ANNOTATED BIBLIOGRAPHY FOR WHITEBARK PINE ECOLOGY

Additions December 2012

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Notes:

a. Using the most recent science contributes to the successful conservation of whitebark pine. This bibliography has become my annual contribution to this objective. Enjoy!

b. As always, if I missed any key work or if you have additional interpretations from any given paper, please let me know.

1. **Keane, Robert E.; Tomback, D.F.; Aubry, C.A.; Bower, A.D.; Campbell, E.M.; Cripps, C.L.; Jenkins, M.B.; Mahalovich, M.F.; Manning, M.; McKinney, S.T.; Murray, M.P.; Perkins, D.L.; Reinhart, D.P.; Ryan, C.; Schoettle, A.W.; Smith, C.M. 2012. A range-wide restoration strategy for whitebark pine (*Pinus albicaulis*). Gen. Tech. Rep. RMRS-GTR-279. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 108 p.** Available at: http://treesearch.fs.fed.us/pubs/40884

2. **Sniezko, Richard A.; Yanchuk, Alvin D.; Kliejunas, John T.; Palmieri, Katharine M.; Alexander, Janice M.; Frankel, Susan J., tech. coords. 2012. Proceedings of the fourth international workshop on the genetics of host-parasite interactions in forestry: Disease and insect resistance in forest trees. Gen. Tech. Rep. PSW-GTR-240. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 372 p.** Available at: http://www.fs.fed.us/psw/publications/documents/psw_gtr240/

3. **Sambaraju, K.R., Carroll, A.R., Zhu, J., Stahl, K., Moore, D. and Aukema, B.H. 2012. Climate change could alter the distribution of mountain pine beetle outbreaks in western Canada. Ecography. 35(3): 211-223.**

Background & Objectives

This studied examined the individual associations of several biologically-relevant cold temperature variables, and other temperature/degree-day terms, with outbreak occurrences in a spatial-temporal logistic regression model using data from the current outbreak.

Main Findings

- Timing, frequency, and duration of cold snaps had a severe negative association with occurrence of an outbreak in a given area.
- Large drops in temperature (>10°C) or extreme winter minimum temperatures reduced the outbreak probability.

Implications

- Increases in mean temperature by 1°C to 4°C profoundly increased the risk of outbreaks with effects first being manifested at higher elevations and then at increasing latitudes.

4. **Lahr, E.C. 2012. Effects of host stored resources on bark beetle-fungal-conifer interactions. PhD. University of Montana. Missoula, MT.**

Background & Objectives

This doctoral work investigated whether stored resources in tree sapwood change after mountain pine beetle attack. This work also studied how phloem and sapwood resources vary with elevation and tree diameter. Finally, this work examines the effect of tree species and diameter on mountain pine beetle host selection.

Main Findings

- Following beetle attack and fungal colonization, sapwood non-structural carbohydrates, lipids and phosphorus declined in attacked trees.
- Resource declines were directly related to the degree of fungal colonization.

- In lodgepole, beetle performance was positively related to stored resources and not in whitebark.
- Stored resources were greater in whitebark pine than lodgepole and increased with elevation and whitebark diameter.
- Beetles attack whitebark even when a larger lodgepole was available.

Implications

- This work suggests that host stored resources influence bark beetles.
- Understanding these relationships may assist in predicting bark beetle dynamics and range expansion.

5. Larson, A. and Cansler, C. 2012. The changing role of fire in whitebark pine population dynamics: implications of conservation. *In* Abstracts for oral presentations. 97th ESA Annual Meeting, August 5-10, 2012. Portland, OR.

Background & Objectives

This work examined contemporary relationships between whitebark regeneration and fire-created early successional habitats at two scales. Large scale relationships were based Monitoring Trends in Burn Severity Database to estimate burned whitebark over a 26 year period (1984-2009). Small-scale relationships were examined by observing patterns of whitebark seedling presence in the Bob Marshall Wilderness in the 1994 Helen Creek Fire.

Main Findings

- Approximately 15% of whitebark pine range burned from 1984 to 2009.
- Whitebark regeneration was present in only 1/3 of plots within the Helen Creek Fire perimeter.
- Whitebark regeneration was most strongly related to landform.

