Designers Lighting Forum – 3/12/2019

Starving for Darkness:

How Exterior Lighting Affects Our Wildlife

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Since the industrial revolution and the invention of the electric light bulb, the natural ecosystems of the Earth spend more and more time bathed in artificial light within a 24 hour cycle.

How does the artificial light and lack of darkness impact wildlife? How does the obstruction of the night's sky affect bird migration and whale migration?

Much of the study of light and health has been dedicated to the impact of light upon humans, however animals and plants are also intrinsically photosensitive and subject to the unwanted effects of stray light.

How can a rethinking of design and codes alleviate some of these harmful effects?

Learning Objectives

At the end of the this course, participants will be able to:

1. To identify exterior lighting conditions that can be harmful to wildlife.
2. To look at existing case studies and projects that have caused harm to wildlife.
3. To understand existing lighting regulations and how these both support wildlife, and what can be done to improve existing standards.
4. To look at existing case studies and projects that have been designed for the wellbeing of wildlife habitats and the environment.

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Copyright Materials

Light Pollution & the Human Impact

Light Pollution

"Light pollution is an unwanted consequence of outdoor lighting and includes such effects as sky glow, light trespass, and glare."[1]

1. "Light Pollution." Lighting Research Center. Rensselaer Polytechnic Institute, February 2007. Web. 9 February 2016.

Skyglow

"Brightening of the sky caused by outdoor lighting and natural atmospheric and celestial factors."[2]

2. "Light Pollution." Lighting Research Center. Rensselaer Polytechnic Institute, February 2007. Web. 9 February 2016.

Human-made Skyglow

Glare

"Excessive brightness that causes visual discomfort and decreases visibility."[3]

3. Fighting Light Pollution: Smart Lighting Solutions for Individuals and Communities. Mechanicsburg, PA: Stackpole Books; 2012. Page 4.

Clutter

"Bright, confusing, and excessive groupings of light sources, commonly found in overlit urban areas."[4]

4. Fighting Light Pollution: Smart Lighting Solutions for Individuals and Communities. Mechanicsburg, PA: Stackpole Books; 2012. Page 4.

The Mechanics of Light Pollution

The air, seemingly invisible, is filled with soft particulate.

These particles serve as trillions of tiny little mirrors, re-reflecting light from the original light sources.

This re-reflection creates clouds of light that obstruct darkness, the natural rhythm of light, and the night's sky.

Light Pollution knows no boundaries, and the effects of polluting light persist as far as 200 kilometers (about 120 miles) from the source.[5]

5. Model Lighting Ordinance. (n.d.). Retrieved March 27, 2018, from http://www.darksky.org/our-work/public-policy/mlo/. User's Guide, Page 4.

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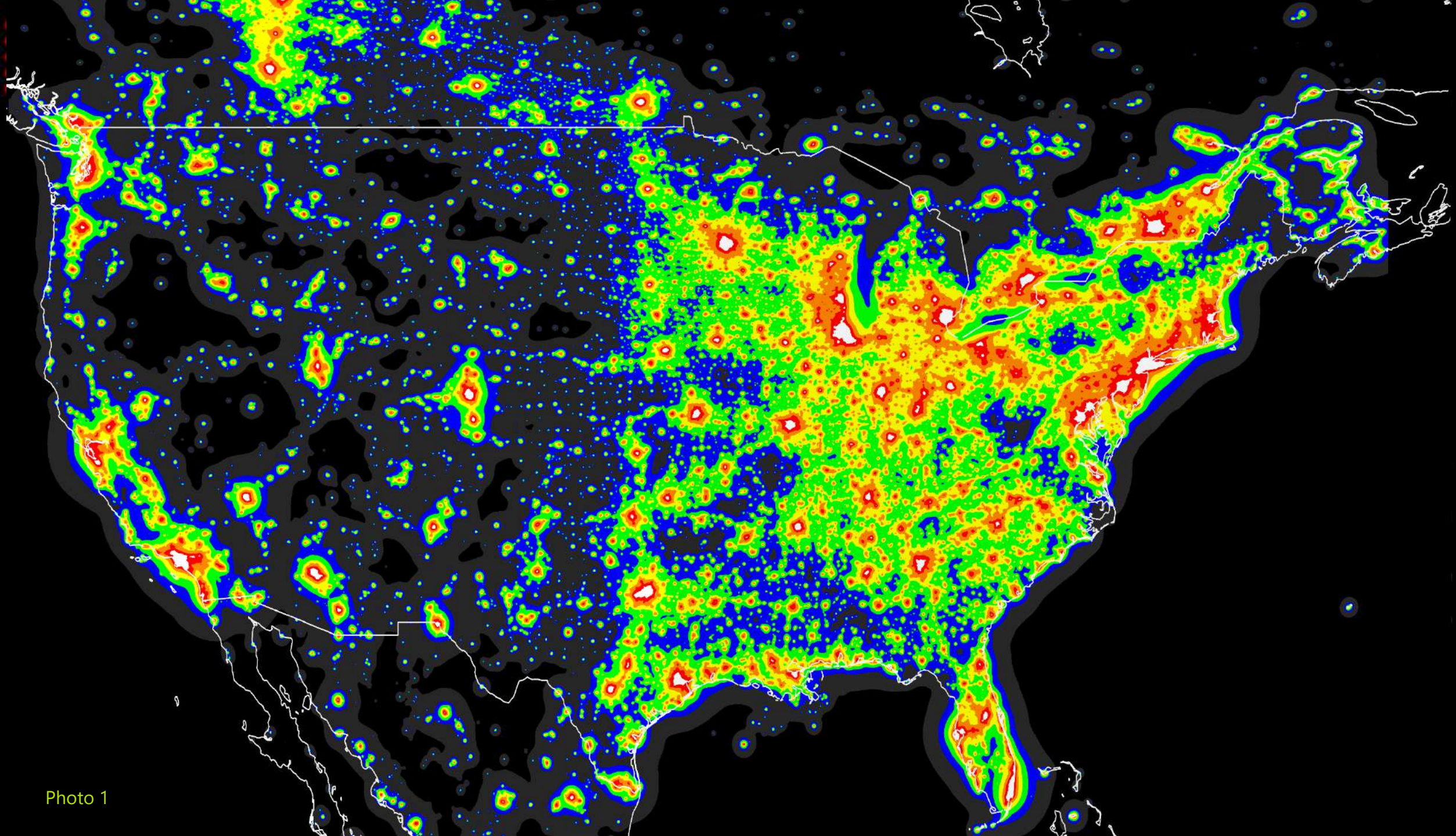
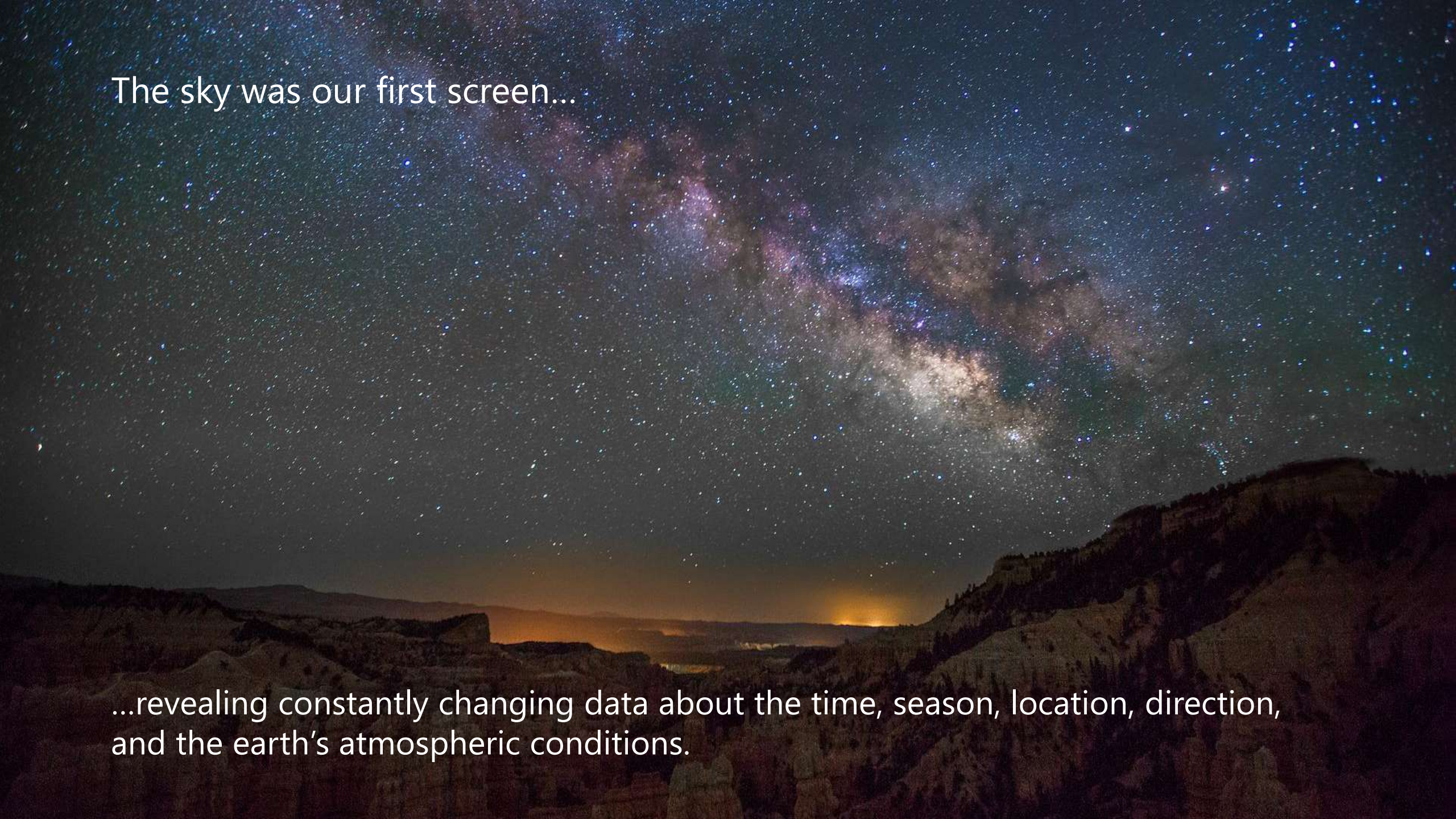


