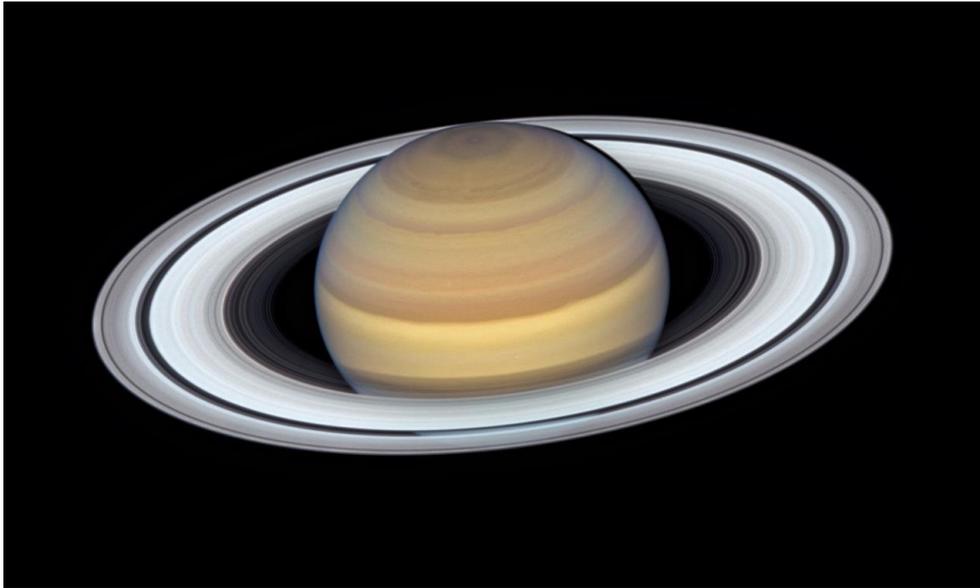


**NIGHT-SCAPE RESOURCES:
NORTHEASTERN NORTH CAROLINA COASTAL SYSTEM**

NORTH CAROLINA LAND OF WATER (NC LOW) & A TIME FOR SCIENCE (ATFS)

www.nclandofwater.org & www.atimeforscience.org



February 25, 2020

**NIGHT-SCAPE RESOURCES:
NORTHEASTERN NORTH CAROLINA COASTAL SYSTEM**

**PART 1: THE NIGHT SKY and NOCTURNAL ENVIRONMENT
OF THE OUTER ALBEMARLE PENINSULA (OAP)**

NORTH CAROLINA LAND OF WATER (NC LOW) & A TIME FOR SCIENCE (ATFS)

www.nclandofwater.org & www.atimeforscience.org

BY

Dr. Stanley Riggs: Director of NC LOW

Mr. Brian Baker: Director of Astronomy, ATFS

Ms. Emily Jarvis: Executive Director, ATFS.

Ms. Karen Clough: Community Outreach Coordinator, NC LOW

FUNDED BY:

North Carolina Sea Grant

North Carolina Space Grant

East Carolina University, Dept. of Geological Sciences

East Carolina University, Coastal Studies Institute

Kenan Institute of Engineering, Technology, & Science

February 25, 2020

COVER PHOTOGRAPHS. Upper panel is the opening act for the nightscape program: often an awesome light show as the Sun sets over the Alligator River. Photograph is by S. Riggs. Lower panel shows a Hubble Space Telescope view of Planet Saturn taken on 6-20-2019 reveals the details of the ring system and a turbulent, dynamic atmosphere intense pattern of clouds swirling in Saturn's turbulent atmosphere. Image is from NASA, ESA, A. Simon (Goddard Space Flight Center) and M. Wong (University of California, Berkeley), and the OPAL Team.

PART 1: THE NIGHT SKY and NOCTURNAL ENVIRONMENT OF THE OUTER ALBEMARLE PENINSULA (OAP)

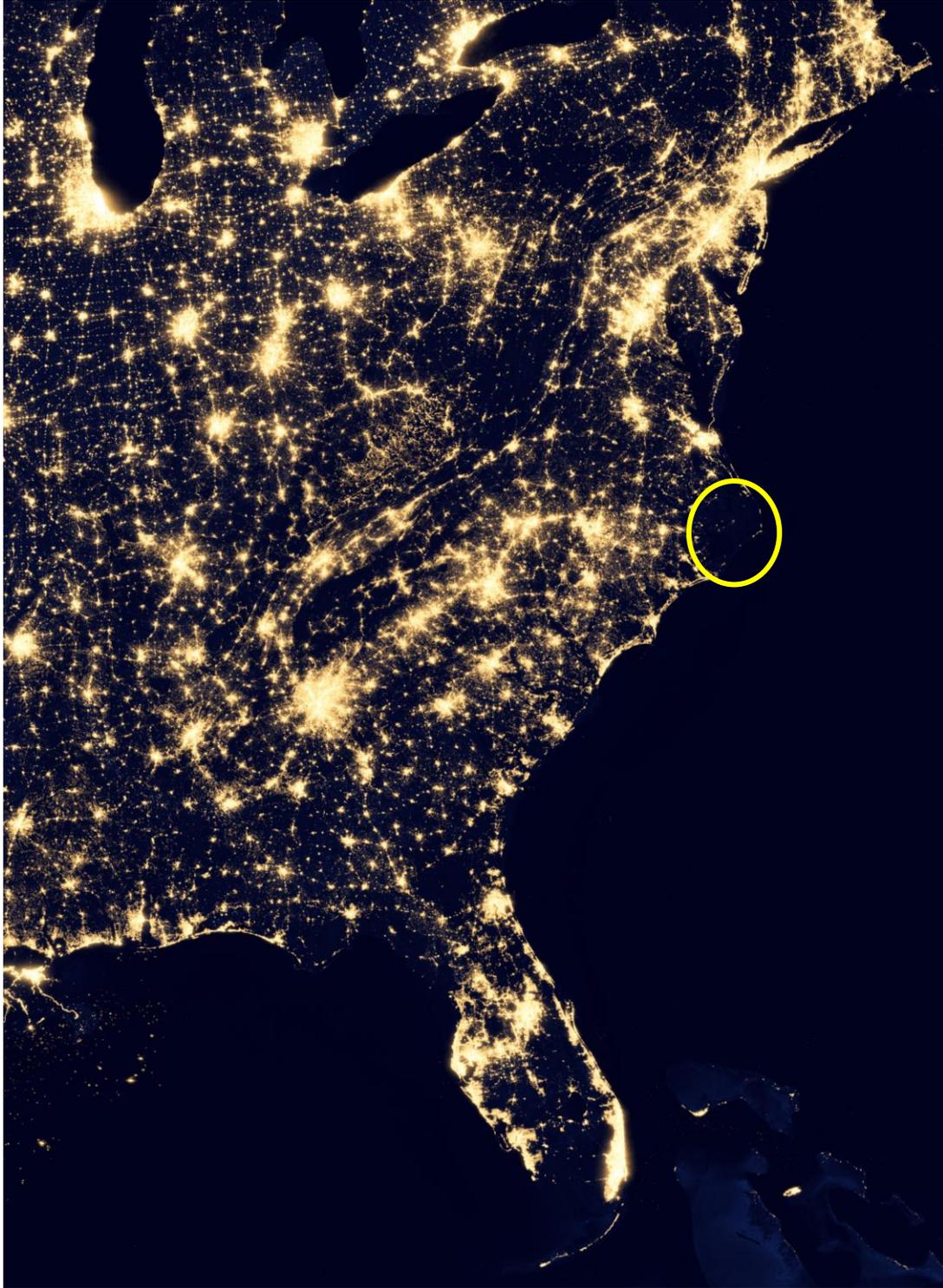
TABLE OF CONTENTS:PART 1

INTRODUCTION	4
OUTER ALBEMARLE PENINSULA (OAP)	7
Project Goals	7
Night-Scape Resource	9
OAP NIGHT SKY ENVIRONMENT	16
The Sun	16
The Moon	17
Eclipses	19
The Planets	20
Meteor Showers	22
Deep Space Objects	24
Constellations	25
The Milky Way	26
The Human Component	27
Satellites and the Wallops Flight Facility	28
OAP NOCTURNAL ENVIRONMENT	30
Clouds in the Nightscape	30
Sun Sets and Moon Rises	34
Geologic Resources	38
Eco-System Resources	40
Eco-System Fauna	43
OBSERVING THE NIGHT SKY	46
Navigating Around in the Night Sky	46
Quality of Clear Night Skies	47
Telescopes and Binoculars	49
Observing Wildlife	50
Stargazing	50
Photography	51
Camping	51
On the Water	51
LIGHT POLLUTION	52
What's the Problem?	52
Types of Light Pollution	53
Effects of Light Pollution	53
Solutions to the Problem	54
NIGHT-SCAPE OUTREACH	57
Communication and Education	57
International Dark Sky Reserve	60

INTRODUCTION

The night skies of the Outer Albemarle Peninsula (OAP) are among the darkest in the entire US Atlantic coastal system for several primary reasons. First, much of the OAP landscape is very low relative to sea level and is dominated by wetlands that today are preserved as national wildlife refuges, state parks and reserves, and vast acreages of public game lands (over 500,000 acres or 780 mi²). The OAP is surrounded by the 2,900 mi² publically owned buffer region consisting of four large estuarine water bodies (Albemarle Sound to the north, Croatan and Pamlico sounds to the east and southeast, and Pamlico River Estuary to the south), two additional National Seashores (Cape Hatteras and Cape Lookout), and two National Wildlife Refuges (Pea Island and Cedar Island) that provide another 105,000 acres or 163 mi². These huge water bodies are extremely dark in all but one narrow zone including Roanoke Island and the Outer Banks north of Oregon Inlet. The public water bodies are not only extremely dark, but provide expansive no light buffer zones around the north, east, and south sides of the OAP with vast horizons for experiencing the night-scape dynamics. The western side of the OAP is dominated by an enormous region of agricultural fields that extend westward to the western edge of the lower Coastal Plain (demarcated by the ancient Suffolk Shoreline) with minimal light sources and spacious horizons. All together this region provides the largest area of public dark skies along the US Atlantic coastal system between Boston and Miami (Figure 1).

The nocturnal environment and their night skies rotate from the brilliant, big sky of the full moons to the blackness of the new moons when the starry sky opens to a dazzling universe (Figure 2). A large seasonal variation is superimposed upon the vastness of the sky itself. This local overprint ranges between two extremes. The cold, crisp, winter nights are dominated by either the overwhelming sounds of flocks of winter waterfowl (e.g., tundra swans and snow geese by the many tens of thousands) moving from the refuge lakes to the farm fields, the lonesome hoots of owls on their evening hunts, howls of roaming coyote packs, or occasionally the rare red wolf. The summer nights are hot and humid and dominated with a cacophony of insects and frogs and massive light and sound displays derived from the outlines of perfect thunderheads as they move across the Albemarle Peninsula. And of course, the never ending parade of early morning sunrises and evening sunsets (Figure 3) provides new mosaics of sky magic.



*FIGURE 1. City lights of the United States in 2012 by NASA Goddard and created on 12-8-2017.
Visible infrared imaging Radiometer Suite
[https://images.nasa.gov/details-GSFC_20171208_Archive_e001590.](https://images.nasa.gov/details-GSFC_20171208_Archive_e001590)*



FIGURE 2. The night sky photograph looks south over Phelps Lake from the pier at Pettigrew State Park Visitor's Center in Tyrrell County. Photograph is by B. Foley.



FIGURE 3. Winter sunset over Pocosin Lakes National Wildlife Refuge. Photograph is by M. Dunn.

In a quest to better understand the nocturnal environment and dark skies of the region, North Carolina Land of Water (NC LOW) and A Time For Science (ATFS) designed a study to map and characterize the landscapes, soundscapes, and viewscapes of the OAP across four eastern NC counties. The study is led by Dr. Stanley Riggs, Coastal and Marine Geologist at NC LOW and lead investigator in this Night-Scape resource project. Ms. Karen Clough is the Community Outreach Coordinator for NC LOW, Ms. Emily Jarvis is Executive Director of ATFS, and Mr. Brian Baker is Director of Astronomy with ATFS. The project has a working partnership with Dr. Reide Corbett, Oceanographer and Executive Director of the ECU Coastal Studies Institute (CSI). Also, three groups of local volunteers constitute the field mapping teams obtaining night time observations in Tyrrell, Washington, and mainland Dare and Hyde counties. The project also has developed working partnerships with the US Fish and Wildlife Service (Alligator River, Pocosin Lakes, Mattamuskeet, and Swanquarter Wildlife Refuges), the NC Wildlife Resources Commission, and NC State Parks.

NC LOW and ATFS are non-governmental 501 c 3 organizations involved in regional coastal research and science education initiatives in the northeastern NC. The mission of these non-profit programs is to contribute to 1) scientific understanding of the dynamic coastal system, 2) delineate potential sustainable eco-tourism opportunities, and 3) carry out regional K-12 and public science education programs within the coastal region. All of their programs are framed around the unique natural resources and rich cultural history of NC's world-class coastal system and utilized to enhance the quality of life of its residents.

OUTER ALBEMARLE PENINSULA (OAP)

Project Goals

1. What are the night-scape resources for the nocturnal environment and the night sky within the vast public lands of the OAP?
2. How can the OAP region decrease the present levels of light pollution and prevent further light pollution in order to maintain a world-class, dark sky natural resource?
3. How can regional night-scape resource programs be incorporated into a) the developing OAP eco-tourism trail system, b) local K-12 school systems, and c) programs for the public?

The night-scape survey teams are comprised of scientists, educators, and students that live and work in the coastal region. Through their combined effort, starting in July 2018 through May of 2019, the teams have surveyed their county on 11 new and 11 full moon nights and accomplished the following night-scape data collection (Figure 4): Mainland Dare: 97 visits to 22 sites; Mainland Hyde: 67 visits to 27 sites; Tyrrell: 54 visits to 22 sites; Washington: 32 visits to 12 sites; TOTAL = 250 VISITS TO 83 SITES. In addition to describing the surrounding environment, accessibility, and apparent urban noise and light pollution at each site through the four seasons, researchers measure quality of the sky darkness, ambient sound, and meteorological parameters.

