Recovery Plan for *Echinocactus horizonthalonius* var. *nicholii* (Nichol's turk's head cactus)
https://ecos.fws.gov/docs/recovery_plan/860414a.pdf

Original Approved: April 14, 1986
Original Prepared by: Clayton J. May, Pima Community College, Tucson, Arizona;
Thomas R. Van Devender, Arizona Sonora Desert Museum, Tucson, Arizona;
Thomas C. Gibson, University of Arizona, Tucson, Arizona;
Mary Butterwick, Bureau of Land Management, Phoenix, Arizona; and
Peggy Olwell, U.S. Fish and Wildlife Service, Albuquerque, New Mexico

DRAFT AMENDMENT 1

We have identified best available information that indicates the need to amend recovery criteria for *Echinocactus horizonthalonius* var. *nicholii* (Nichol's turk's head cactus) since the recovery plan was completed. In this proposed modification, we synthesize the adequacy of the existing recovery criteria, show amended recovery criteria, and the rationale supporting the proposed recovery plan modification. The proposed modification is shown as an addendum that supplements the recovery plan, superseding only the Summary (p. iii) and Part II (p. 16) of the recovery plan.

For
U.S. Fish and Wildlife Service
Southwest Region
Albuquerque, New Mexico

February 2019

BACKGROUND INFORMATION

Recovery plans should be consulted frequently, used to initiate recovery activities, and updated as needed. A review of the recovery plan and its implementation may show that the plan is out of date or its usefulness is limited, and therefore warrants modification. Keeping recovery plans current ensures that the species benefits through timely, partner-coordinated implementation based on the best available information. The need for, and extent of, plan modifications will vary considerably among plans. Maintaining a useful and current recovery plan depends on the scope and complexity of the initial plan, the structure of the document, and the involvement of stakeholders.

An amendment involves a substantial rewrite of a portion of a recovery plan that changes any of the statutory elements. The need for an amendment may be triggered when, among other possibilities: (1) the current recovery plan is out of compliance with regard to statutory requirements; (2) new information has been identified, such as population-level threats to the species or previously unknown life history traits, that necessitates new or refined recovery actions and/or criteria; or (3) the current recovery plan is not achieving its objectives. The amendment replaces only that specific portion of the recovery plan, supplementing the existing recovery plan, but not completely replacing it. An amendment may be most appropriate if

significant plan improvements are needed, but resources are too scarce to accomplish a full recovery plan revision in a short time.

Although it would be inappropriate for an amendment to include changes in the recovery program that contradict the approved recovery plan, it could incorporate study findings that enhance the scientific basis of the plan, or that reduce uncertainties as to the life history, threats, or species' response to management. An amendment could serve a critical function while awaiting a revised recovery plan by: (1) refining and/or prioritizing recovery actions that need to be emphasized, (2) refining recovery criteria, or (3) adding a species to a multispecies or ecosystem plan. An amendment can, therefore, efficiently balance resources spent on modifying a plan against those spent on managing implementation of ongoing recovery actions.

METHODOLOGY USED TO COMPLETE THE RECOVERY PLAN AMENDMENT

The recovery criteria were developed by conducting a comprehensive review of all documents pertaining to *Echinocactus horizonthalonius* var. *nicholii* (herein referred to as var. *nicholii*) on file at the Arizona Ecological Services Field Office. We summarized var. *nicholii* monitoring data collected from 1986 to 1999 on the Bureau of Land Management (BLM) and Tohono O'odham Nation (Schmazel and Francisco 2000) to estimate its abundance in Arizona at that time period, approximate life span, and generation time (e.g., the length of time when an adult produces an offspring). This information is described in the taxon's 5-Year Status Review (U.S. Fish and Wildlife Service [Service] 2009) with some refinement in reported numbers. In 2018, Service and BLM biologists conducted site visits to occupied areas on Federal land where a monitoring plot had been established but had not been evaluated since 1999 and to areas considered to have abundant plant numbers. We collected preliminary data (e.g., alive or dead, tissue color, height and diameter) to assess the current observed condition of the taxon and its habitat to help determine appropriate recovery needs for the taxon. The recovery criteria were designed to be objective and quantifiable, in order to meet the conditions needed to ensure species viability through sustaining populations in the wild that demonstrate resiliency, redundancy, and representation (Shaffer and Stein 2000). We plan to conduct peer review of this amendment concurrent with publication of a Notice of Availability for the draft amendment in the *Federal Register*.