Photo 1

Solastalgia (/sɒləˈstældʒə/) is a neologism that describes a form of psychic or existential distress caused by environmental change, such as mining or climate change. Coined by philosopher Glenn Albrecht in 2003, it was formed from a combination of the Latin word sōlācium (comfort) and the Greek root -algia (pain).[6]

6. Solastalgia. (2017, September 12). In *Wikipedia, The Free Encyclopedia*. Retrieved 00:48, February 12, 2018, from https://en.wikipedia.org/w/index.php?title=Solastalgia&oldid=800200969


The sky was our first screen…
…revealing constantly changing data about the time, season, location, direction, and the earth’s atmospheric conditions.

Circadian Entrainment

The daily and precise rhythm of night & day has occurred for millennia

Wildlife utilizes light as a basis for timing and behavior above other key factors such as temperature

Year over year, temperature can fluctuate rather dramatically

Therefore, the length of day is a very reliable factor for entraining behaviors such as reproduction, feeding, and molting

Serotonin and Melatonin

Photo 2

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How does exterior lighting affect wildlife?

Sea Turtles

LEDucation®

"All animals, not just humans, depend on a regular interval of daylight and darkness for proper functioning of behavioral, reproductive, and immune systems." [7]

7. Fighting Light Pollution: Smart Lighting Solutions for Individuals and Communities. Mechanicsburg, PA: Stackpole Books; 2012. Page 25.

LEDucation

Biodiversity & Interdependence

leducation.org

Indirect Effects of Light Pollution on Wildlife

"The delicate balance of interspecies interaction can be upset when outdoor lighting artificially extends the length of daylight."[8]

8. Fighting Light Pollution: Smart Lighting Solutions for Individuals and Communities. Mechanicsburg, PA: Stackpole Books; 2012. Page 26.

Nocturnality

Around 70% of Mammals are Nocturnal

Photoreceptors and hormones are different across species

Direct Effects of Light Pollution on Wildlife

Disorients and distracts animals

Triggers reproductive behaviors at the wrong periods

Frustrates behaviors around feeding and pollination

Alters migration

How exterior lighting affects specific species:

- Fireflies
- Bees
- Monarch Butterflies
- Dung Beetles
- Bats
- Whales
- Birds
- Zooplankton
- Trees

Insects

According to Naturalist E. O. Wilson of Harvard University:

If all mankind were to disappear, the world would regenerate back to the rich state of equilibrium that existed ten thousand years ago.

If insects were to vanish, the environment would collapse into chaos.

Fireflies

A Language of Light

Photo 3

Fireflies and Human Impact

- There are over 2000 species of fireflies[9]
- Fireflies inhabit every continent except Antarctica
- One study showed a 50% decrease in Firefly flashes in the presence of light[10]
- The broader spectrum of LED lights compared to High Pressure Sodium may increase disruption in communication

9. Fireflies Need the Dark to Talk with Light. (2017, July 26). Retrieved March 25, 2018, from http://www.darksky.org/fireflies-need-the-dark-to-talk-with-light/
10. Costin, K. J., & Boulton, A. M. (2016). A Field Experiment on the Effect of Introduced Light Pollution on Fireflies (Coleoptera: Lampyridae) in the Piedmont Region of Maryland. The Coleopterists Bulletin, 70(1), 84-86. doi:10.1649/072.070.0110

