Final report

Conservation of Clark's Nutcrackers in the Crown of the Continent Ecosystem:

Clark's Nutcracker Summer Use of Whitebark Pine Communities

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Diana F. Tomback, Ph.D.

Professor and Associate Chair
Department of Integrative Biology, CB 171
P.O. Box 173364
University of Colorado Denver
Denver, CO 80217-3364

303-556-2657

Agreement Technical Representative:

Tara Carolin
Acting Director

Tara_Carolin@nps.gov

Office: 406-888-7919, Fax: 406-888-7990

Crown of the Continent Learning Center
Glacier National Park
P.O. Box 128
West Glacier, Montana 59936

Overview of research, responsibilities, and the final report

In 2008, Glacier National Park had obtained from IMRICO funding for a two-year study "Conservation of Clark's Nutcrackers in the Crown of the Continent Ecosystem." The objectives of this study were "(1) to determine the occurrence and distribution of Clark's Nutcrackers in whitebark pine forests and alternative habitats in the Crown of the Continent Ecosystem, (2) to investigate the behavior of nutcrackers in the healthiest whitebark pine stands, and (3) to create a rigorous, tractable monitoring protocol for Clark's Nutcrackers that can be used wherever nutcrackers are found." This project was divided between two investigators: Kim Sullivan, Utah State University, and myself, Diana Tomback, University of Colorado Denver. Each investigator recruited and collaborated with a master's student to work on the project.

We, Dr. Diana Tomback and graduate student Jennifer Scott, were responsible for 1) determining if and how nutcrackers use whitebark pine communities, and 2) density estimates of nutcrackers in whitebark pine habitat in both Glacier and Waterton Lakes National Parks. We were also responsible for 3) devising a state-of- field transect-based monitoring protocol and for establishing and conducting surveys of the transects, gathering additional behavior data, and for data management and analysis. We have accomplished most of these objectives.

In 2009, I spent about a month in the field in Glacier and Waterton Lakes National Parks with Scott, In July, I worked with Scott setting up transects, teaching forest health assessment methods, and running transects. We decided to increase the number of study areas to five, including one study area in Waterton Lakes National Park, in order to obtain a reasonable geographic distribution both east and west of the Continental Divide and north and south across the combined parks; we included only one to two transects in each area for a total of 10 transects.

The final report presented here is modified from the draft thesis written by Scott in partial fulfillment of the Masters of Science in Biology. **I need to make the disclaimer that this is based on Scott's preliminary analysis of the data, and the final statistical results may be different than what we report here.**

I have edited and rewritten portions of this thesis for the purpose of this report. Also, since this study began, my research program has published a paper (Barringer et al. 2012) based in part on data from both Glacier and Waterton Lakes National Parks, relating number of nutcrackers to magnitude of local cone production. We incorporated the data from this study in the scatterplot generated by Barringer et al. (2012) for general comparison. It is our intention to publish a peer-reviewed paper based on but modified from the Scott thesis.

Acknowledgments: Dr. Michael Wunder, Department of Integrative Biology, served as a consultant for the use of Distance Sampling and other statistical analyses throughout the study. Monika Maier and Jen Scott helped each other with field support in 2009. Taylor Turner provided very capable field support to Jennifer Scott in 2010.

INTRODUCTION

Whitebark pine (*Pinus albicaulis*) is one of five stone pines worldwide (Subgenus *Strobus* Subsection *Cembrae*), and the only stone pine in North America. It is restricdted to upper subalpine and treeline elevations in the mountains of western North America (McCaughey and Schmidt 2001, Tomback and Achuff 2010). Both a keystone and foundation species, whitebark pine maintains subalpine biodiversity and ecological function. Its seeds are a critical food source for grizzly bears (*Ursus arctos horribills*), red squirrels (*Tamiascurus hudsonicus*) and Clark's Nutcrackers (*Nucifraga columbiana*), as well as other granivorous birds and mammals (Tomback et al. 2001a, Ellison et al. 2005, Tomback and Achuff 2010). Additionally, the species protects watersheds by regulating snowmelt and reducing soil erosion, and promotes post-fire community regeneration (Tomback et al. 2001a).

Whitebark pine populations are threatened by white pine blister rust, caused by the exotic fungus *Cronartium ribicola*, mountain pine beetle (*Dendroctonus ponderosae*) and altered fire regimes in the northwestern U.S. and southwestern Canada (Tomback et al. 2001a,Tomback and Achuff 2010) . Fire exclusion has led to successional replacement of whitebark pine by shade tolerant species, which may reduce the potential for regeneration of the shade-intolerant whitebark pine. Additionally, fuel accumulations may lead to increased tree mortality when fire eventually reoccurs (van Mantgem 2004, Tomback and Achuff 2010). The northern Rocky Mountains of the U.S., the Olympic and western Cascade Ranges and the Coastal and Rocky Mountains of southwestern Canada have high rates of blister rust infection and mortality rates reaching more than 90% in some areas (Tomback et al. 2001a, Kendall and Keane 2001, Schwandt 2006). Approximately 50% of the whitebark pine in Waterton-Glacier International Peace Park are dead, with 70% infected, and an estimated 5% per year increase in mortality in Waterton Lakes National Park (Smith et al. 2008). In addition to blister rust in the vast majority of its range, whitebark pine is facing serious decline especially across the Greater Yellowstone Ecosystem as well as other regions, due to unprecedented mountain pine beetle outbreaks. In some of these areas, mortality has exceeded 90% of cone bearing trees (Gibson et al. 2008, Logan et al. 2010). Loss of whitebark pine will likely have consequences to local and regional watershed hydrology, including more rapid snowmelt and increased soil erosion. This may adversely impact people and local economies within associated watersheds through the use of water for consumption, irrigation and for watering livestock. Additionally, it is predicted that with the loss of whitebark pine, there will be a decrease in forested area at high elevations, along with diminished microhabitats which facilitate colonization of other tree and plant species in the harsh conditions where whitebark pine grows (Tomback and Kendall 2001).

