# Tumacácori National Historical Park International Dark-Sky Park Designation Nomination Package



©ARC Photography

Tumacácori National Historical Park Tumacácori, Arizona

### Acknowledgements

The cover photo for this nomination package is courtesy of Anu Condon, owner of ARC Photography. This picture of Tumacácori's mission church was taken during the "Starry Night and Photography Workshop" held at Tumacácori National Historical Park on December 12, 2014.

Tumacácori would like to thank all whom have supported the park through this nomination process including all of the Tumacácori Historical National Park staff and volunteers, park visitors, supporting organizations, and our friends at the International Dark-Sky Association.

Specifically, we would like to thank International Dark-Sky Association's Program Manager, Dr. John C. Barentine, for his commitment to stand by Tumacácori as an application supervisor. John provided timely feedback, exceptional advice, and excellent support throughout the entire application process.

We would also like to thank Dr. Constance E. Walker, National Optical Astronomy Observatory scientist, President of Astronomical Society of Pacific, Vice President of IAU Commission C.B7, director of Globe at Night, and member of IDA Board of Directors, for her reliable assistance in providing Tumacácori with an Unihedron SQM-L model Sky Quality Meter, which was an essential tool needed to record Dark-Sky measurements throughout this process. Without a meter, we wouldn't have been able to provide the necessary data needed for this nomination package.

Lastly, we would like to thank the Santa Cruz County community and all organizations in the area who have expressed their support throughout this process. It is up to the community to continue to support the reduction of light pollution and stress the importance of dark skies.

## Contents

Acknowledgements	2
Tumacácori National Historical Park	4
Dark-Sky Summary	4
Nomination Letter	5
Letter of Support	6
Description of Tumacácori NHP	16
Location and Description of Park	16
Map of Tumacácori unit	17
Significance of Park Resources	19
Weather, Climate, and Visibility	20
Isolation from Light Pollution	21
Tumacácori Night Sky Resources	26
Sky Quality Data	26
Events and Outreach	32
Dark-Sky Restoration Project	41
Park Lighting Inventory	45
Management Documents	55
NPS Management Policies Supporting Dark Skies	55
Tumacácori National Historical Park Lightscape Management Plan	56
Future Plans	63
Long Term Monitoring	63
Contributors	64

### Tumacácori National Historical Park Dark-Sky Summary

Tumacácori National Historical Park located in the mesquite highlands of southern Arizona is known for the preservation of early Spanish colonial mission ruins. However, Tumacácori NHP strives to protect not only its cultural resources, but its natural resources as well. This culturally enriched area reflects the desired criteria for designation as a Bronze-tier Dark-Sky Park recognized by the International Dark-Sky Association (Figure 7). Tumacácori NHP has the ability to join fellow designated Dark-Sky Parks in serving as a role model in the conservation of night skies. It also has the ability to expand and cement the culture of night sky protection in the southern Arizona region. Tumacácori NHP is eager to become an environmental leader on dark-sky issues by communicating the importance of dark skies to its surrounding community.

### **Nomination Letter**



January 9, 2018

International Dark-Sky Association Board of Directors 3223 North First Avenue Tucson, Arizona 85719-2103

Dear IDA Board of Directors,

As a Lifetime Member of the International Dark-Sky Association (IDA) and the Southern Arizona IDA Chapter Leader, it gives me great pleasure to nominate the Tumacacori National Historical Park (NHP) to be designated an International Dark-Sky Park by the IDA. The Park is located in Southern Arizona.

Our Southern Arizona IDA Chapter has been working for over twenty years to carry out the IDA mission focusing on education of citizens to help them understand the importance of protecting and restoring our night skies. We cover the Greater Tucson area all the way south to Nogales, Arizona, Tumacacori NHP is right in the middle of this area. Having them designated an International Dark Sky Park, in conjunction with their ongoing educational outreach activities, would be a huge asset for all of us to help carry out the IDA mission.

If approved, our Chapter is available to assist Tumacacori NHP as necessary to be sure the Dark Sky Park status is maintained. Thank you for your consideration to include this very significant and important National Landmark.

Sincerely,

& grama

Joe Frannea Chapter Leader (520) 575-7126

joef@sa-ida.org www.sa-ida.org

## Letter of Support



## **United States Department of the Interior**

NATIONAL PARK SERVICE Tumacácori National Historical Park Post Office Box 8067 1891 East Frontage Road Tumacácori, AZ 85640



January 12, 2018

IDA Board of Directors International Dark-Sky Association 3223 North First Avenue Tucson, AZ 85719

Dear IDA Board Members:

As the Superintendent of Tumacácori National Historical Park, I strongly support this nomination for International Dark Sky Park designation. Located in a rural southern Arizona, in an area famous for its clear, dark nights, the Park enjoys spectacularly beautiful night skies. This treasured resource contributes significantly to the rich cultural landscape that is preserved at Tumacácori.

Unspoiled night landscapes have natural, cultural and scenic importance, and by policy the NPS is charged with the protection of natural darkness. Tumacácori has been providing public interpretation programs involving night skies for many years, but has expanded our offerings this year with the support of the Tucson Amateur Astronomy Association and the Sonoran Astronomical Society. These programs have been a popular additions, and have greatly enhanced our education offerings.

We are fortunate to be in a region where dark skies are valued and celebrated. Our nomination has broad support as indicated by the attached letters from the Fred Lawrence Whipple Observatory, Tucson Amateur Astronomy Association, Bat Researcher Karen Krebbs, Tubac Presidio State Historic Park, Anza Trail Coalition, Friends of the Santa Cruz River, Vatican Observatory, and Patagonia Area Resource Alliance.

We appreciate your consideration of Tumacácori's designation as a Dark Sky Park.

Sincerely, PW. Jone

Robert Love Park Superintendent

Smithsonian Astrophysical Observatory

Fred Lawrence Whipple Observatory

**Pascal Fortin** 

670 Mount Hopkins Road Amado, AZ 85645 (520) 879-4419 pafortin@cfa.harvard.edu

January 3, 2018

Board of Directors International Dark-Sky Association 3223 North First Avenue Tucson, AZ 85719-2103

Dear International Dark-Sky Association Board of Directors.

On behalf of the Smithsonian Astrophysical Observatory, I am pleased to provide my support to the Tumacacori National Historical Park's (NHP) application for designation as an International Dark Sky Park.

The Fred Lawrence Whipple Observatory is located less than 15 miles from the Tumacacori NHP. The observatory is home to the MMT – one of the largest telescopes in the world, VERITAS – the only gamma-ray telescope in the US, as well as MINERVA, MEarth, HATS, and the 48" and 60" telescopes.

Preservation of the night skies is critical to the mission of the observatory and the Tumacacori NHP has the ability to join fellow designated Dark-Sky Parks in serving as a role model in the conservation of night skies.

I fully endorse the Tumacacori NHP's nomination for IDA Dark Sky Park status.

Respectfully,

Epal D

Pascal Fortin Site Director

670 Mount Hopkins Road Amado AZ 85645-6369 U S A 520.879.4400 Telephone



## **Tucson Amateur Astronomy Association**

January 5, 2018

International Dark-Sky Association 3223 N 1<sup>st</sup> Ave Tucson, AZ 85719-2103

Dear IDA Board of Directors,

The Tucson Amateur Astronomy Association (TAAA) fully supports the Tumacácori National Historic Park (NHP) application for an International Dark-Sky Park designation. TAAA has supported Tumacácori NHP with public star parties in the past and will continue to support them into the future. Tumacácori's location and leadership is ideal to facilitate the expansion of this extremely important environmental program for future generations. Tumacácori's skies, with limited light pollution, provide exceptional dark-sky public observing opportunities.

Their designation as an International Dark Sky Park would attract additional visitors and enhance their ability to educate the public in night-sky awareness and proper night-sky friendly lighting. We encourage the International Dark-Sky Association to favorably process Tumacácori's request to become an International Dark-Sky Park.

Please let me know if you have any questions. Thank you.

Sincerely,

Bonger Bing

Benjamin Bailey President Tucson Amateur Astronomy Association

P.O. Box 41254, Tucson, AZ 85717 (520) 792-6414 • http://www.tucsonastronomy.org January 5, 2018

Board of Directors International Dark-Sky Association 3223 North First Avenue Tucson, AZ 85719-2103

Dear Board Members,

I would like to submit this letter of recommendation on behave of Tumacácori National Historical Park (TUMA) as a Dark-Sky Park.