ADEQUACY OF RECOVERY CRITERIA

Section 4(f)(1)(B)(ii) of the Endangered Species Act (Act) requires that each recovery plan shall incorporate, to the maximum extent practicable, "objective, measurable criteria which, when met, would result in a determination…that the species be removed from the list." Legal challenges to recovery plans (see Fund for Animals v. Babbitt, 903 F. Supp. 96 (D.D.C. 1995)) and a Government Accountability Audit (GAO 2006) have also affirmed the need to frame recovery criteria in terms of threats assessed under the five threat factors (Act 4(a)(1)).

Recovery Criteria

The final Recovery Plan includes one objective, measurable criterion to reclassify var. *nicholii* from endangered to threatened (Service 1986). It does not reflect the most up-to-date information on the taxon's biology, nor does it address all five delisting factors that are relevant to the taxon. When the Recovery Plan was finalized in 1986, there were limited data available to quantify the taxon's total population abundance or other biological and ecological requirements;

therefore criteria for delisting the taxon were not established (Service 1986). The existing downlisting criteria can be found on pages iii and 16 in the Recovery Plan and will remain unchanged.

Synthesis

Our understanding of var. *nicholii* has not changed substantially since completion of the 5-year Status Review (Service 2009), including existing knowledge gaps in biology and ecology. Most of what is known about var. *nicholii* in Arizona is described in Schmazel and Francisco (2000) which includes information collected from 1997 to 1999 at monitoring plots and transects on the Tohono O'odham Nation between 1988 and 1999 on the BLM. Below is a summary of new information that has become available since the 5-Year Status Review.

Several botanists question the taxonomic validity of var. *nicholii* suggesting that it is not distinct from the common var. *horizonthalonius* that grows in the Chihuahuan Desert (Service 2009, FNA 2004). However, Vargas et al (2018), in their study of the genetics of *Echinocactus*, concluded that there is molecular evidence to recognize *E. horizonthalonius* subsp. *nicholii* as a unique entity, separating it from subsp. *horizonathalonius* by 4 spines per areole rather than 1 to 2, and in having short cylindrical stems with curved spines and pink to crimson flowers, rather than depressed stems, straight spines, and light pink flowers of subsp. *horizonthalonius*.

In 2012, 83 *E. horizonthalonius* individuals were found near Mazatán and Nácori Grande in central Sonora (Van Devender and Reina-Guerrero 2012), which are approximately 380 km (236 miles) south-southeast from Waterman Mountain. They are believed to be var. *nicholii* and may possibly comprise a fifth population depending on a taxonomic analysis (Van Devender and Reina-Guerrero 2012).

In 2018, BLM, Service, and Department of Defense (DOD) biologists documented 62 individual var. *nicholii* on approximately 40 acres of DOD land adjacent to Ironwood Forest National Monument (IFNM). Their occurrence is believed to have been known and recorded by DOD just recently. The plants appear to be a continuation of those growing on a northeast bajada of the main Waterman range, but are separated by a utility right-of-way and unpaved road.

<u>2018 Waterman Mountain Site-Visits</u>

In the spring and summer of 2018, BLM and Service biologists visited six var. *nicholii* areas on the Waterman Mountains to compare the taxon's status to assessments from the 1980s and 1990s. Our efforts were not exhaustive and we did not record the location of every var. *nicholii* observed, nor did we attempt to relocate plants that had been documented on state trust land given restricted access. In total, we found 781 individual var. *nicholii,* consisting of 541 live and 240 dead plants. This included 66 total plants on DOD land and 715 total plants on BLM land. Eighty-eight of total plants found were equal or less than 7.5 cm (3 in) tall and considered a seedling or immature plant. Forty-six of the total plants had tissue discoloration such as half black and half red, purple, orange, white or gray; all red, yellow, or orange; or were partially uprooted. These appeared to be dying and may not survive through next spring. Surrounding native cactus species such as *Opuntia* sp., and trees also appeared to be dying or drought stressed (K. Robertson, pers. observation 2018).