The Clark's Nutcracker and whitebark pine are coevolved mutualists (Tomback 1982). Nutcrackers harvest seeds from whitepark pine cones and cache them in a variety of habitats from lower elevation forests, which include western hemlock (*Tsuga heterophylla*) and Douglas-fir (*Pseudotsuga menziesii*), to high-elevation forests dominated by subalpine fir (*Abies lasiocarpa*) and whitebark pine, and will return to feed on the cached seeds for up to a year (Tomback 2001). Nutcrackers are the principal mode of seed dispersal for whitebark pine, and unretrieved seeds the primary source for regeneration (Tomback 1978, 1982, Hutchins and Lanner 1982, Tomback 2001). By killing the upper canopy—the cone producing branches of whitebark pine—blister rust infection reduces or ends cone production, thus reducing regeneration potential (McDonald and Hoff 2001).

Previously, McKinney and Tomback (2007) found in their study in the Bitterroot and Salmon national forests, Montana and Idaho, respectively, that whitebark pine stands with higher levels of blister rust infection and damage had lower cone densities than those stands with lower levels of blister rust infection and damage. They also found that stands with lower cone densities had a relatively lower proportion of cones surviving to ripening, and thus stands with a lower proportion of cones surviving were less likely to have seeds dispersed by nutcrackers.

McKinney et al. (2009) found that whitebark pine forest decline due to blister rust was most severe in their Northern Divide Ecosystem study sites, which included 10 study sites within Glacier National Park and the adjacent Flathead National Forest. Other study ecosystems included the Bitterroot Mountain Ecosystem in west-central Montana and east-central Idaho and the Greater Yellowstone Ecosystem (GYE) in southwestern Montana and northwestern Wyoming. In the Northern Divide Ecosystem, however, they found rust infection and tree mortality levels to be the highest, and live basal area and cone production the lowest among the three ecosystem study areas. Here, they also discovered low nutcracker visitation rates over the three year study, with nutcrackers present in only 14% of the total hours sampled and seed dispersal activities in only 20% of their research sites. Similarly, Barringer et al. (2012) found that whitebark pine regeneration was much lower in their study sites in Glacier National Park and Waterton Lakes National Park (northern region) compared to their sites in the GYE (southern region). In fact, they found that regeneration was 74 times lower in the northern region than in the southern region, and that cone density was 57 times lower in the northern region. They also found blister rust infection rates to be significantly higher in the northern region when compared with the southern region. In addition, they observed far more Clark's Nutcrackers in the southern region that in the northern region, probably due to the greater abundance of live whitebark pine trees in the southern (higher live basal area and greater proportion of live trees).

McKinney and Tomback (2007), McKinney et al. (2009), and Barringer et al. (2012) suggest that loss of whitebark pine cone production due to tree damage and mortality caused by blister rust and mountain pine beetle (*Dendroctonus ponderosae*) will likely lead to a decline in nutcracker visits over time, and thus a reduction in future whitebark pine regeneration (Fig. 1). With continued losses of whitebark pine, it is likely that nutcrackers will no longer be attracted to whitebark pine communities, and thus the potential for natural regeneration will be lost (Tomback et al. 2001a; Tomback and Kendall 2001). Currently, this may be happening both locally and regionally where tree damage and mortality from blister rust and mortality from mountain pine beetle is highest. It is also possible that as blister rust spreads and fewer whitebark pine cones are available, regional nutcracker populations will decline (Tomback and Kendall 2001, McKinney and Tomback 2007, McKinney et al. 2009; Barringer et al. 2012).