Implications

- This work suggests that early successional whitebark habitat is not a limiting factor.
- Blister rust and mountain pine beetle have fundamentally altered the role of early successional habitat in whitebark pine population dynamics.
- Whitebark recruitment is likely limited by seed production and dispersal and not by suitable habitat for seedling establishment.
- Prescribed or natural fire may only benefit whitebark when augmented with manual planting.

6. Margoles, D.S. 2011. Mountain pine beetle-whitebark dynamics in a subalpine ecosystem of the Pioneer Mountains, southwest Montana. M.S. Thesis. University of Minnesota. 124 p.

Background & Objectives

This study identifies the timing, and collapse, of a mountain pine beetle outbreak in the Pioneer Mountains, and the differences in growth patterns between whitebark killed by beetle and those that survived.

Main Findings

- The outbreak began in 1924, peaked in 1930 and ended abruptly in 1933 synchronous with the coldest recorded temperature for Dillon, MT.
- During the outbreak, the beetles killed the most vigorous whitebark pine.
- Whitebark that survived the outbreaks has slow growth and responded more strongly to wet and dry yrears.
- Whitebark killed earlier in the outbreak has slower growth than those killed later.

Implications

- This work suggests there may not be a linear relationship between host stress and susceptibility to beetle attack.

7. Dooley, E. 2012. Mountain pine beetle outbreaks in high elevation whitebark pine forests: the effects of tree host species and blister rust infection severity of beetle productivity. M.S. Thesis. University of Montana. Missoula, MT. 122 p.

Background & Objectives

This master's work examined mountain pine beetle productivity in whitebark pine compared to lodgepole pine and in whitebark pine of varying blister rust infection severity.

Main Findings

- Mountain pine beetle attack density was lowest on whitebark with the most severe rust infection.
- Emergence rates and beetle size were greatest on whitebark with the most severe rust infection.

Implications

- This work indicates that whitebark stands with high rust severity may support rapid beetle population growth.
- Data also indicated that whitebark has greater host quality for the beetle than lodgepole.

8. Maier, M. 2012. Clark's nutcracker seed harvest patterns in Glacier National Park and a novel method for monitoring whitebark pine cones. M.S. Thesis. Utah State Univeristy. Logan, UT. 68 p.

Background & Objectives

This study identified factors affecting seed harvest by Clark's nutcracker.

Main Findings

- Nutcrackers use every site that has cones, regardless of the number of cones available.
- Nutcrackers harvest the greatest proportion of seeds at sites where they began harvesting earlier.
- Red squirrels depleted cone source more rapidly in stands where more whitebark are dead and in some stands removed all the cones before the nutcrackers began harvesting.

Implications

- This study identifies characteristics of stands that may regenerate naturally versus those that may need to be planted.
- Red squirrel cone use may negatively affect whitebark regeneration in some stands of whitebark.

9. Keville, M. 2011. Impacts of mountain pine beetle (Dendroctonus ponderosae) outbreak on biogeochemical cycling in a high elevation whitebark pine (Pinus albicaulis) ecosystem. M.S. Thesis. Carleton College. 69 p.

Background & Objectives

This thesis work investigated the effects of the current mountain pine beetle outbreak on carbon and nitrogen cycling by measuring above and below ground nitrogen and carbon pools and fluxes at three times near attacked and unattacked whitebark pine trees.

Main Findings

- Litterfall inputs were 10 times greater under attacked whitebark and thus soil ammonium, NH_4^+, increased 200%.
- Soil nitrate increased following attack.
- Microbial mass did not change.

Implications

- This study suggests that beetle attacks cause a pulse of C and N to the forest floor.

10. Wong, C. 2012. Understanding disturbance, facilitation, and competition for conservation of whitebark pine in the Canadian Rockies. PhD. University of British Columbia, Vancouver. 119 p.

Background & Objectives

This doctoral study sought to understand forest resilience to novel disturbances and how tree interactions will be affected by global change.

Main Findings

- Compiled data indicated 20-90% whitebark mortality over 50 years in 16 stands.
- Climate growth relationships suggested blister rust increased whitebark pine sensitivity to summer precipition and thus reduced resistance to beetles.

Implications

- Whitebark is more resilient at sites with low abiotic stress and low disturbance severity.