In BLM's North and South Waterman Mountain plots, Service and BLM biologists relocated and recorded all tagged and untagged var. *nicholii* and compared our findings to past monitoring data (Schmazel and Francisco 2000) (Table 1). In the North Plot, we found 166 total tagged and untagged individuals consisting of 115 live and 51 dead plants. Most of the tags from 1987 and 1988 were found except for 12 tags. In some cases, we believe the tagged plants found in 2018 were the same original plants tagged and recorded from the late 1980s. For example, plant number 20 was 2 cm tall in 1988 and is 20 cm in 2018. Plant 58 was 7 cm tall in 1988 and is now 28 cm tall in 2018. In other cases, if a small sized plant (less than 15 cm) or seedling was growing next to a tag, it was assumed that the original adult plant had died. In the South plot, we relocated 148 tagged and untagged individuals consisting of 63 live and 101 dead plants. Of the detected var. *nicholii* mortalities, 32 tags were piled together outside of the plot and plants were assumed dead,16 tagged plants were previously reported as dead from 1994 to 1998, and 53 plants, some tagged, had died after 1999. An additional 25 tags and associated plant could not be relocated. Observations of dead plants included collapsed and uprooted plants, spine baskets lacking tissue, partial remains of a plant, or a tag with plant missing. Although it is too difficult to assess a trend based on a single-year visit, we believe plant numbers are generally down in the Waterman Mountain population and drought is likely is a contributing factor.

Table 1. Variety *nicholii* census and status comparison (1987 to 2018), North and South Waterman Mountain Area of Critical Environmental Concern monitoring plots, Arizona[1]

North Plot	**1988**	**1989**	**1990**	**1991**	**1994**	**1997**	**1998**	**1999**	**2018**
Alive Plants	103	105	101	---	---	102	109	115	115
Dead Plants	0	7	6	---	---	16	2	4	51
South Plot	**1987**	**1989**	**1990**	**1991**	**1994**	**1997**	**1998**	**1999**	**2018**
Alive Plants	114	123	133	131	119	120	124	121	63
Dead Plants	0	4	3	2	9	22	7	4	85

[1]Source: (Schmazel and Francisco 2000, Arizona Game and Fish Department 2018).
[2]Data for years 1997, 1998, and 1999 were collected two or more times and the average is reported.

Sufficient information describing long-term var. *nicholii* population trends is not available. McIntosh et al. (2007) continues to monitor the taxon's status in four plots on the Waterman Mountains. The plots of 129 plants were established in 1995 (Service 2009). Plant numbers fluctuated between 1995 and 2001 with an average of 126 individuals during that period. After 2003, plant numbers declined and by 2009, were down to 68 individuals. As of 2017, 31 tagged plants remain (Nichol's Turk's Head Cactus Working Group 2018). Of concern is that the habitat on Waterman Mountains was considered to support the largest and most dense patch of plants. The Service visited the south-facing slopes and south-east ridge in June 2018 to ground-truth the area for var. *nicholii*. The search was not extensive due to the steep, loose rocky terrain and surface reflectivity from limestone. We located 70 plants within a three acre area; 44 were alive and 28 were dead. Plants on the Tohono O'odham Nation were last visited in 1999 due to access restrictions. The habitat between the Waterman Mountains and the Tohono O'odham Nation is homogenous and therefore, we assume plants on Vekol Mountain slopes and possibly Koht Kohl Hill likely have also declined since 1999.

Threats

The final Recovery Plan and 5-Year Status Review identify a variety of threats to var. *nicholii*. In the Recovery Plan, threats were listed as mining, off-road vehicle use (OHV), urban development, and over-collection. The 5-year Status Review listed the threats as: 1) mining on State Trust and private lands on IFNM and on the Tohono O'odham; 2) habitat disturbance from illegal immigration, drug smuggling, and law enforcement activities; 3) spread of invasive plant species such as buffelgrass (*Pennisetum ciliare*) and the resultant competition for resources and increased fire frequency; 4) herbivore depredation; and 5) climate change (Service 2009).

