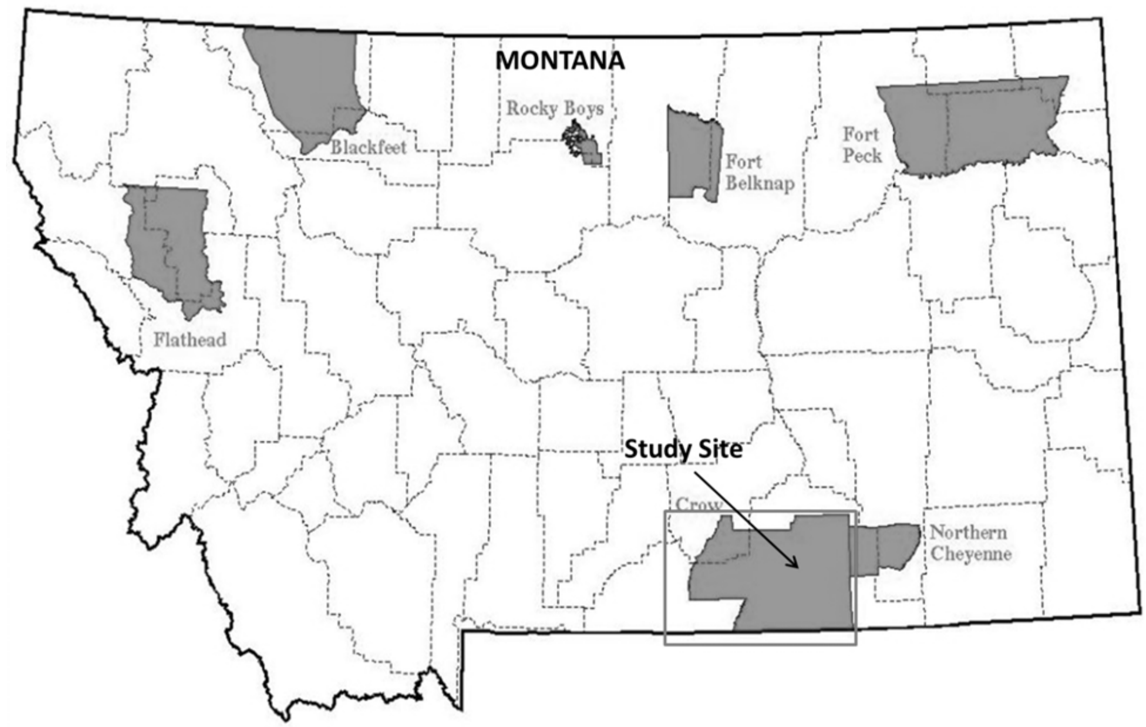

Figure 2.2. Map of Montana denoting the seven Reservations. The site of this study was the Crow Indian Reservation in South-Central Montana.

2.2.2 Field sampling

In July, 2010, we used an opportunistic field data collection method to obtain presence points of *E. angustifolia* trees using a handheld Global Positioning System (GPS) (Garmin-Oregon 450 Olathe, KS, USA). We collected 1178 presence points along the Little Bighorn and Bighorn Rivers and associated floodplains where access was possible and allowed. In some cases we were able to gain access by boat or all-terrain vehicles. Riparian and floodplain areas were roughly delineated from ArcMap (ESRI 2009 ArcGIS Desktop: Release 9.3.1. Redlands, CA, USA. Environmental Systems Research Institute), and we used a 1.61 to 2.0 km buffer zone from the center of each river to focus collection points. Ancillary data collected included northing, easting, datum, zone, species, and distance to surface water. Plant composition variables included tree/shrub height, diameter at breast height (dbh), species, and presence of native and non-native species. These data were uploaded from a handheld GPS, converted to a comma delimited format, and uploaded to the National Institute of Invasive Species Science website (http://www.niiss.org).

Species distribution models have become an important tool for invasive species monitoring and management. Spatial distribution models use the current presence of a species within a geographical context to predict potential future distributions (changes in habitat suitability) using climatic and environmental layers. These models require large amounts of data storage and the knowledge of several software programs. The advent of the internet and increased server capacity now enables development of user-friendly online mapping and modeling systems (Graham et al. 2010). In partnership among Colorado State University (CSU), the United States Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), and other organizations, the Global Organism Detection and Monitoring (GODM) cyber infrastructure was added to the National Invasive Species Institute Science website. Available via the World-Wide-web, GODM provides open-access, and user-friendly invasive species modeling capabilities.

We used a maximum entropy predictive model (MaxEnt) (Phillips et al. 2006) in a web-based system through the National Institute of Invasive Species Science (NIISS) to map current and predict potential distribution of the invasive *E. angustifolia* along the Little Bighorn and Bighorn River systems within the Crow Indian Reservation, Montana, USA. We used predictive variables such as precipitation and mean annual temperature (Table 2.1) from the BioClim dataset (http://worldclim.org/bioclim) in our MaxEnt models. MaxEnt uses presence points and associated environmental and background factors, which users are allowed to select, to distinguish suitable habitat from non-suitable habitat. Predictions of the model are defined by values for area under the curve (AUC), which are then compared to a random distribution. An AUC ranges from 0 to 1, where a score of 1 indicates predictive discrimination, a score of 0.5 suggests that the discrimination is no different than prediction at random, and a score below the 0.5 suggests that the model fit the data, yet did not accurately predict distribution.

Table 2.1. Climate predictor variables used as environmental layers in MaxEnt model.

Temperature	Annual Precipitation
Maximum Temperature: Warmest Month	Precipitation: Wettest Month
Enhanced Vegetation Index	Mean Temperature: Coldest Quarter
Precipitation: Driest Month	Frequency of Precipitation
Precipitation: Wettest Quarter	Annual Mean Temperature
Isothermality	Mean Temperature: Driest Quarter
Mean Temperature: Wettest Quarter	Precipitation: Warmest Quarter
Mean Temperature: Coldest Quarter	Enhanced Vegetation Index/ Mean
Precipitation: Coldest Quarter	Precipitation Seasonality
Mean Diurnal Range	Precipitation: Driest Quarter
Annual Grow Days	Minimum Temperature: Coldest Month

2.2.3 Cottonwood plot data

We collected data from plots located near (< 150 m) and far (> 2.4 km) from Sundance and Crow Fair ceremonial sites to determine differences in riparian forest (cottonwood) structure. Likewise, there is a Sundance held within 150 m of the Crow Fair campground, providing an excellent site in which to test for differences in size classes of plains cottonwood available to harvest for socio-cultural and ritual purposes (V. Small, pers. obs). To determine size class distributions of cottonwood available to harvest, we used Geographic Information System (GIS) maps to randomly select 10 points along a linear transect adjacent to the Little Bighorn River. These points were used to establish (n = 10) 7.32 m circular plots, representing near and far distances from the Crow Fair Campground/Sundance grounds. Points selected to establish the plots were located using a handheld GPS and uploaded to ArcMap for analysis (ESRI 2009). Plots were also stratified longitudinally according to distance from the river's edge, to obtain size classes available within the entire floodplain (wetland-uplands). Variables measured included tree presence, location, height and dbh for all cottonwood trees and percentage of cottonwood regrowth from stumps. Cottonwood height and densities were analyzed using t-tests assuming unequal variances, to determine the influence of distance from ceremonial site (near vs. far) on available stems for harvest (total number of trees = 387).

We used the following size classes for cottonwood stem height analysis: seedling (0-1.6 m); sapling (1.7-3.5 m); sub-adult (3.6-8.5 m); adult (< 8.6 m). Tree height data were $\log_{10}$ (N + 1) transformed to meet the assumptions of parametric testing (Zar 1999). To analyze dbh, size classes were used to balance sample sizes, as the number of individuals or stems in a particular size class tends to decline with increasing diameter (Condit et al. 1998, Lykke 1998, 2001). We used the following diameter size classes (cm): 1, 2, 3-4, 5-6, 7-8, 9-10, 11-13, 14-16, 17-19, 20-23, 24-27, 28-31, 32-35, 36-39, 40-43, 44-47, 48-51, 52-55, > 55. Size classes were based upon responses from interviews with Crow Elders relative to cottonwood stem height and dbh harvested for Sundance and Crow Fair shade structures.

2.2.4 Perceptions of cottonwood availability

To obtain perceptions of cottonwood availability, we conducted open ended semi-structured interviews (November-April of 2011) with Crow Tribal Elders (n = 11). Knowledge holders of the Sundance ceremony and use of cottonwoods during the annual Crow Fair include nine males and two females, between 49 and 93 years of age. Interviews lasted on average 45 minutes, and consisted of current or former Sundance chiefs, Keepers of cultural knowledge, Sundance participants, or someone who hosted a Sundance in previous years. All knowledge holders participate in the annual Crow Fair celebration. Questions and responses from participants were part of a larger ethnobotany study of *E. angustifolia* and cottonwood knowledge and use, and perceptions of cottonwood availability. Interviews were held individually, to avoid influence from other participants (Phillips and Gentry 1993). For this study, Elders were asked which size class of cottonwoods are harvested and used as construction material for the Sundance (ceremonial) or shade structures (socio-cultural) used during the annual Crow Fair celebration. Elders were asked questions relating to distances to travel to obtain specific stem sizes present-day and 25 ybp. Size classes discussed during the interviews were compared with plot data analysis to determine local perceptions of current versus past availability of this culturally significant resource. Statistical tests used in all analyses were considered significant using α level < 0.05, and calculated employing SYSTAT 12 (Wilkinson 2010).

2.3 RESULTS

2.3.1 MaxEnt model of Elaeagnus angustifolia habitat suitability

Model predictions for *E. angustifolia* habitat suitability were strong, with AUC values exceeding 0.90. The primary predictor variables included mean annual temperature, temperature variability, and the maximum temperature of the warmest month at the 1-km scale (Table 2.2). Thus, the model was able to discriminate between areas with suitable and unsuitable habitat (Figure 2.3).