11. Millar, C.I., Westfall, R.D., Delany, D.L., Bokach, M.J., Flint, A.L., and Flint, L.E. 2012. Forest mortality in high-elevation whitebark pine (Pinus albicaulis) forests of eastern, California, USA; influence of environmental context, bark beetles, climatic water deficit, and warming. Can. J.For.Res. 42:749-765.

Background & Objectives

This study examined stand-level environmental factors and local- to regional-scale climatic variables that may affect tree growth and mortality in high-elevation whitebark pine near Bridgeport, California. Investigations include analysis of USDA FHP aerial detection data and independently conducted plots in areas of high mortality.

Main Findings

- Whitebark mortality event from 2007-2010 affected 7400 hectares with a range of 5 to 38% mortality.
- No sign of blister rust was detected in the studied stands.
- Minimum temperatures have increased over the past 120 years.
- Live and dead trees were found in affected stands; dead trees were codominant to live trees.
- Mortality was greater in stands where tree density was higher.

Implications

- This study shows that water deficit values and tree response to changes in water deficit are better indices to predict tree vigor than climate variables.
- Differences in growth between surviving trees and trees that died suggest adaptive genetic differences.
- The 1920s coincides with a transition to warmer and drier conditions. Trees that grew faster after the 1920s survived beetle epidemic better than those that grew faster prior to 1920s indicating that adaptive differences.
- Beetle epidemic appears to be a natural selection event that removed trees that are less fit under current climate.
- Basal area was reduced in all stands, creating conditions less favorable for beetle outbreaks.

12. Mitton, J.B., and Ferrenberg, S.M. 2012. Mountain pine beetle develops an unprecedented summer generation in response to climate warming. Am.nat. 179(5): 163-171.

Background & Objectives

This study investigated the temperature variation over the past 4 decades, the length and timing of mountain pine beetle flight season and the life cycle of mountain pine beetle at a site in the Rocky Mountains in Colorado.

Main Findings

- Compiled data shows significant warming from 1970 to 2008; the mean annual temperature was 1.5 °C warmer.
- The annual number of days above 0°C increased by 15 days.
- The number of days when temperatures are conducive for mountain pine beetle development increased by 249 days over 4 decades.

- Funnel traps indicated that beetle flight seasons began approximately 6 weeks earlier and lasted twice as long in 2009 and 2010 than any other recorded seasons.
- Trees were initially attacked in June and released some adults by September. The needles of these trees were still green.
- Upper elevation limits of MPB have increased from 2740 meters to 3350 meters.
- Flight season has doubled and a portion of the MPB population is bivoltine.

Implications

- This work suggests that high latitude and high elevation MPB populations should demonstrate the greatest response to development by changes in degree days.
- This supports the MPB range expansion into high elevation forests.
- Selection for faster development and increased fitness may be interacting with rapid climate change to increase rates of MPB development in zones where temperatures were historically low.

13. McLane, S.C., and Aitken, S.N. 2012. Whitebark pine (Pinus albicaulis) assisted migration potential: testing establishment north of the species range. Ecological Applications 22(1):142-153.

Background & Objectives

This study explores the use of translocation of whitebark pine into habitable locations outside of its current range as a means of saving a species vulnerable due to climate change. The study included testing the capacity of whitebark pine to establish relative to climatic and habitat features within its predicted climatic range. Specifically the study examined the impacts of seed maturity, habitat quality, and genetics on whitebark establishment in both its realized and predicted climatic range.

Main Findings

- Species distribution models suggest that whitebark is projected to lose 73% of its current climatic range within British Columbia and 97% within the USA by 2085.
- The models show that much of the area of NW British Columbia is both currently suitable and predicted to be habitable for whitebark in the future.
- All whitebark germinated and survived in common garden experiments.
- Seed mass was primary predictor of establishment potential. Seed mass increased with increased latitude.
- Growing season length and temperature influenced establishment. Snow duration was most important.

Implications

- This study suggests whitebark can germinate and survive hundreds of kilometers north of its current northern range limit.
- Snow played limiting role; early snowmelt was associated with greater survival and low germination rates were associated with thin snowpack (no isolation).
- Balance between sufficient snow duration and growing season is critical to establishment and survival.
- Snow duration variable must be added to climate models to accurately predict whitebark distribution.

14. Barringer, L.E., Tomback, D.F., Wunder, M.B., and McKinney, S.T. 2012. Whitebark pine stand condition, tree abundance, and cone production as predictors of visitation by Clark's nutcracker. 7(5): 1-11.