Many of the threats to the Waterman Mountains population are no longer considered to be impacting the taxon. As of 2018, the BLM has completed most of the recovery actions from the 1986 Recovery Plan. The establishment of IFNM with the signing of the Presidential Proclamation, permanently protects natural resources within the 2,240 acres encompassing var. *nicholii's* habitat. In accordance with the proclamation, IFNM is withdrawn from all forms of mineral extraction and recreational off-road vehicles (Service 2009, BLM 2011, 2013). In implementing recovery actions, BLM has acquired 368 acres out of 550 acres of patented land held by a private owner within occupied habitat and continues to pursue acquisition of remaining private acreages (BLM 2011; D. Tersey BLM, pers. comm 2018). There has been no observed or documented evidence of illegal collection of var. nicholii on or around Waterman Mountains.

Moderate levels of livestock grazing continues throughout var. *nicholii's* habitat and is not considered a threat (Service 1986). Cattle may congregate under large trees for shade in dense patches of var. *nicholii* and disturb the habitat but there is little observed or documented evidence of cows stepping on plants to consider grazing a threat (Service 1986, K. Robertson, pers. observation 2018). The grazing allotment (Agua Dulce Allotment) is managed to promote the conservation of var. *nicholii* (Service 2012). Livestock waters are currently located next to existing roads but those that are causing habitat impacts will be moved or replaced; and future water developments will be placed in locations to move cattle outside of occupied areas (BLM 2013, Service 2012). However, impacts from livestock grazing and bighorn sheep have not been examined but should be considered for a thorough threat assessment.

Habitat disturbance associated with cross-border activity has been reduced in the Waterman Mountains and there are currently no documented impacts to var. *nicholii's* habitat from abandoned vehicles, trash, or driving off-road. Buffelgrass had infested an 18 acre area on the north side of Waterman Mountains. One of the infested areas occurred near hundreds of variety *nicholii* individuals. The Friends of Ironwood created a "Save the Watermans" campaign and, through a large volunteer-led effort, successfully eradicated buffelgrass near the taxon's habitat. Based on this incredible volunteer effort, this population of variety *nicholii* is no longer considered at risk from fire in the Waterman Mountains (Scheuring pers. comm. 2013).

Climate change is considered a threat to var. *nicholii* due to effects from hotter temperatures and increased aridity (Service 2009). Climate change has resulted in some species shifting their range to higher elevation or higher latitude (Hannah et al. 2005, Chen et al. 2011) but for southwestern plants, scientists are finding migration may occur in all directions depending on the species' ability to adapt and available, connected habitat (Stills et al. 2015, Krause and Pennington 2012, Notaro et al. 2012). Variety *nicholii* grows on mountain slopes that could

presumably support more plants in the future if they remain cooler and soils retain more moisture than those on the valley floor. But, alternatively, as temperatures and aridity increase these exposed areas may become hotter, drier and ultimately unsuitable in the future. With the limiting presence of Horquilla limestone on a few mountain ranges, changes in the suitability and amount of available habitat for the taxon could cause dramatic reductions in its range.

AMENDED RECOVERY CRITERIA

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the species is no longer at risk of extinction and may be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants (Lists). Downlisting is the reclassification of a species from an endangered species to a threatened species. The term "endangered species" means any species (species, sub-species, or DPS) which is in danger of extinction throughout all or a significant portion of its range. The term "threatened species" means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Revisions to the Lists, including delisting or downlisting a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered species or threatened species (or not) because of threats to the species. Section 4(b) of the Act requires that the determination be made "solely on the basis of the best scientific and commercial data available." Thus, while recovery plans provide important guidance to the Service, States, and other partners on methods of minimizing threats to listed species and measurable objectives against which to measure progress towards recovery, they are guidance and not regulatory documents.

Recovery criteria should help indicate when we would anticipate that an analysis of the species' status under section 4(a)(1) would result in a determination that the species is no longer an endangered species or threatened species. A decision to revise the status of or remove a species from the Federal Lists of Endangered and Threatened Wildlife and Plants, however, is ultimately based on an analysis of the best scientific and commercial data then available, regardless of whether that information differs from the recovery plan, which triggers rulemaking. When changing the status of a species, we first propose the action in the *Federal Register* to seek public comment and peer review, followed by a final decision announced in the *Federal Register*.

We establish recovery criteria for *Echinocactus horizonthalonius* var. *nicholii*, which will supplement those included in the Nichol Turk's Head Cactus Recovery Plan as follows:

Downlisting Recovery Criteria

Downlisting criteria will remain the same as in the Recovery Plan for Nichol turk's head cactus (Service 1986, p. iii and p. 16).