I am a Conservation Biologist that has worked on bird and bat research in Arizona and Mexico for the past 35 years. My research at TUMA has included both bat and bird research for six years. During the bat fieldwork at TUMA, nine species of bats have been captured. Insectivorous and nectar bats are nocturnal and prefer dark environments to navigate and forage. Fewer bats are captured on evenings when the moon is the brightest because of predation. Most light is detrimental to the survival of bats and they usually avoid it. When I am asked how to discourage bats from roosting on porches at night, I respond by saying a light will usually discourage the bats. Excessive light at TUMA will discourage bats from roosting or foraging in the park. Darkness is advantageous to the survival and health of the bat species at TUMA.

In our modern and technical world dark skies are difficult to find. Arizona's night viewing skies are unique due to the wilderness areas and the darkness. These rare characteristics make this area special. Tumacácori National Historical Park would be an excellent candidate as a Dark-Sky Park and I hope that you give this special park consideration for this honor. I fully support TUMA for this designation.

Sincerely, Karey Kre

Karen Krebbs Conservation Biologist



1 Burruel St, Box 4162 Tubac, AZ 85646 520.398.2252 Fax 520.398.2685 www.tubacpresidio.org

IDA Board of Directors 3223 N. First Avenue Tucson, AZ 85719 Phone: (520) 293-3192 Fax: (520) 293-3192

IDA Board of Directors and Application Review Committee,

I would like to formally submit this letter of recommendation of Tumacacori National Park on behalf of the Tubac Presidio State Historic Park.

As the new Park Director of the Tubac Presidio I have spent the past six months learning about the importance of reducing light pollution thanks to the Tumacacori National Park. The Tubac Presidio stands behind Tumacacori in their request to become a Dark Sky Park.

Having worked with the SCA at Tumacacori National Park, Courtney Giebink, during this process I can state that the Tumacacori National Park is fully capable of managing their dark skies and recognizing it as one of our most precious resources. During this process, I have witnessed the community's support for aiding the park in both treasuring and protecting the dark skies that draw thousands of visitors to Tumacacori every year. It is our goal to see Tumacacori National Park finish their nomination to become Dark Sky Designated Parks. Receiving this designation, would allow Tumacacori to serve as a role model in protection of the night sky in southern Arizona by adhering to dark sky lighting regulations. Tumacacori would also be able to communicate to the surrounding community the importance of dark skies and good lighting, for it affects human health and safety, energy usage, and the disruption of the environment, wildlife, and ecosystems.

Sincerely,

Shannon Stone Park Director Tubac Presidio State Historic Park



Anza Trail Coalition of Arizona, Inc POB 4711, Tubac, Arizona 85646 520-841-6944

January 11, 2018

Board of Directors International Dark Sky Association 3223 North First Avenue Tucson, AZ 85719-2103

Dear Directors,

On behalf of the Anza Trail Coalition of Arizona, a group that works to acquire easements, maintain, and interpret the Juan Bautista de Anza National Historic Trail here in southern Arizona, I would like to express our support of the Tumacácori National Historical Park's efforts to become a Dark Skies designated park.

The Anza Trail draws visitors from all over the region, the country, and the world. Many of them come to this area specifically to see the unique birdlife that lives in or migrates through the Santa Cruz Valley. These visitors and the money they spend while visiting are an important source of revenue to Santa Cruz County.

Light pollution has been shown to adversely impact wildlife, especially birds, along the river corridor. As well, it is a largely avoidable source of carbon pollution. The Tumacácori National Historical Parks ability to both model good stewardship of our environment and educate the public about the impacts of light pollution make them an ideal candidate for inclusion as a Dark Skies Designated Park.

Sincerely,

Kurl

Karol Stubbs, President Anza Trail Coalition of Arizona



January 6, 2018

Board of Directors International Dark-Sky Association 3223 North First Avenue Tucson, AZ 85719-2103

To the Board:

Friends of the Santa Cruz River (FOSCR) supports Tumacacori National Park's proposal to become a Dark Sky Designated Park. Receiving this designation would allow Tumacacori to serve as a role model in protection of the night sky in southern Arizona by adhering to dark sky lighting regulations. Tumacacori would also be able to communicate to the surrounding community the importance of dark skies through a park brochure and programs.

As a volunteer community group dedicated to protecting the critical, bountiful riparian habitat of the Santa Cruz River—which flows through the Park and is the reason waves of settlement occurred on the Tumacacori site—FOSCR strongly encourages you to confer this designation to the Park. It will help protect our diverse wildlife from being stressed by light pollution. And it will help preserve an increasingly rare feature of our region: our gorgeous night skies.

Sincerely, Alm

Sherry Sass President, FOSCR

PO Box 4275, Tubac AZ 85646

www.foscraz.org

foscriver@gmail.com

12

December 29, 2017

Dark Sky Places Committee International Dark-Sky Association

Dear Members of the DSP Committee,

The Vatican Observatory gives its wholehearted support to the application of Tumacácori National Historical Park to become a Dark Sky Place.

Our observatory staff have frequently experienced this Park's commitment to preserving both the cultural inheritance and natural resources of this region of the Sonoran Desert. These two aspects have particular resonance for us since the Tumacácori Mission and its two nearby Missions were founded by the Jesuit, Father Eusebio Kino, who was both missioner and scientist, with a particular expertise in astronomy. Culture and nature came together in Father Kino, as they do in our own work.

The designation of Tumacácori NHP as a DSP will be of very considerable help to its staff and associates both in attracting visitors to enjoy their dark night skies and to educate all their visitors in how they too can join in preserving our common dark sky inheritance. Of great scientific importance, also, will be the help given to keeping skies dark for the Smithsonian's telescopes on nearby Mount Hopkins.

We thank the Committee for your own dedication to fostering dark skies, and we look forward to the designation of Tumacácori NSP as a DSP.

Yours sincerely,

Br. Guy J. Consolmagno, S.J. Director, Vatican Observatory President, Vatican Observatory Foundation

2017 E. Lee Street, Tucson, Arizona 85719



## Kino Heritage Society

Honoring the Life and Legacy of Padre Eusebio Francisco Kino

Dark Sky Parks Committee International Dark-Sky Association 3223 North First Avenue Tucson, Arizona 85719 January 11, 2018

RE: Tumacácori National Historical Park Dark Sky Park Designation

Dear Committee Members:

The Kino Heritage Society strongly supports the designation of Tumacácori National Historical Park (Tumacácori Park) as a Dark Sky Park.

The Kino Heritage Society promotes the history and legacy of Eusebio Francisco Kino, S.J. Padre Kino (1645-1711) was one of the greatest Jesuit missionaries of the New World. He lived his last 30 years in the northern Spanish colonial borderlands where he worked with the indigenous peoples of the Sonoran Desert and defended them from settlers who wanted to steal their lands and enslave them.

Padre Kino was the first European to visit the Sobaípuri O'odham community near today's Tumacácori Park and established its mission in 1691. He is considered to be Arizona's pioneer European founder and Arizona's first European astronomer.

For many years the Tumacácori Park has promoted the preservation of the natural state of the night skies through its many public programs and through its environmentally sensitive electric lighting of the Park. The Tumacácori Park's designation will be a model to its neighbors and to other national and state historical parks and its recognition will further advance dark sky values.

Importantly, the Tumacácori Park's designation will help preserve a three century old tradition that continues to unite people of today's neighboring international border states of Arizona and Sonora. After Padre Kino's death, the O'odham people began an annual Fall pilgrimage to honor Padre Kino at his grave in Magdalena, Sonora. Because of the heat of day and inability to carry sufficient water, the pilgrims still walk mostly at night and early morning. In the evening, the Milky Way is seen overhead - aligned north south at its brightest and widest on the southern horizon - guiding the O'odham people and other pilgrims. Thank you for your consideration.

Sincerely. Mark DI Have

Mark O'Hare Secretary / Treasurer

PO Box 31 Tucson Arizona 85702 Telephone 520.325.2366 Email padrekino@live.com



#### PATAGONIA AREA RESOURCE ALLIANCE

317 McKeown Ave PO Box 1044 Patagonia, AZ 85624

#### www.patagoniaalliance.org

A non-profit community organization with volunteer members. Our volunteers bring skill sets and experience that include:

Geology **Business Management** Ecology Academia Artisan Mining Fundraising Webmaster Skills Marketing Legal Council & Advocacy

The Patagonia area has a heritage that includes ranching, farming, eco-tourism, and multiple uses on public lands that include the Coronado National Forest, Arizona State Parks and Trust Lands, and Bureau of Land Management lands. It is rich with natural resources as well as mineral resources. Working within the legal parameters of local, state and federal governments, PARA's goal is to prevent further environmental degradation as well as promote restoration efforts in order to maintain and preserve our public lands, private lands, our water, and our air for future generations.