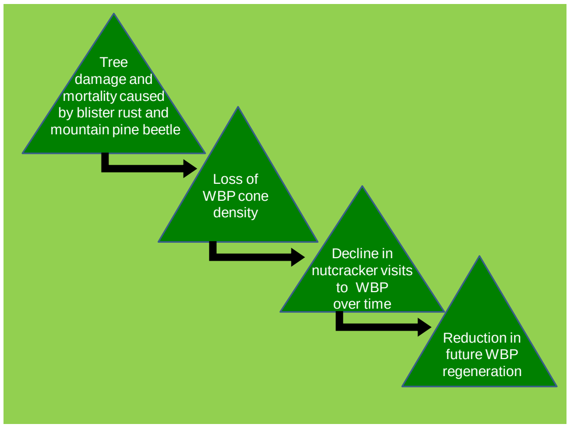

Figure 1. Depiction of predictions made by McKinney et al. (2009) and the processes predicted in McKinney and Tomback (2007) and Barringer et al. (2012)

In view of the fact that McKinney et al. (2009) and Barringer et al. (2012) found whitebark pine damage and mortality the highest, and cone production the lowest in the Northern Divide Ecosystem, we felt that careful investigation of whether nutcrackers were occurring in whitebark pine forests in the Waterton-Glacier International Peace Park was warranted. Nutcracker occurrence in these previous studies was tallied by simple observation and by point counts, respectively. However, neither study assessed the probability of detecting cones or nutcrackers. Consequently, we chose to use a Distance Sampling protocol for assessment of nutcracker occurrence and, in the second season, cone production, in order to determine detectability.

Objectives

Our objectives in this study were to determine: 1) if nutcrackers occur in whitebark pine communities in the park and at what density, 2) how or if nutcracker densities vary with whitebark pine cone production, 3) how cone production varies with whitebark pine prevalence and health in Waterton-Glacier International Peace Park, and 4) whether the relationship between the likelihood of nutcracker visitation and whitebark pine cone density is similar to those results found in McKinney et al. (2009) and Barringer et al. (2012). In addition, we developed a protocol for counting both nutcrackers and whitebark pine cones using a line transect-based distance sampling method. We compared both cone density estimates and nutcracker density estimates obtained by this method with the sampling methods previously used by Barringer et al. (2012).

METHODS

Study Areas and Transect Establishment

In July 2009, study areas were selected in Glacier National Park, Montana, USA, and in Waterton Lakes National Park, Alberta, Canada (Fig. 2), based on both accessibility by trail and location across the Peace Park. We needed to complete a round trip hike to each study area and two surveys for each transect within each study area within one long day.

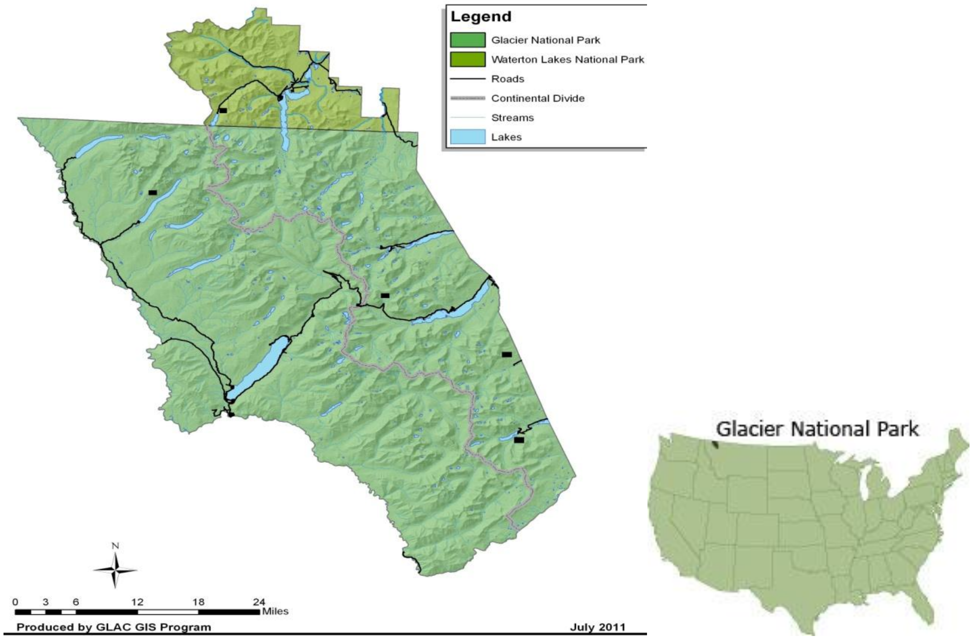

Figure 2. Geographic locations of study areas in Waterton-Glacier International Peace Park (black rectangles). (Maps contributed by GLAC GIS program and NPS).

With these constraints, four study areas were chosen in Glacier National Park (GNP)and one study area in Waterton Lakes National Park (WLNP) (Table 1). Study areas were distributed across the parks in order to capture variation in the community types and health of whitebark pine stands. Transects were placed off trail and varied in number and length, based on our ability to walk the transect (avoiding heavy deadfall, ford creeks, steep slopes, etc.) and to remain within whitebark pine stands. Numa Ridge on the west side of the Park was characterized by an early successional community dominated by young whitebark pine, Douglas fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*). We established two transects along the ride, where the forest was very open with steep, rocky slopes and understory dominated by beargrass (*Xerophyllum tenax*). Three transects were placed in Preston Park, just below Siyeh Pass. Preston Park is characterized by successionally advanced communitie,s small numbers of alpine larch (*Larix lyellii*), subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*), and large, mature whitebark pine, with an understory dominated by beargrass and huckleberry (*Vaccinium* spp.) understory. Two study areas were chosen to represent the east side of the park: Two Medicine and White Calf Mountain. A single long transect was placed at each of these sites. Two Medicine was characterized by dense canopy consisting of mostly Douglas fir and lodgepole pine and widely-spaced old growth whitebark pine, with heavy deadfall in the understory. White Calf Mountain was characterized by large, mature whitebark pine surrounded by dense subalpine fir and heavy deadfall in the understory, which was nearly impassable and impeded visibility for bird observations. Above the dense subalpine forest, we found an ecotone to treeline communities. We placed the transect in this more open community, which paralleled a portion of the denser forest. The open community was composed of younger whitebark pine with a beargrass understory. Within Waterton Lakes National Park, we selected Summit Lake as our study area, which was characterized by mid to late successional communities with both mature and young whitebark pine and an understory of beargrass, the shrub *Menziesia ferruginea*, and globe huckleberry (*Vaccinium globulare*). We established three transects in this study area. For reference in this study, each transect was named by study area and assigned a number.