Background & Objectives

This study quantified whitebark forest structure, health metrics, cone productin, and the frequency of nutcracker occurrence to determine the relationship between cone density and the probability of occurrence of nutcrackers.

Main Findings

- Cone densities were positively correlated with live basal area and nutcracker observations.
- Mean live basal area were no nutcrackers were observed ranged from 0.04-0.33 m^2/ha

- No single variable predicts nutcracker occurrence. Model variables include: proportion live whitebark, geographical region and number of red squirrels.
- Stand assessment plots in the southern region had greater whitebark basal area and lower blister rust infection than northern plots.

Implications

- This study identifies a more appropriate statistical framework for modeling cone density and nutcracker observations.
- Nutcrackers are long-lived and range widely, thus cone density is better monitored at a landscape-level and not a stand-level.

15. Maloney, P.E., Vogler, D.R., Jensen, C.E., Mix, A.D. 2012. Ecology of whitebark pine populations in relation to white pine blister rust infection in subalpine forests of the Lake Tahoe Basin, USA: Implications for restoration. For. Eco. Mgmt. 280:166-175.

Background & Objectives

This study surveyed eight populations of whitebark across range of environmental conditions near South Lake Tahoe, California to determine the effect of blister rust on female cone production, seedling recruitment and survival. In addition the study examined environmental conditions and their relationship to host and pathogen characteristics.

Main Findings

- Mean blister rust incidence was 35%.
- The percent of individuals infected in each population, the average number of infected branches and severity of stem girdling were negatively correlated to cone production.
- Positive relationship found between extent of stem girdling and available water capacity.

Implications

- This study provides empirical evidence that whitebark population stability is adversely affected by blister rust.
- This study provides baseline information for whitebark in these study sites.
- Mortality to cone bearing branches is the most critical effect of blister rust.
- Authors suggest that blister rust may also be exerting a positive effect on whitebark populations through natural selection for resistant individuals.

16. Olyer-McCance, S.J.; Fike, J.A.; Castoe, T.A.; Tomback, D.F.; Wunder, M.B.; Schaming, T.D. 2012. Development and characterization of thirteen microsatellite loci in Clark's nutcracker. Conservation Genetics Resources. DOI 10.1007/s12686-012-9789-0.

Background & Objectives

This study investigates the population structure of Clark's nutcracker to provide insight into the spatial relationships between the nutcracker and whitebark pine.

Main Findings

- Variability among nutcracker populations ranged from 6 to 15 alleles.

Implications

- An understanding of spatio-temporal dynamics of the nutcracker is essential for conservation of whitebark pine.

17. Kegley, A. Sniezko, R.A., Danchok, R. and Savin, D. 2012. Blister rust resistance among 19 families of whitebark pine, *Pinus albicaulis*, from Oregon to Washington – early results from an artificial inoculation trial. *In* Sniezko, Richard A.; Yanchuk, Alvin D.; Kliejunas, John T.; Palmieri, Katharine M.; Alexander, Janice M.; Frankel, Susan J., tech. coords. 2012. Proceedings of the fourth international workshop on the genetics of host-parasite interactions in forestry: Disease and insect resistance in forest trees. Gen. Tech. Rep. PSW-GTR-240. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 372 p.

Background & Objectives

A randomized complete block design was used to test blister rust resistance of 19 families of whitebark pine. Seedlings were planted in 2005 and inoculated in 2006 and 2009.

Main Findings

- As of November 2010, 76.6% of trees had stem symptoms.
- Family means range from 46.9% to 100% symptomatic.
- The mean number of stem symptoms per infected tree was 16.4.
- Mortality from rust is low, 3.7 percent.

Implications

- The families identified with genetic resistance to rust are a key component to successful restoration efforts.

18. Sala, A, Hopping, K. McIntire, E., Delzon, S., Crone, E. 2012. Masting in whitebark pine (*Pinus albicaulis*) depletes stored nutrients. New Phytologist. 196:189-199.

Background & Objectives

This study examined the consequences of masting for short-term growth, nutrients in reproductive branches, and other physiological functions during a mast cone crop in 2005 in Flint Creek in Montana.