"There are some things in the world we can't change--gravity, entropy, the speed of light, and our biological nature that requires clean air, clean water, clean soil, clean energy and biodiversity for our health and well being. Protecting the biosphere should be our highest priority or else we sicken and die."

> David Suzuki award winning scientist, environmentalist, broadcaster

January 11, 2018

**Board of Directors** International Dark Sky Association 3223 North First Avenue Tucson, AZ 85719-2103

Patagonia Area Resource Alliance is a grass roots community alliance working to protect the natural beauty of the Patagonia Mountains and the Sonoita Creek watershed. PARAs focus is to protect against industrialized mining activity including dark skies violations as the result of 24/7 operations.

PARA wholeheartedly supports designation of Tumacacori Mission as a Dark Sky Designated Park.

Curalyn Shafer Carolyn Shafer

Board Member

## **Description of Tumacácori NHP**

#### Location and Description of Park

Tumacácori National Historical Park is located in southern Arizona, 20 miles north of the United States-Mexico border and approximately 45 miles south of Tucson, Arizona. The park protects three Spanish colonial mission ruins: San Jose de Tumacácori (Tumacácori), Los Santos Ángeles de Guevavi (Guevavi), and San Cayetano de Calabazas (Calabazas). With all the three units, the park consists of 360 acres, of which there are no private inholdings. All main park facilities are located at the Tumacácori unit, consisting of 330 acres. Visitors access the park through the Tumacácori Visitor Center from 9:00 a.m. to 5:00 p.m. The Guevavi (9 acres) and Calabazas (21 acres) units are open to the public only as part of a Tumacácori NHP guided tour. These sites are also excluded from this designation due to the importance of cultural resource protection. The Tumacácori unit will be the area of IDSP designation.

Missions Tumacácori and Guevavi, established in 1691, were among more than 20 missions founded by Jesuit Father Eusebio Francisco Kino. These missions were established in the region known to the Spanish as the Pimería Álta, stretching from what is now Sonora, Mexico, through southern Arizona. Calabazas was first recorded in the mission register in 1756.

The construction of the existing Tumacácori church began around 1800 under the administration of Franciscan missionaries. Tumacácori was established as Tumacácori National Monument on September 15, 1908, by President Theodore Roosevelt. Subsequent legislation added the Guevavi and Calabazas units and changed the designation to National Historical Park in 1990. An additional 310 acres surrounding the Tumacácori unit, including a one-mile stretch of the Santa Cruz River and adjacent riparian area, gallery forest, and mesquite bosque (forest), were added to the National Historical Park in 2002. Lastly, the Tumacácori unit also includes a one-mile stretch of the Juan Bautista de Anza National Historic Trail.



Figure 1: Exterior of mission church (left) and convento (right)

Map of Tumacácori unit



Figure 2: Map of Tumacácori, Calabazas and Guevavi Units.



Figure 3: Map of Tumacácori Unit (area of designation)

#### Significance of Park Resources

#### **Natural Resources**

In 2002, more than 300 acres were added to the park, reuniting the church grounds with a small piece of historical mission property, and placing more than a mile of Santa Cruz River riparian environment, mesquite bosque (forest), and a section of the Juan Bautista de Anza National Historical Trail within the park.

The 4.5 mile stretch of the Anza Trail that extends from Tumacácori to the Tubac Presidio State Historic Park in Tubac was the first stretch of this trail to be established in Arizona. The trail follows the river in the shade of mesquite, hackberry, elderberry, cottonwood and willow trees. Along with the surrounding desert shrub, these environments provide shelter to more than 200 species of birds, various types of mammals, reptiles, amphibians, and insects.

#### **Cultural Resources**

The cultural resources of Tumacácori collectively represent the culture of native peoples before and after the arrival of Europeans, as well as, the Spanish effort to colonize the Santa Cruz River valley through the Jesuit and Franciscan missionization of its native people. Tumacácori National Historical Park is the only NPS unit displaying an entire, original institutionalized Spanish mission landscape.

The landscapes at the three mission sites and the broader natural and cultural resources of the Santa Cruz River valley contain important elements of the environment that sustained people before, during, and after the missions were established. These features now allow visitors and residents to imagine and understand the different communities' relationships to these landscapes over time.

All three mission sites contain some of the best remaining examples of Spanish Mission period architectural styles, including original materials, features, and construction techniques.

#### **Archeological Resources and Historic Structures**

The park protects the standing and subsurface ruins of churches, conventos, and parts of the community grounds of missions San Jose de Tumacácori, San Cayetano de Calabazas, and Los Santos Angeles de Guevavi. Along with these ruins, which date to the 1700-1800s, the park also contains subsurface and surface remains of pre-mission O'odham and prehistoric Hohokam and Trincheras cultures, as well as post-mission settlement.

The Tumacácori Visitor Center and Museum, built in 1937, was placed on the National Register of Historic Places in 1987.

#### Weather, Climate, and Visibility

Located above the heat of the low desert, Tumacácori National Historical Park is in the mesquite highlands, close to 3,300 feet in elevation, where temperatures are five to ten degrees cooler than Tucson or Phoenix.

Tumacácori has mild winters and hot summers. From late fall through early spring highs average between 65 and 80°F. November through February are the coolest months, with daily temperatures typically ranging between 35 and 70°F, although frosts are not uncommon. About midway through February, the temperatures start to rise again with warm days, and cool breezy nights. The hot, dry summer months of May and June bring highs typically between 95 and 105°F. Due to the dry air, large temperature swings of 40 °F often occur between day and night.

A unique feature of Arizona climate is the two periods of precipitation. The climate of the area is marked by a bi-seasonal precipitation regime, with a monsoonal flow from the Gulf of Mexico in summer (July through September), and Pacific frontal storms in winter (December through March). "Monsoon season" during the summer includes conditions of scattered, localized, often intense thunderstorms, with torrential, downpours. Tumacácori typically gets about 11 inches of precipitation per year, the majority of which falls during summer monsoon.

The skies of southern Arizona are famous for clear, dark nights, perfectly suited to the study of the heavens. Whether by the glow of a full moon or the sparkle of stars, Tumacácori is a beautiful place to enjoy the night.

Meteoblue, a meteorological service, provides high quality local weather information worldwide. Such information can be utilized to identify local weather information of Tumacácori NHP. The meteoblue stimulation history archive offers access to past weather simulations for every place in the world. Figure 4 shows the stimulation history archive for Tumacácori, Arizona split into three charts highlighting Temperature, Precipitation/Cloud cover, and Wind speed/Wind direction. The second chart (containing the colors yellow, blue, and grey) displays the cloud coverage during 01-01-2016 to 12-3 1-2016 in relation to the precipitation. Clouds are represented by a grey background and clear skies are represented by yellow background.



Figure 4: Weather stimulation history archive for Tumacácori, AZ from January 1, 2016 through December 31, 2016 provided by Meteoblue

According to Figure 4, Tumacácori has experienced low levels of grey compared to the high frequency of yellow present indicating a high frequency of clear skies present. These data points and charts were obtained from Meteoblue's online archive resource.

#### Isolation from Light Pollution

Light pollution can be defined as excessive, misdirected, or obtrusive artificial light. It affects human health and safety, wastes energy, and disrupts the environment, wildlife, and ecosystems. For example, living creatures rely on the Earth's regular day and night rhythm to regulate internal cycles. Many utilize the protection of the darkness to participate in activities such as foraging and mating. Impacting the darkness of the sky through the implementation of artificial light can have severe negative impacts. Mammals such as Pallid bats found at Tumacácori, may suffer additional exposure to predators and have difficulty finding food due to light interference.

The nearest sources of light to Tumacácori NHP are I-19, just 750 feet west of the edge of the park, and Tubac, about 3 miles north of the park. While these sources are relatively close, their impact is minimal. Topography and vegetation efficiently screen out the light pollution coming from both I-19 and Tubac. For I-19, the elevation of the

freeway and screening hills and vegetation effectively deal with interference by light. Likewise, screening hills and vegetation deal with interference by light from Tubac.

Although Tumacácori NHP is locally isolated from highly populated cities and surrounded by towns with low populations and low light pollution conditions, the park is about 45 miles away from Tucson and 20 miles away from Nogales, both highly populated cities with high levels of light pollution. Although Tumacácori NHP may not be in relatively close proximity, the light pollution occurring within these two cities creates "light domes" that are distinct and visible from the park. These light domes affect the darkness of the surrounding area including Tumacácori.

Figures 5-7 capture the light domes approximately matching the visual appearance at Tumacácori. Images were taken on the mission grounds by John Barentine on Monday, 5 February 2018, near astronomical darkness. Although high, thin cirrus covered much of sky, they were more visible near the horizon than overhead. It is likely the case that they were too thin to be visible in front of the stars, and there is not enough ground light at small radii from the site to adequately illuminate them.