Table 2.2. Top environmental predictive variables with Area Under the Curve (AUC) percentages over 1%

	Environmental Variable	AUC > 1%
1	Temperature: Annual Range	72.2
2	Temperature variability	11.4
3	Maximum Temperature: Warmest Month	4.8
4	Annual Grow Days	2.7
5	Precipitation: Driest Month	2.4
6	Precipitation: Wettest Quarter	2.2
7	Isothermality	1.1

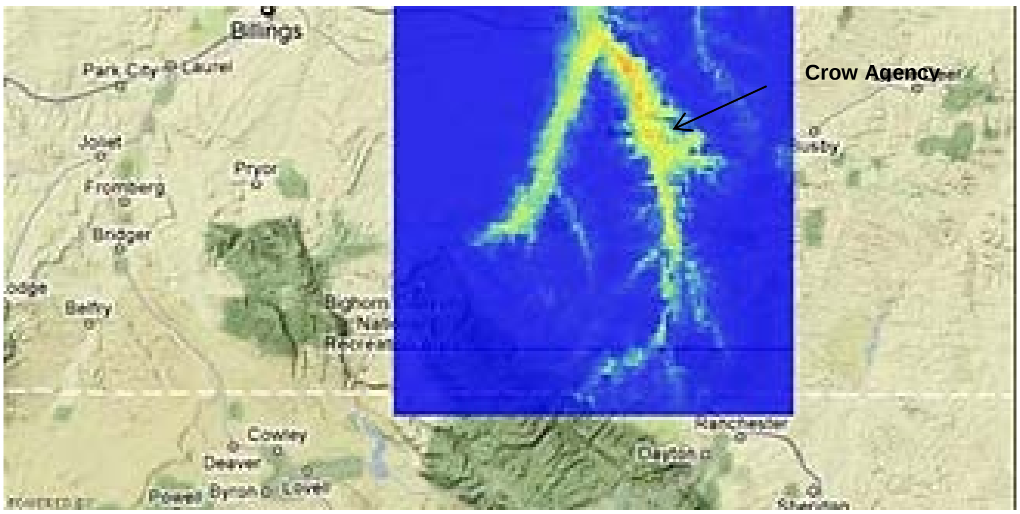

Figure 2.3. Mapped habitat suitability for *E. angustifolia* in the study area. Areas highlighted in blue are less-favorable sites for *E. angustifolia* growth; the color spectrum within the yellow, particularly the orange/red range, indicates high habitat suitability given climate variables used in the model (see Table 2.1).

2.3.2 Cottonwood plot data

Cottonwood trees were significantly taller in near plots than in far when grouped (n=5) ($p < 0.01$) using two-sample t-tests, assuming unequal variances (Table 2.3). Mean number of trees within size classes were not significantly different comparing near vs. far. Stem regrowth from stumps accounted for 23% of all cottonwoods within near plots (< 150 m). Conversely, cottonwood stem regrowth from stumps accounted for less than 3% of total stems within far plots (> 2.4 km). Mean differences between plots for cottonwood dbh was significant ($p < 0.05$) using analysis of variance. Seedling density (< 1 cm) was greater in far, versus near plots (Figure 2.4). Mean number of stems (dbh) within near plots had greater variation between size classes, and slightly more than half of total tree stems were < 1 cm (n = 90).

Table 2.3. Comparing means between grouped plot data for differences in cottonwood stem height (m), using two-sample t-tests (assuming unequal variances) for cottonwood stem height (m). Differences between near (< 150 m) and far (> 2.4 km) from ceremonial sites in Crow Agency were significant at $p < 0.01$ two-tail.

Plot Variables	Near Plots	Far Plots	
Mean	1.41	0.77	
Variance	7.24	6.34	
Df	355	P (T<=t) two-tail	0.01

2.3.3 Local resource interviews

2.3.3.1 Cottonwood tree size class availability

Participants agreed (88%) that sub-adult (3.6-4.5 m) size classes used for construction purposes for ceremonial (Sundance) and socio-cultural uses (Crow Fair camp shade) were more difficult to find now than in the past (25 ybp). Specific size class questions were not applicable in 3 of 11 Elders who were interviewed, as they either did not actually harvest trees or chose not to respond. One of eight participants regarded saplings (1.7-3.5 m) difficult to find present-day; thus, perceptions regarding resource availability for this size class remains largely unchanged over time. Conversely, eight out of eight of the Elders identified sub-adult size classes (3.6-4.5 m) as the most difficult to locate for harvest presently compared to recent past (25 ybp). Stems above 8.5 m are not harvested for Sundance ceremony or for shade structures during the annual

Crow Fair. Saplings harvested for shade purposes placed around the Sundance arbor, and used in building shade structures for the annual Crow Fair will often regenerate from stumps, as evidenced by the number of saplings found within plots located near ceremonial sites. To date, there are currently no large-scale programs that actively replace cottonwoods along the floodplains within the reservation.

2.3.3.2 Distance to travel

The maximum distance traveled for harvest round trip to and from Crow Agency ranged from 0.80 km to 8.0 km for all size classes 25 ybp. Present-day mean maximum distance traveled to obtain specific size classes for shade structures was 98 km, with the greatest distance of 193 km and the shortest as 40 km. Nine participants (82%) indicated distance to travel to harvest sub-adult size class stems increased significantly within the last 25 years. One participant indicated they now re-use sub-adult cottonwood boles for construction of the Sundance arbor, replacing only the sacred pole and saplings for shade, due to economic constraints in travel to harvest, and lack of availability regardless of location within Reservation boundaries.

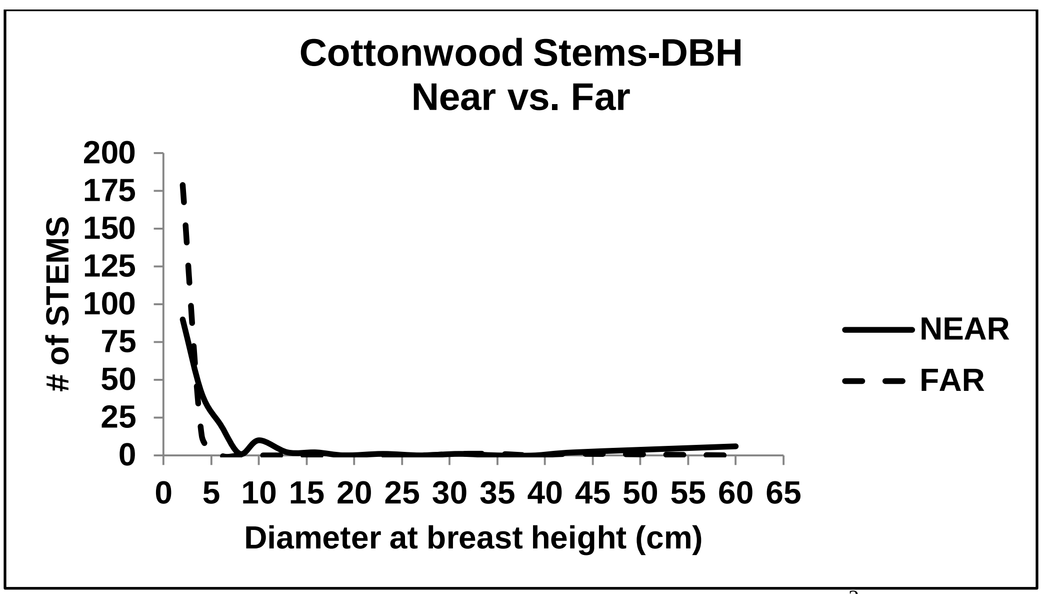

Figure 2.4. Size class distribution of density (number of stems/m^2) for diameter at breast height (dbh) of plains cottonwood between ceremonial sites (near vs. far).

2.4 Discussion

2.4.1 Modeling climate change

MaxEnt model results using the BIOCLIM dataset indicate precipitation and temperature will have the greatest influence on habitat suitability for continued spread of *E. angustifolia* within the Crow Reservation. Model results indicate that the northern reaches of the Little Bighorn and Bighorn Rivers will be particularly vulnerable to near-term invasion (see Figure 2.3). Most western climate change scenarios predict that increases in annual temperature will affect timing of seasonal snowmelt in the semi-arid northwest. Higher annual temperatures within the last decade have also resulted in an increase in storm intensities in the Northern Great Plains of the U.S. (Fay et al. 2008). This prediction is consistent with the occurrence of recent flood events during the past 3 years within the Reservation. In May of 2011, severe flooding due to large rain events and early snowmelt caused in excess of $1million in property damage in the town of Crow Agency, and along mid-portions of the Little Bighorn River (i.e., Lodge Grass). Early snow melt and flooding events have occurred in these same regions, albeit to a lesser degree between 2008 and 2010. A shifting of these seasonal (spring) overflows, and a reduction of ice scouring within these river systems, may serve to increase *E. angustifolia* spread due to its ability to withstand wide environmental fluctuations (Pearce and Smith 2001). Increases in mean temperature, and large abrupt rainfall events, will likely contribute to the future spread of the invasive *E. angustifolia* (Morison and Morecroft 2006).

2.4.2 Plot data

Midsized or sub-adult cottonwoods used in ritual and social practices for the expression of Crow cultural identity, are in desperately short supply throughout the Reservation.

Cottonwood trees were taller in plots located near ceremonial sites, with a smaller number of seedlings than those in far plots. This is due to harvesting of saplings in near ceremonial sites, where there is less physical disturbance. Trees close to ceremonial and socio-cultural sites (Sundance and Crow Fairgrounds) are adult size, or small seedlings, which are not harvested for any purpose. The higher number of seedlings ($n = 179 < 1$ cm dbh) in far plots, compared to near sites may be the result of frequent human disturbance and a lack of harvesting of far sites for either Sundance or Crow Fair construction purposes. Saplings were not indicated in interviews with Elders to be difficult to find, regardless of location along river systems within Reservation boundaries. Availability to harvest sapling size classes was actually slightly greater near ceremony, which suggests Crow practice selective and ecologically sound harvesting techniques, leaving enough stem for vegetative grow back the following year. This is supported by the evidence of coppicing, which were higher in near sites (23%) than those located further from ceremonial sites ($< 3\%$). This also suggests that harvesting for shade structures takes place near, rather than far from ceremonial sites. A large percentage of sapling stem sizes found within near plots were regrowth from stumps. Cladoptosis reproduction through branch propagation has been documented in cottonwoods (Rood et al. 2003). Annual tree growth for *P. deltoides* L. (*Monilifera*) averages up to 3 m, thus stump regrowth (annual stump heights were 0.5 m) would provide required cottonwood resources within 2 years for each Crow Fair Campground shade structures and the Sundance arbor poles.