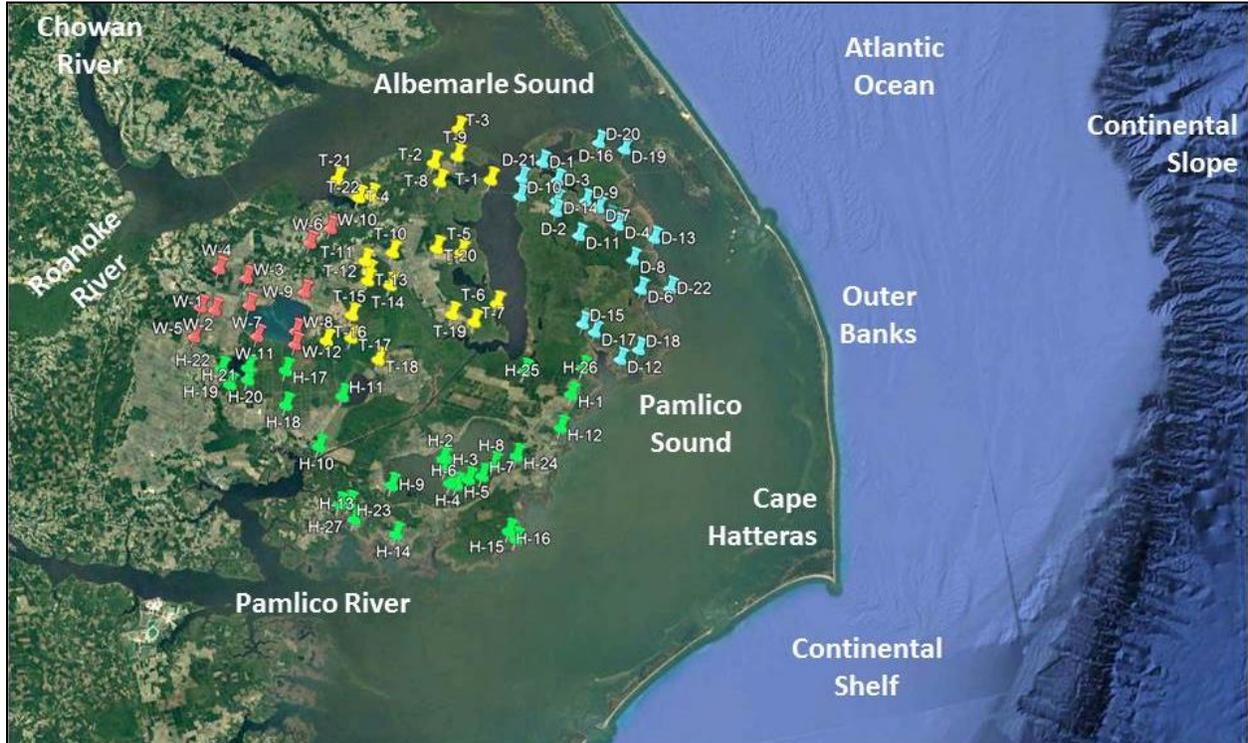


FIGURE 4. A Google Earth image shows the outer Coastal Plain and Continental Margin of northeastern North Carolina. The pins represent the night-scape survey sites on the Outer Albemarle Peninsula: blue pins = mainland Dare County, green pins = mainland Hyde County, yellow pins = Tyrrell County, and red pins = Washington County.

The data from these surveys was used to quantify and map the general night-scape and light pollution in the OAP. This knowledge will help shape plans to protect our unique Night-scape resource, responsibly incorporate the resource into ongoing eco-tourism programs, and potentially enable the OAP to earn regional designation as an “International Dark Sky Place.” The Dark Sky Place title—and accompanying backing of the International Dark Sky Association—helps enhance the visibility of the regional dark sky resource and foster eco-tourism and sustainable economic activity in the OAP.

ATFS, NC LOW, and CSI hosted public **STAR PARTIES** sponsored by the Night-Scape project. The first Star Party was on Tuesday February 5th from 6:00 pm to 9:00 pm at Jennette's Pier in Nags Head, NC with about 500 participants. The second Star Party was on Thursday March 7th from 6:30 pm to 9:00 pm at the Middle School in Windsor, Bertie County, NC with about 300 school participants. The Bertie Star Party followed a two-day science teacher workshop on "Human Time and Geologic Time" that included a major component on the dynamics of our solar system. Each program included the portable planetarium in a large room with 4 project tables around the perimeter that each had a different astronomy related, hands on projects supported by a volunteer teacher. Outside a series of large telescopes were monitored by volunteer astronomers to guide the night sky observations and discussions. Each half hour planetarium program included a 15 minute presentation on light pollution and a 15 minute presentation on our present night sky. The third Star Party on April 13 from 7:00 pm to 9:30 pm at the Pettigrew State Park Visitor's Center in Creswell, NC was totally weathered out. This latter program was to be part of the NC Science Festival's Statewide Star Party. All programs were free and open to the public with a major portion of the participants being K-12 students.

Night-Scape Resource

"North Carolina Land of Water" (NC LOW is a 501 (c) 3 non-profit organization) has developed two relevant programs. First is the "Scuppernong Trail System of Pocosins, Carolina Bays, and Black-Water Streams" (Riggs et al, 2016). The goal of this trail system is to define the natural and cultural resources as the basis for implementing an economically viable trail system within the underserved counties of the OAP. Second is a program for earth and environmental science teachers within the K-12 schools of the OAP counties. The goals of both the NC LOW trails (e.g., paddle, hiking, biking, and vehicle trails) for the past three years and the earth and environmental science teacher education programs for the past year, have focused totally on the potential day-time activities within the more than 758 mi² of public lands and associated 2,900 mi² of public water bodies, and 163 mi² of additional National Seashores and Wildlife Refuges (Figure 5). The night-scape represents an equally important component that has not been previously addressed, but has tremendous potential with enthusiastic young students, general public, and agency interest. Partnering with the 501 (c) 3 non-profit organization **"A Time For Science"** (ATFS) brings their night sky astronomy expertise and science education skills to the OAP.

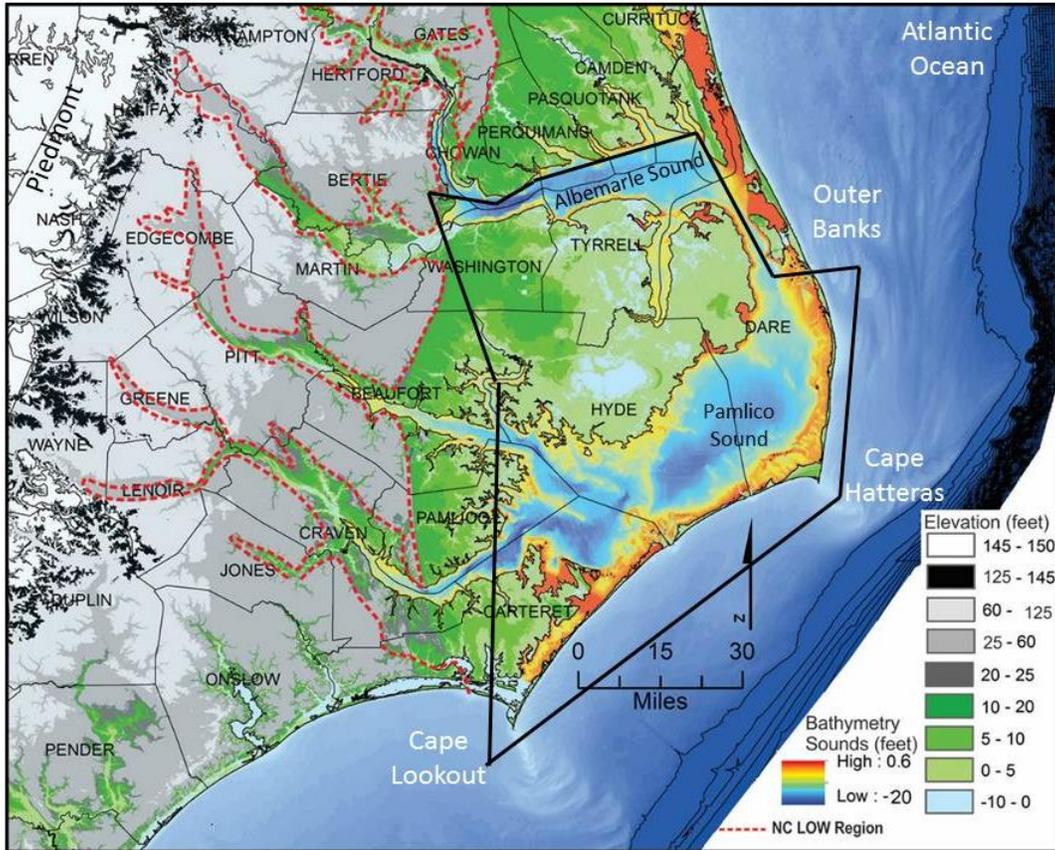


FIGURE 5. Color topography map shows the North Carolina Land of Water (NC LOW) of northeastern North Carolina’s coastal system east of the red dashed line. The Outer Albemarle Peninsula study outlined in a black hexagon includes major portions of Washington, all of Tyrrell and mainland Hyde-Dare counties that are surrounded by the vast areas of the Albemarle Sound to the north, Croatan Sound to the northeast, and the Pamlico Sound to the southeast and south. The Outer Bank, south of Roanoke Island include the Cape Hatteras and Cape Lookout National Seashores are included as critical parts of North Carolina’s dark sky resource.

The night skies within most of the OAP are among the darkest in the entire US Atlantic coastal system. The Albemarle Peninsula is surrounded by four large estuarine water bodies (Figure 5): Albemarle Sound on the north, Croatan and Pamlico sounds on the east and southeast, and Pamlico River Estuary on the southwest. The OAP region consists of Tyrrell, Washington, and mainland Dare-Hyde counties with Columbia, Creswell, Manns Harbor, and Swan Quarter being the largest towns with a total population of about 6,190 in 2010 (~19% of total population) and declining. These towns are located around the outer perimeter of the Peninsula on the highway 64-264-45 corridor (Figure 6). However, most of the population lives in very small, rural crossroads communities (e.g., Goat Neck, Cherry, Kilkenny, East Lake, Stumpy Point, Engelhard, Fairfield, Alligator, Gum Neck, New Holland, etc.). The largest industry is agriculture with vast farm and timber lands along with a small, but growing tourist industry. Four large National Wildlife Refuges occur within the region (Alligator River, Pocosin Lakes, Mattamuskeet, and Swanquarter), vast acreages of NC Wildlife Resources Commission

game lands; a state park (Pettigrew), historic site (Somerset Place), and coastal preserve (Buckridge); and private conservation lands. Thus, over 485,134 acres (758 mi²) of public ecosystems occur within the OAP and contain a unique, complex system of nocturnal environments and associated night skies (Table 1).

TABLE 1.

<u>PUBLIC LANDS: OUTER ALBEMARLE PENINSULA (OAP)</u>	<u>ACRES</u>
1. US National Wildlife Refuges	
A. Alligator River NWR (Dare Co.)	154,453
B. Mattamuskeet (Hyde Co.)	50,174
C. Pocosin Lakes (Tyrrell & Washington Co.)	110,107
D. Swanquarter (Hyde Co.)	16,411
2. NC Wildlife Resources Commission Game Lands	
A. Alligator River (Tyrrell Co.)	14,178
B. US Navy Bombing Range (Dare Co.)	46,055
C. Gull Rock (Tyrrell & Hyde Co.)	28,600
D. Futch (Tyrrell Co.)	600
E. Lantern (Tyrrell Co.)	1,831
F. New Lake (Tyrrell Co.)	1,438
G. Pungo River (Hyde Co.)	472
H. Texas Plantation (Tyrrell Co.)	1,502
I. Van Swamp (Washington Co.)	5,505
4. NC State Parks and Historic Sites	
A. Pettigrew State Park (Tyrrell & Washington Co.)	17,800
B. Somerset Place (Tyrrell Co.)	38
5. NC Coastal Reserve etc.	
A. Buckridge Preserve (Tyrrell Co.)	27,111
6. Conservation Fund	
A. Palmetto Pear-Tree Preserve (Tyrrell Co.)	10,297
7. NC DOT & NC WRC boat ramps, etc.	?
8. The Nature Conservancy & NC Coastal Land Trust	?
9. Miscellaneous Town & County properties	?
TOTAL OAP PUBLIC LAND =	+485,134 ACRES (758 mi²)

PUBLIC BUFFER ZONE WATER+LAND

1. Estuarine Water Bodies (Albemarle, Croatan, & Pamlico Sounds)	1,856,000
2. Cape Hatteras National Seashore (Dare & Hyde Co.)	30,351
3. Pea Island National Wildlife Refuge (Dare Co.)	31,534
4. Cape Lookout National Seashore (Carteret Co.)	28,243
5. Cedar Island National Wildlife Refuge (Carteret Co.)	14,480
TOTAL PUBLIC BUFFER ZONE WATER+LAND =	+1,960,608 ACRES (3,063 mi²)

TOTAL AREA OF PUBLIC NIGHT-SCAPE = 2,445,742 ACRES (3,821 mi²)

The dark-sky survey has generated a detailed map showing three zones of darkness in the OAP region. The primary core, the darkest sky, is the area inside the red highway line on Figure 6. The red highway line represents the secondary ring around the core and contains most of the small villages with widely scattered spots of small light pollution. The third zone surrounds the entire OAP region and is the coastal margin outside the red highway line adjacent to the very large and dark estuarine water bodies (Figure 6). This map outlines the following: 1) defines the possible OAP region that could become the basis for requesting an International Dark Sky Reserve designation, 2) provides a basis for selecting the most ideal viewing sites for promoting the dark sky and nocturnal environment component of a sustainable eco-tourism trail program, 3) produces a baseline to be used for tracking changes in light pollution in the region going forward, and 4) offers an opportunity for developing public and K-12 educational programs. The over-arching goal of this study is to delineate the nocturnal environment and night sky resources and expand the night-scape capabilities for developing educational and sustainable eco-tourism programs in the underserved counties of the OAP and adjoining coastal regions. If successful, it would bring national and international attention to the natural resources and eco-tourism potential of NC's Inner Banks.

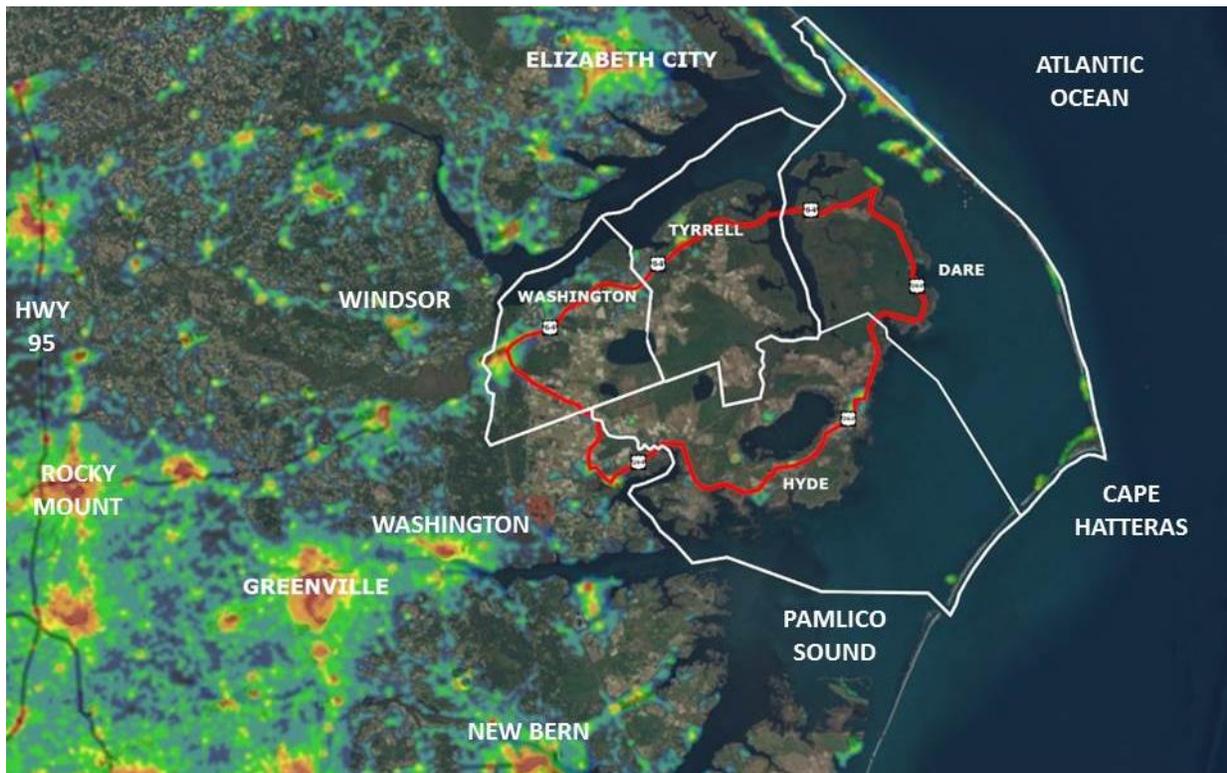


FIGURE 6. A light pollution map shows the four counties of the OAP along with the trace of Highways 64, 264, and 45 (in red) that form a ring around the heart of the dark sky landscape and harbor most of the small villages on the OAP. Seaward of the highway is a coastal rim that also has very dark skies overlooking the estuarine water bodies to the north, east, south, along with vast agricultural fields to the west. Map is modified from Falchi, Fabio, et al. 2016.

