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[1]May be able to assist in education and legislation efforts.
[2]Offers a pamphlet for distribution entitled "Sea Turtles and Lights" and a booklet on general sea turtle biology (Van Meter, 1992).
[3]Maintains worldwide contacts with sea turtle researchers and conservationists.
[4]Compiles national or regional data gathered at sea turtle nesting beaches.
[5]Compiles and distributes information on the causes and effects of light pollution.

APPENDIX J

Responses to some common questions and comments regarding sea turtles and lighting.

When do hatchling sea turtles emerge from their nests?

The first hatchlings of the season emerge from nests approximately eight weeks after the first nesting of the season, and this activity continues for up to eight weeks after the final nesting of the season. Outside the tropics, hatchlings generally emerge throughout the summer and early fall. In the southeastern USA, hatchlings emerge throughout the months of June, July, August, September, and October. It is a myth that hatchlings emerge only around the time of the full moon. Hatchlings ready to emerge wait just beneath the sand surface until conditions become cool. This temperature cue prompts them to emerge primarily at night, although some late-afternoon and early-morning emergences have been documented.

How do hatchling sea turtles know where the ocean is when they emerge from their nests?

Sea turtle hatchlings have an inborn tendency to move in the brightest direction. On a natural beach, the brightest direction is most often the open view of the night sky over, and reflected by, the ocean. Hatchlings also tend to move away from darkly silhouetted objects associated with the dune profile and vegetation. This sea-finding behavior can take place during any phase and position of the moon, which indicates that hatchlings do not depend on lunar light to lead them seaward.

Why do artificial light sources attract hatchling sea turtles?

Hatchlings that crawl toward artificial light sources are following the same instinctive response that leads them seaward on naturally lighted beaches. The apparent brightness and glare of artificial lighting is what often leads hatchlings astray. To a hatchling on a beach, an artificial light source appears bright because it is relatively close by, yet it is not intense enough to brighten the sky and landscape. The resulting glare makes the direction of the artificial source appear overwhelmingly bright—so much brighter than the other directions that hatchlings will ignore other visual cues and move toward the artificial light no matter where it is relative to the sea.

There are other lights near my beachfront property that are visible from the beach. Why should I modify my lights?

Any reduction in the amount of artificial light reaching the nesting beach helps sea turtles. As lighting is reduced, hatchlings emerging on moonlit nights and at locations far from the lighted property will have a better chance of finding the sea.

Can hatchlings be protected by increasing the number of lights on a nesting beach in order to prevent turtles from nesting?

Although artificial lighting tends to deter sea turtles from nesting, many do nest on lighted beaches. Apparently, the level of artificial lighting necessary to misdirect hatchlings is well below the level necessary to deter nesting. But even if beaches were lighted to the extent that no nesting occurred, hatchlings on adjacent beaches would be harmed. Regardless, chasing sea turtles away from nesting beaches means that important habitat is lost to them; therefore, it is not a beneficial conservation strategy.

How bright can a light be without affecting hatchlings or adult sea turtles on the beach?

Unfortunately, no simple measure of light intensity can reveal whether a light source will be a problem. The effects of artificial lighting on sea turtles may actually increase as ambient light-levels decrease on darker, moonless nights. Because any visible light from an artificial source can cause problems, the most reliable "instruments" to use when making judgments about problem lighting may be the eyes of a human observer on the nesting beach. Any light source producing light that is visible from the beach is likely to cause problems for nesting sea turtles and their hatchlings.

What should be done with misdirected hatchlings found on the beach?

Hatchling sea turtles found wandering away from the ocean should be taken to a darkened portion of beach and allowed to walk into the surf on their own. Those that do not crawl vigorously can be placed in the water and allowed to swim away. In all cases, local natural resource or environmental protection agencies should be notified. Consult Appendix I for a list of governmental and non-governmental conservation organizations.

Whom should I notify about a light that is visible from a sea turtle nesting beach?