The lack of sub-adult cottonwood trees to harvest for the purpose of building the arbor in the Sundance ceremony is prevalent throughout reservation floodplains. Elders indicated that regardless of location, sub-adult trees have become more difficult to locate for harvest, and where small patches do exist, this size class is becoming less common. The question as to whether overharvesting sub-adult trees, due to preference and selection of saplings for shade structures is reasonable, and thus should be addressed. However, decline of cottonwoods along other river systems in Montana, such as along the Milk and Marias rivers, are not subjected to cultural harvesting practices. If overharvesting were the cause of the decline in available cottonwoods, particularly in a sub-adult size class, then one would expect to see other regulated river systems to be dissimilar in the presence of sub-adult size class cottonwoods. However, Pearce and Smith (2009) likewise noted reduced presence and abundance of sub-adult cottonwood trees along specific reaches of the Milk River in Northern Montana, and an increase in *E. angustifolia* from 148 trees to 278 trees nine years later, even after post-cutting chemical treatment. Further, more than half (62%) of the saplings of all species counted along the Milk River in Montana were *E. angustifolia*, thus this invasive species is replacing native plains cottonwood as the once dominant riparian species.

Crow Elders indicated that saplings used for shade surrounding the arbor at the Sundance Grounds or for permanent shade structures and roof thatch used at the annual Crow Fair are readily available for harvest. It is perhaps important to note that cottonwoods in general, and in particular saplings and sub-adult sizes, are not harvested solely in this particular area of the Little Bighorn River where plots were established. Saplings used for shade in the Sundance ceremony and for Crow Fair campground structures can be and are harvested along other areas of the Bighorn and Little Bighorn Rivers. There are several other Sundance ceremonies held throughout the summer months on the Crow Reservation. Those interviewed indicated other sites have similar difficulties in locating sub-adult size classes, although saplings appear to be readily available for harvest, and within reasonable distances (less than 3 km in most cases) from ceremonial sites.

Plot results and size class preferences indicated by respondents are well matched: juvenile-adult (3.6-4.6 m) cottonwood sizes are the most difficult to find for harvest. Although it is expected that fast growing species such as cottonwoods would have a larger number of individuals in smaller size classes (Condit et al. 1998), there are other factors that may result in a smaller number of individuals within the mid-size or sub-adult size classes. Human disturbance along these river systems has reduced flow in terms of quantity and timing of natural flood regimes due to diversion and recreation dams. Timing is particularly important for seed germination and establishment on moist substrates, which is required for cottonwoods to grow to adult sizes (Dixon and Turner 2006). Cottonwoods are fast growing species, and thus there should be a higher number of individuals within sub-adult size classes. It is doubtful that populations are currently able to survive past the seedling stages on upper banks of the rivers, as many of the upland trees have reached full maturity, far past the size class used for any ritual or ceremonial purpose by Crow Tribal members. It has been suggested that most of the adult-size class cottonwood trees can be dated to the last 100-year flood, which occurred in 1978 along the Little Bighorn River (J. Friedman, pers. Comm. April 2008).

Harvesting is not strictly limited to the Little Bighorn River, as respondents indicated that they harvest mid-size or sub-adult trees from places where they have been able to locate them in late winter or early spring throughout the Reservation. Even saplings are harvested for Crow Fair by those who live on different areas of the Little Bighorn and Bighorn Rivers and this could explain why the sapling size class is not indicated (one of eight Elders) as difficult to locate for harvest. One respondent reported they are now re-using sub-adult size class stems for construction of the arbor, replacing only the center pole (7.3 to 8.5 m maximum height), which demonstrates resiliency and adaptation to a changing environment. Respondents (eight of eight) indicated locating sub-adult (3.6 to 8.5 m) size class has become too difficult and costly relative to increases in distance to travel to find, regardless of where they attempt to harvest along both river systems.

2.5 Conclusion

The MaxEnt mapping tool suggests that *E. angustifolia* has found highly suitable habitat within the Crow Reservation. It may continue to spread in habitats historically populated by the native plains cottonwoods, particularly downstream of diversion dams along the Little Bighorn and Bighorn Rivers. Drastic reductions in cottonwood sub-adult size classes suggest that *E. angustifolia* has already affected the ability of the Crow to harvest this culturally significant woody riparian species, and this is likewise reflected along other rivers in Montana, where cottonwoods are no longer the dominant woody species (Pearce and Smith 2009). Cottonwood plots reflect reductions in sub-adult stem heights, in-part due to drastic changes in flow regimes within these riverine systems. Regeneration of cottonwood requires a seasonal flood pulse in the spring and subsequent drawdown in the summer to provide moist substrates. Wet banks, sand and gravel bars formed from a natural scouring during spring flooding are essential for cottonwood short-lived, wind-dispersed seeds to successfully propagate (Katz and Shafroth 2003, Northcott et al. 2007). Regulation of both the Little Bighorn and Bighorn Rivers, have indeed altered both the quantity and timing of water flow, drastically reducing cottonwood habitat (Cooper et al. 1999). However, the intentional planting of *E. angustifolia* during the 40s, and again in the 70s, with continued promotion by state and federal agencies are perhaps the best explanation for the large populations now present along both these river systems.

The Sundance ceremony, brought back to the Crow in 1948, exclusively used cottonwoods, and also for shade structures during the annual Crow Fair, which began in 1921. Yet, it is only within the last 25 years that the Crow have seen a reduction of cottonwoods to harvest for either of these events. Lag times in growth and reproduction of *E. angustifolia* would be approximately 25 to 30 years after introduction. River regulation however, began in the late 19^{th} century, with the last one constructed in the late 20s. If the lack of cottonwoods were due solely to river regulation, then cottonwood availability for harvest would have affected their use for ceremonial events before the introduction of *E. angustifolia*. Yet, historically, cottonwood availability for harvest was plentiful and near ceremonial and socio-cultural sites, Crow Elders responses to the increase of distance to travel to obtain specific size classes within the last 25 years suggests that as *E. angustifolia* introductions began to reach reproductive age, they began to grow in sites that were both favorable and unfavorable typical cottonwood sites. As in other Montana and regulated river systems within the northern plains, the native plains cottonwoods are slowly being replaced by the invasive *E. angustifolia*. These results are consistent with other studies of cottonwood decline and *E. angustifolia* invasion of Montana riparian systems (Lesica and Miles, 1999; 2001, Northcott et al. 2007, Pearce and Smith 2009). Despite warming temperatures and impending climate change for the northern Great Plains, the single most positive predictor of non-native species density was dependent upon the current density of native species (Stohlgren et al. 2005).

Plains cottonwoods, a culturally significant woody species used in expression of Crow culture is quickly disappearing from these riparian systems. Increased distance to travel to locate cottonwoods to harvest for ritual purposes may create a significant hardship on the Crow, and thus their ability to express their unique cultural identity through ritual practices. Land management plans must include mitigation of *E. angustifolia* in tandem with efforts to plant cottonwoods along buffer zones. This would allow continued harvesting of saplings and increase the number of individual cottonwoods within the sub-adult size classes, which are in decline. Restoration must include efforts to restore these rivers to their historic hydrologic regimes that support native vegetation. Predicted climate changes within the upper northwest of the U.S. may serve to exacerbate the spread of *E. angustifolia* and the decline of cottonwoods; the Crow's ability to locate cottonwoods for construction purposes in ritual and socio-cultural events will continue to decline in a changing climate.

2.6 References Cited

Akashi, Y. , 1988. *Riparian vegetation dynamics along the Bighorn River*. Ph.D. Dissertation, University of Wyoming, Laramie, WY.

Andersen, D. C., D. J. Cooper, and K. Northcott. 2007. Dams, floodplain land use, and riparian forest conservation in the semiarid upper Colorado River Basin, USA. *Environmental Management*, 40:453-475.

Bearss, E.C. 1970. Bighorn Canyon National Recreation Area, Montana-Wyoming. *U.S. Office of History and Historic Architecture*. 2 v. (xxiii, 687, [88] p.).

Condit, R., R. Sukumar, S. P. Hubbel, and R. B. Foster. 1998. Predicting Population Trends from Size Distributions: A Direct Test in a Tropical Tree Community. *The American Naturalist*, 152:495-509.

Cooper, D. J., D. M. Merritt, D. C. Andersen, and R.A. Chimner, 1999. Factors controlling the establishment of Fremont cottonwood seedlings on the upper Green River, USA. *Regulated Rivers-Research and Management* 15:419-440.

Crummet, M. 1993. *Sundance*. Helena, Montana: Council for Indian Education.

Dixon, M. D., and M. G. Turner 2006. Simulated recruitment of riparian trees and shrubs under natural and regulated flow regimes on the Wisconsin River, USA. *River Research and Applications* 22:1057-1083.

Evangelista, P., S. Kumar, T. J. Stohlgren, K. Jarvenich, A. Crall, J. B. Norman III, and D. T. Barnett. 2008. Modelling invasions for a habitat generalist and a specialist plant species. *Diversity and Distributions*, 14: 808-817.

ESRI 2009. ArcGIS Desktop: Release 9.3.1. Redlands, CA: Environmental Systems Research Institute.

Fay, P. A., D. M. Kaufman, J. B. Nippert, J. D. Carlisle and C.W. Harper 2008. "Changes in grassland ecosystem function due to extreme rainfall events: implications for responses to climate change." *Global Change Biology* 14:1600-1608.

Fielding, A. H.and Bell, J. F. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental Conservation* 24:38-49.

Fitzgerald, M. O. 1991. *Yellowtail: The Medicine Man and Sun Dance Chief Speaks of the Sacred Ways of the Crow*. Norman: University of Oklahoma Press.