The Outer Albemarle Peninsula has an incredible night-scape resource for the following reasons (Figures 5 and 6). 1) The vast area of public wetlands are surrounded by the expansive estuarine system, all of which have minimal human activity. 2) The “Big Night Sky” presents an ideal astronomical wonderland that is generally becoming an endangered environment in the east due to ever increasing light pollution. 3) The 360° horizon vistas provide incredible views of sun rises and sets, moon rises and sets, thunderheads and lightning shows, and glorious zenith and structure of the milky-way. 4) The hot, humid drone of the spring to fall nocturnal soundscape with dramatic, and the cacophony of the winter waterfowl overflights. And 5) the broad open viewscapes provide a pallet for the playmakers of the sky, the clouds, to display an infinite array of forms, patterns, textures, colors, particularly during sun and moon rises and sets.

Sky Quality Meter (SQM-L) readings on the nights of the monthly new moons indicate night sky glow in the survey area ranges between 21.24 to 21.81 mag/arcsec² (Figure 7). Under the International Dark Sky Association (IDA) guidelines for Dark Sky Parks the majority of the OAP falls within a silver rating (21.0 to 21.75 mag/arcsec²) and on cloudless nights many sites have a gold rated dark sky (>21.75 mag/arcsec²). Night sky quality was consistent over the survey duration with location being the primary factor determining SQM-L readings. Numerous sites in the National Wildlife Refuges, State Parks, Wildlife Resources Commission, and Department of Transportation properties have suitable public access with great nightscape viewing.



FIGURE 7. Night sky quality results were taken at each site during the new moon nights. The best readings for each survey date are displayed in the figure. The plot shows the International Dark Sky Association (IDA) designations for night sky quality: Gold (>21.75 = natural, non-polluted, or near natural night), Silver (21.74 to 21.00 = minor light pollution, but still display exemplary night-scapes), and Bronze (20.99 to 20.00 = offering people, fauna, and flora a respite from otherwise degraded nocturnal environments). The OAP falls comfortably within a silver rating, with frequent gold rated dark skies in the core region of the OAP.

The red highway line that borders the core of the OAP in Figure 6 consists of highways 64, 264, and 45 and contains most of the OAP villages. A night sky quality transect was run on a new moon night along highway 64 from west to east through the town of Columbia. The

transect (Figure 8) demonstrates how the high quality dark sky deteriorates from high quality (21 to 22 mag/arc² units) to severe low quality (15 to 20 mag/arc² units) due to light pollution within and adjacent to the town. Figure 9 demonstrates that all 81 of the survey sites within the OAP possess an exceptional or distinguished quality of starry nights and nocturnal environments. The reason there are not more sites that have gold designation is due to 1) the remotest areas of the OAP are low swamplands not accessible by road, 2) some sites are adjacent to one of the major highways but due have minor night traffic, 3) are in close proximity to an individual dwelling, and 4) are located at public boat ramps with minor security lighting.

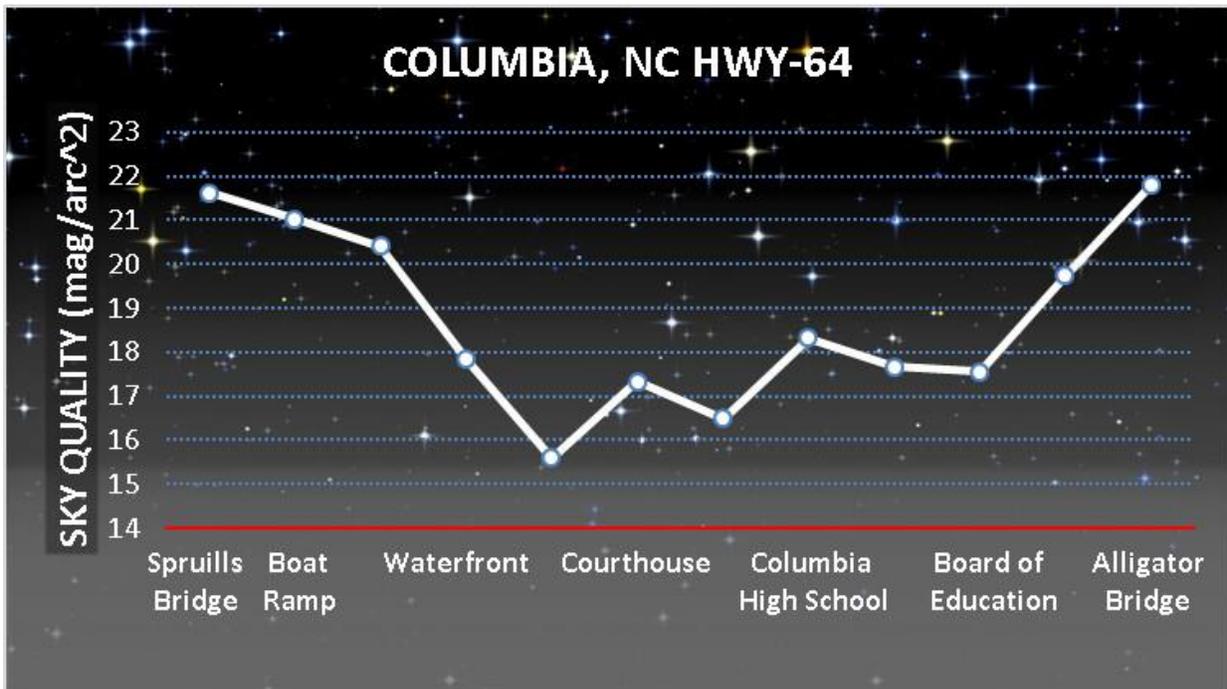


FIGURE 8. Plot shows the change from really dark skies (21 to 22 sky quality units) on both the east and west sides of Columbia with highly variable and major light pollution (15 to 20 sky quality units) within the town limits. The eastern most site is at Futch Gamelands in Alligator and the western most site is Spruill's Bridge in Creswell. The town of Columbia extends from the Tyrrell Co. Board of Education to the town waterfront on the Scuppernon River.

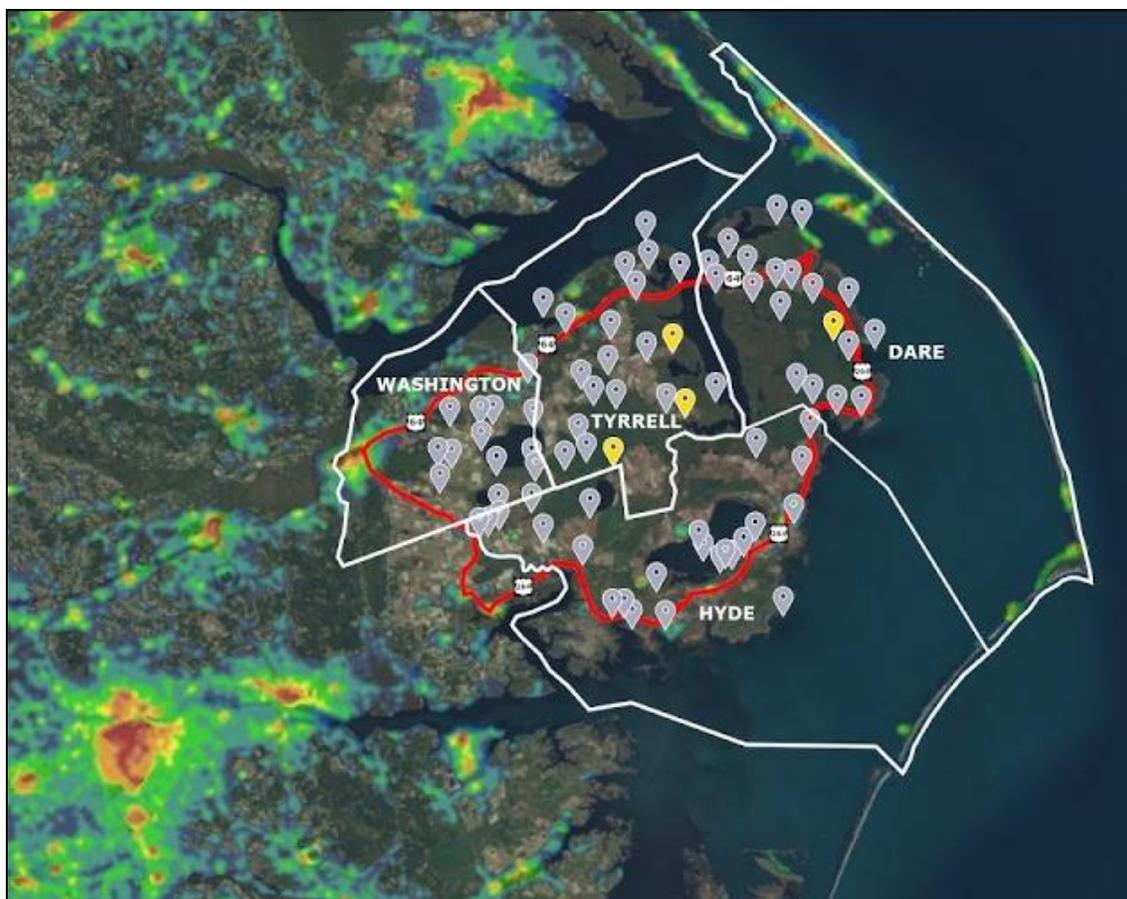


FIGURE 9. Light pollution map of the Outer Albemarle Peninsula study area with the four county boundaries outlined in white. The red line represents highways 64, 264, and 45 that ring the core of the prime night-scape resource area. The pins represent the 81 nightscape study sites none of which are in the villages. The four gold colored pins had night sky quality readings that averaged in the IDSR gold bracket for the new moon surveys and all other survey sites averaged in the silver bracket. The map is modified from Falchi, Fabio, et al. 2016.

An International Dark Sky Reserve (IDSR) (<http://www.darksky.org/idsp/become-a-dark-sky-place/>) requires “a public or private land area of substantial size (270 mi² or 173,000 acres) possessing an exceptional or distinguished quality of starry nights and nocturnal environment and is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment.” The OAP has almost three times this much public land that is protected for its wildness with almost no urban component. This is a world-class natural resource available for developing “resilient communities and economies” in the poorest and truly-rural coastal region in NC. Success of this project will supply the following: 1) development of an adequate data base, 2) set in motion a local interest support system, and 3) lay the groundwork for OAP organizations and communities to develop a plan for obtaining an “International Dark Sky Reserve” designation by the IDA (the first US reserve was established in 2017 in Idaho and a second reserve in Utah in 2018).

OAP NIGHT SKY ENVIRONMENT

The Sun (Figures 10 and 11)

The best known star is the Earth's Sun. However, it is not a particularly hot or big star; just an average star. All other stars in the night sky are just like the Sun. What makes the Sun remarkable compared to all the thousands of other suns in the dark sky is that it is our Sun that is a mere 100 million miles away. The solar energy from this nearby Sun is what makes Earth a habitable planet.

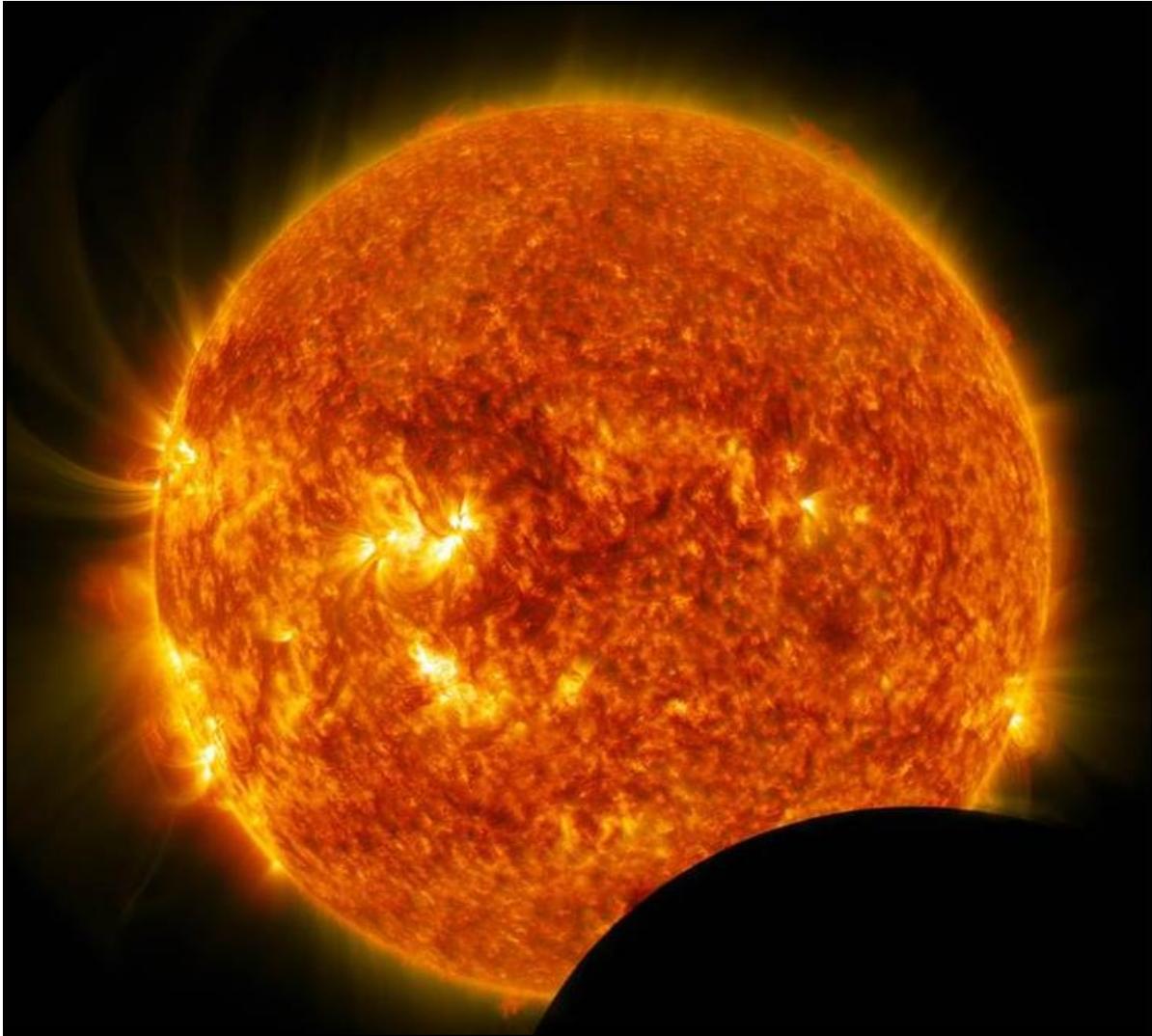


FIGURE 10. On July 26, 2014 the moon crossed between NASA's Solar Dynamics Observatory (SDO) and the sun, a phenomenon called a lunar transit that happens approximately twice a year, causing a partial solar eclipse. The eclipse shows the sun's surface mottled with a series of sun spots (dark spots) and solar flares that eject electromagnetic radiation outward throughout the Solar System. Image is from NASA/SDO.