Pollination and Insects

Vital for plant and crop reproduction

Most Common Pollinators

Bees

Wasps

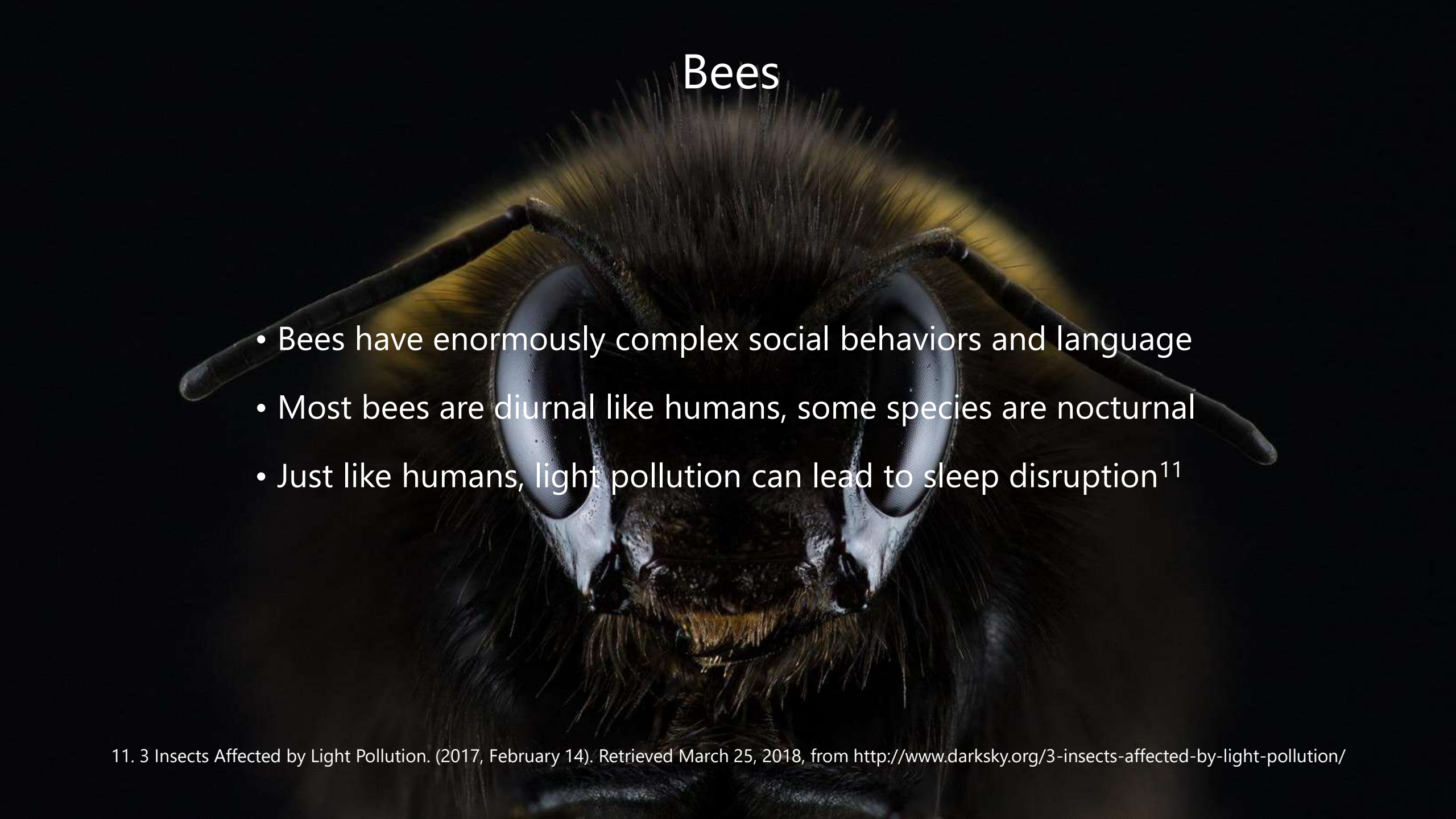
Moths

Butterflies

Flies

Beetles

Bees



- Bees have enormously complex social behaviors and language
- Most bees are diurnal like humans, some species are nocturnal
- Just like humans, light pollution can lead to sleep disruption[11]

11. 3 Insects Affected by Light Pollution. (2017, February 14). Retrieved March 25, 2018, from http://www.darksky.org/3-insects-affected-by-light-pollution/

If the bee disappeared off the surface of the globe, then man would have only four years of life left.

No more bees, no more pollination, no more plants, no more animals, no more man.

-Albert Einstein

Monarch Butterflies

- Migrate thousands of miles each Autumn
- From the Northeast of the U.S. and Canada to Mexico

Monarch Butterflies

- Millions of butterflies travel thousands of miles
- It takes multiple generations to return to their origins[12]
- Meaning, they are hardwired with instincts to navigate to certain points on Earth

Monarch Butterflies

- They are hardwired to return their origins, utilizing signals from sunlight and geomagnetic forces as guides[13]
- Artificial light poses a threat to migration by disorienting the invertebrates as they fly long distances[14]

12. Dell'Amore, C. (2014, January 29). Migrating Monarch Butterflies in "Grave Danger," Hit New Low. Retrieved March 26, 2018, from https://news.nationalgeographic.com/news/2014/01/140129-monarch-butterflies-mexico-animals-science-environment-migration-nation/
13. Bruce-White, C., & Shardlow, M. (2011). A review of the impact of artificial light on invertebrates. Totton: Buglife - The Invertebrate Conservation Trust. Page 14.
14. Dell'Amore, C. (2014, January 29). Migrating Monarch Butterflies in "Grave Danger," Hit New Low. Retrieved March 26, 2018, from https://news.nationalgeographic.com/news/2014/01/140129-monarch-butterflies-mexico-animals-science-environment-migration-nation/

Impacts of Exterior Lighting on Pollination

In one study[15], lit meadows as compared to unlit meadows:

- Received 62% less visits by nocturnal insects
- Had 29% fewer pollinating insects
- Bore 13% less fruits in the plant studied, cabbage thistle

15. Knop, E., Zoller, L., Ryser, R., Gerpe, C., Hörler, M., & Fontaine, C. (2017). Artificial light at night as a new threat to pollination. Nature. doi:10.1038/nature23288

Dung Beetles

- Utilize astro-navigation to travel in straight, efficient paths[16]
- A study placed dung beetles in a planetarium[17]

16. 3 Insects Affected by Light Pollution. (2017, February 14). Retrieved March 25, 2018, from http://www.darksky.org/3-insects-affected-by-light-pollution/
17. Ibid

Dung Beetles

- When the planetarium lights were on, the beetles moved in straight lines[18]
- When the lights were turned off, their paths became scattered and random[19]

18. 3 Insects Affected by Light Pollution. (2017, February 14). Retrieved March 25, 2018, from http://www.darksky.org/3-insects-affected-by-light-pollution/
19. Ibid

Mammals

- Both predators and prey alter their behavior based on the natural cycles of moonlight[20]
- Artificial light interferes with this complex relationship[21]
- Street lighting potentially creates temporary blindness in animals, decreasing their defenses of being struck by vehicles[22]

20. Rich, C., & Longcore, T. (2013). Ecological Consequences of Artificial Night Lighting. Washington: Island Press. Page 28.
21. Ibid
22. Ibid. Page 32.

Bats

- 900 Different Species
- 100% are nocturnal
- They are the only flying mammal
- Help to control insect populations

Bats

"The habit of feeding at artificial lights is now so common and widespread among bats that it must be considered part of the normal life habit of many species."[23]

23. Rich, C., & Longcore, T. (2013). Ecological Consequences of Artificial Night Lighting. Washington: Island Press. Page 43.