Photographs were taken east of the church and north of the convento ruins (at approximately 31°34'07.6"N 111°03'02.0"W, elevation 994 meters), putting the nearest light source, near the parking lot, behind the mission. From this location, a Canon T2i DSLR camera and a Rokinon 14mm wide-angle lens with offsets of 28 degrees in azimuth between frames were used. The optimal exposure time (3.2 seconds) for a given f-ratio (f/2.8) and equivalent film speed (ISO 1600) was determined by taking a series of frames toward the Tucson and Nogales light domes and adjusting the times until the image density on the camera display screen approximately matched the visual appearance of the horizon view.



Figure 5: Light dome from Tucson (75 km). Light dome stops well below location of the bright star Polaris (upper left) which from the site is at an altitude of approximately 32 degrees.



Figure 6: Light dome from Nogales (32 km). The light dome extends up to about the altitude of the bright star Delta Canis Majoris (marked), which is about 20 degrees at the time of observation.



Figure 7: Image shows about 200-degree-wide panorama running northwest (left) to south-southeast (right), including the main sources of light visible on the horizon at Tumacácori.

Tucson and Nogales dominate, yielding light domes of comparable visual brightness despite the different populations and the distances of the two urban centers. In each case, the extent of the domes was limited to about the first 30 degrees above the horizon in each direction, although the presence of clouds made it difficult to say exactly how high each light dome reached. In addition, notice that although Tubac is closer in proximity to Tumacácori NHP, the light pollution from Tucson and Green Valley is much more significant.

The New World Atlas of Artificial Sky Brightness shows anticipated sky brightness as seen from the ground. Maps derived from the atlas can be found at www.lightpollutionmap.info. Figure 8 is screen shot from the site with the ATLAS 2015 overlay, which is more sensitive to faint light. It shows a zoomed out view of southern Arizona that pinpoints Tumacácori while including the cities of Tucson, Nogales, and Sierra Vista.



Figure 8: Screen capture shows anticipated sky brightness in southern Arizona as seen from the ground (Tumacácori NHP is indicated by the red pin). Main highways and cities are labeled. Image was obtained from www.lightpollutionmap.info with ATLAS 2015 overlay. Map derived from the New World Atlas of Artificial Sky Brightness.

Figure 9 below, which shows a closer view of Tumacácori, is a side-by-side comparison of anticipated sky brightness in 2014 versus 2017. As seen in this figure Tumacácori is not immediately, within 5 miles, surrounded by highly populated areas. Even though it is observed to be isolated from light pollution occurring in larger neighboring cities, over the past few years, light pollution is shown to be encroaching.





Figure 9: Side-by-side screen captures compare a) 2014 to b) 2017 anticipated sky brightness in southern Arizona as seen from the ground (Tumacácori National Historical Park is indicated by the red pin). Main highways and cities are labeled. Map derived from the New World Atlas of Artificial Sky Brightness. Images were obtained from www.lightpollutionmap.info with a) VIIRS 2014 overlay and b) VIIRS 2017.

The encroaching light pollution as seen above motivates Tumacácori NHP to work with neighboring towns to ensure that it doesn't become a detriment in the future. Through the process of educating community members to gain support for the designation, supporters, such as Tubac Presidio State Historic Park, have already expressed interest in their own designation and therefore mitigation. Thus, the designation of Tumacácori NHP will be a catalyst for lighting mitigation in the community.

The information collected provides a better insight of the levels of light pollution affecting Tumacácori NHP. Compared to other forms of pollution such as water and air, light pollution is considered a relatively easy environmental problem to resolve. The solutions made to reconcile this pollution are effective, and often save communities money. Knowledge is found to be the largest barrier stopping people from protecting night skies. We are not only protecting night skies for ourselves but for future generation throughout night sky friendly outdoor lighting.

## Tumacácori Night Sky Resources

Sky Quality Data

As previously stated, Tumacácori National Historical Park is locally isolated from highly populated cities and surrounded by towns with low populations and low light pollution conditions. However, high levels of light pollution from the closest highly populated cities create "light domes" that are distinct and visible from the park (Figure 5-7). While

affected from these two cities, Tumacácori NHP still contains beautiful night time skies in which many stars and constellations are visible, including zodiacal light. The degree of night sky quality can be measured by the use of sky quality meters. All measurements at Tumacácori NHP were taken with a Unihedron SQM-L model Sky Quality Meter. The SQM-L is the newer model which incorporates a lens for collecting more light from a narrower field of view. Sky quality meters measure how much light strikes the sensor being used. The meter then converts that amount of light into units of magnitude per square arc-second. The larger the number read on the device, the darker the sky. The following Table displays each average reading collected at Tumacácori NHP using a Unihedron SQM-L meter.

Date	Time (24 hrs)	Location	Cloud Cover	Average Reading (mag/arc <sup>-2</sup> )
06/3/2016	2114	Parking Lot	0%	20.68
06/4/2016	2111	Parking Lot	0%	21.14
08/2/2016	2120	Church Façade	0%	21.11
08/2/2016	2110	Parking Lot	0%	20.67
10/2/2016	2036	Parking Lot	0%	21.20
10/3/2016	2110	Parking Lot	0%	21.16
10/29/2016	2030	Church Façade	0%	20.98
10/29/2016	2040	Parking Lot	0%	20.83
10/30/2016	2010	Church Façade	0%	21.22
10/30/2016	2015	Parking Lot	0%	21.07
10/31/2016	2130	Church Façade	0%	21.09
10/31/2016	2140	Parking Lot	0%	20.73

Table 1: Tumacácori Unihedron SQM-L Measurements

The lowest sky quality reading was observed to be 20.67 while the highest sky quality reading was observed to be 21.22 (Table 1).

The following bar graph displays a distribution of the same original sky quality readings recorded vs relative frequency within the IDA Dark-Sky distinctions.





The majority of the points are between Bronze and Silver tiers of the IDA Dark-Sky distinctions (Figure 10). The highest relative frequency is observed to be at the 21.10-21.19 sky brightness. Based on qualitative and quantitative observation, Tumacacori qualifies for a Bronze-tier International Dark Sky Park designation. According to Dark Sky Park Designation Guidelines, "Bronze corresponds to Areas not meeting the requirements of Silver, yet still offering people, plants, and animals a respite from a degraded nocturnal environment and suitable for communicating the issue of light pollution and connecting people with the many aspects of the night sky."

It is important to note that six data points were discarded from the original data set used to create the table and bar graph above. The points discarded were observed to be higher or lower than expected values, also known as, outliers. These abnormal results could have occurred due to human error or poor weather conditions. They have been removed to provide a more accurate depiction of the night sky quality at Tumacácori.

Provided by the National Park Service Natural Sounds and Night Skies division, an expected ratio map of artificial to natural light can be observed for southwest Arizona (Figure 11). The colors show the expected ratio of artificial to natural light at the zenith from satellite measurements, and the map was made by the NPS Natural Sounds & Night Skies division. Tumacácori's location is indicated by the red pin and the two highly populated cities of Tucson and Nogales are visibly seen to have red, orange, yellow, and green color contours surrounding the area.



Figure 11: Expected Ratio of Artificial to Natural Light at the zenith from satellite measurements. A natural level of night sky brightness is defined as an Artificial Light Ratio of 0 (black contours). Tumacácori is indicated by the red pin. (NPS Natural Sounds and Night Skies division).

The color contours of Tucson and Nogales represent high artificial to natural light ratios which translate to high amounts of light pollution. However, based on where Tumacácori falls relative to the color contours around Nogales and Tucson, the likely ratio there is about 1.0 (i.e., the artificial light in the sky is 100% the amount of natural light). It is expected that this ratio corresponds to a sky brightness of about 21 on the SQM's scale. It is important to understand that a night sky 100% brighter than the natural level is a factor of 2 (i.e., twice as bright). The following figure from NPS Natural Sounds and Night Skies division displays this expectation:



Figure 12: Nomogram showing various scales characterizing night sky brightness (NPS Natural Sounds and Night Skies division, from original by Henk Spoelstra)

Each scale in Figure 12 is lined up to corresponding to equaling valuable. Following a factor to natural sky of 2 equates to a sky brightness of about 21 which is approximately what was recorded using a sky quality meter.

The following table displays the statistical results obtained from the readings displayed in Table 1.

Mean	20.99
Median	21.08
Standard Deviation	0.21
Darkest	21.22
Brightest	20.67
Ν	12

Toblo	$\gamma$ .	TIINAA	CIA		Statiation	Doto
rable	۷.	IUNA	SKY	/ Quality	Statistical	Dala

The data appears to be normal, for the mean and the median have nearly the same value: 20.99 and 21.08, respectively. In addition, the standard deviation is close to zero indicating low variability around the sample mean.