The sun is located at the center of the Solar System, 93 million miles from the Earth. It is a sphere of hot plasma that generates a magnetic field that streams outward into the Solar System as solar wind. The sun is a ball of gas consisting of 91% hydrogen and 8.9% helium held together by gravitational attraction and creating extreme temperatures in the core (27 million degrees F) that causes thermonuclear fusion (hydrogen fuses into helium and releases extreme amounts of energy). This process is the source of all the heat and light emitted by the sun. The electric currents generate a magnetic field that flows through the Solar System by a stream of electrically charged gas (solar winds). The sun's activity is generally fairly gentle, but changes about every 11 years when the poles change their magnetic polarity. When this happens the sun becomes violently active with solar storms (sunspots, solar flares, and coronal mass ejections; Figure 11) releasing huge amounts of energy that can harm satellites and power grids and cause spectacular auroras on Earth.



FIGURE 11. Photograph shows a violently solar storm episode on the Sun's surface. Notice the solar flare, sun spots, and coronal mass ejection. Photograph of a long filament erupting from the sun is by NASA's Dynamics Observatory on 8-31-2012.

The Moon (Figure 12)

The Moon is a companion to and orbits the Earth similarly to the Earth's orbit around the Sun. As the Moon orbits Earth, we see different amounts of its day side through time producing the different phases of the Moon's appearance. With each day that goes by in a month the Moon waxes from a thin crescent at dusk, to a brilliant full Moon in opposition to the Sun, and then wanes to a thin crescent in the dawn. The Moon rises and sets at specific times of day and night depending on these phases.



FIGURE 12. The Earth's full moon, our closest neighbor in the night sky, was photographed by NASA's Lunar Reconnaissance Orbiter on 10-7-2018.

For some the Moon is never more stunning than when it is glimpsed as a crescent accompanying a bright planet in the glow of twilight, others are captivated by a dimly lit landscape during a full Moon. The Moon can create many different and incredible nightscapes to gaze upon. However, there is a need to avoid the moon for the best stargazing which happens during the new Moon. From Earth's perspective, the new Moon occurs when the moon is positioned closest to the Sun, so it rises and sets with the Sun. The richness of the night sky opens up in the absence of the Moon's brilliant glow. A clear moonless night allows you to see more stars and more of the night sky's obscure deep space treasures.

Eclipses (Figure 13)

Occasionally the Moon will fall into alignment with the Earth and Sun, resulting in a visually stunning phenomenon in the sky. This can happen in two ways, depending on whether the Earth or the Moon is in the middle of the alignment. A solar eclipse occurs when the Moon passes directly in between the Earth and Sun. The shadow of the Moon passes over a small part of the Earth's surface, causing day to turn to night along the shadow's path. A lunar eclipse occurs when the Earth is positioned in between the Sun and Moon, resulting in the Moon being completely shrouded by the Earth's shadow. Sun light passing through the Earth's atmosphere is bent in towards the Moon turning it a crimson color.



FIGURE 13. Full Moon Eclipse of Feb 20, 2019 with a Cannon 6D w/EF 70-300mm f/4-5.6L w tripod in Brook Valley, Greenville, NC. The first image on left was taken at 12:26 AM (full eclipse) and the last exposure on the right was taken at 12:50 AM. Photograph is by P. Gemperline.

The Planets (Figures 14 and 15)

Planets are always a prime target for stargazers. Imagine looking skyward on a dark moonless night. You see hundreds of points of light shimmering in the sky. Each point has a particular brightness and color, but not everyone is a star. To the naked eye Planets look like stars. Usually Planets are brighter and bigger than the other stars that are around them. Unfortunately, they are moving targets, so figuring out when and where to spot them requires some background information or experience. Once found they can offer a deeply rich and satisfying observational experience, that is if you are looking at the right one at the right time.

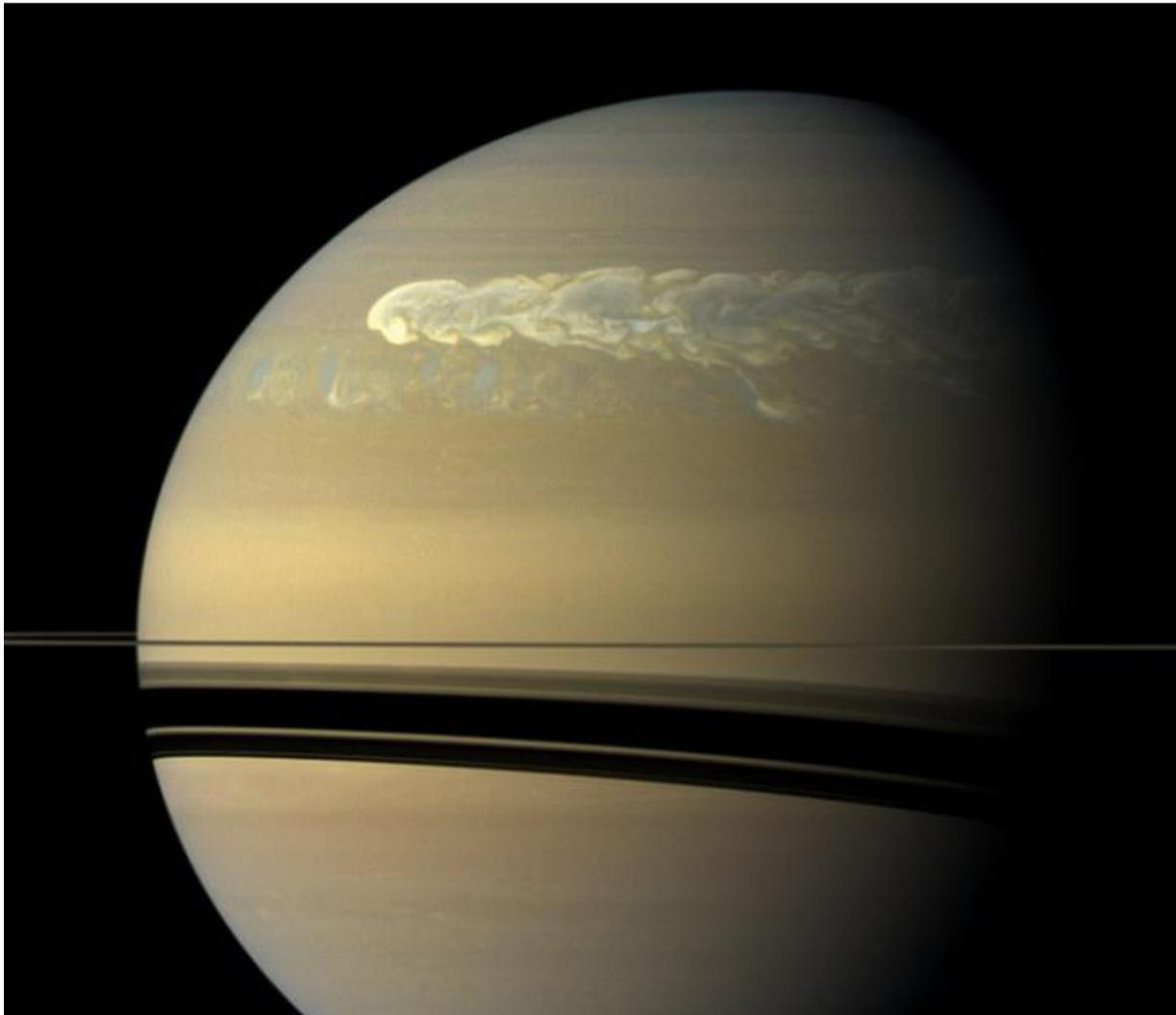


FIGURE 14. Image shows a great white spot, a series of medium sized storms in a sequence, churning through the atmosphere in Saturn's northern hemisphere. This is a true-color view from NASA's Cassini spacecraft. Image was created by JPL-Caltech/Space Science Institute.

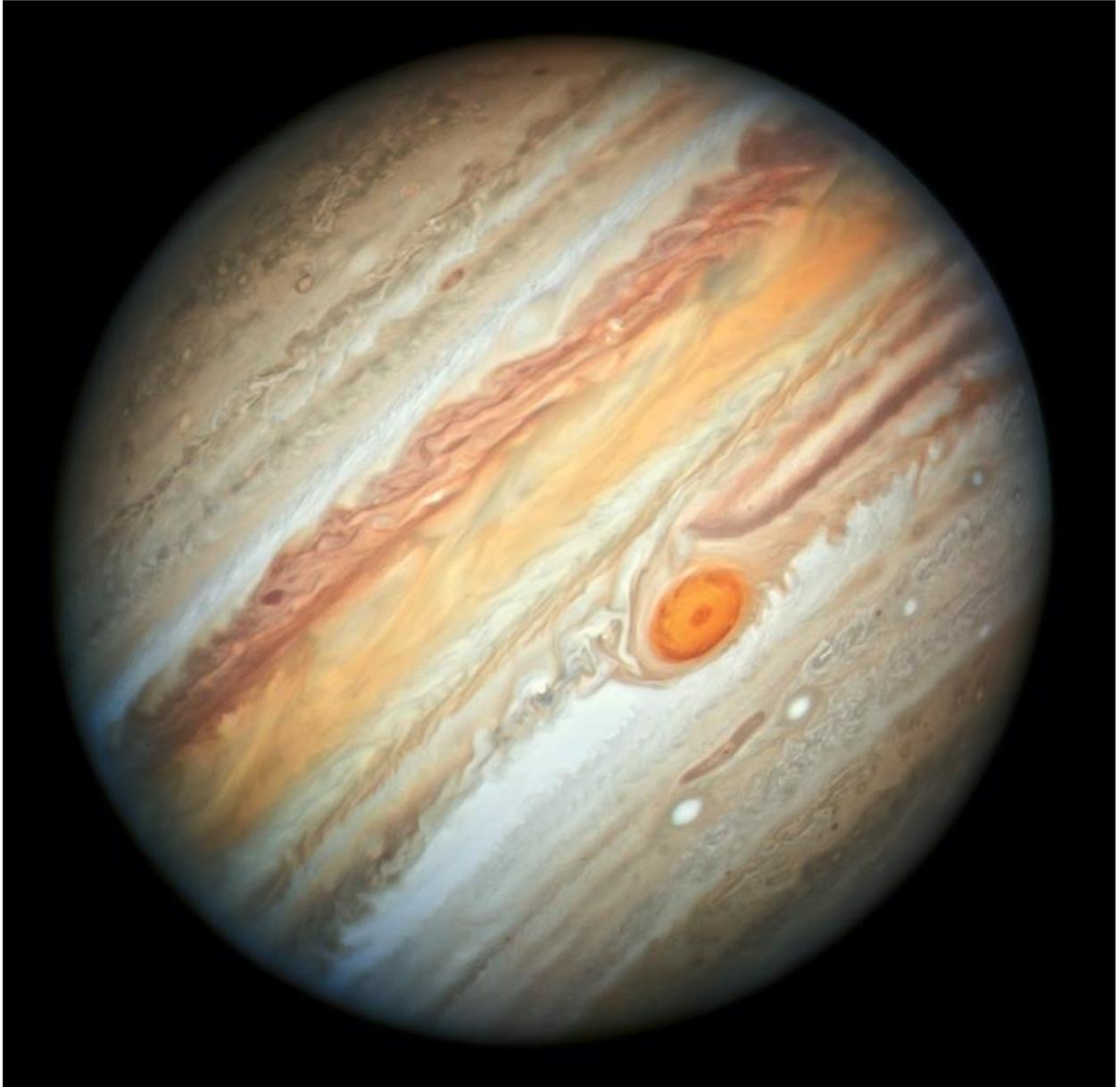


FIGURE 15. A Hubble Space Telescope view of Planet Jupiter taken on 6-27-2019 reveals the giant planet's Great Red Spot and intense pattern of clouds swirling in Jupiter's turbulent atmosphere. Image is from NASA, ESA, A. Simon (Goddard Space Flight Center) and M. Wong (University of California, Berkeley).

The planets are constantly in motion. Sometimes they are close to the Earth, other times far away. No matter where they are in our sky, the planets will be found in a particular set of constellations called the Zodiacs. The Zodiac constellations line a path through the sky that the Sun and Planets follow called the ecliptic.

The best time to view any given Planet is when it is at “opposition”, meaning that the Earth is directly in-between the Planet and Sun. From our perspective on Earth a planet in opposition will rise in the east as the Sun sets in the west. They are on opposite sides of our sky because the Earth is in the middle. After waiting approximately 3 or 4 hours after sunset, you will have the clearest and sharpest view of the Planet.

Not all planets are equally stunning to observe. Jupiter and Saturn are sure to impress anyone who lays eyes on them. Venus and Mercury can be seen waxing and waning with phases just like the Moon. However, with the remaining Planets some perspective might be in order to ensure the observer understands what they are about to witness. When doing amateur astronomy, it is equally important to observe with your mind as it is to observe with your eyes. A little background information and context can turn an underwhelming dot into a distant world just waiting to be explored.

Meteor Showers (Figure 16)

Meteor showers are one of the most well know and anticipated celestial events by the general public. Meteor showers re-occur yearly and produce high rates of “shooting stars”. Two of the most consistent and dramatic meteor showers are the Perseids in mid-August and the Geminids in mid-December. A meteor shower results from the Earth plowing through the debris of a comet. For example, when Halley’s Comet passed through the inner solar system in 1986 it left behind a trail of particles that littered Earth’s orbit in two places creating the Orionids and Eta Aquariids meteor showers.



FIGURE 16. Photograph shows the Eta Aquarids meteor shower and the Milky Way. Photograph is by Li Gang on 5-8-2019.

How a person experiences a meteor shower depends on how dark the night sky is. Light pollution from nearby towns, shopping centers, or streetlights will severely diminish the number of meteors that can be seen. However, there is no greater threat to meteor shower observations than a big moon in the sky. If one is in the middle of the ocean for a meteor shower, the brightness of a full moon would prevent seeing a single “shooting star”.

Ultimately, the best way to view a meteor shower is to lean back in a chair or lay down and look up. You also want a nice big sky with few obstructions like trees or buildings. The goal is to look at as much of the sky as possible. By lying down and looking straight up you are not limited to looking in only one direction and you will increase your chances of seeing more meteors. Telescopes or binoculars are not needed.

Deep Space Objects (Figure 17)

True wonders of the night sky lay far beyond our solar system, deep into the vast expanses of space. Our eyes are not capable of viewing these distant and faint objects, but with the light collecting power of telescopes, they can be unveiled. Among the countless features that reveal the evolution of our universe are nebulae (immense clouds of interstellar gas and dust), supernova remnants (exploded remains of massive stars), and galaxies (the largest star collections in the universe).

The darker the sky and bigger your telescope, the better view you will have of these “faint fuzzies”. The deep space objects represent another example where the importance of observing is not only with your eyes, but with your mind. The implications related to each photon released by one of these objects is profound, and understanding where, when, and how, will allow you to marvel at each photon that strikes your eye.



FIGURE 17. Photograph of deep space nebula (immense clouds of interstellar gas and dust) that is located within the Orion Deep Field. Photograph is by R. Gendler in 2004.

There are many catalogues and surveys of deep space objects. The two most commonly used are the Messier Catalogue: 110 of the brightest objects, and the New General Catalogue: featuring 7,840 objects. Both catalogues are used to guide amateur astronomers to various nebulas, star clusters, and galaxies in the night sky. It is often an entry point for ambitious astronomy enthusiasts to document the observation of the 110 Messier objects.