Fitzgerald, M. O. 2007. *Native Spirit: The Sun Dance Way*. Bloomington, Indiana: World Wisdom, Inc.

Graham, J., Newman, G., Kumar, S., Jarvevich, C., Young, N., Crall, A., Stohlgren, T.J., and P. Evangelista. 2010. Bringing modeling to the masses: A web based system to predict potential species distributions. *Future Internet,* 2:624-634.

Graham, J., G. Newman, C. Jarnevich, R. Shory, and T. J. Stohlgren. 2007. A global organism detection and monitoring system for non-native species. Ecological Informatics, 2:177-183.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An Ecosystem Perspective of Riparian Zones. *BioScience,* 41:540-551.

Howe, W. H., and F. L. Knopf. 1991. On the Imminent Decline of Rio Grande Cottonwoods in Central New Mexico. *The Southwestern Naturalist,* 36:218-224.

Jarnevich C.S,, and L.V. Reynolds. 2011. Challenges of predicting the potential distribution of a slow-spreading invader: a habitat suitability map for an invasive riparian tree. *Biological Invasions,* 13:153–163.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. *The flood pulse concept in river-floodplain systems.* Paper presented at the Proceedings of the International Large River Symposium (LARS), Honey Harbour, Ontario, Canada.

Katz, G. L., and P. B. Shafroth. 2003. Biology, ecology and management of *Elaeagnus angustifolia* L. (Russian olive) in Western North America. *Wetlands*, 23:763-777.

Lesica, P., and S. Miles. 2001. Natural history and invasion of Russian olive along eastern Montana rivers. *Western North American Naturalist*, 61:1-10.

Lesica, P., and S. Miles. 1999. Russian olive invasion into cottonwood forests along a regulated river in north-central Montana. *Canadian Journal of Botany*, 77:1077-1083.

Lykke, A. M. 1998. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. *Biodiversity and Conservation*, 7:1261-1275.

Lykke, A. M. 2001. Local perceptions of vegetation change and priorities for conservation of woody-savanna vegetation in Senegal. *Journal of Environmental Management*, 59:107-120.

Mitchell, C. E. and A. G. Power. 2003. Release of invasive plants from fungal and viral pathogens. *Nature*, 421: 625-627.

Morison, J. I. L. and M. D. Morecroft, Eds. 2006. Plant Growth and Climate Change. Oxford, UK, Blackwell Publishing Ltd.

Moss, E. H.. 1938. Longevity of seed and establishment of seedlings in species of *Populus. Botanical Gazette*, 99:529-542.

Murphy, M. 2004. Romancing the West. *Frontiers: A Journal of Women Studies*, 25:165-171.

National Oceanic and Atmospheric Administration. 2008. Western Regional Climate Center Climatological data—Montana. Local Climate Data Summaries, Billings, Montana, USA.

Northcott, K., D. C. Anderson, and D. J. Cooper. 2007. The influence of river regulation and land use on floodplain forest regeneration in the semi-arid upper colorado river basin, USA. *River Research and Applications* 23:565-577.

Pearce, C. M., and D. G. Smith. 2009. Rivers as conduits for long-distance dispersal of introduced weeds: example of Russian Olive (*Elaeagnus angustifolia)* in the northern Great Plains of North America. In: *Invasive Plants on the Move: Controlling Them in North America.* F.J. Espinosa-Garcia, B.L. Harper-Lore and T. Hubbard (eds.). Tucson, The University of Arizona Press.

Pearce, C. M., and D. G. Smith. 2001. Plains cottonwood's last stand: Can it survive invasion of russian olive onto the Milk River, Montana floodplain? *Environmental Management,* 28:623-637.

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum Entropy modeling of species geographic distributions. *Ecological Modelling*, 190:231-259.

Phillips, O and A. H. Gentry. 1993. The Useful Plants of Tambopata, Peru: I. Statistical Hypotheses Tests with a New Quantitative Technique. *Economic Botany,* 47:15-32.

Reynolds, L.V., and D.J. Cooper. 2010. Environmental tolerance of an invasive riparian tree and its potential for continued spread in the Southwestern US. *Journal of Vegetative Science*. doi:10.1111/j.1654-1103.2010.01179.x

Reed, P. B., Jr. 1988. National list of plant species that occur in wetlands: national summary. U.S. Fish and Wildlife Service, Biological Report 88:24. 244pp.

Rood, S.B., and J.M. Mahoney. 1990. Collapse of riparian popular forests downstream from dams in western parairies: probable causes and prospects for mitigation. *Environmental Management*, 14:451-464.

Rood, S. B., and J. M. Mahoney. 1995. River damming and riparian cottonwoods along the Marias River, Montana. *Rivers*, 5:195-207.

Rood, S. B., A. R. Kalischuk, M. L. Polzin, and J. H. Braatne. 2003. Branch propagation, not cladoptosis, permits dispersive, clonal reproduction of riparian cottonwoods. *Forest Ecology and Management*, 186:227-242.

Rood, S. B., G. M. Samuelson, J. H. Braatne, C.R. Gourley, F. M. Hughes, and J. M. Mahoney. 2005. Managing River Flows to Restore Floodplain Forests. *Frontiers in Ecology and the Environment*, 3:193-201.

Rood, S. B. and J. M. Mahoney. 1990. Collapse of riparian popular forests downstream from dams in western parairies: probable causes and prospects for mitigation. *Environmental Management*, 14:451-464.

Shafroth, P. B., Auble, G.T., and M. L. Scott. 1995. Germination and Establishment of the Native Plains Cottonwood (*Populus deltoides* Marshall subsp. monilifera) and the Exotic Russian-Olive (*Elaeagnus angustifolia* L.) *Conservation Biology*, 9:1169-1175.

Scott, M. L., and G. T. Auble. 1997. Flood dependency of cottonwood establishment along the Missouri River, Montana. *Ecological Applications*, 7:677-690.

Stohlgren, T. J., Barnett, D. Flather, C. Kartesz, J. and B. Peterjohn. 2005. *Plant species invasions along the latitudinal gradient in the United States.* Ecology 86:2298-2309.

Stohlgren, T. J., K. A. Bull, Y. Otsuki, C. A. Villa, and M. Lee. 1998. Riparian zones as havens for exotic plant species in the central grasslands. *Plant Ecology*, 138:113-125.

Voget, F. 1984. *The Shoshoni-Crow sun dance*. Norman: University of Oklahoma Press.

Wilkinson, L. 2010, SYSTAT. WIREs Comp Stat, 2:256–257. doi: 10.1002/wics.66

Zar, J.H. 1999. *Biostatistical analysis*. 4th edition. Prentice Hall, Upper Saddle River, NJ.

CHAPTER 3: LOSING TRADITION: THE BIOCULTURAL EFFECTS OF RUSSIAN OLIVE (*ELAEAGNUS ANGUSTIFOLIA* L.) ON THE CROW INDIAN RESERVATION, MONTANA, USA

3.0 Summary

Native plant diversity in riparian systems is currently threatened by the invasive *Elaeagnus angustifolia* L. replacing woody riparian species, including plains cottonwood (*Populus deltoides* Marsh). The Apsáalooke or Crow Tribe of Indians of south-central Montana harvest culturally important woody plant biota along the Bighorn and Little Bighorn Rivers, yet cultural diversity may be threatened by *E. angustifolia*. We quantify the use of plains cottonwood, and other culturally significant woody species harvested along the floodplains within the Crow Indian Reservation, and determine knowledge and use of *E. angustifolia*. We conducted personal interviews, and a community survey to determine Crow knowledge of *E. angustifolia*, and if this species is problematic or useful. Elders reported 23 uses of cottonwood and the branches of this species as the most often used plant part. Pine (*Pinus* ssp.) and buffaloberry (*Shepherdia canadensis (L.) Nutt. argentea*) were mentioned most often as important to Crow culture. Crow Elders and community survey participants reported that they do not use *E. angustifolia*, and Elders consider this species problematic. Gender differences in knowledge of *E. angustifolia* were marginally significant, as males were more knowledgeable than females, and the oldest age groups (> 65 years old) were more knowledgeable than younger age groups ($p < 0.10$). We conclude that *E. angustifolia* is threatening cultural diversity of native plant biota used in Crow culture through displacement of cottonwood and other important woody species.

3.1 Introduction

Biodiversity of riparian forests and their adjacent floodplains in the Northwest are currently threatened by the invasive shrub/small tree *Elaeagnus angustifolia* L. (Lesica and Miles 1999, Simberloff and Strong 2000, Pearce and Smith 2001, Katz and Shafroth 2003). Biological invasions negatively affect the ecological integrity of riparian and terrestrial ecosystems, at an estimated cost of 120 billion dollars each year in the U.S. (Pimental et al. 2005). *Elaeagnus angustifolia* has negatively altered riparian and terrestrial ecosystems through displacement of native riparian species such as the dominant native plains cottonwood (*Populus deltoides* L.) and willow (*Salix* sp.) (Howe and Knopf 1991, Lesica and Miles 1999, Pearce & Smith 2001, 2009; Jarnevich et al. 2011). For instance, *E. angustifolia* is now the second most dominant woody species along the Milk River in northwest Montana, with large populations invading riparian systems along the Yellowstone and Bighorn Rivers (Akashi 1988, Lesica and Miles 1999, Pearce and Smith 2001). Invasive species can also reduce cultural diversity through visual distortion of the landscape, or acting as physical barriers to harvest culturally important plant species (Pfeiffer and Ortiz 2007). Ecological disturbances that alter ecosystems and landscapes, likewise affect the cultural landscape, or storyscapes of indigenous people. These storyscapes are shared through songs or harvesting rituals and are place-based (Basso 1996). Indigenous people carry important ethnobiological information shared with succeeding generations, such as harvesting practices and plant identifications (Pretty 2002, Pfieffer and Voeks 2008).