Table 1. Transect and stand assessment plot descriptions. Elevation and aspect were measured at transect mid-point. Latitude/longitude were taken from GPS readings at the start point of each transect.

Park	Study Area	Transect	Length of Transect (m)	Elevation (m)	Habitat	Lat/Long	Aspect (°)
Glacier NP	Numa Ridge	1	450	A-1935 B-1969	Lodgepole, beargrass	48°52.816 114°10.449	A-230 B-230
		2	450	A-2032 B-2054		48°52.907 114°10.602	A-204 B-204
	Preston Park	1	700	A-2121 B-2155	Subalpine fir, Engelmann spruce	48°42.471 113°39.296	A-250 B-260
		2	500	A-2151 B-2175		48°42.764 113°39.366	A-210 B-210
		3	450	A-2055 B-2050		48°42.583 113°39.342	A-160 B-160
	Two Medicine	1	700	A-1772 B-1977	Lodgepole, Douglas fir	48°38.882 113°38.882	A-290 B-200
	White Calf	1	500	A-1989 B-2005	Subalpine fir	48°38.191 113°23.561	A-116 B-76
Waterton Lakes NP	Summit Lake	1	500	A-1961 B-1964	Subalpine fir	49°00.556 114°01.291	A-210 B-220
		2	500	A-1991 B-1993		49°00.605 114°01.416	A-290 B-290
		3	500	A-1946 B-1958		49°00.407 114°01.427	A-220 B-64

Within each study area, the transects were between 0.5 and 1 km in length and oriented along a fixed heading. We marked the beginning and end points with a 10 inch metal nail, surveyor's flag, and aluminum tag. Every 50 m along each transect was also marked with an aluminum tag. These points were geo-referenced with a Garmin map 60CSx GPS unit. Points were also geo-referenced every 10 meters in order to facilitate the creation of a virtual transect within GIS for use with distance sampling where nutcrackers were sighted.

Stand Assessment Plots

The starting point and mid-point of each transect, respectively, were selected for the establishment of two 50 m x 10 m stand assessment plots to survey for stand structure and composition and whitebark pine cone production and health; methods generally followed Tomback et al. (2005). The stand assessment plots were created by measuring 50 m from the start point and mid-point of each transect in the direction of the transect endpoint and 5 m to either side of the transect line, which was demarcated with surveyor's tape. Pin flags running parallel to the surveyor's tape outlined the boundaries of the plot. The start and endpoints of each plot were geo-referenced and marked with a metal spike and tag. Once the data were taken, the pin flags and surveyor's tape were removed and the process was repeated later for each cone count. All whitebark pine that were 2 cm or greater diameter at breast height (DBH, approximately 1.37 m above ground) were measured for DBH, and examined for 1) white pine blister rust, 2) canopy damage, 3) percent whitebark canopy cover, 4) percent of mountain pine beetle infestation symptoms, 5) percent tree mortality and cause, 6) whitebark pine regeneration, and 7) cone numbers. A whitebark pine was considered infected with blister rust if we found active, sporulating cankers or old, inactive cankers. We also noted the following symptoms of blister rust infection: branch flags, resin weeping, and bark stripping by rodents. Canopy damage was categorized into one of the following classifications: 1(0-5%), 2(6-15%), 3(16-25%), 4(26-35%), 5(36-45%), 6(46-55%), 7(56-65%), 8(66-75%), 9(76-85%), 10(86-95%), 11(96-100%). A tree was considered living if it had >1% green foliage, even if we found signs of blister rust infection or mountain pine beetle infestation. Mountain pine beetle infestation was indicated by beetle entry holes with pitch plugs or J-shaped galleries in the wood (Gibson et al. 2009).

Cones were counted within these stand assessment plots three times for each field season, the last time coinciding with seed dispersal. An observer using binoculars counted the cones produced by each whitebark pine within each plot, standing on two different sides of the tree. The stand assessment was performed once in 2009, while the cone counts took place three times in 2009 and 2010. Whitebark pine seedlings ≤ 50 cm in height were counted within each plot and then summed over both plots, in order to compare regeneration among study areas. Additionally, mature cone bearing canopy level trees within each stand assessment plot were counted to determine percent stand composition by species.