Constellations (Figure 18)

Constellations are shapes and patterns created by a group of stars in the night sky. Every culture around the world has their own unique way of interpreting the stars, and each individual can determine their own understanding of the night sky. This gives way to infinite constellations with our imagination being the only limit. However, the International Astronomical Society designates 88 official constellations that draw primarily from western Greek culture and depict heroes, creatures, and objects.

As the Earth orbits the Sun, we see different parts of our Milky Way galaxy giving us different constellations to observe over the course of a year. The constellations are broken up into four seasonal groups. During a single night you can see three seasons of constellations. For example, during autumn the summer constellations are visible during the first few hours after sunset, autumn constellations are visible all night long, and winter constellations are visible for a few hours before sun rise. Each group of constellations has its own unique characteristics and produces distinctive viewing experiences.

The winter constellations are known for very bright stars and deep space objects. The most prominent winter constellations are Orion, Canis Major, Gemini, and Taurus. The spring constellations lay in the realm of the galaxies. During spring we look up and out of the Milky Way Galaxy and into intergalactic space, where we observe thousands of other galaxies. Leo, Boötes, and the Big Dipper are among the dominant constellations during spring. Summer constellations hold the center of our galaxy and a treasure trove of deep space objects. It is truly the most impressive part of the sky to view under exceptionally dark conditions. Look for Scorpius, Lyra, Cygnus, and Sagittarius in the summer skies. The autumn constellations lack bright stars, but do contain our largest galactic companions, the Andromeda and Triangulum galaxies. Notable autumn constellations are Pegasus, Cassiopeia, and Pisces.



FIGURE 18. Photograph shows the constellation Orion, a hunter in Greek mythology, during a late fall night sky. The brightest star is Betelgeuse, a red supergiant star that forms the right shoulder as he faces the observer. The second brightest star in Orion is Rigel, a blue-white supergiant that forms the left foot. Photograph is by Pixabay on 11-12-2017.

The Milky Way (Figure 19)

The most visually stunning component of a truly dark, summer night sky is the center of our own galaxy, which stretches across the sky like a massive cloud of stars. The Milky Way is the collective star-light from thousands of stars, each too far away and faint to be individually seen by the human eye. Sweeping through the Milky Way with a telescope reveals a starry wonderland, and a window deep into the center of our galaxy. A trail of darkness composed of interstellar gas and dust constitutes the galaxy's spiral arm as it cuts through the starry cloud. Within this starry cloud is a treasure trove of nebulae and star clusters—a star-gazer's playground.



FIGURE 19. Photograph shows the summertime view of the Milky Way galaxy where the Solar System is located. Photograph is by Brunier in 6-8-2005.

The Milky Way is also on display in the winter skies as it stretches through the constellations of Cepheus, Cassiopeia, Perseus, Auriga, and Puppis. However, during the winter months we look towards the outer edge of the galactic disk. Though it is not as rich and obvious as its summertime counterpart it still offers a starry wonderland worthy exploration.

The Human Component (Figure 20)

The International Space Station (ISS) is a colossal structure flying nearly 248 miles above Earth. It orbits the Earth every 90 minutes at an astonishing speed of about 17,500 mph. The ISS was designed to be a laboratory, observatory, and factory while providing transportation, maintenance, and a low Earth orbit staging base for possible future missions to the Moon, Mars, and asteroids.



FIGURE 20. The fully complete International Space Station as it appeared over the Earth on October 2018. Photograph is by NASA.

The ISS is visible to the naked eye as a slow-moving, bright white dot in the dark night sky. The ISS takes about 10 minutes to pass from the eastern horizon to the western horizon and is only visible part of the time because it moves into or out of the Earth's shadow. Tools are provided by a number of websites such as Heavens-Above.com as well as smartphone applications that use orbital data and the observer's longitude and latitude to indicate when the ISS is visible.

Satellites and the Wallops Flight Facility (Figure 21)

The NASA Wallops Flight Facility is a rocket launch site on the eastern shore of Virginia. The site includes the Mid-Atlantic Regional Spaceport, which can send off interplanetary and International Space Station missions. These rocket launches can be viewed from regions across Eastern North Carolina. Night launches offer the best opportunity to observe a launch. Launch schedules can be found at nasa.gov/centers/wallops/home as well as through the Wallops Mission Status Center Launch App for smart devices.



FIGURE 21. Launch of an Antares A-One space ship at Wallop's Island Flight Facility, VA on April 22, 2013.

OAP NOCTURNAL ENVIRONMENT



FIGURE 22. One can appreciate the beauty of the high level cirrus clouds in the night sky if the star-gazing is limited by these clouds.

Clouds In The Night-Scape

People are programed to think of clouds as characteristics of the day-time sky, but clouds are equally varied and abundant in the night sky. They play a critical role in the beauty and pattern of sun and moon rises and sets, night lightning shows, darkness of the night sky, and the ability to see the astronomical wonderlands. Warm air contains water vapor that rises skyward and cools causing water vapor to turn into tiny water droplets or ice crystals. As more air cools down, more droplets form and eventually a cloud develops. The World Meteorological Organization produced the International Cloud Atlas (2017) with four genera (underlined) and many variant species of clouds that form in the atmosphere and are generally described by their elevation of formation. A fifth category has been added that forms directly in response to human activity.

1. High Level or Cirrus Clouds (Figures 22 and 23): High level clouds form above 20,000 feet where the air is cold, consist mostly of ice crystals, and usually have the prefix "cirro" or "cirrus" in their name (cirrus, cirrocumulus, cirrostratus).
2. Middle Level or Alto Clouds (Figure 23): Middle level clouds form between 6,500 and 20,000 feet, may consist of either water droplets or ice crystals, and usually have the word "alto" in their name (altocumulus, altostratus).
3. Low Level or Strato Clouds (Figures 24, 25, and 26): Low level clouds form below 6,500 feet, are composed mostly of water droplets, and usually have the word "stratus" in their name (stratus, stratocumulus, nimbostratus or "rain cloud").
4. Vertical or Cumulous Clouds (Figure 27): These clouds are dense and tall clouds that may span several cloud levels, and usually have the word "cumulus" in their name (cumulus, cumulonimbus or "thunderheads").
5. Human-Produced Clouds (Figure 28): Airplane condensation trails (contrails) are formed by burning petroleum fuels to produce energy for the plane to fly, plus CO₂ and H₂O are produced as exhaust. With time the upper atmospheric winds blow the contrails into various types of cirrus and altostratus clouds.



FIGURE 23. Left panel is a photograph of high level cirrus cloud and the right panel is of middle level alto clouds. Photographs are by S. Riggs.



FIGURE 24. Initial development of nimbostratus cloud banks (left panel) that soon develop into the big mushroom-shaped cumulonimbus thunderheads. Photographs are by S. Riggs.



FIGURE 25. Image of a cumulonimbus cloud developing in the late afternoon.. Photograph is by S. Riggs.



FIGURE 26. Photograph is of a fast moving and tumultuous frontal system of nimbostratus storm clouds (left panel) and a close-up of the turmoil within the storm cloud. Photographs are by S. Riggs.



FIGURE 27. Left panel is a low-level, rain producing nimbus storm cloud and the resulting rain squalls from the storm cloud. Photograph is by S. Riggs. Right panel is a spectacular night lightning show resulting from a cumulonimbus thunderhead. Photograph is from freeimages.com.



FIGURE 28. Photographs of high level, human formed contrails that with time get blown into high level cirrus clouds. Left panel is by S. Riggs and right panel is from freeimages.com.

Sun Sets and Moon Rises

If the late afternoon sky is partly cloudy and will interfere with star gazing, then there is a pretty good chance of being rewarded with a spectacular sunset drama. Find a western facing location that has a broad open view with low horizons, such as the many unique water bodies of the OAP, and wait for the show to begin. The introduction occurs when the sun is still above the horizon with a broken cloud field that is top lite grading downward to dark gray under-bellies (Figure 29A). As the sun approaches the horizon, lighting slowly shifts from above the clouds to even with the clouds (Figure 29B) and to the under-belly as the fire in the sky is ignited (Figure 29C). As the sun sinks over the waters of Albemarle Sound, the fire builds, filling the sky and brushing orange frosting on ripples in the water (Figure 29D). The sun is now gone and the orange fire in the sky grades into deep red and dark gray (Figure 29E). The sun set finale is a momentary blood red climax that quickly goes black as the dark sky of night settles in (Figure 29F). Now turn around to the east for the encore and watch the full moon rise above the horizon and play hide and seek through the scattered clouds (Figure 29G). All of photographs in Figures 29A through 29F are by S. Riggs.



FIGURE 29A.



FIGURE 29B.

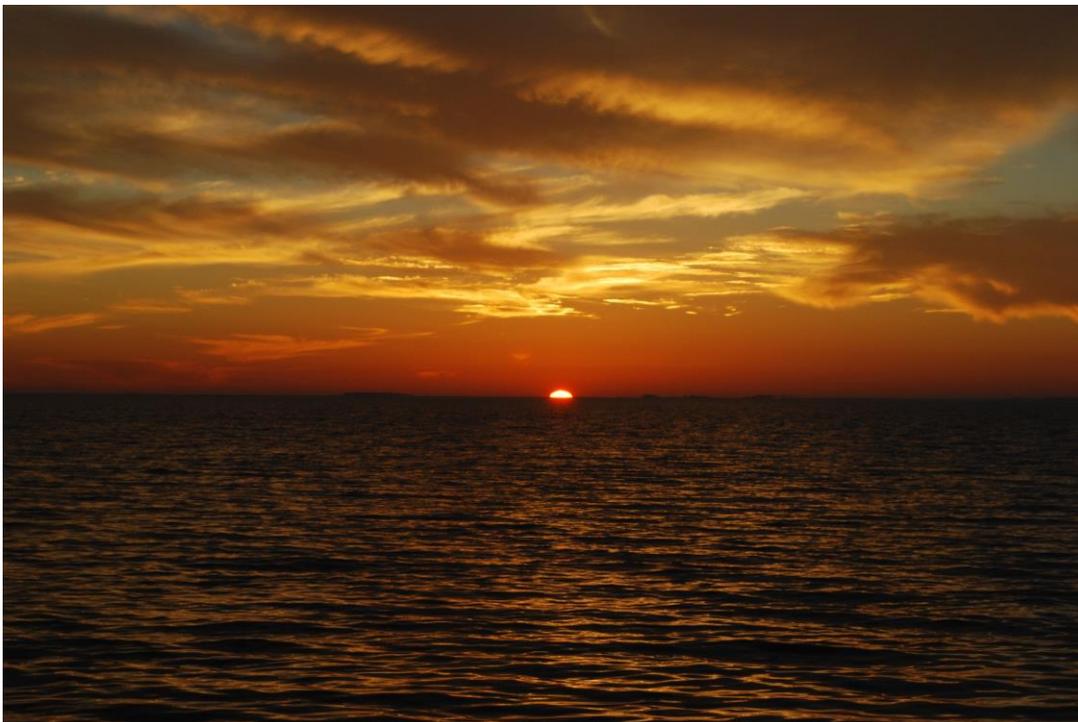


FIGURE 29C.



FIGURE 29D.



FIGURE 29E..



FIGURE 29G. Photograph is by J.G. Wang on 1-4-2015.

Geologic Resources

The story of the Outer Albemarle Peninsula is an environmental history of a small coastal system through approximately 125,000 years of climate change and landscape evolution. The cultural over-print on these landscapes and their ecosystems represent eleven millennia of human occupation. This OAP story is the natural and cultural history of a dynamic geologic landscape, a complex and highly diverse set of ecosystems, and the human groups who inhabited and modified this region that has always been characterized by dramatic environmental evolution.

The Albemarle-Pamlico coastal sounds are the drowned-river valleys of the Roanoke and Tar Rivers, respectively (Figure 5). A complex set of geologic landscape features comprise the OAP region that includes ancient ocean shorelines, riverine terraces, and a complex network of incised tributary streams and associated pocosin swamp forests. The spectacular black-water tributary streams transition upstream into a series of smaller tributary streams whose headwaters are in the elevated wetlands of perched upland pocosins (Native American name for a “swamp on a hill”). Unique fresh-water, Carolina Bay lakes are situated in the pocosins and on the high inter-stream divide between Albemarle Sound and the Pamlico River estuaries. Numerous small towns and villages are interspersed among vast areas of drained farmland, riverine wetlands and swamp forests.

Figure 30 is a map that shows the location of the A-A’ topographic profile across the North Carolina Coastal Plain as shown in Figure 31. The surface of the Lower Coastal Plain constitutes the Pamlico Terrace that is bounded on the west by the Suffolk Shoreline and on the east by the Outer Banks barrier islands. The Suffolk Shoreline represents sea level during the warm period of the previous interglacial high-stand about 125,000 to 75,000 years before present. To the east of the interglacial Suffolk Shoreline was a large shallow water, ocean embayment now known as the Pamlico Terrace and forms the Lower Coastal Plain.

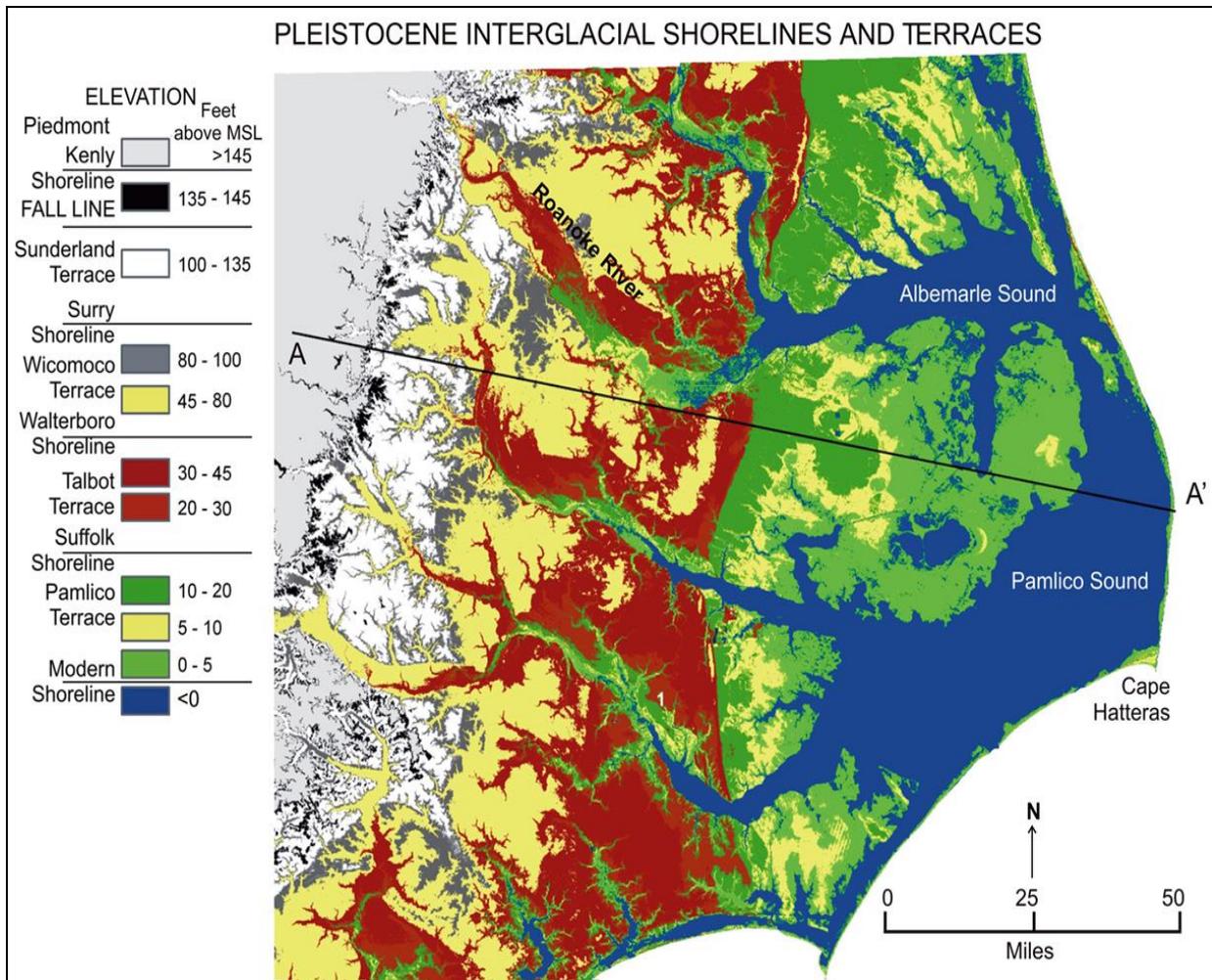


FIGURE 30. This color topography map shows the land elevation for northeastern North Carolina. The location above mean sea level of the Pleistocene interglacial ocean shorelines and associated terraces are color coded. Topographic profile A-A' shown in Figure 31 runs across the Coastal Plain from Rocky Mount (A) on the west to Rodanthe on the Outer Banks (A'). The gray zone is the Piedmont Province and the black zone is the Fall Line between the Piedmont (west) and Coastal Plain Province (east). Geologic data are from Farrell et al. (2013) and topographic map data are from the North Carolina DOT 2007 LiDAR.