More recently, a full set of sky brightness data was taken. On Monday, 5 February 2018, John Barentine used both direct calibrated imagery and the Sky Quality Meter

(narrow acceptance angle 'L' device). Figure 13 shows a calibrated version of an image taken that had been stretched and the color saturation reduced to approximate the visual appearance of the night sky over Tumacácori. The all-sky image data were reduced with the method of Kolláth and Dömény<sup>1</sup>, using the 'dslrlum' software written by Prof. Zoltán Kolláth (University of Western Hungary).



Figure 13: Direct calibrated imagery at Tumacácori with a scale indicating the sky luminance in millicandelas per square meter (mcd/m<sup>-2</sup>).

A luminance of approximately  $0.415\pm0.002 \text{ mcd/m}^{-2}$  was measured at the zenith. The brightest values were toward Tucson and Nogales, about 2.5 times the luminance at the zenith. In astronomer units, the measured luminance corresponds to approximately 21.2 magnitudes per square arcsecond.

A set of spectrally-weighted broadband sky radiance data using the SQM-L device was also obtained, as a check on the luminance measurement. After the first reading was discarded due to a known systematic issue, the remaining nine measurements gave an average of  $21.21\pm0.01$  magnitudes per square arcsecond. It is in good agreement with both the calibrated DSLR results and 2016 SQM-L data obtained from the park, which had a mean and scatter of  $21.1\pm0.2$  magnitudes per square arcsecond. This suggests that, in the short term, night sky brightness levels over the park are relatively stable.

<sup>&</sup>lt;sup>1</sup> 2017, International Journal of Sustainable Lighting 19, pp. 61-68; <u>https://arxiv.org/abs/1705.09594</u>

#### Events and Outreach

Tumacácori is a beautiful place to enjoy the night sky. Although the visitor center is closed after 5:00 p.m., visitors are still able to access the park at night via the Anza trail. The park also hosts special nighttime events where the benefits of a dark sky are valued and interpreted. These events include "Experience the Night", "Family Sleepover: A Night at the Mission in 1916", and "Bat Night". Under a dark sky, visitors can view astronomical events and nocturnal creatures.

#### **Experience the Night**

Once each month from October through February, the park opens after dark until 8:30 p.m. to showcase the night sky. The 2016-17 events occurred exclusively during full moon nights, whereas the 2017-18 events will occur during a meteor shower, a supermoon, and a full moon. Night time activities include guided walks by candlelight featuring Father Kino, ghost stories, astronomy, and other topics. To help interpret the events, astronomical societies from Nogales and Tucson are invited. Members often bring telescopes to enhance the benefits of the dark sky for visitors. Visitor attendance ranges from twenty to a hundred and fifteen people.

2017-2018 Experience the Night Event Dates		
October 14 <sup>th</sup> , 2016	October 5, 2017	
November 14 <sup>th</sup> , 2016	November 17, 2017	
December 13 <sup>th</sup> , 2016	December 13, 2017	
January 11 <sup>th</sup> , 2017	January 2, 2018	
February 10 <sup>th</sup> , 2017	February 16, 2018	



Figure 14: Visitors during a Full Moon night (photo credit Lauren Hillquist)

#### Family Sleepover: A Night at the Mission in 1916

Under a beautiful Tumaccori night sky, thirty visitors are welcome to stay overnight at the mission. Event occurs Saturday night at 5:00 p.m. through Sunday morning. The following is an excerpt from a press release describing the event:

"The year is 1916 and a group of "ranger recruits" gather in Tumacácori's picnic area to receive instruction. The agenda includes checking on reports of a cow loose in the mission grounds, locating and documenting archeological artifacts, conducting a night patrol by candle light, and consuming the all-important evening meal. The evening winds down with live music and campfire treats before the recruits curl up on their bedrolls to spend the night under the stars or sheltered by adobe ruins."

As visitors recline under the night sky, the benefits are dark sky are interpreted by NPS Rangers. They explain how natural day-night cycles affect our circadian rhythms. Artificial light can interrupt those rhythms by suppressing melatonin, a hormone that helps one sleep. Since sleep helps the body heal and protect itself, light pollution can negatively affect one's health. The dark sky at Tumacácori ensures visitors a good night's rest, just as the park ancestors would have experienced.

2016-2018 Family Sleepover Event Dates			
April 2, 2016	October 8, 2016	March 18, 2017	
April 1, 2017	September 23, 2017	April 7, 2018	



Figure 15: As an alternative to sleeping inside the church, visitors may choose to bed down on the museum patio under the stars. This visitor took full advantage of experiencing lying out under the night sky.

#### **Bat Night**

The first annual bat night occurred in 2017 on National Bat Appreciation Day (April 17) with a visitor attendance of thirty people. The event takes place from 7:00 to 8:30 p.m. Since spring is the season bats return from their annual migration south or begin to emerge from hibernation, it is a great time to explore the role bats play in nature and how scientists are working to learn about and conserve bat populations. Visitors will be able to meet bats, learn from bat biologists, sample some foods pollinated by bats, create a bat craft, and go on a nature walk in search of active bats on the hunt. Bat biologists and NPS Rangers discuss the benefits of a dark sky in relation to bats. As mentioned earlier, Pallid bats found at Tumacácori, may suffer additional exposure to predators and have difficulty finding food due to light interference.

2	17-2018 Bat Night Event Dates
April 17, 2017	April 17, 2018



Figure 16: Debbie Buecher, bat biologist, teaches visitors about bat conservation.

#### **Previous Events**

Tumacácori has had the pleasure of having clubs such as the Sonora Astronomical Society host special nights on park grounds. In the spring of 2014, Tumacácori hosted "Exploring the Night Sky Star Party" for the Sonora Astronomical Society (Stars Ed.). At this event six club members participated as presenters discussing topics such as the Milky Way galaxy, Solar System, and telescopes to forty-five visitors.

In previous years, Tumacácori has also hosted Starry Saturdays, an event that encouraged the public to spend one Saturday night a month at Tumacácori exploring the night time sky. A special photography workshop was held during the December 20<sup>th</sup>, 2014 Starry Night. During this workshop visitors were invited to spend the evening taking photographs under a galaxy of stars. Led by a professional photographer, visitors learned the principles of dark-sky photography, practical "how-to" guidance, and a photography assignment within the park.



Figure 17: Tumacácori church exterior at night (credit ARC Photography)





Figure 19: Tumacácori bell tower with Milky Way (credit ARC Photography)

#### **Night Sky Products**

Tumacácori has had the pleasure of offering amazing night sky products in the Visitor Center gift shop. Items include a rotating star finder, a first astronomy light kit, a field guide to the constellations, and Night Sky Tour T-shirts.

#### **Rotating Star Finder**

The Night Sky is a rotating star finder (planisphere) that allows the user to recognize the constellations for any time of night, any day of the year. The sky appears to rotate (due to the rotation and orbital motion of the earth), so to be successful recognizing the constellations a beginner needs to know which stars are above the horizon at any time. This is the full-sized version of The Night Sky suitable for the 30°-40° latitude zone (southern half of the US, North Africa, Middle East, etc.). There are editions for the following latitude zones: 50°-60°, 40°-50°, 30°-40°, 20°-30°, and the Southern Hemisphere. There are also pocket-sized versions available for the same latitude zones.



Figure 20: The Night Sky, rotating star finder

#### First Light Astronomy Kit

The First Light Kit brings together everything a beginner needs to get off to a successful start observing the sky. The kit contains *The Night Sky*, our uniquely designed low-distortion star finder (planisphere), *Exploring the Night Sky with Binoculars*, our award winning introduction to observational astronomy, and *Sky Atlas for Small Telescopes and Binoculars*, our sky atlas designed specifically for beginners with small optics, and our *Night Reader*, our specially designed red light for reading the chart in the dark without depleting your night vision. With this kit you will be finding constellations, galaxies, globular clusters, double stars, nebulae and more in no time at all. This kit is the perfect companion resource for use with a new telescope or binoculars. Packaged in a handsome box the kit includes all of the above with detailed instructions for using each of the tools in the kit and access to our website for additional tools such as our Planet Locator, Moon Phase Calendar, observing log, and a table of the best meteor showers.