Distance Sampling: Cone Counts and Nutcracker Surveys

For each visit to a study area, nutcrackers were counted by the line transect Distance Sampling protocol (Buckland et al. 2001) (Fig. III.2). Surveys were conducted on each transect during optimal light conditions (avoiding early morning and evening), and avoiding inclement weather. Two observers began at the transect start point and moved along the transect at a slow, steady pace, 10 m apart. The amount of time it took to walk the transect was noted. When a nutcracker was sighted, one observer used a Nikon ProStaff 550 laser rangefinder to determine the distance between the transect line and the tree that the nutcracker was in, or the nearest tree to a bird in flight. The other observer fixed and recorded the GPS point on the transect line. A standard compass was used to determine the angle of the sighting from the transect line, with the observer oriented toward the endpoint of the transect line. This information was then used to determine the direct perpendicular distance from the sighted bird to the transect line. The nutcracker's activity was also noted, as well as the number in a group (if more than one), the tree species where the nutcracker was observed, the presence/absence of cones and the general health of the tree. Vocalizations were considered an observation. If a vocalization was heard, distance and direction to the bird were estimated by observers.

In 2010, in addition to counting cones within the stand assessment plots, the same protocol for Distance Sampling of nutcrackers was implemented to estimate cone density. One observer conducted all Distance Sampling cone counts to maintain consistency and reduce variability.

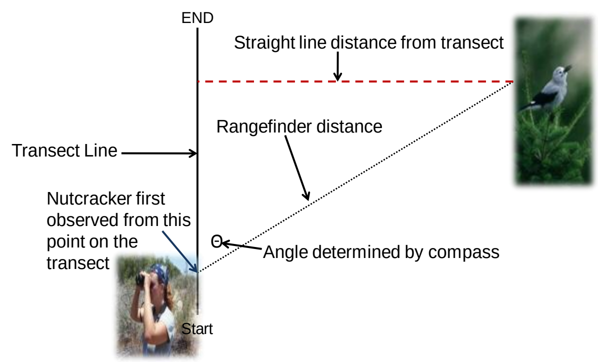

Figure 3. Nutcracker surveys: Distance sampling. Nutcrackers population density was estimated by use of the line transect. Distance sampling protocol (Buckland et al. 2001).

Study Timeline

The study was conducted over two field seasons, 2009 and 2010. Transects and stand assessment plots were established in early July 2009. Nutcracker Distance Sampling surveys, and cone counts for each transect were conducted three times in 2009: in mid-July, mid-August and mid-September. In 2010, surveys of each transect were conducted beginning July 5th, as soon as snowmelt permitted, and each study area was visited seven times from July through mid-September. This number was deemed necessary to increase the accuracy of the Distance Sampling estimate of nutcracker density. The sites were visited in generally the same order throughout the season. Cone counts using the line transect Distance Sampling protocol (Buckland et al. 2001) were conducted on three visits, and on the same days that the stand assessment plot cone counts were conducted.

Data Analysis

Nutcracker and Cone Density Estimates. We used Distance Sampling techniques and software platform Distance (Buckland et al. 2001) to estimate nutcracker densities within the Park. By using this method, we were able to estimate a detection probability as a function of the distance from our transect lines. From this function, population sizes can be estimated from the basic relationship: $D = n/(a*p)$, where D is nutcracker or cone density, n is number of animals or objects sighted, a is area sampled, and p is probability of detection. For line transects, a is written as 2wL, resulting in the following equation: $D = n/ 2wLP_a$, where P_a is the average probability of detecting nutcrackers or cones, w is the effective detection distance or effective strip width, and L is the total transect length of all sampled transects. P_a and w are both derived from detection probability function described above. Program distance fits these data to each of several competing hypotheses about the functional form of the detection model. The detection model results are then used to compute an estimate of density and the uncertainty around that estimate. The procedure also estimates the degree of model selection uncertainty using AIC weights, so we computed a model-averaged estimate of density. We report the model-averaged density of nutcrackers and of cones (both in number per hectare) for the areas that we sampled in the park.

We used this method to estimate nutcracker densities in 2009 and 2010 but used the method for cone density estimates in 2010 alone. This gave us the opportunity to compare the stand assessment method for cone density estimates with the cone density estimates derived from using the program Distance. We also compared the nutcracker density estimates produced by Distance to the counts of individual nutcrackers that we collected in the field.

Stand assessment plot calculations. We used whitebark DBH measurements to calculate live whitebark pine basal area per hectare (m^2/ha) by using the sum live basal area from the two 500 m^2 stand assessment plots and multiplying times a factor of 10. We found percent whitebark pine canopy by dividing the number of canopy level live, mature, cone-bearing whitebark by the total number of all individuals of all species of canopy level trees within the plots. We also reported percent of live whitebark pine trees with blister rust, mean canopy kill class, and mean whitebark pine DBH based on both stand assessment plots per transect. Additionally, total number of dead and live whitebark pine and regeneration numbers reported were based on sums across both stand assessment plots of each transect.