Delisting Recovery Criteria

Echinocactus horizonthalonius var. *nicholii* will be considered for delisting when the following conditions are met:

1. Conserve and protect all existing var. *nicholii* individuals in the three or more extant populations through land protection, land management actions, and restoration techniques (i.e., population augmentation). Each var. *nicholii* population must have available habitat of sufficient quality and size for natural population dynamics and expansion, and habitat for pollinators, allowing pollen exchange within, and if possible, between populations (approximately a 600 meter radius around each plant). Sufficient var. *nicholii* habitat is defined as areas that contain the appropriate geology, elevation, soil type, Sonoran Desert native plants and trees, and pollinators, with minimal ground disturbance and limited non-native invasive grass species.

   Justification: Variety *nicholii* occurs in a small number of populations making it essential to conserve and protect at minimum the three extant populations in Arizona for redundancy against catastrophic events (e.g., wildfire). As a means to quantify how much habitat around each plant or population to conserve and protect, we chose to use the maximum foraging distance of the cactus bee (*Diadasia rinconis*), a solitary cactus bee that has been observed visiting flowers of a var. *nicholii* and other cactus species. The 600 meters would protect habitat for the cactus needed for germination, pollinator habitat, connectivity, and gene exchange with other plants. As more information becomes available in the future, we would assess if the distance should be revised or replaced with another appropriate measure. As an endemic taxon with a narrow geographic distribution, the persistence of these populations also maintains the taxon's representation in most of its range. Due to past var. *nicholii* monitoring efforts and its natural history, a stable or increasing population trend over a 30-year period will help to identify its resilience and recovery against environmental stochasticity or climatic events.

2. Each var. *nicholii* population must be self-sustaining, with annual recruitment exceeding mortality over any 20 years of a 30-year period. Long-term monitoring every 3–5 years demonstrates that the annual total estimated population size among three or more extant populations is maintained at or greater than 3,700 individuals for a minimum of 20 years over a 30-year survey period. Threats must be managed so that populations can be maintained at target levels (a minimum of 3,700 total individuals) for a minimum of 20 years over the 30-year period. At year 30, the number of individual var. *nicholii* in three or more extant populations must be greater or equal to 3,700 individuals. Expected yearly fluctuations in plant abundance due to changes in precipitation, fire, or other causes, may result in one monitoring event during the time period that does not meet these targets.

   Justification: Variety *nicholii* are long-lived, with an estimated life span of 30 years or longer. Monitoring data indicates plants become reproductive after 10 years of age and mature plants produce offspring over the subsequent 10-20 years. Therefore, 30 years captures several generation times and allows for the detection of demographic trends, as plants respond to annual and decadal climate variability in temperature, precipitation, and the El Niño Southern Oscillation patterns that are compounded by extreme events (e.g., a severe long term drought or a wildfire). Because we've determined since the 1980's an Arizona-wide 3,700 plant estimate, a stable or increasing trend of this size for an additional 30 years would demonstrate the plants persistence under changing environmental conditions

(representation), and that threats are managed or ameliorated. The time period needed for recovery may be revised as more demographic trend information is obtained.

3. Develop a long-term ex-situ (off-site) var. *nicholii* conservation program that includes captive propagation, germination trials, guidelines for supplementing natural populations, and post-introduction monitoring that demonstrates the introduced cacti are fully functioning in their environment, including flowering, seed production, and survival.

   Justification: Climate change (hotter temperatures and reduced precipitation) has been documented affecting the Waterman Mountains var. *nicholii* population and likely other populations. Predicted climate change will likely alter habitat suitability and potentially result in var. *nicholii* shifting its distribution. An off-site conservation program will allow for viable seeds and plant material to be available for future reintroductions and ensure the survival and persistence of var. *nicholii* in the future.

Rationale for Amended Recovery Criteria

The viability of a species to sustain populations over time can be assessed in terms of the 3R's: resilience, representation, and redundancy (Shaffer and Stein 2000). In general, the greater the resiliency, representation, and redundancy of species, the more protected it is from stochastic events, the better it can tolerate stressors, and better its adaptive capacity is to future changes, and thus more viable it is.