Whales

Humpback Whale Migration

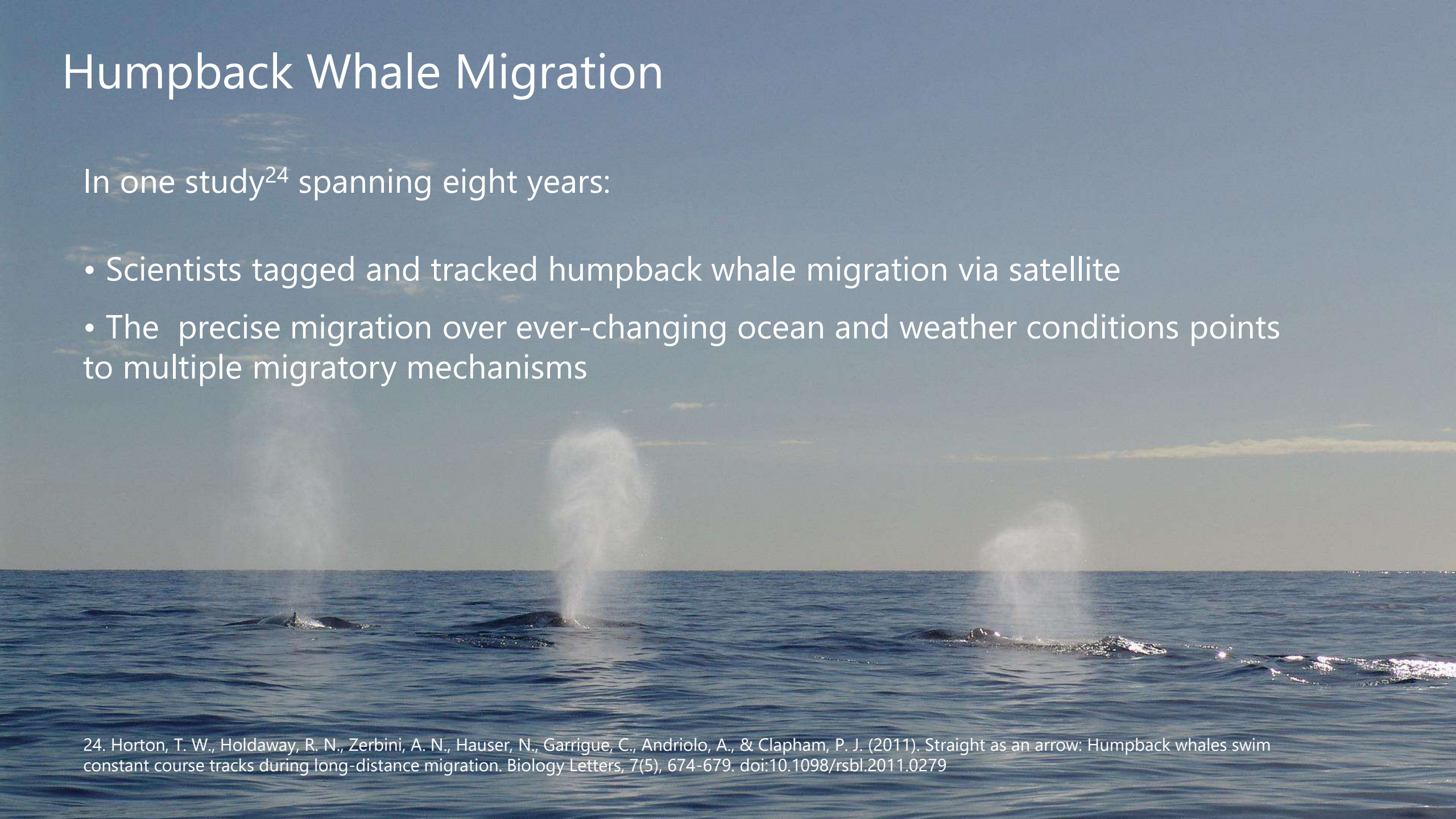
- Whales migrate over many thousands of miles of open ocean

- The waters have strong currents and unpredictable turbulence

Humpback Whale Migration

In one study[24] spanning eight years:

- Scientists tagged and tracked humpback whale migration via satellite
- The precise migration over ever-changing ocean and weather conditions points to multiple migratory mechanisms



24. Horton, T. W., Holdaway, R. N., Zerbini, A. N., Hauser, N., Garrigue, C., Andriolo, A., & Clapham, P. J. (2011). Straight as an arrow: Humpback whales swim constant course tracks during long-distance migration. Biology Letters, 7(5), 674-679. doi:10.1098/rsbl.2011.0279

Humpback Whale Migration

According to the study[25]:

- A whale's journey from the poles to the tropics can span up to 5,000 miles
- No one migratory mechanism would be sufficient, such as geomagnetic forces or solar navigation

25. Horton, T. W., Holdaway, R. N., Zerbini, A. N., Hauser, N., Garrigue, C., Andriolo, A., & Clapham, P. J. (2011). Straight as an arrow: Humpback whales swim constant course tracks during long-distance migration. Biology Letters, 7(5), 674-679. doi:10.1098/rsbl.2011.0279

Migration Patterns

- Humpback whale migration never deviated more than 5 degrees off course
- Often not more than 1 degree[26]

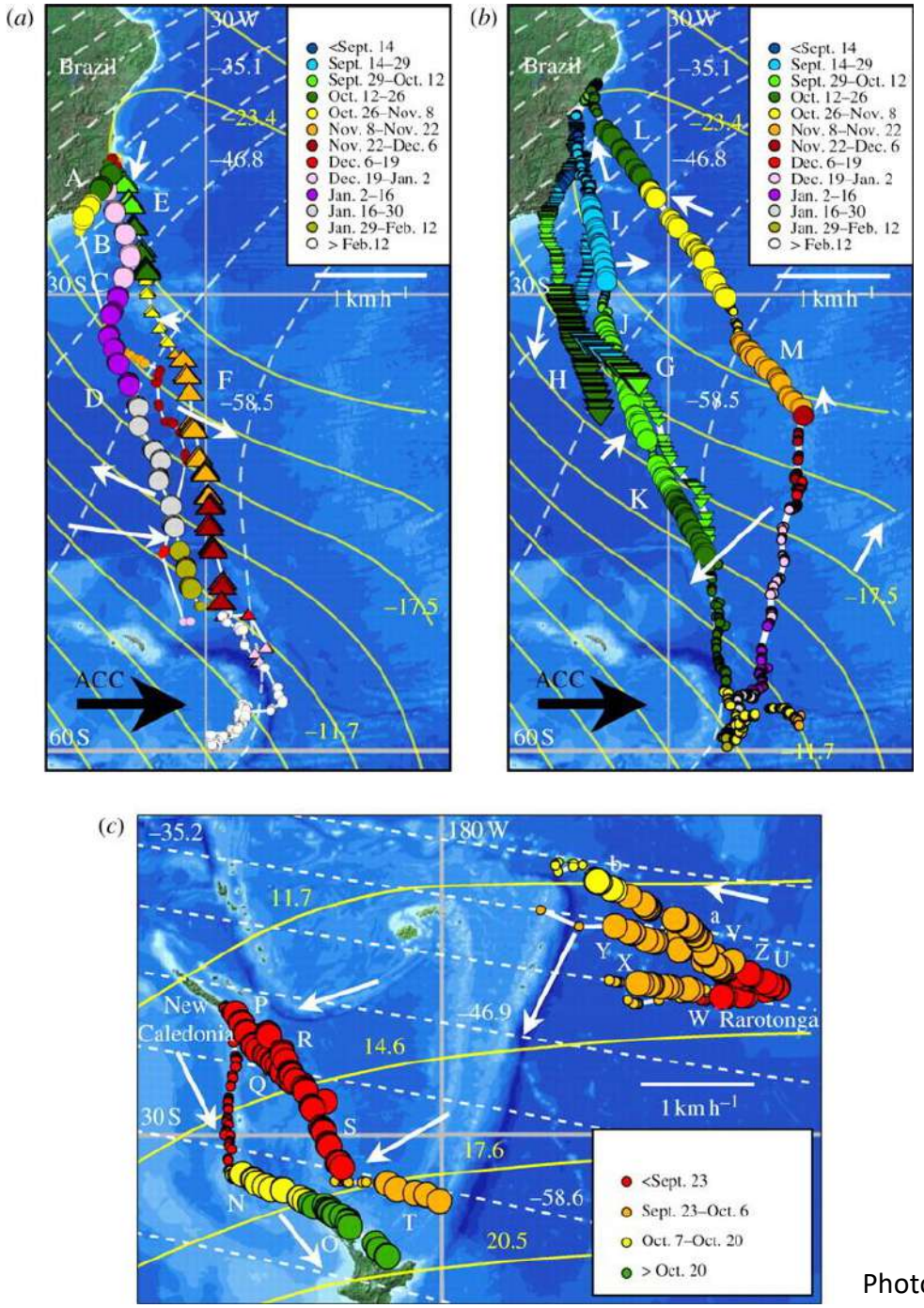


Photo 2

26. Horton, T. W., Holdaway, R. N., Zerbini, A. N., Hauser, N., Garrigue, C., Andriolo, A., & Clapham, P. J. (2011). Straight as an arrow: Humpback whales swim constant course tracks during long-distance migration. Biology Letters, 7(5), 674-679. doi:10.1098/rsbl.2011.0279