Main Findings

- Trees produced an average of 125 cones in 2005 and 15 in 2006.
- Nitrogen and phosphorus declined in needles, reproductive branches and terminal branches during 2005 mast year.
- Nutrient decline ranged from 13 to 72%.
- Short-term growth was not affected.

Implications

- This study may help to explain the variability in masting by whitebark pine across their distribution.
- Further studies will integrate the synchrony of climate cues and nutrient availability.

19. Mahalovich, M. 2011. Molecular genetic variation in whitebark pine (*Pinus albicaulis*) in the Inland West. *In* Keane, R.E., Tomback, D. F., Murray, M.P., & Smith, C.M. eds. 2011. The future of high-elevation, five-needle white pines in Western North America: Proceedings of the High Five Symposium. 28-30 June 2010; Missoula, MT. Proceedings RMRS-P-63. Fort Collins, CO: USDA, Forest Service, Rocky Mountain Research Station. 376 p.

Background & Objectives

This study estimates the levels of genetic variation within and among 163 individual whitebark pine.

Main Findings

- Genetic diversity within whitebark samples is high.
- Of the total variation measured, very little is among zones: seed zones share large degree of genetic similarity.
- Species diversity is due to large geographic range, long-life span, high fecundity, wind dispersed pollen and seed dispersal by nutcrackers.
- Greater Yellowstone-Grand Teton seed zone shows larger degree of differentiation from other zones.

Implications

- Success of genetic restoration program depends on understanding of species' genetic structure.

- Seed sources at risk of being lost that have genetic uniqueness will facilitate gene conservation.
- This study combined with another genetic study supports the consolidation/realignment of some seed zones.
- There is sufficient genetic diversity and variation to continue to support rust screening.

20. Irvine, K., Higgs, M., Shanahan, E., Legg, K., Podruzny, S., and Schwartz, C. *In Review.* Incidence of mountain pine beetle and white pine blister rust in whitebark pine in the Greater Yellowstone Ecosystem. Canadian Journal of Forest Research.

Background & Objectives

This study is a summary of the 176 permanent blister rust monitoring transects.

Main Findings

- Blister rust was prevalent in 26.6% of live whitebark sampled.
- Mountain pine beetle was prevalent in 3% of live whitebark sampled.
- Of recently dead trees, 36.7% had evidence of mountain pine beetle.
- Probability of blister rust incidence decreases at higher elevations and at eastward sample sites.
- The probability of blister rust incidence was greater on steeper slopes.

Implications

- This long-term study provides high quality data to address immediate and evolving questions regarding whitebark pine in the Greater Yellowstone.

21. Meddens, A., Hicke, J., Ferguson, C. 2012. Spatiotemporal patterns of observed bark beetle-caused tree mortality in British Columbia and the western United States. Ecological Applications. 22(7):1876-1891.

Background & Objectives

This study developed a gridded mortality area product from aerial survey data in British Columbia and the western United States. This work provides a spatial and temporal pattern of beetle-caused tree mortality in addition to estimations of mortality.

Main Findings

- In British Columbia, from 2001 to 2010, bark beetles killed 5.5 Mha out of a total of 55 Mha of forest, or 10% and MPB accounted for >90% of the damage.
- From 1997 to 2010, in the United States a total of 5.4 Mha of beetle-caused mortality were estimated and MPB accounted for 63% of tree mortality.

Implications

- Findings suggest that USFS ADS data underestimates number of trees killed by beetles.
- Important to account for: data collected is limited to areas flown in a particular year; information does not indicate which part of the grid cell is affected (fine-scale analysis must take place in the field); aerial surveys are subject to observer differences; and finally estimated areas of mortality include both dead and live trees.

22. Bunnell, F., Kremsater, L. 2012. Migrating like a herd of cats: climate change and emerging forests in British Columbia. Journal of Ecosystems and Management. 13(2): 1-24.

Background & Objectives

This study combined autecology and climate preferences of tree species with disturbance agents to describe possible changes species distribution in British Columbia. Disturbance agents assessed include: insects, disease and fire.

Main Findings

- Tree species have different genetic potential to respond to climate variables and varied seed dispersal mechanisms, resulting in varied distribution changes.
- Whitebark pine may run out of suitable habitat above them.
- Whitebark pine must migrate north and upward and nutcracker provides good opportunity for migration.