Native Americans are uniquely tied to their environment and connect to the natural biota through language and sacred ceremonies (Basso 1996, Deloria 1997, LaDuke 2007, Pfeiffer and Ortiz 2007). The Apsáalooke or Crow Indian tribe of south-central Montana has lived in this region for centuries, passing down to successive generations plant knowledge and use of native woody riparian species such as the plains cottonwood (*Populus deltoides* W. Bartram ex Marshall ssp. *monilifera* (Aiton) Eckenwalder) buffaloberry (*Shepherdia canadensis* (L.) Nutt.), and chokecherry (*Prunus virginiana* L.). *Elaeagnus angustifolia* was intentionally planted as a shelterbelt along the Little Bighorn and Bighorn Rivers on the Crow Indian Reservation, beginning in the late 19th century (Read 1958). Subsequent land policies implemented with the passage of the Dawes Act in 1887, and poverty during the Great Depression, resulted in the loss of large portions of Crow Indian lands through illegal sales and/or extensive leases (i.e., 50-100 years) while non-Indian land barons culled Crow horses to make way for cattle ranching and crop agriculture (Otis 1973, Belue 1991, Anderson 2001).

Land changes coincided with river regulation projects, including construction of diversion dams, irrigation earthen ditches and canals (Northcott et al. 2007). Diversion dams have permanently altered the natural disturbance pattern of seasonal flooding that native riparian vegetation such as plains cottonwood require for establishment and survival (Andersen et al. 2007, Lesica and Miles 1999, Katz and Shafroth 2003). Crop agriculture in this semi-arid region of the northwest included federal agency subsidization and promoted planting of *E. angustifolia* for field windbreaks and bank stabilization projects (Olson and Knopf 1986 a). This fast growing species quickly escaped cultivation and is now naturalized within the floodplains of the Crow reservation (Olson and Knopf 1986b, Pearce and Smith 2001, Jarnevich et al. 2011). Land cessations to the federal government and a restrictive land tenure system resulted in Indian land held in trust status and managed by the trust agent appointed by the federal government, the Bureau of Indian Affairs (BIA) (Andersen, 2001). A complex land tenure system resulted in a mosaic of land ownership within reservation boundaries, reducing access and management of land to the high-water mark or full-bank width on the Bighorn River, and along the forest edges within current reservation boundaries (Belue 1991, Turner et al. 2003).

Cottonwoods play an important role in ritual and socio-cultural practices of the Crow people (Fitzgerald 2007). Cottonwoods of various sizes are used in the practice of the Sundance (*Ashkisshe*) ceremony and socio-cultural events such as Crow Fair, held each summer (Crummett 1993, Murphy 2004, Fitzgerald 2007). In a separate study, we found that many native riparian species are becoming more difficult to locate for harvest comparing current day experiences to those of 25 years ago (D. Old Elk 2011). Crow Elders retired from the irrigation department at the BIA have also indicated that they have trouble controlling the rapid growth of *E. angustifolia* along earthen irrigation canals and ditches after spring dredging (B. House 2005). *Elaeagnus angustifolia* populations are now ubiquitous along the floodplain from Reno Creek diversion dam to the confluence of the Little Bighorn River and Bighorn River, just north of Crow Agency and southwest of Hardin, MT, respectively (V. Small pers. obs.)

Invasive plants have affected cultural diversity by decreasing availability of native plant species to harvest for ceremonial, economic or socio-cultural use (Suagee 1999, Turner et al. 2000, Pfeiffer and Ortiz 2007, LaDuke 2007). The spread of Salt cedar (*Tamarix* spp.) in the southwest has displaced native plant species, causing the Hopi Tribe to redistribute culturally important native species, such as cottonwoods (*Populus fremontii*) and willows (*Salix* spp.) closer to the reservation to preserve these native species for cultural use (Dudley 2000, Pfieffer and Voeks 2008). Cultural diversity of Native American peoples in California is threatened by the invasive yellow starthistle (*Centaurea solstitialis*) which presents a physical barrier to access native plants used in basketry (Pfeiffer and Ortiz 2007). Displacement of native plant species, however can and do affect indigenous cultures, through altering or covering the landscape to such an extent that it is unrecognizable (LaDuke 1994, Basso 1996, Deloria 1997).

Elaeagnus angustifolia has become ubiquitous within the Crow reservation, yet Crow people's knowledge and/or use of this species is currently unknown. In this study, we obtain Crow community knowledge of use and perception of *E. angustifolia* as either useful or problematic. Further, we quantify the use of plains cottonwood and other culturally significant woody species growing along the floodplain, and determine if *E. angustifolia* is affecting traditional plant harvesting practices. We assess said knowledge through a community survey, analyzing gender and age differences in community knowledge of *E. angustifolia*. Through personal interviews with Crow knowledge holders, hereafter referred to as Elders, we quantify use of plains cottonwood, and of other woody riparian species culturally important to Crow for ceremonial use or harvesting of traditional food sources. The Crow Tribe has a complex history of land tenure where land access and management have been restricted due to their trust status with the federal government. Therefore, we examine our results within the context of land trust status and the economic realities that affect the population of Crow people residing within reservation boundaries.

3.1.1 Study location

This study was conducted on the Apsáalooke Nation Indian, formerly known as the Crow Reservation in South-central Montana, USA. In 2010, we mapped *E. angustifolia* presence points (trees) using an opportunistic field method along the Bighorn and Little Bighorn Rivers, and include these in our study site map to demonstrate distribution and extent of invasion (Figure 3.1). The reservation consists of approximately 1,133,120 hectares of land held under trust by the federal government. Land within the reservation consists of approximately 890,000 hectares of short-grass prairie (Northern Great Plains) and is bordered by the Wolf, Bighorn and Pryor Mountains. Vegetation ranges from mixed hardwood/conifer forests in the mountains, to grasslands and riparian forests along the rivers and streams. The economic basis within reservation boundaries is crop agriculture, both dryland and irrigated, as well as grazing land for cattle, primarily owned or leased by non-Indians (Belue 1991). The climate on the reservation has a wide range, with 61 cm of annual precipitation in the Bighorn Mountains, to the semi-arid climate around Crow Agency, located at 884 m above sea level with 31 cm of annual precipitation (National Oceanic and Atmospheric Administration, NOAA Western Regional Climate Center 2010).

Crow Agency is considered the headquarters, or seat of government, for the Crow Reservation. The total population of the reservation is approximately 8,143 or 71.7% of the total 11,357 enrolled Apsáalooke Tribal members (http://crowtribe.com/pop.htm). Approximately 4,000 of those residing within reservation boundaries are under the age of 17 years. Crow members living on-reservation reside in the small communities of Crow Agency, Lodge Grass, Wyola, Pryor, Saint Xavier and Fort Smith. The remaining members or ~ 29% live off-reservation in the neighboring cities of Hardin, Billings and in other small rural areas within Bighorn and Yellowstone County. Crow Agency is the largest community on the reservation with a population of 1,550 in 2000 (US Census 2000). Total employment on the reservation is approximately 2,200 jobs, with government, education and Crow Tribal employment making up the largest classes of employment.

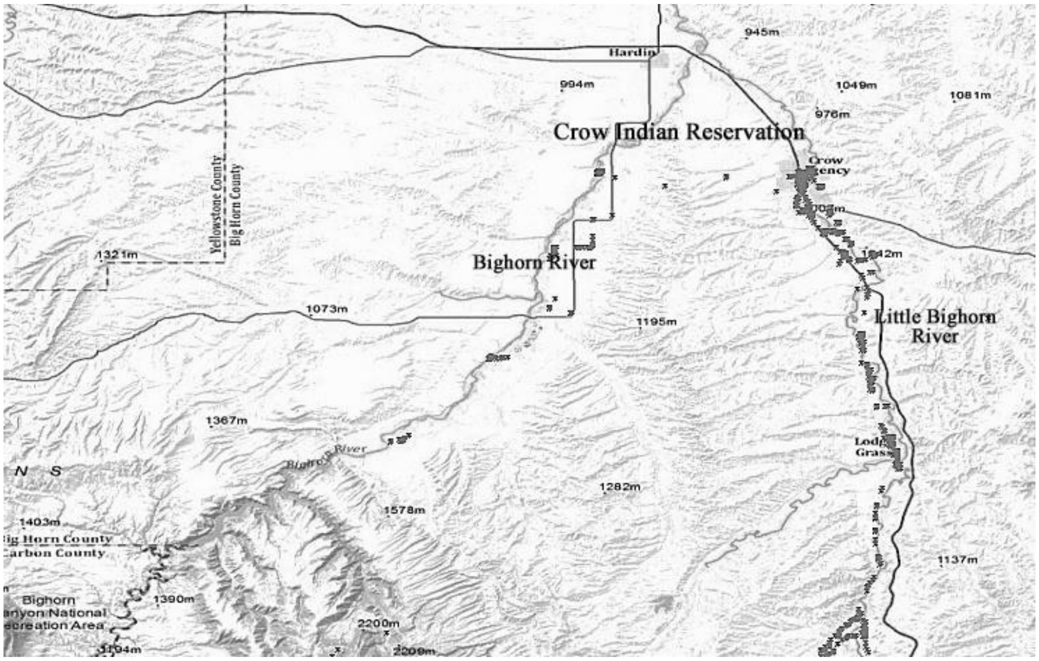

Figure 3.1. Crow Indian Reservation, Bighorn County Montana, USA. Mapped *E. angustifolia* trees (darkened areas) along floodplains just east and adjacent to the Bighorn River to the west and areas marked on both sides of the Little Bighorn Rivers.

3.1.2 *Crow ceremony*

The annual Crow Fair, held every 3rd weekend in August since 1903, hosts a 4-day powwow and rodeo where tribes from across the nation come to compete in dancing and cultural celebration (Murphy 2004). This socio-cultural event takes place in the small town of Crow Agency, also referred to as the Teepee Capitol of the World, located just off I-90. During the annual Crow Fair, teepees are erected within a large campground located on the banks of the Little Bighorn River surrounding a large arbor where an open powwow is held with Tribes invited to attend from all over the US. This celebration consists of ceremonial drumming and singing, which can often be heard throughout the river valley during the 4-day event (Figure 3.2).

Figure 3.2. Aerial photo of the annual Crow Fair campground. Photo by T. McCleary, August 2, 2012.