Representation is the ability of a species to adapt to changing environmental conditions over time as characterized by the breadth of genetic and environmental diversity within and among populations. Resiliency is the assurance that each population is sufficiently large to withstand most stochastic disturbance events, which usually is directly related to size of the habitat it occupies. Redundancy involves ensuring a sufficient number of populations to provide a margin of safety for the species to withstand catastrophic events. The amended criteria address resiliency, representation, and redundancy by reducing demographic threats such as climate change to var. *nicholii*.

Representation

Representation is met by conserving and protecting the existing geographic distribution of var. *nicholii* throughout its narrow range. Considering the Waterman Mountains population has been documented since the late 1980s and continues to be present in known occupied areas after 30 years, it suggests that the taxon is able to adapt to environmental conditions over time. Although, we have no genetic information describing diversity within and among populations, we assume that individual var. *nicholii* occurring within these areas have genetic variability to enable them to adapt and thus persist. However, gene flow may not exist between populations. Therefore, maintaining a continuity of potential suitable habitat throughout the taxon's range is a conservation priority. We recognize the need and recommend genetic studies are conducted among and between populations. Long-term demographic monitoring would detect population trends and determine population dynamics over the next 30-year period.

Resiliency
Resiliency is met but having enough individuals among all populations to withstand demographic stochasticity (random fluctuations in germination rates), environmental stochasticity (variation in the amount and timing of rainfall), or human-caused effects. We do not have sufficient information on the current number of individual var. *nicholii* within each population that is required to achieve population resiliency. Greater resiliency will enable the species to better withstand the effects of climate change and other threats that may be acting on populations outside of federal lands. Based on the best available data, var. *nicholii* can achieve resiliency by meeting the target threshold (3,700 individuals among three or more populations) for the time period indicated in criteria 2. As more information becomes available, we will revisit the target number.

Redundancy
Redundancy is met by conserving and protecting all existing populations that are broadly distributed over the taxon's range. Because the taxon occurs in few populations, additional populations or supplementing populations may be may be established if unoccupied areas become suitable in the future.

The 1986 Recovery Plan noted that a complete census of var. *nicholii* within its habitat was necessary before quantitative information for delisting could be achieved. In the intervening 32 years, very little information has been gained on species life history, distribution, abundance, and threats, as described in the Synthesis section above. The new quantitative delisting criteria are measurable, and objective and tier from the downlisting criterion by ensuring long-term protection of the var. *nicholii* and its habitat and thus viability. Incorporation of the amended criteria will improve the taxon's resiliency, redundancy, and representation.

ADDITIONAL SITE SPECIFIC RECOVERY ACTIONS
Not applicable.

COSTS, TIMING, PRIORITY OF ADDITIONAL RECOVERY ACTIONS
Not applicable.

LITERATURE CITED

Arizona Game and Fish Department. 2018. *Echinocactus horizonthalonius* var. *nicholii*. Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. pp.1-26.

Bowers, J. 2005. Effects of drought on shrub survival and longevity in the northern Sonoran Desert. Journal of Torrey Botanical Society:132(3). pp. 421-431.

Bureau of Land Management (BLM). 2013. Approved Ironwood Forest National Monument Resource Management Plan and Record of Decision. Tucson Field Office, Tucson, Arizona. Signed February 19, 2013.

Bureau of Land Management (BLM). 2011. Proposed Ironwood Forest National Monument Resource Management Plan and Final Environmental Impact Statement. Tucson Field Office, Tucson, Arizona. Signed September 2011.

Chen, I-C., J. K. Hill, R. Ohlemüller, D. B. Roy, and C. D. Thomas. 2011. Rapid range shifts of species associated with high levels of climate warming. Science 333, 1024 (2011). doi:10.1126/science.1206432

Dimmitt, M.A., and T.R. Van Devender. 2003. Biological Survey of Ironwood Forest National Monument. Prepared for Bureau of Land Management; Tucson Field Office, Arizona Sonora Desert Museum, Tucson, Arizona.

Diario Oficial de la Federación (DOF). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Secretaría de Medio Ambiente y Recursos Naturales. México, D.F. Marzo 6, 2002.