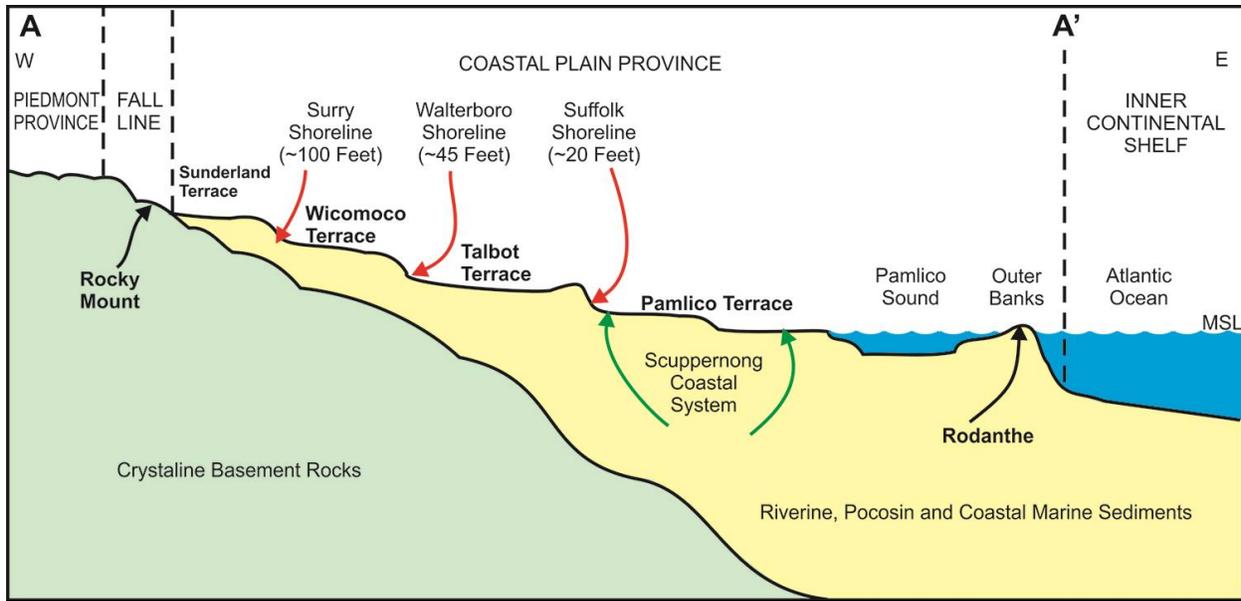


FIGURE 31. A schematic west to east cross-section drawn across the northeastern North Carolina Coastal Plain from Rocky Mount on the Fall Line, through the Albemarle-Pamlico Peninsula to Rodanthe on the Outer Banks (see Figure 30 for cross-section location). The Scuppernong-Alligator coastal system (green arrows) is shown as part of the Pamlico Terrace. Geologic data are from Farrell et al. (2013).

In summary, the OAP region occurs on the Pamlico Terrace of the Lower Coastal Plain as a low, flat plain that is close to and at sea level. It is dominated by swamp forests formed on top of marine clay-rich sediments deposited during the marine occupation of the Paleo-Suffolk Shoreline during the previous interglacial episode. During the subsequent last glacial maximum, tributary streams incised the flanks of the Albemarle-Pamlico interstream divide, which survived as a topographically high erosional remnant. As the climate warmed during the modern interglacial period, increased amounts of water were held on these low sloping, upland clay surfaces. A thick growth of shrub-scrub, swamp forest vegetation developed and produced abundant organic matter that accreted vertically. Thick peat soils accumulated to produce the geologically and ecologically different blackland soils than the peat deposits that formed in riverine valley floodplains or sea level dependent estuarine marshes.

Eco-System Resources

The ecosystems of the OAP are far more diverse than one might imagine. Variations of land topography result from the previously described geologic history. These differences are critical as the land surface interfaces with different types of aquatic systems to produce various landscapes with high biodiversity and variants in ecosystem services. This land-water interface has historically and continues to work together with natural and human disturbances to foster contrasts in ecological conditions.



FIGURE 32. Photograph of the black-water Scuppernong River and its associated floodplain swamp forest from the Columbia boardwalk at sunrise. Photograph is by M. Dunn.

The regions' ecosystems represent continuums that are impacted by both human modification (clearing, agriculture, forestry, and industrial development) and the high-energy natural climate system dynamics (e.g., precipitation, droughts, river floods, storm surge, and sea-level rise). Each ecosystem supplies its own suite of ecosystem services and represents potential components of a healthy social system, as well as a viable and sustainable ecotourism economy. Thus, to maximize both the social and environmental resources into the future it is critical that a solid scientific understanding be integrated with the management policies of an expanding natural resource-based, eco-tourism economy.

The Bertie Peninsula is situated within the middle Coastal Plain with extremely diverse habitats. The natural ecosystems range from old growth forests to black-water streams, riverine swamp forests, and open-water estuaries, and scrub-shrub pocosins. The riverine ecosystems of the Bertie Water Crescent range from the large brown-water drainage basins, to the small black-water tributary stream systems, and end in the tidally influenced, drowned river estuarine water bodies. Integrating the highly diverse natural landscapes with the waterscapes of the Bertie Water Crescent, that determined the cultural history represent an ideal blend of nature, history, and recreation.



FIGURE 33. Photograph shows a typical pocosin swamp forest ecosystem. Photograph is by S. Riggs.



FIGURE 34. Left panel shows a grassy road along the top of a dike built from the sediment dug from the adjacent canal, as well as two different ecosystems dependent upon maintenance of the water levels on either side of the dike. Photograph is by S. Riggs. Right panel is a gravel road in the Pocasin Lakes National Wildlife Refuge. These roads run on top of the dike built with sediment dug from the canals on the side of the road. Photograph is by M. Dunn.



FIGURE 35. Left panel is Phelps Lake fresh water shoreline at Pocosin Overlook in Pettigrew State Park. Right panel is the fresh water marshes at East Lake in Alligator River National Wildlife Refuge. Photographs are by S. Riggs.

Eco-Systems Fauna

North Carolina is ranked ninth in the U.S. in terms of the number of species found within its boundaries (McKerrow et al., 2006). Much of the diversity of vertebrate species (excluding fish) in NC are found within its Coastal Plain as shown in red, pink, purple, and dark blue on Figure 36. The OAP falls within areas of NC that are particularly diverse likely due to the high concentration of natural areas managed by Federal (e.g., Wildlife Refuges), State (NC Game Lands and State Parks), and non-government organizations (The Conservation Fund, etc.).

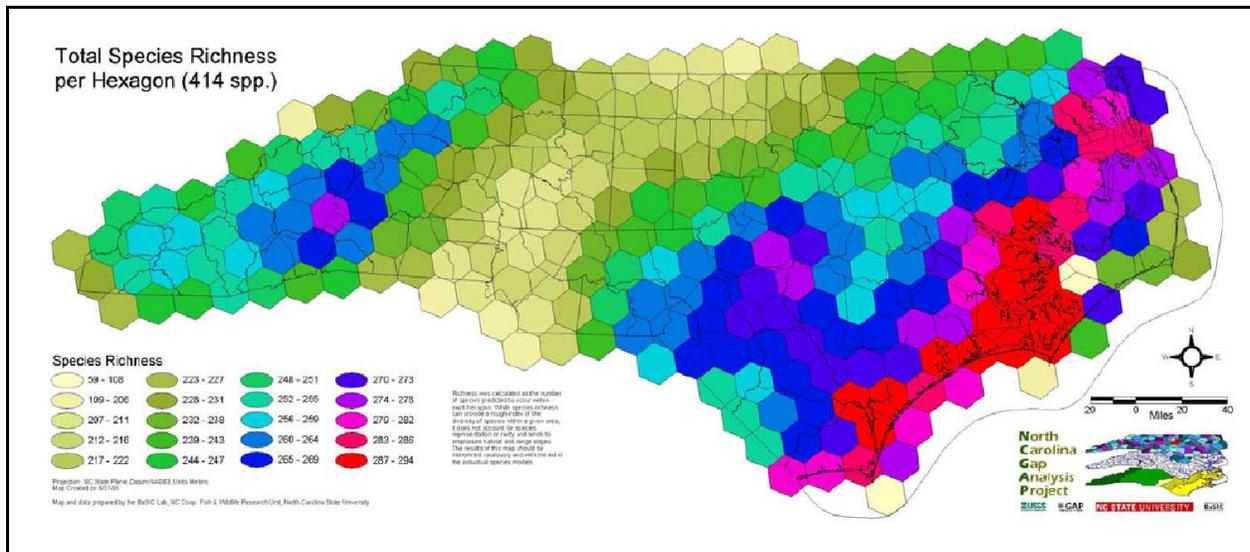


FIGURE 36. Number of vertebrate species (except fish) expected to be found within North Carolina. Expected numbers are based on the predicted distributions of 414 species that are known to reside/breed in North Carolina. Map is from McKerrow et al. (2006).

The high diversity of vertebrate species within the OAP includes a relatively large number of mammals, amphibians, and reptile species (Figure 36). The waterways of the Albemarle-Pamlico estuarine system and the surrounding creeks and lakes provide roosting and foraging habitat for overwintering migratory waterfowl (Figure 37). Hundreds of thousands of birds comprised of approximately 25 species descend on the region in the winter months (November-February). The birds also attract predators; bald eagles and harriers are a common sight in the winter; and golden eagles are spotted occasionally. The Pocosin Lakes NWR has a species list of more than 200 birds overall. Much of the diversity of amphibians is represented by frogs and toads which can produce thrilling choruses at night under the correct environmental conditions (warm and rainy nights around May). Black bears, otters, (Figure 38) coyotes, and various endangered species occur within the OAP region in the highest density east of the Mississippi River because of the vast wetland areas within NC's Land of Water. And of course, the nightscape of a warm muggy summer night would not be memberable without the overwhelming chorus of insects and frogs (Figure 39), along with swarms of biting bugs which is why we always carry netting. In contrast, the same winter nightscape would not be memorable without a bitterly cold and breezy night filled with stars and the cacophony of winter waterfowl (Figure 39) and why we always are layered in down clothing.



FIGURE 37. The nocturnal environment of the winter night sky is frequently dominated by the cacophony of the tundra swans that winter over in the AOP by the many tens of thousands. Photograph is by S. Riggs.



FIGURE 38. Photographs show common black bears and river otter of the OAP region. Photographs are by M. Dunn.



FIGURE 39. Left photograph is a flock of snow geese in a field and right panel is a green tree frog. Photographs are in the Pocosin Lakes National Wildlife Refuge by M. Dunn.

OBSERVING THE NIGHT SKY



FIGURE 40. Observing the night sky with the Milky Way Galaxy across the vast view scape provided by a water body. Notice the urban glow in the distance. Photograph is by Allen Phelps Photography.

Navigating Around in the Night Sky

Imagine star gazing with friends under a night sky full of thousands of stars (Figure 40). How does one point out iconic constellations or subtle features within that mass of night sky objects? How do you effectively communicate to someone else what you are looking at? After all, there is no measuring stick in the sky. When astronomers measure the sky, they do so in terms of angles and triangles to determine distances. A small triangle relates to larger ones of the same proportions to calculate the size or distance of an object you that can't be measured directly.

This technique can be used in the field to determine distances above the horizon and between the stars. But how can this method be applied to star gazing? The answer is quite “handy”. It turns out that the proportion between an individuals’ hand size and arm length is fairly consistent from person to person. Thus, if two observers stand side by side, each close one eye, hold up an outstretched arm, line up the bottom of a closed fist (thumb tucked inside) on the

distant horizon, both persons will block out the same portion of the sky with the top of the fist measuring about 10 degrees. In this position now extend the little finger which measures about one degree. By extending only the index, middle, and ring fingers together will measure a five degree angle. Stretching your index and little fingers away from each other will measure about fifteen degrees, whereas stretching your thumb and little finger away from each other will measure about twenty five degrees.

Using these angles will allow observers to communicate distances or positions of specific objects in the sky by relating their positions to something easily observable such as a tree or a very bright star. For example, take the big dipper which is easy to recognize and stands out clearly with its seven bright stars, follow the two stars that form the outer edge of the cup 30 degrees upwards (three fists) to locate the North Star. This handy technique allows for the quick and effective way to navigate the sky with an audience in an interactive way. Nothing more is needed than an outstretched hand, a good eye, and a reference point.

Quality of Clear Night Skies

An important question to ask on a clear night is how dark is the night sky? The quality of a clear night sky can vary significantly depending on where you are. To an astronomer “seeing” and “transparency” are two values used to compare quality of the sky from night to night and place to place. “Seeing” is a measure of how stable the sky is and “transparency” is a measure of how clear the sky is. Both “seeing” and “transparency” are easy observations to make, require no special equipment, and can be determined by a simple rating scale with results subject to the observer’s judgment.

How stable the night sky is depends on the Earth’s atmosphere which is both chaotic and turbulent as evidenced by twinkling stars. Before the fine pinpoint of light from a distant star reaches your eye, it must pass through the Earth’s dense atmosphere. In this process the light is scattered, refracted, and distorted, resulting in the stars twinkling. The more the stars twinkle the more atmospheric distortion is taking place. One thing to note is that the stars closer to the horizon twinkle more intensely than the stars near the zenith, the point directly above you. Star light within the zenith passes through significantly less atmosphere than star light lower on the horizon.

SEEING GUIDE: HOW STABLE IS THE SKY?

- E** Excellent: Brighter stars are not twinkling at all.
- VG** Very Good: Stars are twinkling slightly, but the brighter planets are not twinkling.
- G** Good: Brighter planets are twinkling slightly.
- F** Fair: Brighter planets are obviously twinkling.
- P** Poor: Atmosphere is turbulent making observation not practical.