The Crow begin to camp along the Little Bighorn River 10 days before the first official day of competitive powwow dancing, where over a thousand teepees are erected. Cottonwood saplings measuring ~ 3.5 m tall are harvested to surround a three-sided pre-built open shade structure (Figure 3.3). Large branches and/or smaller saplings measuring ~ 2.5 m tall are harvested and used for roof thatch. Shade structures provide a cool place in which to prepare meals and escape the heat of the mid-day sun.

Figure 3.3. Crow Fair Campground shade structure using cottonwood saplings and branches for roof thatch. Photo V. Small 2012.

Ethnobiology studies of plants used in sacred ceremonies such as the Sundance are scarce, perhaps due to the need to restrict interviews to Elders or Shamans. This naturally reduces sample size due to a limited number of Knowledge Holders within American Indian Tribal cultures. Perhaps more importantly, holy men and or women are reluctant to discuss the intimacies of certain Tribal rituals, as some view sharing this information as a threat to their cultural identity and sacred practices. Most indigenous people do not wish to share such information outside the circle of those who possess sacredly held knowledge (Hoxie 2001, Crummett 1993; Fitzgerald 2007). Hence, we do not cover details of specific ceremonial use of this or any other species mentioned by the Elders, as this is discussed in detail elsewhere (Fitzgerald 2007). The sacred Sundance ceremony is constructed as an open three-sided wooden circular arbor. An adult-size cottonwood tree ~ 6 m tall is marked for harvest or selected by the

Sundance Chief in late winter or early spring. This adult pre-harvested cottonwood tree is then re-buried in the center of the arbor, also referred to as the Big Lodge by the Crow (Fitzgerald 2007). The outside of the arbor is then covered with cottonwood saplings (3-4 m) to provide shade for the Sundance participants located on the inside of the half-circle lodge with the opening facing east (Figure 3.4).

Figure 3.4. Sundance arbor at sunrise, with the sacred cottonwood tree in the center, seen here rising above the lodge. Cottonwood saplings and pine trees (used as an alternative to cottonwood) are visible surrounding the three-sided structure. Photo by V. Small 2011.

3.2 Methods

3.2.1 Interview Methodology

We examined cultural use and of cottonwood, and other riparian woody species mentioned by each participant, through oral interviews conducted with a group of pre-selected Elders (n = 11). Participants consisted of 9 males and 2 females, with ages ranging from 49 to 93 years (average age = 62 years). Participants are well-known respected Elders in the Crow community, including retired Sundance Chiefs and plant knowledge holders. In addition to participating in the sacred Sundance, the Elders we interviewed also camp during the annual Crow Fair and re-thatch shade structures within their respective camps.

Personal interviews with these Elders were held between November 2010 and April 2011 at Little Bighorn College, or at a mutually agreeable quiet location at the request of the Elder. One Elder chose to share the Crow Creation story which included cottonwoods, rather than respond to questions, thus $n = 10$ is our final sample size. Interviews lasted on average 45 minutes, depending upon the number of uses mentioned for cottonwood. Interview methodology consisted of nine semi-structured quasi-open ended questions to engage Elders in free dialogue and discussion with the lead author. Interview questions were related to importance and use of plains cottonwood for cultural, ritual and ceremonial practices. For each use mentioned, we asked whether there are acceptable alternative species, or if traditional practice requires the use of only plains cottonwood. In addition, we encouraged open discussion regarding other woody species within the floodplains and obtained specific purpose for said use. Pictures of cottonwood and *E. angustifolia* were used during the interviews to assure proper identification of both species. Each interview was held privately, to prevent undue influence in responses (Phillips et al. 1994, Byg and Balslev 2001). We recorded the interviews with a digital voice recorder (Sony Model ICDMX20DR9), transcribed, and uploaded to QSR NVivo 8.0 qualitative software for analysis. We capture subjective comments using the ‘compound’ query function relative to the importance of cottonwoods to Crow ceremony and culture. Finally, we ask each participant whether they feel *E. angustifolia* is useful or problematic. Transcriptions were also analyzed using the text and word frequency “queries” function of NVivo.

Pre-selected categories are often the standard method used to stratify plant taxon use within or between cultures. The inherent problem of researcher-selected use categories is an assumption that all cultures group or categorize plant use according to a European construct (McClatchey, 2006). For example, a single plant may be used for both construction and firewood, resulting in a lack of independence between "events" or variables. To address this problem we follow previous studies which suggest that "use categories" be obtained directly from the participants, rather than pre-determined from the researcher (Hoffman and Gallaher, 2007).

3.2.2 Ethnobotany indices

We performed analysis of transcribed interviews using a set of previously described frequency-based ethnobotany indices (Phillips and Gentry 1993; Gomez-Beloz 2002). Indices are based upon frequency or number of times a particular use is mentioned, which works on the premise that the more times individuals mention a use, it is an indicator of the overall value for that species. A specific use value (SU) is defined as the number of different uses of cottonwoods mentioned to allow partitioning of the data into general use categories. We then calculated reported use values (RU_{is}) as the number of times a specific use was mentioned by each participant (i), and summed these to obtain total use values for cottonwood. We analyzed the importance of a specific plant part for cottonwood use for any cultural purpose using the index for plant part value (PPV), defined as the ratio between number of total reported uses (RU) for each plant part divided by the total number of reported uses for the whole plant: PPV = (RU[plant part]/ΣRU) (Gomez-Beloz, 2002). Specific plant parts used in calculations were user-defined as follows: leaves, branch, bark, root, and stump. Use values (UV_{is}) for species mentioned other than cottonwood were calculated as the sum of participant use values for that species divided by the total number of informants (n = 10).

3.2.3 General community survey methodology

To determine general knowledge and use of the invasive *E. angustifolia*, we conducted a community survey in the summer of 2009 (n=102). We conducted convenience-sampled surveys at various Tribal and Government Agency sites located within the town of Crow Agency, including Tribal Administration offices, BIA, Indian Health Services, and Little Big Horn College (Gomez-Beloz 2002). The survey instrument used was a short-form questionnaire which asked: Did you know that *E. angustifolia* is not supposed to be here? Responses were categorized using a Likert scale: highly agree, agree, neutral, disagree, and highly disagree. We used two-way analysis of variance (ANOVA) to evaluate gender and age differences knowledge of *E. angustifolia* , and results were considered significant using $\alpha < 0.10$. Statistical analysis was conducted using SYSTAT 13 (Wilkinson 2010).

Two questions in the survey instrument were formatted using binary format (yes/no) as response variables. We ask the following questions: 1) Do you use *E. angustifolia*, and if so, for what purpose? 2) Do you know what *E. angustifolia* looks like? We evaluated gender and age differences using these response variables to create a contingency table. Distributions for age groups were normal, and were grouped as: 17 or less, 18-25 years, 26-35 years, 36-45 years, 46-55 years, 56-65 years and greater than 65 years; 59 females and 43 males participated in this survey (n = 102).

3.3 Results

3.3.1 Personal interviews

Elders mentioned 23 uses for plains cottonwood, although to protect some sacred knowledge, we do not report these separately; rather, we grouped these into an appropriate category based upon specific use. Specific use values were used to partition the data into seven general use categories, with the highest number of uses mentioned for cottonwood in Sundance, ceremonial/sacred, and fire (Table 3.1). Reported use values or the sum of all use values indicated for a specific use of cottonwood for all participants was = 700 (Table 3.2). The importance of cottonwood to Crow culture was a repeated theme throughout the interviews as with the following statements:

> "The cottonwood is called "real wood", *balátaale (*Crow name literally translated as genuine wood), and we use every part of the cottonwood."
>
> "Cottonwood is probably one of the most important trees that we use here for our ceremonies, especially in the Sundance."
>
> "We use it for the Sundance, you know the poles, especially the center pole, other poles you can use cottonwood, but the main one has to be cottonwood, because it signifies water."

Ratios for plant parts to calculate an intraspecific use value (IUV) for cottonwood were as follows: trunk (0.09); root (0.26); leaves (1.27); branches (1.56); and bark (0.09) (Table 3.3). Branches and leaves had the highest value ratios, thus used more often than other parts of the cottonwood tree. Species other than cottonwood mentioned by Elders suggested a wide range of use and purposes, including Sundance, food source, fire, sweat lodge construction material, and teepee stakes. Total number of reported uses (RU) for species other than cottonwoods was 43, where buffaloberry (*Shepherdia argentea* and *S. canadensis)* as well as pine (*Pinus* spp.) had the highest mentioned use values (Table 3.4.) Subjective comments from Elders regarding the use of *E. angustifolia*, and perceived effects on native plant species are as follows:

Question: "Do you consider *E. angustifolia* to be a problem, and if so why?"

Response: "You bet ya it's a problem, because they are everywhere and plus they grow in big patches like that and then a long time ago there used to be roads that we used to be able to 4-wheel through and all that, and now you cannot because of the *E. angustifolia*."

"Well there are friends of mine from South Dakota, Pine Ridge and Eagle Butte, Cheyenne River, and I would tell them, 'oh NO you don't'! They want it for wind break, but it takes over, especially near riparian areas, and that's another thing too is that obviously it has changed the environment, because introduced Chinese pheasants, that's their habitat, *E. angustifolia*."

Question: "Do you use *E. angustifolia*, and if so, for what purpose? Do you consider this species to be problematic or useful?"

Response: No, it's everywhere and if you use for fire, it stinks. Our pasture is full of this species, and our chokecherry and wild plum are all gone now."

Question: "Do you find it more difficult to find cottonwoods now? Also, do you find it difficult to find other traditionally harvested woody species now?"

Response: "Yes, because we are running out of trees, basically."

3.3.2 Community survey

Community surveys results indicated females were less knowledgeable than males when asked "did you know *E. angustifolia* was not supposed to be here?" ($p < 0.10$; Figure 3.4). Two-way analysis of variance (ANOVA) indicated older age groups falling within the group > 55 years, were significantly more knowledgeable than younger age groups ($p < 0.10$; Figure 3.5). However there were no significant interactions between gender and age for this question. Approximately 53% of males (23 of 43) surveyed, and 32% of females (19 of 59) responded “yes” to the question “do know what *E. angustifolia* looks like?” Conversely, 47% of males (20) 68% of females responded that they did not “know” what *E. angustifolia* looks like or were unable to identify this species (Figure 3.6).