Hannah, L. T.E. Lovejoy, and S.H. Schneider. 2005. Biodiversity and climate change in context. In: T.E. Lovejoy and L. Hannah, editor. Climate Change and Biodiversity.Yale University Press. New Haven, CT. pp. 3-14.

Krause, C. and D. Pennington. 2012. Strategic decisions in conservation: using species distribution modeling to match ecological requirements to available habitat. pp. 131-154 *In:* J. Maschinski and K.E. Haskins. Plant reintroduction in a changing climate, promises and perils. Island Press. Washington, D.C.

McIntosh, M.E., L.A. McDade, A.E. Boyd, and P.D. Jenkins. 2007. Patterns of growth and mortality in the endangered Nichol's Turk's head cactus (*Echinocactus horizonthalonius* var. *nicholii* L. Benson; Cactaceae) in southeastern Arizona *In*: Barlow-Irick, P.; Anderson, J.; McDonald, C., tech eds. Southwestern rare and endangered plants: Proceedings of the Fourth Conference; March 22-26, 2004; Las Cruces, New Mexico. Proceedings. RMRS-P-48CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. pp. 77-82.

Nichol's Turk's Head Cactus Working Group. 2018. Nichol's turk's head cactus, *Echinocactus horizonthalonius* var. *nicholii* - Data Repository. The University of Arizona Herbarium, Tucson, AZ. Accessed from: https://cals.arizona.edu/herbarium/content/nichols-turks-head-cactus-working-group.

Scheuring, J. 2013. The Waterman Restoration Project. Press Release. Provided to Arizona Ecological Services Office by email.

Schmalzel R.J. and J. Francisco, June 2000. Distribution of Nichol's Turk's head cactus (*Echinocactus horizonthalonius* var. *nicholii*) Populations on the Tohono O'odham Nation and Waterman Mountains (Pinal and Pima Counties, Arizona) and a Singe year

demographic study of each population. Service files, unpublished. Arizona Ecological Services Office, Phoenix, Arizona.

Shaffer ML, Stein MA. Safeguarding our precious heritage. In: Stein BA, Kutner LS, Adams JS, editors. Precious heritage: the status of biodiversity in the United States. New York: Oxford University Press; 2000. pp. 301-321.

Still, S.M., A.L. Frances, A.C. Treher, and L. Oliver. 2015. Using two climate change vulnerability assessment methods to prioritize and manage rare plants: a case study. Natural Areas Journal, 35(1): 106-121.

Vargas-Luna MD, Hernández-Ledesma P, Majure LC, Puente-Martínez R, Macías HMH, Luna RTB (2018) Splitting *Echinocactus*: morphological and molecular evidence support the recognition of *Homalocephala* as a distinct genus in the Cacteae. PhytoKeys 111: 31–59. https://doi.org/10.3897/phytokeys.111.26856

U.S. Fish and Wildlife Service (Service). 1986. Recovery Plan for the Nichol's Turk's Head Cactus (*Echinocactus horizonthalonius* Lemaire, var. *nicholii* L. Benson). Southwest Region, Albuquerque, NM. pp 1-74.

U.S. Fish and Wildlife Service (Service). 2009. 5-year Review: summary and evaluation for the Nichol's Turk's Head Cactus (*Echinocactus horizonthalonius* var. *nicholii*). Arizona Ecological Services Office, Phoenix, AZ. pp 1-30.

U.S. Fish and Wildlife Service (Service). 2012. Final Biological Opinion and Conference Report for Ironwood Forest National Monument (IFNM) Resource Management Plan (02EAAZ00-2012-F-0257). Arizona Ecological Services Office, Tucson, AZ. Available online at: https://www.fws.gov/southwest/es/arizona/.

Wiens, J.F., T.R. Van Devender, and M.A. Dimmitt. 2015. Vegetation and vascular flora of Ironwood Forest National Monument, Pima and Pinal Counties, Arizona. Desert Plants (30)2:71 pp. The University of Arizona for the Boyce Thompson Arboretum, Tucson, AZ.

Zimmerman, A.D. and B.D. Parfitt. 2004. *Echinocactus horizonthalonius*. In: Flora of North America Editorial Committee, eds. 1993+. Flora of North America North of Mexico. 20+ vols. New York and Oxford. Vol. 4, pp. 186-189.