Humpback Whale Migration

The study's conclusion hypothesizes[27]:

- That whales also utilize the moon and stars to orient themselves on their long paths
- In addition, it is also thought that whales communicate and share location information via whale songs

27. Horton, T. W., Holdaway, R. N., Zerbini, A. N., Hauser, N., Garrigue, C., Andriolo, A., & Clapham, P. J. (2011). Straight as an arrow: Humpback whales swim constant course tracks during long-distance migration. Biology Letters, 7(5), 674-679. doi:10.1098/rsbl.2011.0279

Birds

It is estimated that nearly one billion birds die from flying into buildings and windows in North America every year.[28]

28. St. Fleur, N. (2016, April 7). Illuminating the Effects of Light Pollution. The New York Times.

The Fatal Light Awareness Program (FLAP)

- A non-profit organization in Canada
- Created to protect birds from fatal light attraction


Photo 4

Low Light Levels and Avian Reproduction

"Birds exposed to light at night developed their reproductive system up to one month earlier, and also moulted earlier, than birds kept under dark nights."[29]

29. Dominoni, D., Quetting, M., & Partecke, J. (2013). Artificial light at night advances avian reproductive physiology. Proceedings of the Royal Society B: Biological Sciences, 280(1756), 20123017-20123017. doi:10.1098/rspb.2012.3017

The things we do not see: microorganisms

Zooplankton

- Tiny animals inhabiting water, sometimes microscopic in size
- Exquisitely sensitive to light
- Vertically migrate depending on small shifts in light magnitude
- They avoid the surface of the water during the day due to to predators and UV light[30]

30. Rich, C., & Longcore, T. (2013). Ecological Consequences of Artificial Night Lighting. Washington: Island Press. Page 372.

Zooplankton

- Artificial light can alter the migration of Zooplankton, both in time and distance[31]
- Inhibiting the migration of Zooplankton can drastically alter the water's ecosystem, such as potentially causing algae blooms

31. Rich, C., & Longcore, T. (2013). Ecological Consequences of Artificial Night Lighting. Washington: Island Press. Page 372.

Trees

Artificial light can have the following impact:

- The photoperiod, or duration of light, impacts:
  - Leaf development, shape, and pigment[32]
  - Leaf fall and timing in Autumn[33]
  - Root growth[34]
- Constant light prevents dormancy during the harsh winter[35]
- Flowering patterns can also be altered[36]

32. Chaney, W. R. (2002). Does Night Lighting Harm Trees? Forestry and Natural Resources, Purdue University, 3. Retrieved March 26, 2018, from https://www.extension.purdue.edu/extmedia/fnr/fnr-faq-17.pdf. Page 3.
33. Ibid
34. Ibid
35. Zielinska-Dabkowska, K. M. (2014, November 5). Journey towards light – evolutionary adaptations of humans, flora and fauna. Guidelines for safe and healthy illumination. Retrieved March 26, 2018, from www.researchgate.net/publication/285056341. Page 272.
36. Ibid

Plants

Interventions

Model Lighting Ordinance (MLO), 2011

Created as a joint effort of:

The International Dark-Sky Association (IDA)
The Illuminating Engineering Society of North America (IESNA)

Model Lighting Ordinance (MLO), 2011

- Loss of the night's sky first began to be noticed in the 1970's
- Little to no consensus or understanding across lighting practices, laws, and ordinances
- This document is an effort to find consensus among lighting guidelines and to greatly reduce light pollution
- Offers municipalities a language and strategy for implementing more effective outdoor lighting

37. Model Lighting Ordinance. (n.d.). Retrieved March 27, 2018, from http://www.darksky.org/our-work/public-policy/mlo/

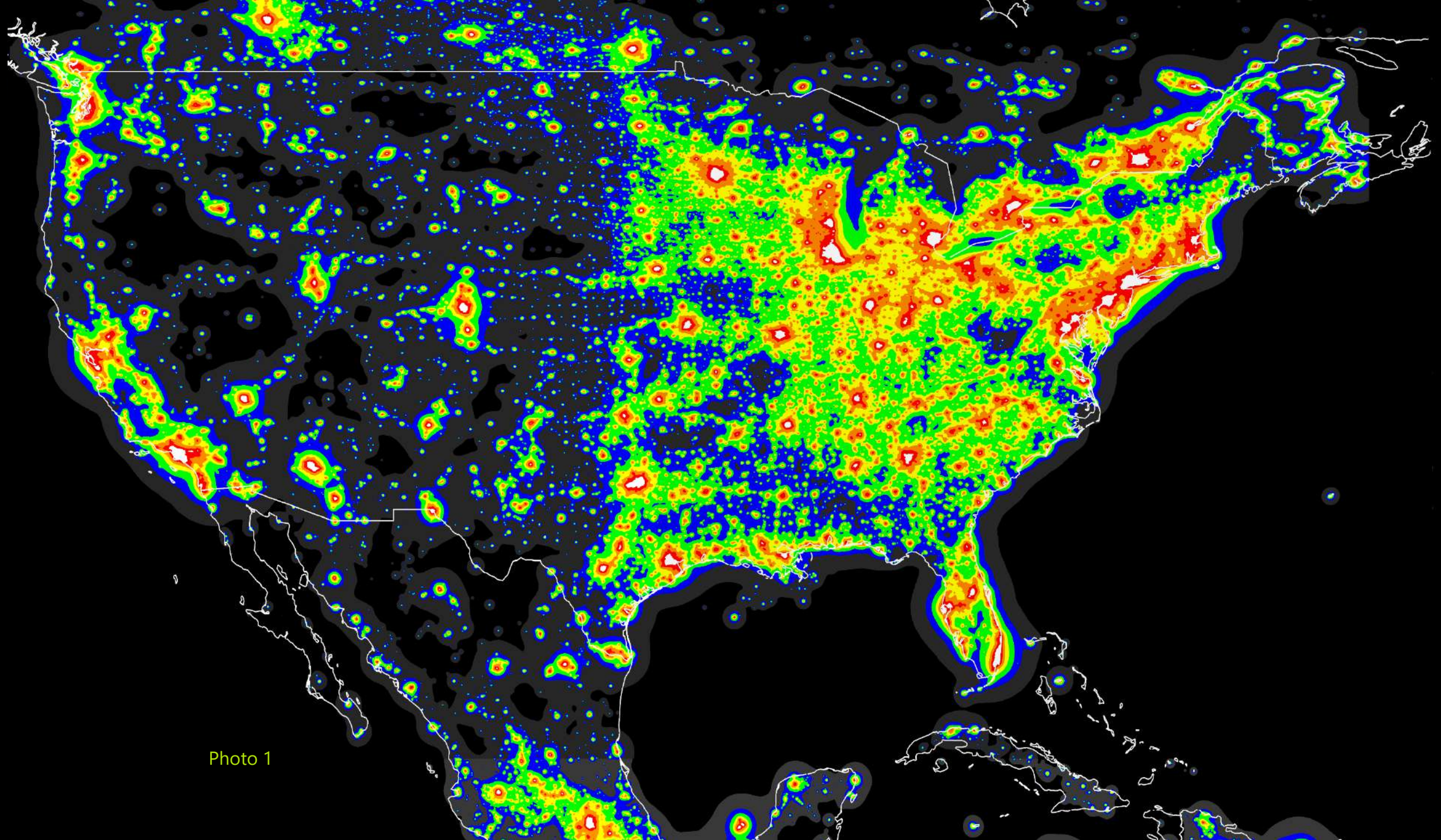


Photo 1

Bar Harbor, Maine: passed strict lighting ordinances to protect the night

Sky Village, Arizona: considered the darkest place in the South West

Model Lighting Ordinance (MLO)