Transparency is a scale of how clear the sky is or how many stars you can see. This comes down to how much starlight your eye is able to detect amongst all the other light in your environment. For this technique it is important to know how bright a particular star is to understand how much light from the stars you are receiving. To simplify this you can use one well know and simple constellation, the Little Dipper. Four of the seven stars of the Little Dipper

are close to the limit of what the human eye can detect. Any slight variations to transparency and sky quality will hamper your ability to see all seven stars of the Little Dipper and thus the stars in the Little Dipper offer a convenient and consistent way to gauge transparency. To determine transparency, find the Little Dipper (Ursa Minor) and note how many of its' seven stars can be seen (Figures 41 and 42).

TRANSPARENCY GUIDE: HOW CLEAR IS THE SKY?

- Excellent: If stars near the Little Dipper that are not part of the stick figure are visible.
- Very Good: If all 7 stars in the Little Dipper are visible.
- Good: If 6 of the 7 stars in the Little Dipper are visible.
- Fair: If any stars in the handle of the Little Dipper are visible.
- Poor: If the two stars are visible at the outer edge of the Little Dipper cup (Kochab and Pherkad).
- Very Poor: If the North Star Polaris is visible.
- Not Clear: If the North Star Polaris is NOT visible.

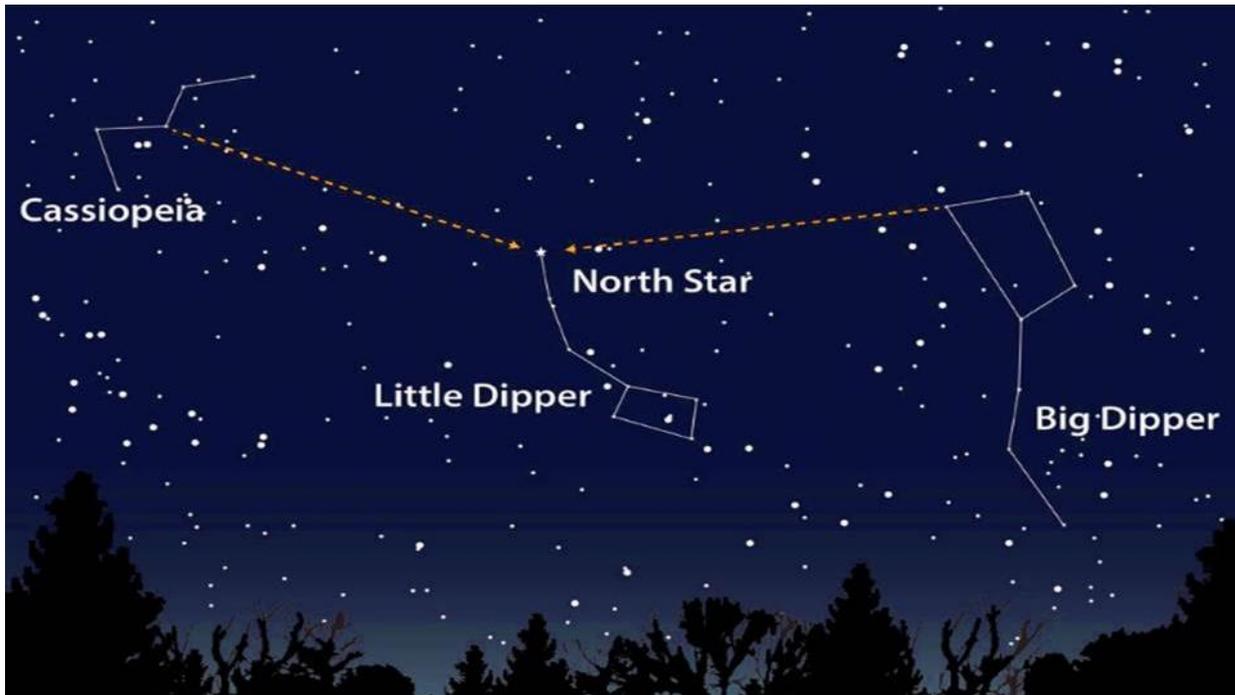


FIGURE 41. Diagram showing the relative location of the Little Dipper in the night sky.

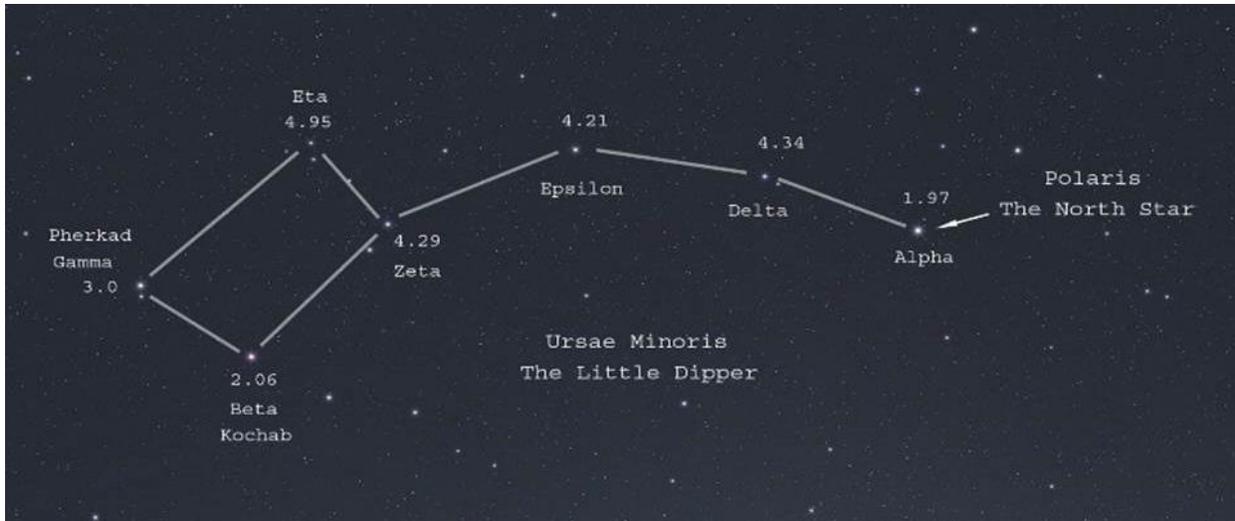


FIGURE 42. Diagram identifying the stars within the Little Dipper constellation .

Telescopes and Binoculars

Telescopes and binoculars (Figure 43) ultimately serve similar functions. They both focus light from distant objects to make far away things seem bigger and brighter. The differences in how this is done with telescopes and binoculars lead to wide ranges of capabilities and many different conditions.



FIGURE 43. Left panel is an example of telescopes at dusk on a clear night sky by M. Quinn on 6-10-13. Right panel is an example of binoculars that are useful for viewing both the nocturnal environment and the night sky.

The main difference between telescopes and binoculars is size and weight. Telescopes are generally large and unwieldy, stationary objects that need time to set up. The advantage to its large size allows it to collect more light, resulting in greater magnification and resolution of images. Binoculars on the other hand are light and nimble and can be used in almost any situation. Since binoculars are smaller, they do not have the light collecting power of a telescope, but do offer a wider field of view and ease of use. There is also a difference between how telescopes and binoculars focus light. Binoculars solely use glass lenses to focus light. They create images that are right side up. In contrast, many telescopes use mirrors to focus light resulting in images that are inverted. This characteristic makes binoculars much more intuitive to use.

Observing Wildlife

Telescopes are generally overkill in observing wildlife. Their narrow field of view and complex mounts make it difficult to view and track moving targets. Telescopes can perform this task well, but require particular types of mount and eyepieces to be practical. If the plan is to be stationary with time to prep, a telescope will allow detailed observations of animals and other natural features.

However, it is hard to imagine a better tool for sightseeing than a good pair of binoculars. Binoculars are portable and ready for use at any moment if they are hung around the neck or sitting in arms reach. Binoculars provide magnification that ranges from 6x up to 15x, meaning that images will appear six to fifteen times larger than with your naked eye. This makes binoculars perfect for resolving fine details at medium range.

Stargazing

Telescopes are made for stargazing! There is no better instrument to explore the wonders of the night sky. Wide telescope apertures allow them to collect significant amounts of light and produces images of objects in the sky that are both incredibly faint and far away. Telescopes provide clear views of the craters on the moon, the planets in our solar system, and even far away stars and galaxies. Many things should be considered when choosing a telescope for stargazing. Telescopes come in a wide verity from small “kiddy” scopes that are less than one hundred dollars to high-end robotic systems that cost tens of thousands of dollars. A 6-inch or 8-inch dobsonian telescope offers a good balance of affordability, capability, portability, and ease of use--a good place for an introductory telescope.

Binoculars are also amazing instruments for stargazing. Binoculars don't have the light collecting power of telescopes, but the magnification they provide dramatically opens up the night sky wonders beyond what the human eye is capable of seeing. The biggest advantage of binoculars over telescopes for stargazing is their field of view. When looking through a pair of binoculars you get a magnified view of a large area of the sky. For example, it is advantageous to use binoculars when trying to get a good look at star clusters.

Photography

Telescopes are remarkable tools for photographers. Since telescopes make far away things look bigger and brighter, allows great shots to be made of subjects off in the distance. However, the most common reason for hooking a camera up to a telescope is to capture images of the night sky. Astrophotography is based on combining a telescope and a camera. With modern equipment and photo processing software stunning images can be made of the most remarkable features of the Universe. Binoculars are not commonly used in photography. However, the image produced by a pair of binoculars does match up well with the aperture of a typical smart phone camera. Smartphone adapters for binoculars are available and greatly improve the capabilities of this combination.

Camping

Telescopes and binoculars are excellent tools to go along with camping trips. Binoculars are most useful for hiking and spotting wildlife. Telescopes can be bulky and cumbersome, however there are smaller portable models designed for quick set ups. These telescopes are great since most camping is in dark areas far from light glow of cities, making possible incredible explorations of the night sky.

On the Water

When on the water, traditional telescopes are almost useless; they need to be steady to have useful observations. Telescopes magnify such small points of the sky that even the slightest motion will move it far from the intended target. Binoculars, on the other hand are great tools to have on boats and in large bodies of water at night. Pristine dark sky conditions occur on larger water bodies since there are very few sources of light pollution and vast horizons. A pair of binoculars in this situation provides an incredible stargazing experience. Also, many models of binoculars have features that improve their performance and durability in wet situations.

LIGHT POLLUTION

This section is largely summarized from the International Dark Sky Association website (<https://www.darksky.org/light-pollution/>), US National Park Service website (<https://www.nps.gov/subjects/night skies/growth.htm>), and US NASA website (<https://images.nasa.gov/details>).

What's the problem?

Over the last 75 years the night sky has been taken over by the glare of city lights (Figure 44). Continued urbanization and population growth have greatly increased the number of artificial lights used to light up the night. We are losing the dark at the speed of light! It is now common to gaze into the night sky only to see a hand-full of stars. Eighty percent of the world's population cannot see the Milky Way and its thousands of stars that stretch across the sky every night. Evidence is mounting that the increased and widespread use of artificial light at night is not only impairing our view of the universe, it is also adversely affecting our environment, our safety, our energy consumption, and our health.

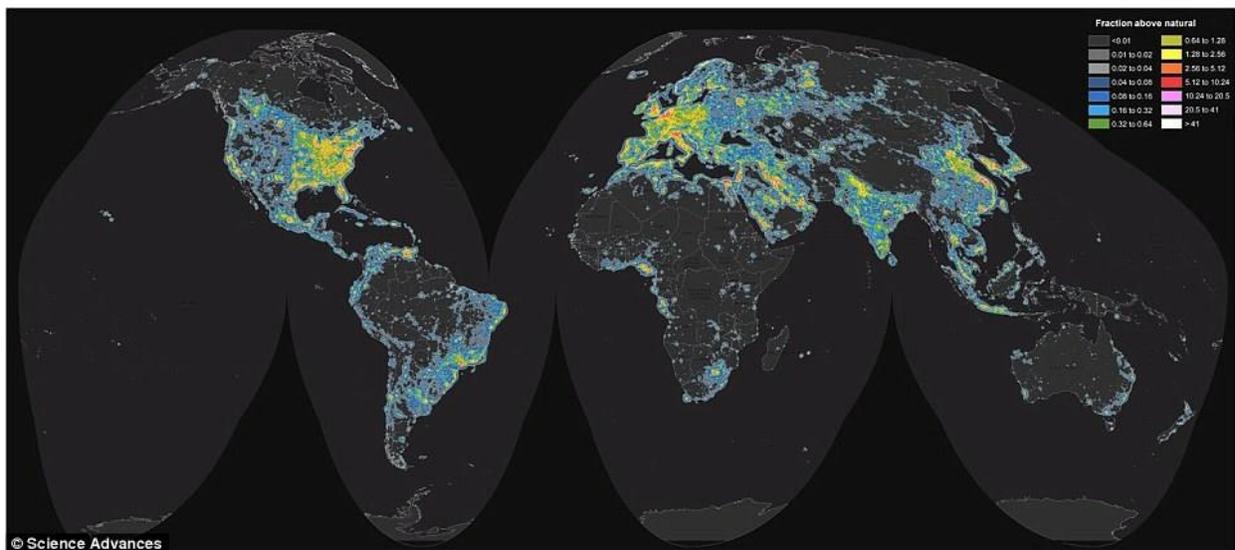


FIGURE 44. Map of the “new world’s atlas” of artificial night sky brightness is by Falchi et al., 2016. In *Science Advances*, v. 2, no. 6, e1600377.

Most of us are familiar with air, water, and land pollution, but light can also be a pollutant. Light pollution is the inappropriate or excessive use of artificial light (Figure 45). Until recently, life on Earth has existed in a rhythm of light and dark by the illumination of the Sun, Moon and stars. Now, artificial lights overpower the darkness, disrupting the natural day-night pattern and eroding the delicate balance of nocturnal environments. The negative effects of the loss of this inspirational natural resource might seem intangible, but a growing body of evidence links the brightening night sky directly to measurable negative impacts on human health, wildlife ecosystems, and energy consumption.



FIGURE 45. The last pristine and public night sky along the Atlantic coastal system between Boston and Miami in 2012 by NASA Goddard and created on 12-8-2017. Visible infrared imaging Radiometer Suite https://images.nasa.gov/details-GSFC_20171208_Archive_e001590.

Types of Light Pollution

Light pollution comes in a verity of forms. *Glare* is excessive brightness that causes visual discomfort leading to loss of contrast, or even temporary blindness. Glare from unshielded lighting is a public-health hazard, especially for older drivers. *Light trespass* is when light falls where it is not intended or needed. Light trespass is often felt by residents who live near shopping centers, gas stations, or in apartment complexes where unwanted light shines into a bedroom window, removing the dark and disrupting one's sleep. *Sky Glow* is the brightening of the night sky over populated areas. Sky glow is a side effect of an industrial civilization where all the reflected, unused, and upward-directed light combines as it escapes up into the sky. Its sources include building exterior and interior lighting, advertising, commercial properties, factories, streetlights, and illuminated sporting venues.

Effects of Light Pollution

The negative impact of artificial lighting on wildlife is well documented. Everything from trees and flowers to frogs and birds, have a delicate relationship with the night. Some trees can be hampered by prolonged exposure of artificial light and fail to respond to seasonal variations. This, in turn, has implications for wildlife that depend on those trees for their natural habitat. Light pollution can also alter behaviors, foraging areas, and breeding cycles of insects, turtles, birds, fish, and reptiles. Sea turtles provide a dramatic and well know example of the interaction between light pollution and animal behavior. Artificial lights on the beach disorient newly hatched turtles causing them to navigate toward the artificial light source and away from the sea (Figure 46).