We compared our data with those of McKinney et al. (2009) and Barringer et al. (2012) by adding our data points to the graph (Fig. 4) of proportion of observation hours resulting in one or more sightings of a nutcracker vs. average number of whitebark pine cones per hectare, based on survey plots in Barringer et al. (2012). We calculated the proportion of observation hours resulting in at least one nutcracker observation from the number of nutcracker observations per transect and the total number of hours spent on each transect. We then incorporated our 2009 and 2010 observed values for proportion of observation hours resulting in nutcrackers with the values from the McKinney et al. (2009) and Barringer et al. (2012) studies along with our cone density data per hectare from 2009 and 2010.

RESULTS

Stand Assessment Plots

We documented the following trends (Table 2): Overall, the mean DBHs of whitebark pine based on the two assessment plots per transect ranged from 6.5 cm to 37.4 cm. The White Calf study area had the smallest diameter and presumable youngest whitebark pine measured of any of the study areas (6.5 cm, respectively), whereas the two assessment plots at Two Medicine had the largest and presumably the oldest whitebark pine on average (37.4 cm). However, Preston

Park consistently had the largest whitebark pine measured among the assessment plots of all its three transects (30.5 cm, 34.2 cm, and 36.6 cm, respectively).

Table 2. Transect stand assessment plot variables for whitebark pine (WP). Percentages, canopy kill class, and DBH based on means of both stand assessment plots per transect. Live basal area (LBA), total number of dead and live WBP, and regeneration (no. of seedlings per transect) numbers were based on sums across both stand assessment plots of each transect.

Park	Study Area	Transect	Avg DBH (cm), SD	Percent live trees with blister rust	Avg canopy kill class	LBA m2/ha per transect	Total no. dead WBP	Total no. live WBP	Percent WBP in overstory	No. seedlings per transect
GNP	Numa Ridge	1	11.4 (7.3)	75	4.6	0.181 1.81	16	16	13	16
		2	10.9 (4.6)	76	6	0.669 6.69	29	29	30	33
	Preston Park	1	30.5 (12.1)	50	5.5	0.183 1.83	12	2	4	0
		2	34.2 (11.9)	80	5.2	1.105 11.05	17	10	3	2
		3	36.6 (27.3)	50	3	0.269 2.69	0	2	3	0
	Two Medicine	1	37.4 (13.6)	67	4	0.487 4.87	2	3	3	0
	White Calf	1	6.5 (3.2)	75	2.3	0.048 0.48	0	12	100	4
WLNP	Summit Lake	1	15.8 (11.3)	55	2.4	0.294 2.94	1	11	15	0
		2	32.6 (32.6)	33	4.3	0.042 0.42	2	3	4	0
		3	18.5 (13.4)	75	4.7	0.078 0.78	2	4	8	0

The highest percent of live trees with blister rust was found for transect 2 at Preston Park with 80% infection. The lowest percent of live trees with blister rust was found on the assessment plots at Summit Lake on transect 2 with 33% infection. The highest average category of canopy kill (6.0) for whitebark pine occurred on the assessment plots for transect 2 at Numa Ridge. The lowest average canopy kill class was found at White Calf (2.3) with transect 1 at Summit Lake a close second. The lowest value for live basal area for whitebark pine was found on transect 2at Summit Lake with 0.42 m^2/ha, and the highest at Preston Park on transect 2 with 11.05 m^2/ha. Numa Ridge overall had the greatest number of live WBP, the greatest number of dead WBP and the greatest number of seedlings on the assessment plots. Transect 3 at Preston Park had only 2 living whitebark pine and no dead whitebark pine on assessment plots with only 3% whitebark pine among canopy trees. No regeneration was found on six transects, including all of Summit Lake and the Two Medicine transects, and only 2 seedlings documented on all three transects at Preston Park.

Distance Sampling for Nutcrackers and for Cones

We detected at total of 65 nutcrackers in 2009 and 2010 combined over a total of 52.5 km of transects traversed (Table 3). In 2009, for all three Distance Sampling efforts, we saw no nutcrackers in Two Medicine or on the three transects in Preston Park. In 2009, we saw the

Table 3. Numbers of Clark's Nutcrackers observed during Distance Sampling in 2009 and 2010, with combined cone counts from stand assessment plots. Note that surveys were conducted three times from July through September in 2009 but seven times over this time period in 2010.

Park	Study Area	Transect	2009 Time in summer					2010 Time in summer								
			1	2	3	Total	No. cones	1	2	3	4	5	6	7	Total	No. cones
GNP	Numa Ridge	1	0	12	0	12	3	0	0	0	0	0	0	0	0	0
		2	0	0	0	0		0	0	0	0	0	0	0	0	
	Preston Park	1	0	0	0	0	8	0	0	0	0	0	1	0	1	58
		2	0	0	0	0		3	0	1	0	0	0	2	6	
		3	0	0	0	0		0	0	0	0	0	0	0	0	
	Two Medicine	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	White Calf	1	3	0	0	3	0	0	0	4	8	0	0	0	12	0
WLNP	Summit Lake	1	1	1	0	2	2	0	0	1	0	0	0	0	1	5
		2	18	0	0	18		0	0	0	0	0	0	0	0	
		3	0	1	0	1		0	0	4	0	0	5	0	9	

greatest numbers of nutcrackers on Numa Ridge and at Summit Lake. In 2010 during all seven Distance Sampling surveys, we saw no nutcrackers at Numa Ridge and none again at Two Medicine. We saw the greatest numbers of nutcrackers at White Calf and Summit Lake. No particularly time appeared best for nutcracker sightings, suggesting a degree of randomness in encounters.