Figure 21: First Light Astronomy Kit

#### A Field Guide to the Constellations

Stargazing is among the most peaceful and inspiring outdoor activities. *Night Sky*, the award-winning book by Jonathan Poppele, makes it more fun than ever! Take a simple approach to finding 62 constellations by focusing on one constellation at a time, instead of attempting to study dizzying charts. Start with the easy-to-find constellations during each season and work toward the more difficult ones. Better yet, you'll learn how to locate any constellation in relation to the Big Dipper, the North Star, and the top of the sky. With two ways to locate each constellation, you'll know where in the sky to look and what to look for! Along the way, you'll be introduced to mythology, facts, and tidbits, as well as details about the planets, solar system, and more! As an added bonus, the book comes with a red-light flashlight for night reading.



Figure 22: Night Sky: A Field Guide to the Constellations

#### Night Sky Tour T-shirts

Starry Starry Night Tour T-shirt includes a park ranger pointing to numerous constellations on the front and the names of various parks with Night Sky interpretative events. Tumacácori is proud to be listed on the back of the Starry Starry Night Tour T-shirt.



Figure 23: Starry Starry Night Tour T-shirt

### Dark-Sky Restoration Project

Tumacácori has made a commitment to set an example as a leader in community. In particularly the park has set a leadership example in the restoration of dark skies by producing a "night sky friendly" lighting project that is publicly visible and interpreted. In conjunction with a new Visitor Center entrance garden, Tumacácori's night sky friendly lighting project includes the addition of pathway lights listed in the IDA's Fixture Seal of Approval program. This program "certifies outdoor lighting fixtures as being Dark Sky friendly, meaning that they minimize glare while reducing light trespass and sky glow." Table 3 details the specifications of the bulb.

	Table 5. Opecificati	ons for pairway lights	).
Item Number	Description	Power Supply	Lumens
		Requirement	
G4-20-12V-830	20 watt equivalent	3W	300
	LED Bi-Pin 3000K		

#### Table 3: Specifications for pathway lights.

The importance of this beautiful restoration project is interpreted to guests through a National Park Service formatted brochure. The following is literature from the International Dark-Sky Park brochure:

"An important element of the project was installation of night sky friendly lighting. Along the path to the visitor center entrance, six VOLT Max Spread Path & Area Lights were installed. These lights are listed in the IDA's Fixture Seal of Approval program. This program 'certifies outdoor lighting fixtures as being Dark Sky friendly, meaning that they minimize glare while reducing light trespass and sky glow.' These lights will provide guidance along the entrance path during night activities while minimizing the harmful effects of light pollution."



Figure 24: Tumacácori Visitor Center Entrance including night sky friendly lighting

This brochure also includes sections detailing the International Dark-Sky Association, the effects of light pollution, and the dark sky quality readings collected at Tumacácori. This brochure will be available to visitors for free at the front desk of the Visitor Center immediately after walking on the pathway surrounded by dark-sky friendly lighting. In addition, the brochure will be distributed to visitors during night programs. Then, visitors will have a clear understanding of the harmful effects of light pollution and the mitigations against it.

## Tumacácori

National Park Service Department of the Interior Turnacàcori National Historical Park





**Dark-Sky Designation** 

Over the past year Tumacácori has been taking the steps required to become designated as an IDA (International Dark-Sky Association) International Dark Sky Park. The IDA is the recognized authority on light pollution and advocate for the protection of the night sky.

Under the International Dark-Sky Places program, the IDA offers five types of designa-tions including International Dark-Sky Parks. A certified International Dark-Sky Park has "land possessing an exceptional or distin-guished quality of starry nights and a nocturnal environment that is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment.\* Tumacácori anticipates recieving designation as a Dark-Sky Park in 2017.

Effects of Light Pollution Light pollution is excessive, misdirected, or obtrusive artificial light. It affects human health and safety, wastes energy, and disrupts the environment, wildlife, and ecosystems.

#### Wildlife

Plants and animals depend on the Earth's daily cycle of light and dark to govern life-sustaining behaviors such as reproduction, nourishment, sleep, and protection. For example, mammals such as pallid bats (right), which live at Tumacácori, may suffer additional exposure to predators and have difficulty finding food.

Human Health Humans are susceptible to circadian disruption due to light pollution. This occurs when our "biological clock" is out of sync with the day-night light cycles, affecting our natural sleep patterns. In response to the circadian rhythm our bodies produce the hormone melatonin. Melatonin's induces sleep, boosts the immune system, lowers cholesterol, and helps the functioning of various organs.

#### Safety

Do lights really mean safety? The Chicago Alley Lighting Project found correlation between brightly lit alleyways and increased crime. This and similar studies counter the common mis-conception that brighter lights result in safety. In fact, crimes, including vandalism and graffiti, thrive on night lighting.

Glare from bright, unshielded lights also creates hazardous situations. Light glare creates deep shadows, making it more difficult to see objects, animals, and people in a scene..







#### Energy Loss Wasting energy results in huge economic and environmental consequences. The IDA estimates that "at least 30 percent of all outdoor lighting in the U.S. alone is wasted, mostly by lights that aren't shielded." Unshielded fixtures throw light into the sky, rather than directing it downward where it can be of use. This lost light alone adds up to approximately \$3.3 bil-lion and the release of 21 million tons of carbon dioxide into the atmosphere per year. To offset this amount we would have to plant 875 million trees annually. **Dark Sky Quality** Tumacácori National Historical Park is sur-The table below shows actual sky quality readrounded by towns with low populations and ings recorded at Tumacácori. Sky quality meters low light pollution conditions. However, the measure how much light strikes a sensor. The park is about 50 miles from Tucson and 20 larger the number, the darker the sky. miles from Nogales, both highly populated cit-ies with high levels of light pollution. The light pollution occurring within these two cities cre-Tumacácori observed sky brightness readings between 20.7 and 21.4, indicating a dark sky rated between "bronze" and "silver" in IDA ates "light domes" that are very distinct and visstandards ible from the park. These light domes affect the darkness of the surrounding area, including Tumacácori.



#### Projects at Tumacácori

#### Tumacácori Visitor Center Entrance

The new entrance garden celebrates the diverse microclimates of Santa Cruz County with native plantings. Shady areas feature riparian plants, while sumy borders focus on desert species. Supported by volunteer Master Gardeners and Tumacácori National Historical Park staff, the garden also includes a path, seating, and revamped front entrance lighting.

An important element of the project was installation of night sky friendly lighting. Along the path to the visitor center entrance, six VOLT Max Spread Path & Area Lights were installed. These lights are listed in the IDA's Fixture Seal of Approval program. This program "certifies outdoor lighting fixtures as being Dark Sky friendly, meaning that they minimize glare while reducing light trespass and sky glow." These lights will provide guidance along the entrance path during night activities while minimizing the harmful effects of light pollution.

#### Dark Sky Programming

Recognising the value of it's clear, dark nights, Tumacácori has been providing an ever increasing number of evening and night visitor opportunities. Recent programs include such events as Starry Saturdays, Full Moon Nights, Bat Appreciation Night, and Family Sleepovers. Updated program information is available at NPS.gov/tuma.

#### Dark-Sky Designation

Turnacácori will be submitting a Designation Nomination Package to the International Dark-Sky Association Dark Sky Parks Committee in the summer of 2017. Perhaps next time you visit we will be a proud member of the Dark Sky Parks program. Wish us luck, and celebrate your night skies!



### Park Lighting Inventory

Tumacácori National park has a very limited lighting footprint due to minimal lighting surrounding only NPS buildings. Currently, there are 35 light fixtures located on the mission grounds. However, prior to removal of a light fixture not incompliance with Tumacácori's Light Management Plan there were 36 light fixtures. The majority of the lights are located on the park's administrative offices and maintenance building. All lights are located in the forefront of the park's unit.



Figure 25: Map of Tumacácori highlighting location of park lighting (Lighting area circled in yellow)

The following table summarized the status of the lighting compliance within the Tumacácori unit as of May 2017.

	# lights	# comply	# not-comply	% compliance
Tumacácori	36	33	3	91.7%

Table 4: Lighting statistics within the Tumacácori unit

The following table includes the lighting inventory of Tumacácori NHP. Lights throughout the unit have been identified and given an ID. This ID corresponds to Table 5, a picture guide of the lighting inventory, showing the light fixture.