Exterior lighting is organized into five zones of ambient light levels:

Lighting Zone 4: not considered a default lighting zone

Model Lighting Ordinance (MLO)

Utilizes (3) Lighting Design Methods, increasing in complexity:

MLO Challenges:

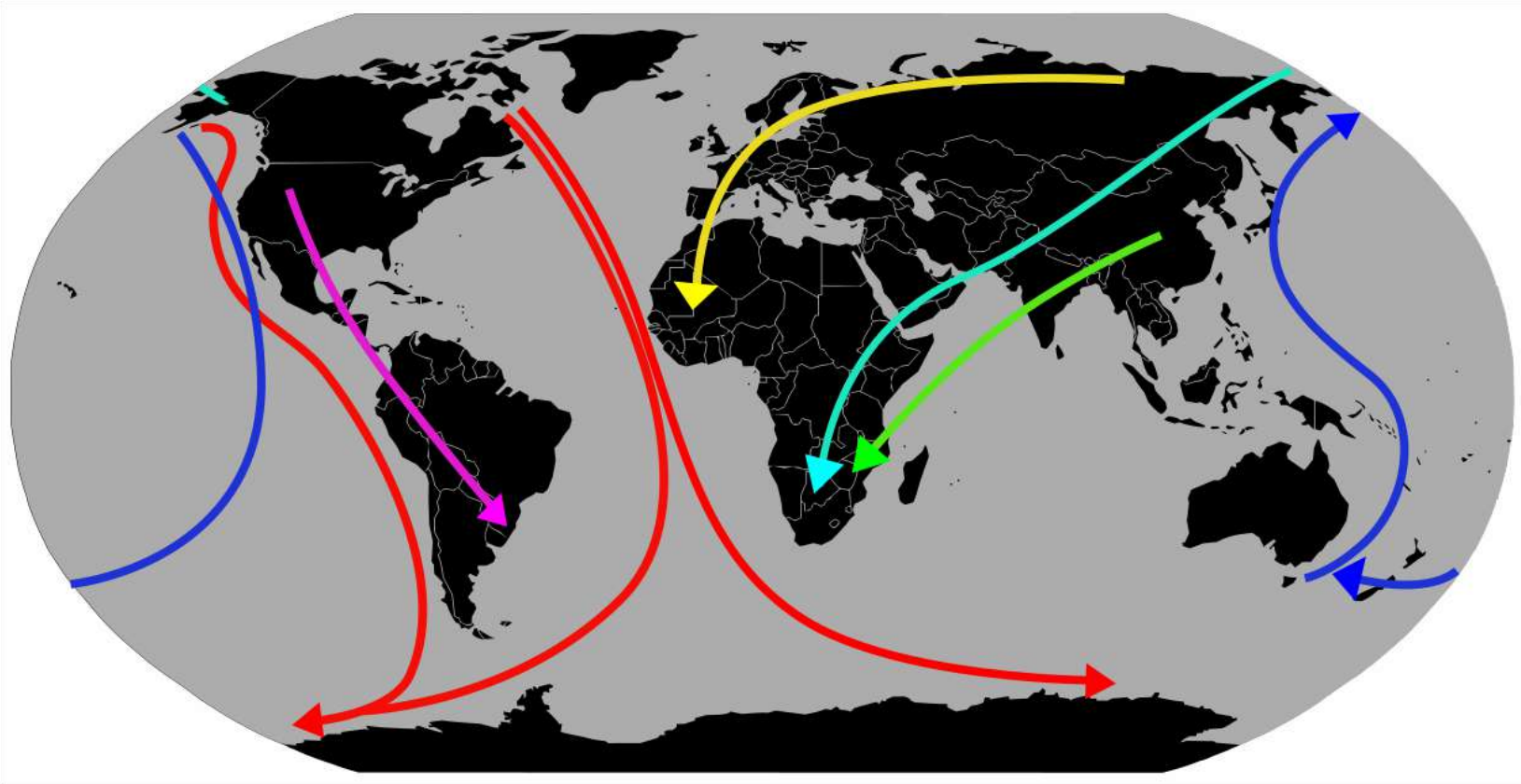
- Adoption
- Consistent Results
- Education & Awareness
- Consensus

Lighting Design for Wildlife

- Utilize controls in in response to night as well as migratory periods
- Avoid triggering wavelengths of species in local habitats
  - White, blue, and green light can cause disorientation for fish[38]
  - Red Light between 620-660nm is ideal for sea turtles[39]
- Utilize window coverings

38. Zielinska-Dabkowska, K. M. (2014, November 5). Journey towards light – evolutionary adaptations of humans, flora and fauna. Guidelines for safe and healthy illumination. Retrieved March 26, 2018, from www.researchgate.net/publication/285056341. Page 274.
39. Ibid