Table 3.1. Specific use of plains cottonwood (total = 700) and associated frequencies used to partition the data into general use categories for all individuals (n=10). Totals are mutually exclusive.

Use Categories	SU
Sundance	200
Fire	159
Sweat Lodge	35
Trade/economics	5
Ceremonial/sacred	171
Forage	17
Crow fair	113
Total Uses	700

Table 3.2. Intraspecific plant part use of cottonwoods calculated as the ratio of plant parts over total uses reported for entire tree = 23. Branches and leaves have highest use of all plant parts.

Plant Part	Frequency of Uses Mentioned	Ratio or IUV Divided/23
Trunk	2	0.09
Roots	6	0.26
Leaves	34	1.27
Branches	36	1.56
Bark	2	0.09
Total	113	

Table 3.3. Reported use (RU) and Use value for other species mentioned by Elders. (See text for explanation of indices).

Common Name	Scientific Name	Crow Name	Specific Use	$^{**}RU_{is}$	$^{*}UVs = (\Sigma UV_{is}) / (n_i)$
Ash	*Fraxinus pennsylvanica*	bilippíte	Firewood	11	1.1
Willow	*Salix amygdaloides*	biliiché	Sweat lodge construction	2	0.20
Buffaloberry	*Shepherdia canadensis* or *Shepherdia argentea*	baalashiísshe	Food source	15	1.5
Pine	*Pinus* spp.	bishkaakaáshe	Shade Sundance Construction arbor poles	13	1.3
Chokecherry	*Prunus*	baáchuutaale;	Food source;	2	0.20

	virginiana	balápua	Teepee stakes; Switch-sweat		
Total Uses				43	

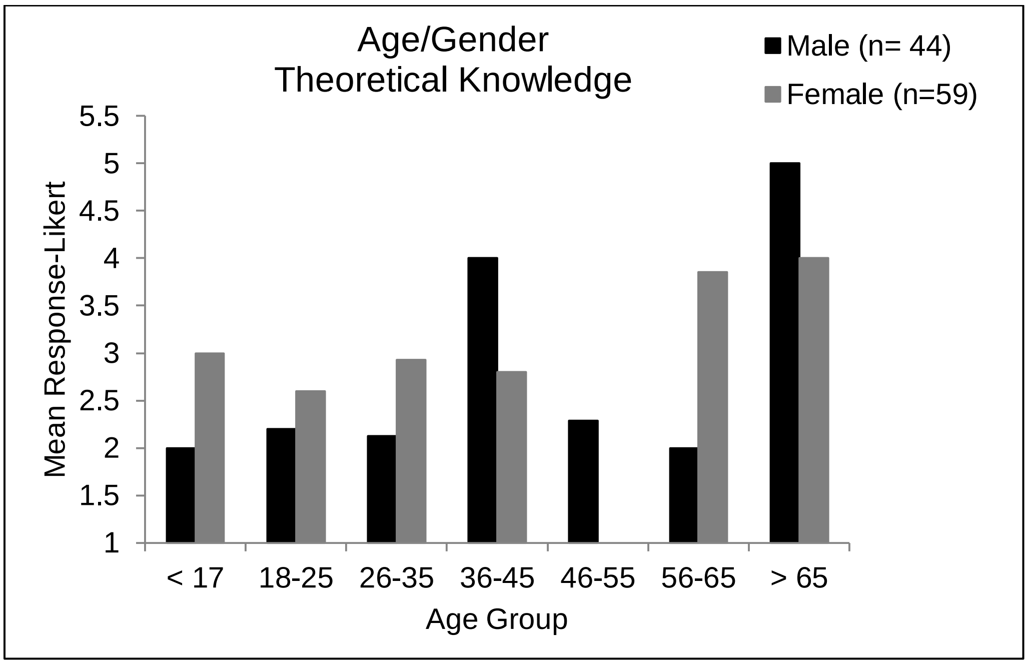

Figure 3.4. Likert scale mean community survey responses in theoretical knowledge. Males and Elders were more knowledgeable for the question: "do you know *E. angustifolia* is not supposed to be here?" Males and oldest age groups (< 56) were significantly (albeit marginally) more knowledgeable than females and younger age groups ($p < .08$).

Figure 3.5. Community survey for expected vs. observed responses for question: "Do you know what *E. angustifolia* looks like?" Males were less knowledgeable than expected by chance.

3.4 Discussion

Given the historical abundance of cottonwood throughout the Northern Great Plains region, it is not surprising that cottonwood became a culturally significant woody species used extensively by Crow people. Cottonwood is used for multiple ceremonial and socio-cultural purposes, including fire, Crow Fair and the Sundance. Our interviews with Elders showed that branch use was mentioned most often as an important part of the tree, used for roof thatch during the annual Crow Fair. Woody riparian species such as pine, ash (*Fraxinus pennsylvanica* L.) and buffaloberry reported the highest ratios of use in construction of the Sundance arbor, fuel for fire, and as a traditional food source, respectively. Fire is an important component of most ceremonial and ritual practices, not simply for heating homes, but also frequently used for cooking. Elders mentioned that, in addition to cottonwood, ash is used to heat stones for the sweat lodge. Pine is used as shade on the outside of the Sundance arbor, normally only used when the ceremony is held in the mountains. However, Elders mentioned that areas where cottonwood saplings have normally been harvested along the floodplains are now being replaced by *E. angustifolia*, or that harvesting is becoming more difficult due to the growth and density of this thorny shrub.

Lack of female participation for the interview portion of our study may be due to established cultural norms for sharing information, as men are the ones who traditionally speak on behalf of the Tribe as a whole. However, this may also be due to established roles for harvesting woody species, as males traditionally harvest hardwood species. Two female Elders who participated mentioned uses associated with cooking and naming ceremonies, but were also concerned over the decline in cottonwood and traditional food source plants. All of the Elders interviewed (n=10) indicated that they do not use *E. angustifolia*, and stated that loss of woody species in general were due to the spread of this species.

The fact that older age groups were more knowledgeable is expected, since this is why Elders are so valued in the community. In theory, however this knowledge is normally passed down to younger generations, since collection of cottonwood and other woody species is not age limited and often performed with other male family members. One might, therefore, expect higher positive responses among younger age groups relative to this practical type of harvesting knowledge. The presence of *E. angustifolia* is so predominant along the floodplains, invading into pastures, irrigation canals and ditches, that it permeates the landscape. If this type of plant knowledge were being transferred, one would expect higher or more positive responses in knowing what *E. angustifolia* looks like, in younger age groups. Observed age differences for lack of knowledge regarding the fact that *E. angustifolia* is not a species native to these floodplains may be due to the timing of its initial introduction. The first known large-scale planting of *E. angustifolia* occurred during the Great Depression with the Indian Civilian Conservation Corp. (ICCC) (Gower 1972), according to Dr. Barney Old Coyote, Jr. (pers. comm. 2011) who worked for the ICCC as a young adult. His father told him not to plant *E. angustifolia* along the Little Bighorn River and irrigation canals, as he had already witnessed that this species had escaped cultivation and was quickly spreading along the Bighorn River floodplains. A comment from the community survey revealed that *E. angustifolia* was planted at the direction of the BIA as an ornamental during the 1970s for the new federal housing project town of Crow Agency. Individuals who were not of age during this earlier time period would have no knowledge that *E. angustifolia* is an introduced species, unless this type of knowledge were being transferred by older family members during times of harvesting for cottonwood or ash. We purposely did not use the ecological term "invasive" since this is a western scientific term that may not be familiar to the Crow community members. It is perhaps likewise important to consider that "weed" is a term not unfamiliar to most people in general. When one identifies or pictures this term, small herbaceous plants and grasses normally come to mind, although a tree is seldom thought of in these terms. This may also explain why there were such low numbers of males responding positively to practical knowledge of *E. angustifolia*.

The idea of land connectedness is a general theme among indigenous peoples; however, a history of colonization processes including land dispossession have restricted access to and management of what land within the reservation boundaries remains in Crow Tribal ownership status (allotted and Tribal) and held in trust by the federal government. Early land policies were enacted for the purpose of removing communal land ownership tenure, and to European constructs of productive land use. The effects of said land policies established a paternalistic relationship with the federal government, and the BIA continues in present-day to be responsible for management of Crow Tribal natural resources and land assets. Conversely, the tradition of harvesting and gathering traditional food sources continues into present day, where Crow women harvest fruit from woody species such as buffaloberry and chokecherry. Elders who were interviewed (8 of 10) mentioned that these traditional food plants, as with cottonwood, are in decline, as *E. angustifolia* now occupies places previously dominated by these fruit-bearing shrubs.

The importance of 'place' predominates how the Crow view and connect with their environment, which is defined in relation to surrounding habitat. Perhaps the most significant negative effect of *E. angustifolia* is how the dense growth characteristic of this shrub has visibly changed the landscape view. An Elder tells the story of a woman who wished to visit her childhood home site, yet she was unable to locate due to the drastic visual change in the landscape from native woody tree species, to dense thickets of *E. angustifolia* shrubs (T. McCleary pers. comm.). This is a particularly salient point, given that the Crow speak a form of the Siouan family of languages, which is descriptive rather than symbolic. For instance, the Crow word for the ash tree '*bilippíte*' is literally translated as "absorbs water."

The physical location of the population of current-day Crow tribal members living on-reservation versus off-reservation is an important factor to consider when interpreting the ability to transfer plant use and knowledge. One must not only possess said knowledge, but must also live within the natural environment to pass this to succeeding generations. According to Tribal enrollment records to date, there are roughly 8,000 members living within reservation boundaries and most of these members live in the small towns rather than on parcels of land allotted to their families. Furthermore, lack of housing and employment opportunities within the reservation are factors that limit the ability of Crow tribal members to live within reservation boundaries, and thus interact with the natural biota.