Nutcrackers, in most sightings, were observed flying through whitebark pine communities or perched in trees—both whitebark pine and other species. In 2009, family groups of nutcrackers were observed in some areas in July, and especially in Preston Park. By late summer, nutcrackers were occasionally observed harvesting seeds. No nutcrackers were observed to cache seeds, although some caching was suspected to have occurred in the vicinity of White Calf Mountain. Birds were observed transporting seeds with full throat pouches.

We modeled the detection probability across the two years and across all study areas and transects, because the detection function varied by year, and sample sizes were relatively small for each year. This generated a single density estimate for the entire Glacier and Waterton Lakes Peace Park. The computed density of Clark's Nutcrackers was 0.94 birds/ha, and the 95% confidence interval around that estimate was 0.42 to 2.10 birds/ha. The combined area of Glacier National Park and Waterton Lakes National Park is about 4,605 km^2. Given that there are 100 hectares per km^2, the combined parks represent about 460,500 ha. Given that our observations were restricted to whitebark pine habitat, the estimated population density should be based roughly on total whitebark pine habitat.

With the exception of Preston Park in 2010, neither year appeared to be a good cone year for any of the study areas, based on cone counts from the stand assessment plots (Table 3). However distance sampling surveys counted more cones than present on the assessment plots and provided a more realistic assessment. The density estimate of whitebark pine cones across both study years, both parks, and all transects was 67.11 cones/ha, and the 95% confidence interval around this estimate was 31.26 to 144.08 cones/ha.

Relationship between Nutcracker Sightings and Cone Production

The data on cone counts on stand assessment plots and numbers of nutcrackers sighted on transects were transformed and added to the scatterplot published as Fig. 4b in Barringer et al. (2012). The original Barringer et al. (2012) scatterplot includes data collected by Barringer et al. plus the data published by McKinney et al. (2009) across several ecosystems, including observations from the Northern Divide Ecosystem. Here, in the new scatterplot (Fig. 4), the triangles represent the data from the Waterton-Glacier International Peace Park. There are 20 data points, but a number of overlapping points with 0 cones and 0 nutcracker sightings.

Similar to the findings in Barringer et al. (2012), it appears that nutcrackers may occur in any whitebark pine community even if cone production is low. However, the likelihood of occurrence of nutcrackers tends to be low with low cone production. The cone production of both 2009 and 2010 was low compared to the range of values obtained across all three studies and the proportion of hours with nutcracker sightings was generally low, as expected.

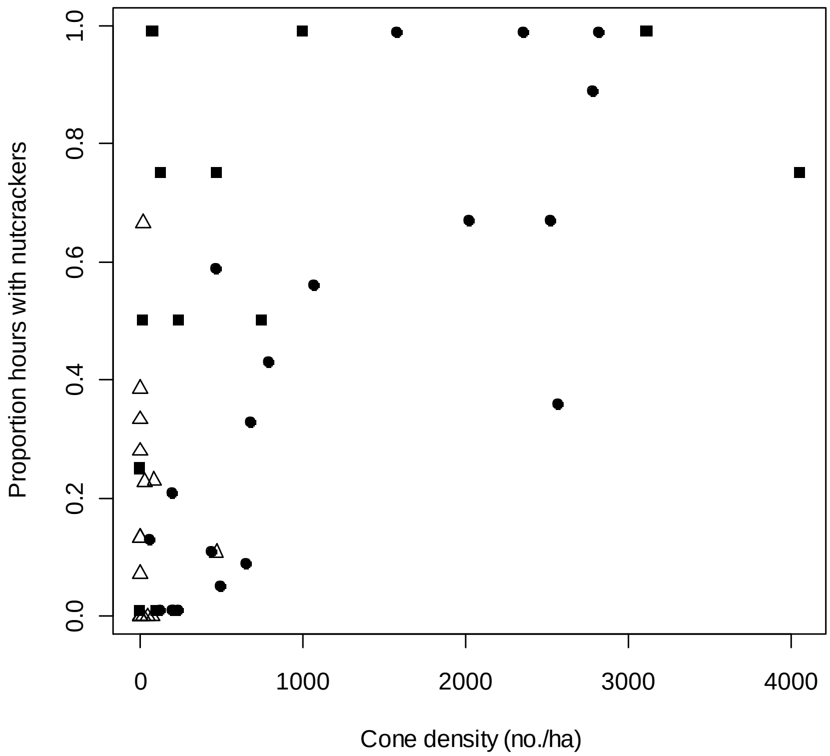

Figure 4. General relationship between nutcracker observations and cone production over three research studies including data from Glacier National Park. Proportion of observation hours resulting in a sighting of Clark's Nutcracker in relation to number of whitebark pine cones produced per ha determined from stand assessment plots sampled in this study (triangles) combined with those sampled in McKinney et al. (2009) (circles) and Barringer et al. (2012) (squares).