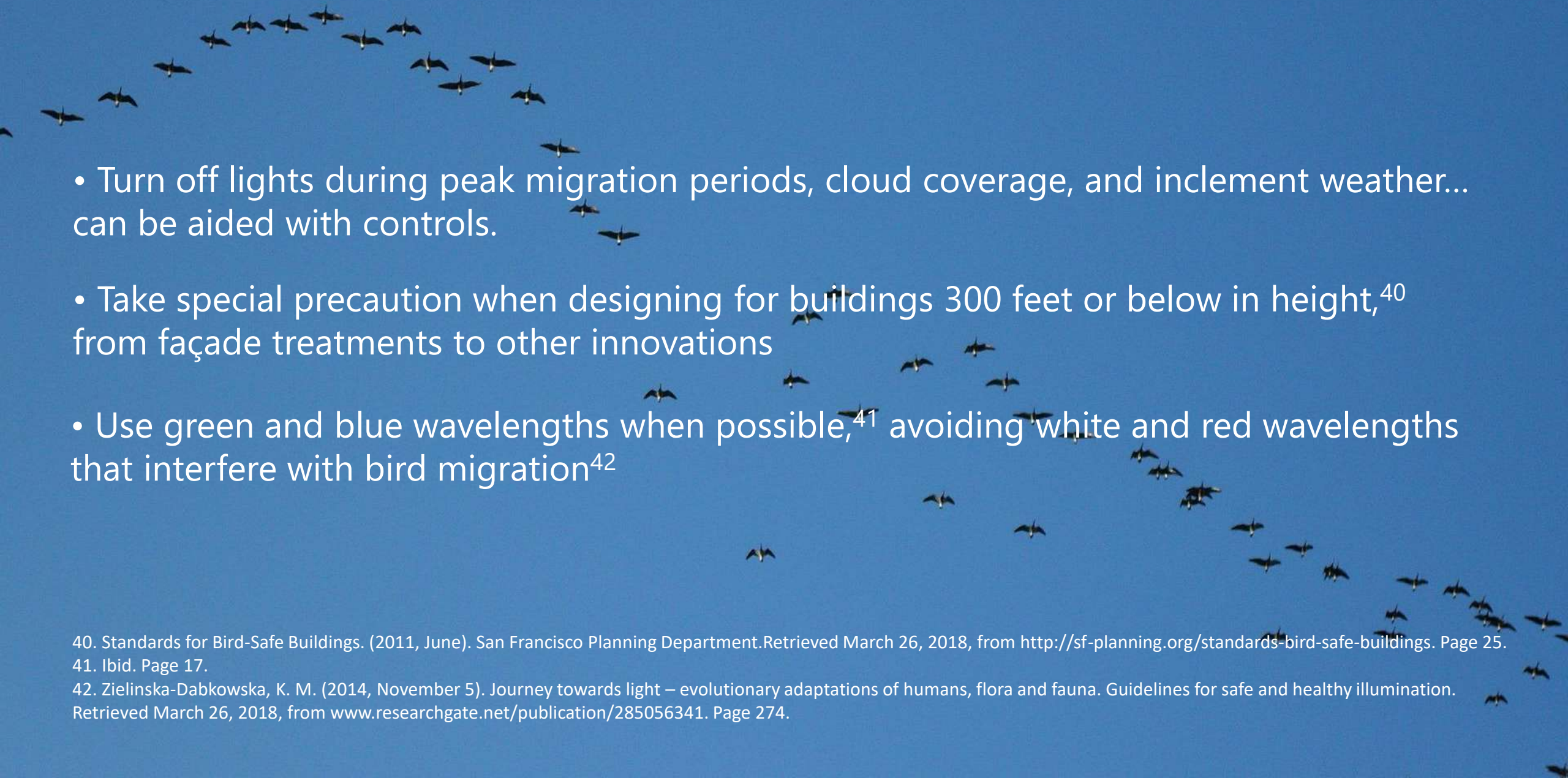
Lighting Design for Birds



Oenanthe oenanthe		Northern Wheatear
Sterna paradisaea		Arctic Tern
Falco amurensis		Amur Falcon
Puffinus tenuirostris		Short-tailed Shearwater
Philomachus pugnax		Ruff
Buteo swainsoni		Swainson's Hawk

Photo 14

Lighting Design for Birds



- Turn off lights during peak migration periods, cloud coverage, and inclement weather… can be aided with controls.

- Take special precaution when designing for buildings 300 feet or below in height,[40] from façade treatments to other innovations

- Use green and blue wavelengths when possible,[41] avoiding white and red wavelengths that interfere with bird migration[42]

40. Standards for Bird-Safe Buildings. (2011, June). San Francisco Planning Department.Retrieved March 26, 2018, from http://sf-planning.org/standards-bird-safe-buildings. Page 25.
41. Ibid. Page 17.
42. Zielinska-Dabkowska, K. M. (2014, November 5). Journey towards light – evolutionary adaptations of humans, flora and fauna. Guidelines for safe and healthy illumination. Retrieved March 26, 2018, from www.researchgate.net/publication/285056341. Page 274.

Lighting Design Case Studies

Flagstaff, Arizona

Successful advocacy for Dark Sky conducted over many years:
1958: City-wide ordinance for outdoor lighting
2001: Named the world's first International Dark Sky Place

Photo 5
First International Dark-Sky City, Flagstaff, Arizona
skyglowproject.com

Flagstaff, Arizona

Exterior Lighting Utilized High Pressure Sodium and Low Pressure Sodium Sources:

- Light Emissions were around 14 times more dim than Cheyenne in Wyoming, a city of a similar size[43]
- In addition, the radius of light pollution around Flagstaff is 8 times smaller than Cheyenne[44]
- High Pressure and Low Pressure Sodium fixtures emit light in warmer wavelengths, significantly reducing impact

43. Flagstaff AZ Images at Night Show Success with Years of Dark Sky Advocacy. (2017, January 20). Retrieved February 11, 2018, from http://www.darksky.org/flagstaff-az-images-at-night-show-success-with-years-of-dark-sky-advocacy/
44. Ibid

Photo 6

Flagstaff, Arizona

Photo 7

First International Dark-Sky City, Flagstaff, Arizona

skyglowproject.com

Big Park, Arizona

- One of the newest places to be designated an International Dark Sky community
- Now the densest area of IDA Dark Sky Communities in the world, including Sedona and Flagstaff

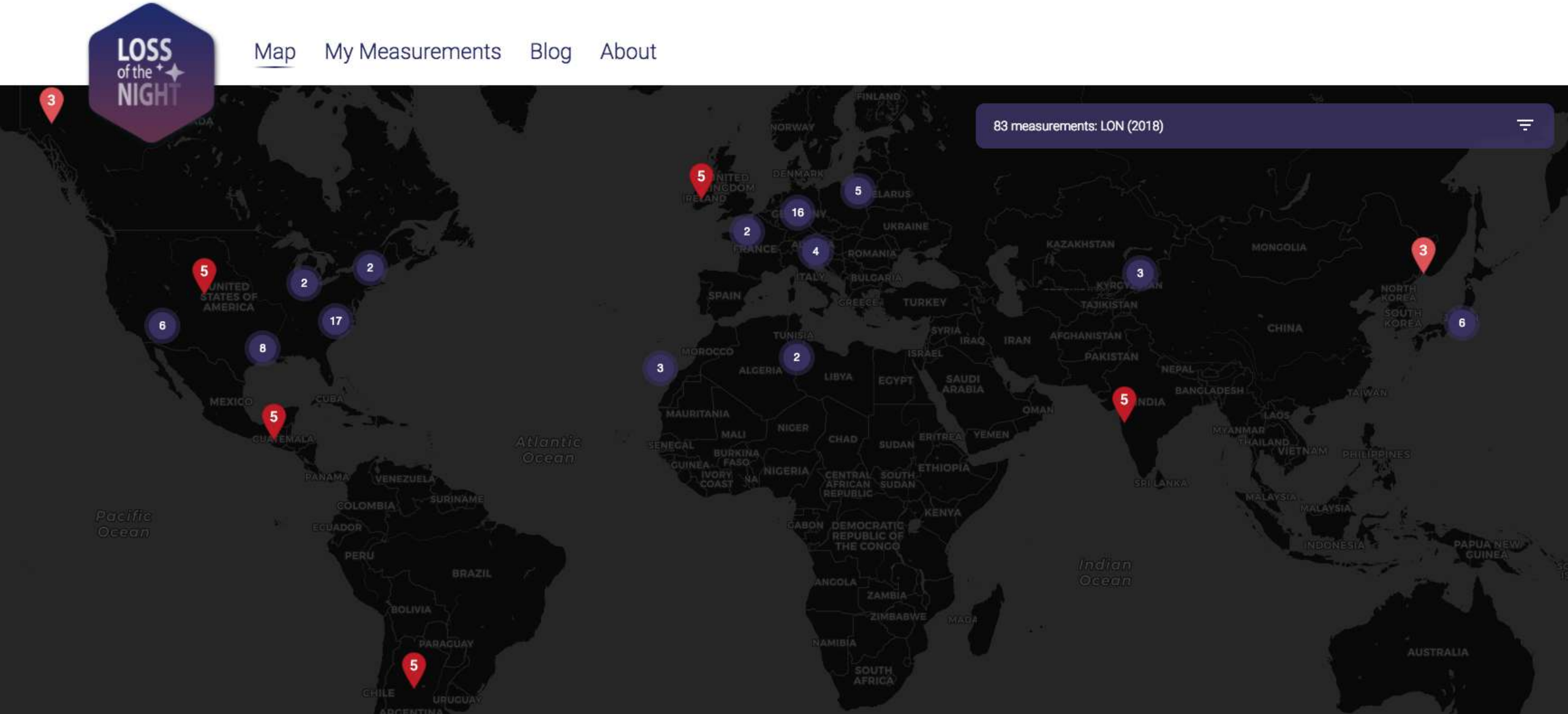
Awareness

The Bortle Scale, 2001

- Named after the astronomer, John Bortle
- Bortle developed a scale to help judge the darkness of sites
- Classes are divided 1-9, the darkest being a 1
- Very few Class 1 sites exist in North America today