Western scientists view *E. angustifolia* in terms of its ecological effects on the decline of cottonwood. However, it is important to identify how the Crow people view their natural environment from a cultural perspective. This cultural perspective is apparent in the results from our community survey that indicated just under half of males and three-fourths of the females lacked practical knowledge in their ability to recognize *E. angustifolia*. Most men who reside within the reservation harvest cottonwood for use in various ritual practices (i.e., sweat lodge, Crow Fair shade). In addition, women traditionally harvest berries and roots of plants that are important food sources, which require their interaction with woody plant species, found growing along the floodplains. Today, however, most Crow women purchase chokecherry from a group of Hutterites (colony of German Anabaptists such as Amish and Mennonite) who live on private land within the reservation. Comments from community members indicated that they are no longer able to locate this traditional food source in places where they have historically been harvested. This would partially explain why so few females, regardless of age, were aware that *E. angustifolia* was not "supposed to be here" and unable to identify this species. Within the last 5 years, the Crow have lost two well-known and respected female Elders who possessed specialized plant knowledge. Cottonwood, buffaloberry, chokecherry, willow, and wild plum (*Prunus americana* Marshall), however, are not considered specialized, as all Crow harvest these species. Thus we feel our survey findings were not biased due to the absence of specialized plant knowledge holders in our sample.

Comments from Elders during personal interviews indicated that buffaloberry is sometimes found to grow within thickets of *E. angustifolia*. Buffaloberry is a traditionally important food source for the Crow; however, *E. angustifolia* is visually similar in terms of growth form, and leaf color. This may be a reason that so few females were aware of *E. angustifolia*, as they may be unable to determine differences between *E. angustifolia* and buffaloberry. Species of silver buffaloberry (*Sherherdia canadensis* var *argentea* L.) are closely related species (members of the Elaeagnaceae family). Chokecherry and wild plums, however, are unable to survive amongst *E. angustifolia*, and are now visibly absent from traditional harvesting places (T. McCleary 2012 pers. comm.).

3.5 Conclusion

The findings of this study confirms that the invasion by *E. angustifolia* is indirectly affecting the cultural diversity of the Crow people by displacing traditionally harvested food plant sources and cottonwoods used in a variety of culturally expressive forms. *Elaeagnus angustifolia* has also dominated these floodplains to the point where the landscape is visually unrecognizable to those attempting to revisit places that are either historic or sacred. This loss of place-based knowledge is particularly troublesome as the Crow Elders are unable to pass related storyscapes on sacred or former homestead sites. These stories often pass knowledge that instills values and morals of behavior towards the natural environment. The physical barrier of this dense thorny shrub inhibits access to harvesting of important traditional food sources. Restricted access, land loss and changing of the landscape in combination with a vast diaspora of Crow leaving the reservation suggests that transference of traditional plant use knowledge is likely suffering initial stages of erosion; for how can plant knowledge be transferred if they are no longer directly connected to the land, or no longer have these species to harvest from? *E. angustifolia* invasion and spread not only reduces biodiversity, but is likewise reducing cultural diversity of the Crow people. *Elaeagnus angustifolia* removal and re-vegetation projects using culturally important native plant species will not only increase biodiversity and health of these ecosystems, but in so doing, preserve Crow traditional plant knowledge and sense of place for future generations.

3.6 References Cited

Akashi, Y. 1988. Riparian vegetation dynamics along the Bighorn River. Ph.D. thesis. University of Wyoming, Laramie, WY.

Andersen, D.C., D.J. Cooper, and K. Northcott 2007. Dams, floodplain land use, and riparian forest conservation in the semiarid upper Colorado River Basin, USA. *Environmental Management*, 40: 453-475.

Anderson, T.L. 2001. Land tenure and Agricultural Productivity in Indian Country In: *Trusteeship in Change* (eds. Clow, R.L. and I. Sutton). Pp 35-54. Boulder: University Press of Colorado.

Basso, K. H. 1996. *Wisdom Sits in Places: Landscape and language among the Western Apache*. Albuquerque: University of New Mexico Press.

Belue, C.T. 1991. *White Oppression and Enduring Red Tears: Indian Law and Real rules for White Control of Crow lands.* Madison: University of Wisconsin Law School.

Byg, A. and H. Balslev. 2001. Diversity and use of palms in Zahamena, Eastern Madagascar. *Biodiversity and Conservation* 10: 951-970.

Crummett, M. 1993. *Sundance: the fiftieth anniversary Crow Indian Sundance*. Falcon Press Publishing, Co., Inc: Helena.

Deloria, J.V. 1997. *Red earth, white lies*. Golden: Fulcrum Publishing.

Dudley, D.R. 2000. Wicked weed of the west. *California Wildlife* 53(4): 32-35.

Fitzgerald, M.O. 2007. *Native Spirit: The Sun Dance Way*. Bloomington: World Wisdom, Inc.

Gómez-Beloz, A. 2002. Plant use knowledge of the Winikina Warao: The case for questionnaires in ethnobotany. *Economic Botany* 56: 231-241.

Gower, C.W. 1972. The CCC Indian Division: Aid for Depressed Americans, 1933-1942. *Minnesota History* 43(1): 3–13.

Hoffman, B., and T. Gallaher. 2007. Importance Indices in Ethnobotany. *Ethnobotany Research & Applications* 5:201-218.

Howe, W.H., and F.L. Knopf. 1991. On the Imminent Decline of Rio Grande Cottonwoods in Central New Mexico. *The Southwestern Naturalist* 36: 218-224.

Hoxie F., P.C. Mancall, and J.H. Merrell. (eds) (2001) *American nations: encounters in Indian country, 1850 to the present.* New York: Routledge.

Jarnevich, C.S., and L.V. Reynolds. 2011. Challenges of predicting the potential distribution of a slow-spreading invader: a habitat suitability map for an invasive riparian tree. *Biological Invasions*. 13:153–163.

Katz, G.L., and P.B. Shafroth. 2003. Biology, ecology and management of *Elaeagnus angustifolia* L. (Russian olive) in Western North America. *Wetlands.* 23:763.

LaDuke, W. 1994. Traditional ecological knowledge and environmental futures. *Colorado Journal of International Environmental Law and Policy*. 5: 27–148.

LaDuke, W. 2007. Ricekeepers: a struggle to protect biodiversity and a Native American way of Life. Orion Magazine. June/July 2007. URL http://www.orionmagazine.org/index.php/articles/article/305 (Accessed on February 23, 2010).

Lesica, P., and S. Miles. 1999. Russian olive invasion into cottonwood forests along a regulated river in north-central Montana. *Canadian Journal of Botany.* 77: 1077-1083.

McClatchey, W. 2006. Improving quality of international ethnobotany research and publications. *Ethnobotany Research and Applications* 4:1-9

Murphy, M. 2004. Romancing the West. *Frontiers: A Journal of Women Studies*, 25: 165-171.

National Oceanic and Atmospheric Administration. 2008. Western Regional Climate Center Climatological data—Montana. Local Climate Data Summaries, Billings, Montana, USA.

Northcott, K.D., C. Anderson, D.J. Cooper. 2007. The influence of river regulation and land use on floodplain forest regeneration in the semi-arid upper Colorado river basin, USA. *River Research and Applications* 23: 565-577.

NVivo qualitative data analysis software; QSR International Pty Ltd. Version 10, 2012.

Olson, T.E., and F.L. Knopf. 1986a. Naturalization of Russian olive in the western United States. *Western Journal of Applied Forestry* 1: 65-69.

Olson, T.E., and F.L. Knopf. 1986b. Agency subsidization of rapidly spreading exotic. *Wildland Society Bulletin* 14: 492-493.

Otis, D.S. 1973. *The Dawes Act and the allotment of Indian lands*. In: The civilization of the American Indian series. (ed. Prucha, F. P.). Volume 123. Pp. 160. Norman: University of Oklahoma Press.

Pearce, C.M., and D.G. Smith 2009. Invasive saltcedar (*Tamarix*): it's spread from the American southwest to the northern Great Plains. *Physical Geography* 28(6):507-530.

Pearce, C.M., and D.G. Smith. 2001. Plains cottonwood's last stand: can it survive invasion of Russian olive onto the Milk River, Montana floodplain? *Environmental Management* 28: 623-637.

Pfeiffer, J.M. and E.H. Ortiz. 2007. Invasive plants impact California native plants used in traditional basketry. *Fremontia* 35(1): 7–13.

Pfeiffer, J.M. and R.A. Voeks. 2008. Biological invasions and biocultural diversity: linking ecological and cultural systems. *Environmental Conservation* 35(4):280-293.

Phillips, O.L., and A.H. Gentry. 1993. The Useful Plants of Tambopata, Peru: I. Statistical Hypotheses Tests with a New Quantitative Technique. *Economic Botany* 47(1):15-32.

Phillips, O.L., A.H. Gentry, C. Reynel, P. Wilkin and C. Galvez-Durand. 1994. Quantitative ethnobotany and Amazonian conservation. *Conservation Biology* 8: 225-248.

Pimentel, D., Zuniga, R. and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52:273-288.

Pretty, J. (2002) Landscapes lost and found. In: *Agri-culture: Reconnecting People, Land and Nature*, (ed. Pretty, J.) Pp. 10–26. London: Earthscan Publications.

Read, R.A. 1958. *The Great Plains shelterbelt in 1954.* Great Plains Agricultural Council. Lincoln: University of Nebraska Experiment Station NE, Pub 16.

Simberloff, D.S. and D.R. Strong. 2000. Exotic species seriously threaten our environment. *Chronicle of Higher Education* 47(2): B20.

Suagee, D.B. 1999. The cultural heritage of American Indian tribes and the preservation of biological diversity. *Arizona State Law Journal* 31(483): 82.

Turner, N. J., M. B. Ignace, and R. Ignace. 2000. Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological Applications* 10: 1275–1287

Turner, N.J., I.J. Davidson-Hunt, and M. O'Flaherty. 2003. Living on the edge: ecological and cultural edges as sources of diversity for social-ecological resilience. *Human Ecology* 31(3): 439–461.

US Census Bureau. 2000. Census 2000 Summary File 2, Matrix PCT1 for Montana. Available: www.ceic.mt.gov/C2000/urban_rural_indian.xls (Accessed 15 September 2012)

Wilkinson, L. 2010, SYSTAT. WIREs Comp Stat, 2:256–257. doi: 10.1002/wics.66