Table 5: 2016 Lighting inventory of Tumacácori unit including light description, conformity, and mitigation notes

Lighting Inventory of Tumacácori National Historical Park					
Location	ID #	Light Description/Application	Color Temperature of Lamp	Conformity with LMP	Notes/Mitigation (If needed)
	1	front entrance, security lights		Yes	Mitigation: Removed
	2	side entrance	2850K	No	Mitigation: Retrofit needed
	3	courtyard hallway, flood lights	2900K	Yes	Shielded by overhang
	4	front entrance garden, path light	2700K	Yes	
Visitor Center	5	front entrance garden, path light	2700K	Yes	
	6	front entrance garden, path light	2700K	Yes	
	7	front entrance garden, path light	2700K	Yes	
	8	front entrance garden, path light	2700K	Yes	
	9	front entrance garden, path light	2700K	Yes	
	10	side near casita, security flood lights	2900K	Yes	Motion Sensor
	11	left side entrance, security flood lights	2900K	Yes	Motion Sensor
	12	left side entrance, small shielded	2900K	Yes	Shielded by overhang
Administra	13	front entrance left corner, security flood lights	2800K	Yes	Motion Sensor
tion	14	front door, historic fixture	2700K	Yes	Shielded by overhang
	15	front entrance right corner, security flood lights	2900K	Yes	Motion Sensor
	16	front entrance right side, security flood lights	2900K	Yes	Motion Sensor
	17	back corner, security flood	2900k	Yes	Motion Sensor

		lights			
	18	back entrance, historic fixture	No Bulb	Yes	Shielded by overhang
	19	back entrance, small shielded light	2900K	Yes	Shielded by overhang
	20	back entrance, small shielded light	2900K	Yes	Shielded by overhang
	21	back entrance, large shielded	3500K	Yes	Shielded by overhang
	22	front entrance left side, small shielded light	2900K	Yes	Shielded by overhang
Maintenan	23	front entrance right side, historic fixture	2850K	Yes	Shielded by overhang
се	24	right side, office back entrance	3500K	Yes	Shielded by overhang
25 26 27	25	right side, office back entrance, small shielded	2900K	Yes	Shielded by overhang
	26	right side of building, large shielded, security	3500K	Yes	Shielded by overhang
	27	right side of building, small shielded	2900K	Yes	Shielded by overhang
Boundey House 29	28	side entrance, historic fixture	3000K	Yes	Shielded by overhang
	29	front entrance, historic fixture	2600K	Yes	Shielded by overhang
Stoff	30	front entrance, historic fixture	2500K	Yes	Shielded by overhang
Housing	31	back entrance	2800K	Yes	Shielded by overhang
	32	garage, security flood lights	2900K	Yes	Motion Sensor
Casita	33	front entrance, flood lights	2800K	Yes	Shielded by overhang
Casila	34	front entrance, historic fixture	No Bulb	Yes	Shielded by overhang
Metal	35	front entrance, large shielded	4000K	No	Mitigation: Remove
Barn	36	back entrance, large shielded	4000K	No	Mitigation: Remove

The following table corresponds to Table 4 and provides the picture of each lighting fixture within Tumacácori.

Location	ID #	Light Fixture
Visitor Center	1	
	2	
	3	
	4-6	

Table 6: Lighting Fixture Inventory including pictures before and after mitigation if needed

	7-9	
Administratio n	10	
	11	
	12	
	13	



Maintenance	20	
	21	
	22	
	23	
	24	
	25	

	26	
	27	
Boundey	28	
House	29	
Employee	30	
Housing	31	

	32	
Cosito	33	
Casita	34	
Metal Barn	35	



## **Management Documents**

### NPS Management Policies Supporting Dark Skies

#### National Park Service Organic Act

The Organic Act was passed in 1916 to protect and manage the national park lands of the United States. The act protected the ecological and scenic values within federal lands, under which falls dark sky resources. "The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

#### 2006 NPS Management Policies

#### 4.10 Lightscape Management:

The Service will preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human caused light....The stars, planets, and Earth's moon that are visible during clear nights influence humans and many other species of animals, such as birds that navigate by the stars or prey animals that reduce their activities during moonlight nights. Improper outdoor lighting can impede the view and visitor enjoyment of a natural dark night sky. Recognizing the roles that light and dark periods and darkness play in natural resource processes and the evolution of species, the Service will protect natural darkness and other components of the natural lightscapes in parks. To prevent the loss of dark conditions and of natural night skies, the Service will minimize light that emanates from park facilities, and also seek the cooperation of park visitors, neighbors, and local government agencies to prevent or minimize the intrusion of artificial light into the night scene of the ecosystems of parks. The Service will not use artificial lighting in areas such as sea turtle nesting locations where the presence of the artificial lighting will disrupt park's dark-dependent natural resource components. The Service will

• restrict the use of artificial lighting in parks to those areas where security, basic human safety, and specific cultural resource requirements must be met;

• use minimal-impact lighting techniques;

• shield the use of artificial lighting where necessary to prevent the disruption of the night sky, natural cave processes, physiological processes of living organisms, and similar natural processes.

#### NPS Green Parks Plan, 04/2012 (www.nps.gov/greenparksplan)

The Green Parks Plan (GPP) is a management plan that identifies a "collective vision and a long-term strategic plan for sustainable management of NPS operations." It focuses on the impact of park faculties on the environment and human welfare and encourages NPS employees to adopt sustainability in their daily activities. The GPP includes nine strategic goals, including continuously improve environmental performance, be climate friendly and climate ready, be energy smart, be water wise, green our rides, buy green and reduce, reuse, and recycle, preserve outdoor values, adopt best practices, and foster sustainability beyond our boundaries. Each goal is supported by performance objectives. Under the "Preserve Outdoor Value" goal the NPS states that it will minimize the impact of facility operations on the external environment.

The performance objectives listed to support this goal:

1. The NPS will reduce light pollution from park facilities with the goal of dark night sky preservation.

2. The NPS will minimize sound pollution in the outdoor environment.

3. The NPS will ensure that all facilities and operation are sustainable integrated into the park landscape to minimize impact on the natural and cultural environment.



#### Night Sky Team (www.nature.nps.gov/sound\_night/)

Starry night skies and natural darkness are important components of the special places the National Park Service protects. National parks hold some of the last remaining harbors of darkness and provide an excellent opportunity for the public to experience this endangered resource. The NPS is dedicated to protecting and sharing this resource for the enjoyment of current and future generations.

The NPS uses the term "natural lightscape" to describe resources and values that exist in the absence of human-caused light at night. Natural lightscapes are critical for nighttime scenery, such as viewing a starry sky, but are also critical for maintaining nocturnal habitat. Many wildlife species rely on natural patterns of light and dark for navigation, to cue behaviors, or hide from predators. Lightscapes can be cultural as well, and may be integral to the historic fabric of a place. Human caused light may be obtrusive in the same manner that noise can disrupt a contemplative or peaceful scene. Light that is undesirable is a natural or cultural landscape is often called "light pollution.

## Tumacácori National Historical Park Lightscape Management Plan

#### I. Statement of Scope

This management plan will serve as a guideline for preserving naturally dark skies at Tumacácori National Historical Park located in Tumacácori, Arizona. It will be the basis for management decisions in regards to lighting upkeep and future plans. The current light fixtures in Tumacácori that do not conform to the Light Management Plan will be mitigated to appropriate fixtures to achieve 100% compliance within ten years. This plan follows the regulations set by the International Dark-Sky Association and Royal Astronomical Society of Canada. In particular the RASC/IDA Guidelines for Outdoor Lighting, as well as<sub>7</sub> the Santa Cruz County Zoning and Development Code, were consulted when creating the following Light Management Plan (LMP).

The objectives of this Lightscape Management Plan are:

- Preserve the dark sky quality of Tumacácori National Historical Park and the surrounding area.
- To promote good lighting practices and serve as a role model for the community.
- To protect local wildlife and ecosystems by decreasing light pollution effects.
- Provide a guideline for future lighting projects within the park and ensure darksky designation is upheld.

Tumacácori's policy shall be to not install new outdoor lighting unless a specific public safety hazard exists that can only be mitigated with the use of outdoor light. Otherwise, permanent installations of light will not be allowed if they are not in correspondence with the Tumacácori National Historical Park Lightscape Management Plan.

### II. Lighting Guidelines

All exterior lights at Tumacácori National Historical Park will be designed to eliminate excessive, misdirected, or obtrusive artificial light. Tumacácori will follow the National Park Service's direction to use artificial light on an "only as needed" basis and to minimize light impact whenever possible. NPS Management Policies also recommend a six-step process for evaluating outdoor lighting in parks and protected areas. These six-steps were utilized throughout the evaluation process for Tumacácori's light inventory and will be consulted in any future lighting projects.