FIGURE 46. Turtle hatchlings instinctively orient away from the dark silhouette of the nighttime shore. Here hatchlings have been temporarily distracted by a bright lamp. Hatchlings and mother turtles distracted by shorefront lights can wander onto nearby roadways. Photograph is by B. Witherington,

Though the effects are not as well defined as with wildlife, there exists a compelling amount of evidence concerning the relationship between artificial lighting and human health problems. The connection between artificial light and sleep disorders is a fairly intuitive one. Difficulties with adjusting the circadian clock can lead to a number of sleep disorders. In fact, the introduction of artificial lighting has changed our basic concept of a good night sleep. Prior to the beginning of the industrial age people slept in two 4-hour shifts (“first sleep” and “second sleep”) separated by a late-night period of quiet wakefulness. Even more serious are the correlations being found linking artificial lighting to increased risk of cancer. Melatonin, a hormone produced by the pineal gland, is secreted at night and is known for helping to regulate the body’s biologic clock. The body produces melatonin at night, and melatonin levels drop precipitously in the presence of artificial or natural light. Numerous studies suggest that decreasing nocturnal melatonin production levels increases an individual’s risk of developing cancer.

Solutions to the Problem

Unlike other forms of pollution, the effects of light pollution can be reversed instantaneously. Once excessive lighting is removed from an environment the negative impacts cease immediately. It’s not the case that we need to get rid of all outdoor lighting and live in the dark ages. We just need to be more intentional about our outdoor lighting. Fortunately, there are some very simple steps that can be taken to make a big impact on light pollution.

By far the vast majority of the artificial lighting that we use at night goes unutilized (Figure 47). Lights that shine horizontally or upwards towards the sky are wasting energy and disrupting the nocturnal environment. Light in these situations travel freely through the air and illuminate the atmosphere over a large region. This stray light often creates hazardous glare that can affect public safety and diminishes our view of the stars. In many cases it is possible to replace problematic lighting rather than removing the light all together. All that is required is to ensure that any outdoor lighting is fully shielded, meaning that all the light is directed towards the ground, where it would actually be useful. With all the light directed toward the ground you are effectively getting more illumination where it matters, while using less energy.

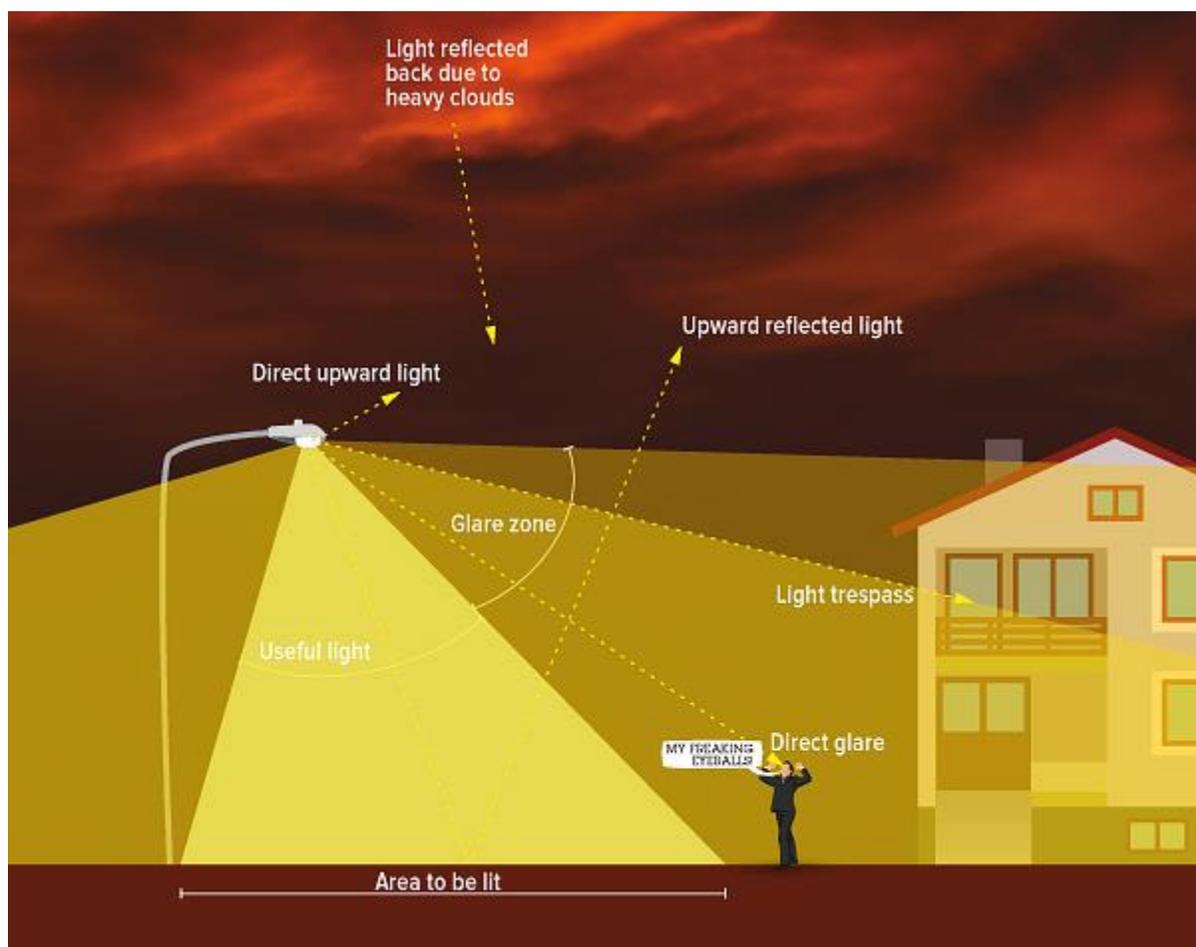


FIGURE 47 The infographic above illustrates the different components of light pollution and what “good” lighting looks like. Image is by Anezka Gocova, in “The Night Issue”, *Alternatives Journal* (2013, v. 39, no. 5).

The choices that are made concerning outdoor lighting are very important. Shielded lights are no more expensive than non-shielded lights. The difference is just having the knowledge of how our lighting impacts the world around us. Outside of shielded and non-shielded lighting there are many different aspects to consider. Common light sources include low-pressure sodium (“LPS”), high-pressure sodium (“HPS”), metal halide, and light emitting diodes (“LEDs”). Each of these light sources produce different colors of light which impact the nocturnal environment differently. Timers and triggers are incredibly important as well. With these features lights can be activated when they are needed and turned off when they are not.

Ultimately, this is a local community issue that is in the hands of each resident. Many people who become concerned about light pollution want to know what they can do to make a difference in their community. Beyond fixing your own lighting, one thing you can do is work to get an outdoor lighting ordinance adopted in your community. Outdoor lighting ordinances or codes are a great tool for ensuring that municipalities implement good, safe outdoor lighting. A well-written ordinance with proper lighting installed will save the public money and increase safety. Thousands of cities have adopted such codes and they can be a great tool for communities to use in controlling light pollution, including glare, light trespass and sky glow (Figure 48).

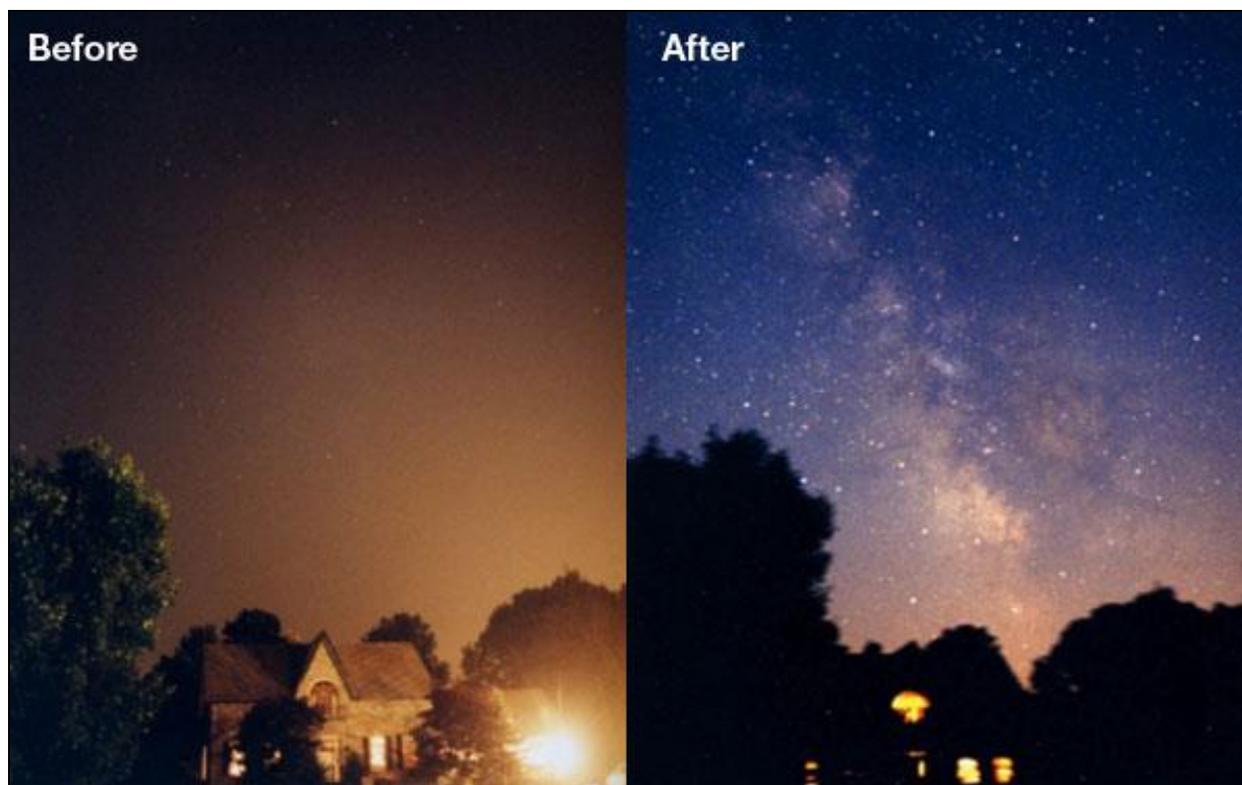


FIGURE 48. Photographs were taken before and during the 2003 Northeast blackout, a massive power outage that affected 55 million people. Photographs are by T. Carlson on the IDA website <https://www.darksky.org/light-pollution/>.

NIGHT-SCAPE OUTREACH

Communication and Education

The opportunities for building programs around the nocturnal environment and night sky are unlimited for both the public and associated school systems and can readily be integrated with other outdoor programs. Day time lectures can be offered at specific facilities, evening field trips can be taken to various outdoor locations good for night viewing and listening, and course curricula can be implemented within the K-12 regional schools. Multiple day eco-tourism workshops and field programs dealing with the natural and cultural resources of the Albemarle region can include components associated with nocturnal environments and astronomy of the night sky that are integrated into the region's landscape and ecosystem programs.

Natural resource education of the youth, public, and leadership of the Roanoke-Albemarle region is critical not only for the protection and management, but also the potential for developing sustainable eco-tourism for the region's future. The over-arching goal of the nightscape project was to delineate the nocturnal environment and night sky resources and expand the night-scape capabilities into the existing plan for developing educational and sustainable eco-tourism programs for the underserved counties of the northeastern NC. If successful, it would bring national and international attention to the natural resources and eco-tourism potential of NC's Inner Banks. Thus, an important sub-goal of the NC LOW and ATFS nightscape project was the outreach communication and education during the project year (Aug 1, 2018 to July 31, 2019).

1. Educational workshops provide local science teachers with new ideas to incorporate into their lesson plans, having impacts on a vast number of K-12 students of northeastern NC coastal region (Figure 49).
2. A series of eight K-12 science teacher education workshops were held in Bertie County during the year to deal with the natural resource base of the region followed by one evening "night-scape star party". NC LOW, ATFS, and CSI hosted two public **STAR PARTIES** sponsored by the Night-Scape project (Figure 50). The first Star Party was on Tuesday February 5th from 6:00 pm to 9:00 pm at Jennette's Pier in Nags Head, NC with about 500 participants. The second Star Party was on Thursday March 7th from 6:30 pm to 9:00 pm at the Middle School in Windsor, Bertie County, NC with about 300 participants. The third Star Party was to be held on April 13 at the Pettigrew State Park Visitor's Center in Creswell, NC. This latter program was part of the NC Science Festival's Statewide Star Party but had to be canceled on the program day due to severe weather and very cloudy skies at Lake Phelps.

3. The Star Party programs were free and open to the public with a major portion of the participants being K-12 students. Each Star Party had rotating programs every half hour in a portable planetarium that included a 15 minute presentation on light pollution, a tour of the planets and constellations, a film titled “Losing the Dark” to introduce light pollution issues with simple actions to mitigate it. Numerous volunteer astronomers manned their large telescopes and science educators tended four activity tables. The portable planetarium, which holds 45 people, was also utilized for night sky presentations to 4th grade classes at over twenty regional public schools in other northeastern coastal counties.



FIGURE 49. There were eight science teachers workshops focused on “What’s in Your Backyard” which includes the landscapes, waterscapes, and nightscapes. The wrap-ups for these workshops were the regional Star Parties. Photographs are by S. Riggs



FIGURE 50. There were eight science teachers workshops focused on “What’s in Your Backyard” which includes the landscapes, waterscapes, and nightscapes. The wrap-ups for these workshops were the regional Star Parties. This photograph shows the portable planetarium and various activity tables. Photographs are by S. Riggs

4. As an integral part of the communication and education program, the science teachers were taken on 4 major field trips to explore “what’s in your backyard”. These trips all dealt with the water-land intersection. A plan is being developed for a regional K-12 scientific and environmental instruction program titled “From Rivers to Sounds” built on the newly acquired 1,000 acre “Salmon Creek State Natural Area”, now part of the NC Division of State Parks.
5. In September 2018 A Time for Science began a new outreach program serving 10,000 fourth grade students in Eastern North Carolina. STEP into STEM is a traveling interactive science exhibition that visits regional schools to bring the fourth-grade science curriculum alive by letting students blast off to the moon to learn about the lunar cycle, visit a portable planetarium to see programs on our night sky and learn how to limit light pollution, as well as other relevant science topics.

6. Various media organizations produced a series of articles, news releases and documentary films concerning the OAP natural resources and its Dark Skies.

International Dark Sky Reserve

An International Dark Sky Reserve (DSR) (<http://www.darksky.org/idsp/become-a-dark-sky-place/>) requires “a public or private land area of substantial size (270 mi² or 173,000 acres) possessing an exceptional or distinguished quality of starry nights and nocturnal environment and is specifically protected for its scientific, natural, educational, cultural heritage, and/or public enjoyment.” The 758+ mi² of public lands within the OAP plus the surrounding 2,900 mi² of public estuarine waters totals to over 3,700 mi² of public land and water that is protected for its wildness with almost no urban component. The NC dark sky region is more than 14 times what IDSR requires for designation as an International Dark Sky Preserve. Thus, the Outer Albemarle Peninsula and its associated waterscape is a world-class natural resource available for developing “resilient communities and economies” in the poorest and truly-rural coastal region in NC. The present project has developed a wealth of data about the nightscape resource and obtained local recognition of this vast resource. Now the local communities must lay the groundwork with a plan to obtain an “International Dark Sky Reserve” designation by the IDA (the first US reserve was established in 2017 in Idaho and a second in 2018 in Utah). This designation will put the northeastern coastal section of NC on the national and international map and provide marketing material to help build a nightscape component to complement the daytime recreational and educational opportunities in rural coastal NC.