DISCUSSION

Here, we address the objectives of this study, rephrased as questions, in relation to the data and observations that we collected.

1) Do nutcrackers occur in whitebark pine communities in the park and at what density?
Nutcrackers did occur in most of the whitebark pine communities that we surveyed, but unpredictably and usually with low numbers. To put this in perspective, of the 30 Distance Sampling surveys conducted on transects in 2009, nutcrackers were sighted in only 6 surveys or 20%. Of the 70 surveys conducted in 2010, nutcrackers were sighted in only 9 of these surveys or 12.8%. The overall computed density of Clark's Nutcrackers was 0.94 birds/ha, and the 95% confidence interval around that estimate was 0.42 to 2.10 birds/ha. This number multiplied times the whitebark pine habitat in the Park may give a very rough estimate of the population that may use the Park.

2) Does nutcracker density vary with whitebark pine cone production?

Whitebark pine cone production appeared to be sporadic and comparatively low on all transects in both years of this study, especially in relation to cone production observed in other ecosystems with more reliable occurrence of nutcrackers (McKinney et al. 2009, Barringer et al. 2012). The variation across study areas and transects in general appeared insufficient to generate major differences in nutcracker sightings. It is possible that we may have been working in generally low cone production years. Alternatively, the numbers of dead trees, low live basal area, degree of canopy kill from blister rust, and high blister infection levels indicate that these communities as a whole are in serious decline and high cone production years are unlikely.

The Barringer et al. (2012) study (their Fig. 2) reports a mean of 24 cones/ha for the "north," which comprised study areas in both Glacier and Waterton Lakes National Parks, and a mean of 1030 cones/ha for the "south," which comprised Yellowstone and Grand Teton National Parks. The Distance Sampling density estimate of whitebark pine cones that we obtained for study areas in Glacier and Waterton Lakes National Parks and across both study years and all transects was on the same order of magnitude-- 67.11 cones/ha--and the 95% confidence interval around this estimate was 31.26 to 144.08 cones/ha. The northern value that Barringer et al. (2012) report is actually a lower number than our Distance Sampling density estimates. Distance Sampling for cones may well be a more reliable way of assessing this resource as opposed to counts on limited fixed plots. Regardless, both studies are consistent in reporting low cone production for the Waterton-Glacier Peace Park over the period of the two studies combined, 2008 through 2010.

The Barringer et al. (2012) study (their Fig. 2) reported a mean of 1.7 nutcrackers per transect (each transect = 1 km in length, with 6 point count stations) in the "north" but a mean of 21 nutcrackers per transect in the "south." The Distance Sampling estimates of numbers of nutcrackers (0.94 birds/ha) that we obtained does not depart greatly from this previous assessment.

For regeneration, the numbers of seedlings reported in Fig. 2 in Barringer et al. (2012) were taken from a sampling protocol directly comparable to ours (two 50 m x 10 m plots per transect). They report a mean number of seedlings of 6.4 for the "north" and 170.2 seedlings for the "south." We found in our study that only one study area, Numa Ridge, had any significant amount of regeneration on the stand assessment plots associated with transects.

To summarize the implications of our results, Fig. 4 above indicates that higher levels of cone production generate more reliable occurrences of Clark's Nutcrackers. This in turn results in more reliable seed dispersal. Overall, it appears that cone production, seed dispersal, and subsequent regeneration are not dependable in the Waterton-Glacier Peace Park.

3) How does cone production vary with whitebark pine prevalence and health in Waterton Lakes-Glacier International Peace Park? Cone production was low in general and did not seem to correspond to greater numbers of living whitebark pine or live basal area or with more or fewer nutcrackers. Preston Park had high living basal area on one transect and produced the highest number of cones in 2010. Nutcrackers did visit this study area that year.

4) Was the relationship between the likelihood of nutcracker visitation and whitebark pine cone density similar to those results found in McKinney et al. (2009) and Barringer et al. (2012)? As shown in Fig. 4 above, the relationship between cone production per hectare and proportion of observation hours with one or more nutcrackers occurring did correspond to the previous data generated for the Northern Divide region (McKinney et al. 2009) and specifically the Waterton Lakes-Glacier International Peach Park. Given the low numbers of cones produced as assessed in all three studies represented in Fig. 4, the relationship indicates that there is a lower likelihood of visitation by nutcrackers in the Northern Divide.

However, the graph does show that even with no cones produced, nutcrackers may occur in whitebark pine communities. This latter observation is consistent with the idea that nutcrackers explore widely or “cruise” among whitebark pine communities, checking for cone production (Barringer et al. 2012). This also raises the hope that if restoration projects were to occur and cone production eventually restored, nutcrackers may again return to disperse seeds.

5) Was the Distance Sampling protocol developed for this study a useful approach to assessment of nutcracker visitation and cone production? We developed a protocol for counting both nutcrackers and whitebark pine cones using a line transect-based Distance Sampling method. This method takes detectability into consideration and generates a more reliable density estimate than the previous count methods (McKinney et al. 2009, Barringer et al 2012). It has proven useful under a range of stand conditions. The one drawback is the number of repeated observations required to obtain a reliable estimate.

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