Implications

- Future forests will be product of migration and adaptation.
- Subalpine forests are more challenged than other forest types as they can only move northward and to higher elevations.
- Shifts in species composition will also occur.

23. Wulder, M., White, J., Coggins, S., Ortlepp, S., Coops, N., Heath, J. & Mora, B. 2012. Digital high spatial resolution aerial imagery to support forest health monitoring: the mountain pine beetle context. Journal of Applied Remote Sensing. 6: 1-9.

Background & Objectives

This paper is a review of the use of high resolution spatial digital aerial imagery for forest health monitoring.

Main Findings

- Imagery can provide individual tree-level attributes
- High resolution imagery can be used to calibrate Landsat or Quickbird imagery.

Implications

- This paper is a great resource that must be consulted when selecting spatial data for aerial monitoring.
- Digital aerial imagery is cost effective and high resolution.
- Detail afforded by this imagery supports a broad range of information needs.

24. Field, S., Schoettle, A., Klutsch, J., Tavener, S., and Antolin, M. 2012. Demographic projection of high-elevation white pines infected with white pine blister rust: a nonlinear disease model. Ecological Applications. 22(1): 166-183.

Background & Objectives

This study presents a disease model for population dynamics of high-elevation white pines in the face of blister rust. In addition, this work presents the parameters of mathematical models that must be calculated in order to correctly capture the dynamics of populations facing pathogens.

Main Findings

- Blister rust management commonly coincide with short-term transient phases of pathogen-host dynamics, rather than an equilibrium eventually reached in long-term, especially in a long-lived species like whitebark pine.
- Disease models must capture population dynamics at equilibrium and also during transience.
- The model presented in this study identifies strong density-dependent effects on population dynamics, particularly seedling recruitment.
- Model suggests that low infection rates in seedlings results from disease induced mortality and short residence time in the seedling stage.
- Model indicates that following period of transience, individuals reach an equilibrium stable stage distribution after 600 years.
- The effect of blister rust is larger on populations with interspecific competition.

Implications

- Models must capture sensitivities to relative change in order for management and policy decisions to be appropriate.
- Models approached this way will promote the recognition of critical parameters and ecological processes.

- Model indicates that the sustainability of high-elevation white pine stands infected with blister rust depends on infection probability and regeneration competition.
- Model suggests that white pine populations are capable of tolerating moderate levels of blister rust infection as long as seedling recruitment is maintained and stands are not simultaneously impacted by other disturbance agents, such as mountain pine beetle.
- Authors support critical need for stimulating natural regeneration and planting genetically resistant seedlings.

25. Gillette, N., Hansen, E., Mehmel, C., Mori, S., Webster, J., Erbilgin, N., and Wood, D. 2012. Area-wide application of verbenone-releasing flakes reduces mortality of whitebark pine, *Pinus albicaulis*, caused by the mountain pine beetle*, Dendroctonus ponderosae*. Agricultural and Forest Entomology. 1-9.

Background & Objectives

This study tested the efficacy of Disrupt Micro-Flake Verbenone Bark Beetle Anti-Aggregant flakes, by Hercon Environmental, Inc. Verbenone was applied at 370 g/ha at two locations. Beetle flight and control sites were also measured.

Main Findings

- Application of verbenone flakes significantly reduced the proportion of trees attacked by >50% and the number of beetles present at the sites by approximately 50%

Implications

- This study suggests that aerial application of verbenone may be a viable option for high-elevation pines
- Authors encourage the use of verbenone as part of a broad integrated pest management strategy that also includes removal of infested trees where possible.

26. Macfarlane, W., Logan, J., and Kern, W. 2012. In Press. An innovative aerial assessment of Greater Yellowstone Ecosystem mountain pine beetle-caused 4 whitebark pine mortality*, Dendroctonus ponderosae*. Ecological Applications.

- Further publication of data presented in the annotations 2011.

27. Arno, S. 2012. Nutcracker notes: Fall/Winter 2013. Issue Number 23.

- Issue includes articles on the following topics: grafting whitebark pine, limber pine in Rocky Mountain National Park, mapping whitebark at Crater Lake, whitebark restoration and the mining industry and many others.
- This newsletter is available to Whitebark Pine Ecosystem members online at: http://www.whitebarkfound.com/nutcrackerNotes.shtml