Awareness – Citizen Science Project

World-wide crowd-sourcing of dark sky data: www.myskyatnight.com



HARUN MEHMEDINOVIĆ | GAVIN HEFFERNAN

SKYGLOW

Photo 8

Photo 9
Los Angeles, California
skyglowproject.com

Photo 10
Ancient Bristlecone Pine Forest, California
skyglowproject.com

Photo 11
Death Valley National Park, California
skyglowproject.com

Photo 12
Vermilion Cliffs National Monument, Arizona
skyglowproject.com

Photo 13
Crater Lake National Park, Oregon
skyglowproject.com

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The Best Prescriptions For Exterior Lighting

- Design for specific applications
- Conduct photometric studies
- Provide the right amount of light: not more, not less
- Use Dark-Sky compliant fixtures/ Shielding
- Utilize warmer CCTs, or SPDs with higher wavelengths
- Utilize controls to limit impact
- Avoid uplighting always

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The Importance of Consensus

Bibliography

1. "Light Pollution." Lighting Research Center. Rensselaer Polytechnic Institute, February 2007. Web. 9 February 2016.
2. Ibid
3. Fighting Light Pollution: Smart Lighting Solutions for Individuals and Communities. Mechanicsburg, PA: Stackpole Books; 2012. Page 4.
4. Ibid
5. Model Lighting Ordinance. (n.d.). Retrieved March 27, 2018, from http://www.darksky.org/our-work/public-policy/mlo/. User's Guide, Page 4.
6. Solastalgia. (2017, September 12). In *Wikipedia, The Free Encyclopedia*. Retrieved 00:48, February 12, 2018, from https://en.wikipedia.org/w/index.php?title=Solastalgia&oldid=800200969
7. Fighting Light Pollution: Smart Lighting Solutions for Individuals and Communities. Mechanicsburg, PA: Stackpole Books; 2012. Page 25.
8. Ibid. Page 26.
9. Fireflies Need the Dark to Talk with Light. (2017, July 26). Retrieved March 25, 2018, from http://www.darksky.org/fireflies-need-the-dark-to-talk-with-light/
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17. Ibid
18. Ibid
19. Ibid
20. Rich, C., & Longcore, T. (2013). Ecological Consequences of Artificial Night Lighting. Washington: Island Press. Page 28.
21. Ibid
22. Ibid. Page 32.
23. Ibid. Page 43.
24. Horton, T. W., Holdaway, R. N., Zerbini, A. N., Hauser, N., Garrigue, C., Andriolo, A., & Clapham, P. J. (2011). Straight as an arrow: Humpback whales swim constant course tracks during long-distance migration. Biology Letters, 7(5), 674-679. doi:10.1098/rsbl.2011.0279
25. Ibid
26. Ibid
27. Ibid
28. St. Fleur, N. (2016, April 7). Illuminating the Effects of Light Pollution. The New York Times.
29. Dominoni, D., Quetting, M., & Partecke, J. (2013). Artificial light at night advances avian reproductive physiology. Proceedings of the Royal Society B: Biological Sciences, 280(1756), 20123017-20123017. doi:10.1098/rspb.2012.3017
30. Rich, C., & Longcore, T. (2013). Ecological Consequences of Artificial Night Lighting. Washington: Island Press. Page 372.
31. Ibid
32. Chaney, W. R. (2002). Does Night Lighting Harm Trees? Forestry and Natural Resources, Purdue University, 3. Retrieved March 26, 2018, from https://www.extension.purdue.edu/extmedia/fnr/fnr-faq-17.pdf. Page 3.
33. Ibid
34. Ibid
35. Zielinska-Dabkowska, K. M. (2014, November 5). Journey towards light – evolutionary adaptations of humans, flora and fauna. Guidelines for safe and healthy illumination. Retrieved March 26, 2018, from www.researchgate.net/publication/285056341. Page 272.
36. Ibid
37. Model Lighting Ordinance. (n.d.). Retrieved March 27, 2018, from http://www.darksky.org/our-work/public-policy/mlo/
38. Zielinska-Dabkowska, K. M. (2014, November 5). Journey towards light – evolutionary adaptations of humans, flora and fauna. Guidelines for safe and healthy illumination. Retrieved March 26, 2018, from www.researchgate.net/publication/285056341. Page 274.
39. Ibid
40. Standards for Bird-Safe Buildings. (2011, June). San Francisco Planning Department.Retrieved March 26, 2018, from http://sf-planning.org/standards-bird-safe-buildings. Page 25.
41. Ibid. Page 17.
42. Zielinska-Dabkowska, K. M. (2014, November 5). Journey towards light – evolutionary adaptations of humans, flora and fauna. Guidelines for safe and healthy illumination. Retrieved March 26, 2018, from www.researchgate.net/publication/285056341. Page 274.
43. Flagstaff AZ Images at Night Show Success with Years of Dark Sky Advocacy. (2017, January 20). Retrieved February 11, 2018, from http://www.darksky.org/flagstaff-az-images-at-night-show-success-with-years-of-dark-sky-advocacy/
44. Ibid
45. Night Sky Data to the People! (2015, December 08). Retrieved February 11, 2018, from http://www.darksky.org/night-sky-data-to-the-people/

Photographic Sources

1. File:global_northam_Vb.tif (2000). Light Pollution Science and Technology Institute. Retrieved March 25, 2018 from http://www.inquinamentoluminoso.it/worldatlas/pages/fig2.htm.
2. File:Synthesis of Melatonin from Serotonin through two enzymatic steps.png. (2017, February 4). Wikimedia Commons, the free media repository. Retrieved 10:55, February 19, 2018 from https://commons.wikimedia.org/w/index.php?title=File:Synthesis_of_Melatonin_from_Serotonin_through_two_enzymatic_steps.png&oldid=232389703.
3. MacGillivray, M. (2010, June 5). Firefly [After nightfall, the last open field before the wood lot is almost always filled with the green blinking lights of fireflies, otherwise known as lightning bugs.]. Retrieved February 16, 2018, from https://www.flickr.com/photos/qmnonic/4684229596. License: https://creativecommons.org/licenses/by/2.0/
4. St. Fleur, N. (2016, April 7). Illuminating the Effects of Light Pollution. The New York Times. Photo by Leighton Jones.
5. Skyglow Project by Harun Mehmedinovic and Gavin Heffernan
6. File:High Pressure Sodium Lamps.JPG. (2016, December 14). Wikimedia Commons, the free media repository. Retrieved 19:44, March 26, 2018 from https://commons.wikimedia.org/w/index.php?title=File:High_Pressure_Sodium_Lamps.JPG&oldid=226243205.
7. Skyglow Project by Harun Mehmedinovic and Gavin Heffernan
8. Ibid
9. Ibid
10. Ibid
11. Ibid
12. Ibid
13. Ibid
14. Wikipedia contributors. (2019, February 18). Bird migration. In Wikipedia, The Free Encyclopedia. Retrieved 03:37, March 1, 2019, from https://en.wikipedia.org/w/index.php?title=Bird_migration&oldid=883846430 L. Shyamal - Own work. Migration routes of birds based on Newton, I. 2008. The Migration Ecology of Birds. Academic Press.

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