- Warranting- Light only WHERE you need it
  - Lighting installations should be placed only where uses dictate.
- Controls- Light only WHEN you need it
  - Rather than defaulting to a dusk-till-dawn operation cycle, lighting controls should be designed to minimize the amount of time the light is on while still fulfilling the need meet by installing the light at that spot in the first place.
- Shielding- SHIELD lights and direct them downward
  - No fixture should emit light above the horizontal. In most cases, beams of light should be restricted even further.
- Spectrum- Select lamps with WARMER COOLERS
  - a. Humans and many other animals are most sensitive to blue/white light. Most evening lighting goals can be achieved using warmer temperature lighting, which decreases the disruption to wildlife (including insects), maintains the human ability to adapt to low light conditions, and decreases sky glow.
  - b. The color tint of white light is measured in Kelvins (K), a scale in which warm-toned white light has smaller values (1800-3000K) and cold-toned light has larger values (5000K and higher). Between 3000 and 5000K, light is said to be "neutral" in tone. The common incandescent lamp is 2700K.
  - c. Traditional incandescent lighting is about 2700K, a warm toned light considered normal for residential and hospitality lighting in North America. For reasons of consistency and appearance, light sources should be 2700-3000K with a minimum Color Rendering Index of 70. Amber or

yellow light sources are preferable, both to limit attraction by insects and to reduce sky glow. Light sources should be chosen for energy efficiency, long life and low maintenance. Because some locations in the park experience extremes of temperature, elevation and exposure, light 41 sources must be suitable for all expected operating conditions. The following light sources are acceptable for outside use:

- LED 2700K "warm" white lamps, yellow, or amber colored, 1, 3, or 7 watt. LED's superior 54 life, energy efficiency, instant starting and low temperature performance are superior but some capabilities of the source are limited. Use with caution in hot climates. Use amber LEDs in most environmentally sensitive areas.
- ii. Compact fluorescent, 9 watt, twin tube and 13 watt double twin tube or Edison base spiral 3, 7, 10, 13 or 26 watt (2700K only or yellow "bug lamps"). Because of low starting temperature and low cost components, this light source can be used for many basic outdoor lighting applications.
- Halogen IR, 20 watt, 12 volt MR16 lamp. Uses are generally limited to temporary (presence detector activated) lighting applications. Because of their low luminous efficacy they should not be used in continuous duty applications.
- iv. Ceramic metal halide lamps, 20 watts, T4.5 and 39 watt, T6, 3000K only. In general, these are the most powerful light source to be used outdoors, but warm up and restrike time preclude use where frequent switching or power quality issues are present.
- Intensity- Use the MINIUMUM AMOUNT of light necessary
- Efficiency- Select the most ENERGY EFFICIENT lamp and fixture

#### III. Lighting Standards

To remain in compliance, all future lighting installations must conform to the following lighting standards:

- 1. New, current, and retrofitted lighting must meet the Park's LMP.
- 2. Any lighting fixtures above 500 initial lumens are required to use **fully shielded** fixtures emitting no light at or above the horizontal.
- 3. Methods for determining the appropriate type of lamp (color, efficiency, technology) and fixture that should be used with goals to maximize energy efficiency and minimize impact to human vision dark adaptation/recovery time, wildlife, and the nocturnal ecology. The correlated color temperature of lamps installed in the Park shall **not exceed 4000K**, and a CCT of 2500K or less is recommended to minimize the impact on most wildlife.
- 4. All existing lighting and additions must follow the **Santa Cruz County Zoning** and **Development Code** and **NPS Management Policies**.

5. Lights should be directed downward and shielded.

#### IV. Existing Standards and Codes

A Royal Astronomical Society of Canada (RASC) Dark Sky Park is defined as an area whose night sky has little or no sky glow and minimal lighting within the DSP. As such, Tumacácori has created and adapted a lighting guideline outline that minimizes the lighting within the park.

The NPS Interim Outdoor Lighting Guidelines was a document developed by the Night Sky Team to "help parks immediately address lighting concerns, guide development and compliance, and provide a best management practice template to parks and park partners".

Best management practices for outdoor lighting will:

- Curtail and reverse the degradation of the nighttime visual environment and the night sky, including casual observation, astronomy, and air quality related values.
- Minimize glare, light trespass, obtrusive light, and artificial sky glow by limiting outdoor lighting that is misdirected, excessive, or unnecessary.
- Ensure —good neighbor lighting by minimizing light trespass.
- Help minimize suspected health risks to humans from adverse exposure to light at night.
- Help protect natural ecosystems from the damaging effects of night lighting.
- Permit reasonable and rational use of outdoor lighting for nighttime safety, utility, security, and productivity.
- Help to conserve energy and resources.
- Minimize maintenance and operating costs.
- Provide some flexibility for architectural and artistic lighting within the above constraints.

Santa Cruz County Zoning and Development Code (2015)

The Outdoor Light Regulations (Article 28) listed in the Santa Cruz County Zoning and Development Code contain the following contents:

**ARTICLE 28 – OUTDOOR LIGHTING REGULATIONS** 

- --2801—ADMINISTRATION
- --2802—DEFINITIONS

--2803—GENERAL REQUIREMENTS

--2804—PROHIBITIONS

--2805—TEMPORARY EXEMPTIONS

--2806—OTHER EXEMPTIONS

--2807—OUTDOOR ADVERTISING SIGNS

--2808—SPECIAL USES

--2809—LAW GOVERNING CONFLICTS

--2810— CONDITIONAL USE PERMIT

--2811— ENFORCEMENT AND PENALTY

SEC. 2803 GENERAL REQUIREMENTS

A. Applicability. The table in this Section gives requirements of the total light output permitted per acre excluding designated natural open space as defined in this Code for the different lighting options. These requirements shall be met for all lighting installations subject to this Article.

B. Total Outdoor Light Output. Total outdoor light output shall not exceed the lumen limits given in Table 2800-1. In the table, Total means the sum of shielded and unshielded exterior lighting

C. Lamp Type and Shielding Standards.

1. All Outdoor light fixtures shall be fully shielded (FS) except:

a) Residential flood or spot lamps shall be shielded and shall be aimed no higher than 45 degrees to the horizontal (half-way between straight down and horizontal) when the source is visible from any adjacent residential property in order to minimize light trespass.

b) Seasonal decorations using unshielded incandescent lamps shall be permitted from Thanksgiving to January 15th.

c) Neon lighting.

d) 3000 lumen exemption as per Table 2800-1

2. In the shielding requirements of this Article, all light fixtures on the residential side of commercial property adjacent to residential property shall be fully shielded and shall be a maximum of 5 feet above grade at the property line and no higher than a line rising 25 degrees above the 5 feet until 100 feet from the property line. All outdoor lighting within one mounting height of residential areas shall have internal house-side shields.

Appendix A contains examples of acceptable and unacceptable lighting fixtures for use in complying with this Article.







To find the maximum allowable mounting height, take the distance (b) from the property line to the base of the fixture location and multiply it by .47. This will give you (a), the height above the 5 foot starting level. Add (a) to 5 feet to find the maximum allowable mounting height.

In the diagram, a fixture 20 feet (b) from the property line has a height maximum of 14.4 feet.	(20) x (.47) = 9.4 9.4 + 5 = 14.4 felet;
a fixture 40 feet (b) from the property line has a height maximum of 23.8 feet.	(40) × (.47) = 18.8 18.8+ 5 = 23.8 figet







## **Future Plans**

#### **Outdoor Lighting Compliance**

The NPS employees of Tumacácori National Historical Park are committed to mitigating the three outstanding light fixtures that do not conform to the Light Management Plan within the ten years. Two of the three light fixtures are currently set for complete removal by the Facilities Management department. The mitigation to these light fixtures will provide Tumacácori NPH with a 100% compliance rate. Tumacácori NHP is also committed to ensure all future lighting projects follow the guidance provided by the Tumacácori Light Management Plan.

### Long Term Monitoring

The NPS employees of Tumacácori National Historical Park are committed to collecting long-term sky quality measurements. Specifically, the Natural Resource staff will work with the Facilities Management staff to ensure all lighting changes are made following the guidelines of the Lightscape Management Plan. Staff will track all lighting updates and mitigations in the "Dark-Sky Park Data Collection" log.

Additionally, the collection of night sky quality data is located in this record and will be updated each year. Tumacácori Natural Resource staff will collect data within the park at a minimum once per year and record data in the Tumacácori Dark-Sky Park Data Collection log. A report detailing the information recorded

from the past year will be submitted to the IDA by October 1<sup>st</sup> of each year detailing activities and progress towards fulfilling IDA DSP goals during the previous year.

TUMACACORI, ARIZONA

DARK-SKY PARK DATA COLLECTION 2017-2021

INTERNATIONAL DARK-SKY ASSOCATION

NATURAL RESOURCES TUMACACORI NATIONAL HISTORICAL PARK

## Contributors

Tumacácori National Historical Park

Yasmeen Luna, SCA Natural Resource Management Intern Aaron Stover, Biological Science Technician Courtney Giebink, SCA Integrated Resource Intern Anita Badertscher, Chief of Interpretation and Education