The owner or resident of the property where the light source is located should be contacted. In most cases, people are simply unaware rather than uncaring. Local government conservation agencies should also be notified. A growing number of coastal communities have adopted ordinances that prohibit lighting on the beach during the nesting season. Code enforcement offices often oversee the enforcement of these ordinances. If there is inadequate regulation of beach lighting in your area or if lighting problems persist, private conservation organizations may be able to help. Consult Appendix I for a list of governmental and non-governmental conservation organizations.

I do not have the ability to turn off a problem light that is located on my property. What can be done?

Luminaires that do not have convenient on-off switches are most often controlled by the utility company. Property owners should contact the entity to whom electricity bills are paid or to whom lighting lease payments are made.

Will lighting on a pier affect sea turtles on the adjacent beach?

Yes. Lighting on piers is very difficult to shield from the beach. Hatchlings on adjacent stretches of beach may crawl for great distances in the direction of the lighted pier. Hatchlings that enter the water near the pier may linger in the glow beneath the lighted structure and fall prey to fish, also attracted to the light, rather than disperse offshore.

Will placing bright lights on platforms offshore guide hatchlings into the water off lighted beaches?

Apart from being an overly expensive and complicated solution, lighting the ocean to draw hatchlings offshore would probably create additional problems. Lighting on the water can interfere with hatchling dispersal and increase mortality from fish predation.

There is not enough sea turtle nesting on this beach to justify beach-darkening efforts. Why is light-management legislation needed?

Beaches where small numbers of turtles nest can be very important. The entire nesting range of a population may be made up of sparsely nested beaches. Hawksbill turtles, for instance, one of the most endangered sea turtles, do not nest in great numbers anywhere. Moreover, any group of nesting turtles may constitute a genetically unique and vulnerable unit. Losing even small populations may mean the permanent loss of diversity. The irony in disregarding lighting problems at sparsely nested beaches is that artificial lighting may have caused the nesting to be so low. Many lighted beaches with little nesting may again attract more nesting turtles once they are darkened.

Crime will increase if the beach is not lighted.

Generally, beaches are not areas where there is a great need for crime prevention. Very little valuable property is stored on beaches and there is seldom much nighttime human activity to require security. Fortunately, areas adjacent to nesting beaches where people reside, work, recreate, and store valuables can be lighted for protection without affecting turtles on the nesting beach. Where this type of light management was legislated in Florida coastal communities, the Florida State Attorney's Office has found no subsequent increase in crime.

Implementing a beach-darkening program will be prohibitively expensive.

Darkening nesting beaches for sea turtles is one of the least expensive ways we can benefit the environment. The simplest solution to the problem—turning off lights visible from the beach during the nesting season—

costs little or nothing and may actually save money in electricity costs. Most of the essential lighting that remains can easily be shielded so that the light performs its intended function without reaching the beach. Proper shields can be fashioned from inexpensive metal flashing and fastened with screws. Replacing fixtures is more expensive but is necessary only when an owner decides that greater lighting efficiency or aesthetics are a concern. Choosing well-designed fixtures and incorporating light-management techniques into the plans for coastal development are the most effective ways to fulfill lighting needs while protecting sea turtles.

There are too many disadvantages to using low-pressure sodium-vapor lighting to protect sea turtles.

As is true for any light source, there are both advantages and disadvantages to using low-pressure sodium-vapor (LPS) lighting. The following is a list of issues specific to LPS.

Expense—The initial costs of LPS are substantially higher than for incandescent and fluorescent sources but are only slightly higher than costs for high-intensity discharge lighting (*e.g.*, HPS). Operating costs, however, are generally much lower for LPS than for any other commercial source.

Color—Because LPS sources are monochromatic, they give poor color rendition. For safety and security applications, however, full-spectrum color is seldom needed. At U.S. Air Force installations near nesting beaches in Florida (areas certain to have rigorous security requirements), most outside security areas are lighted by LPS sources.

Disposal—The lamps within LPS luminaires contain elemental sodium, a substance that can cause fires if not disposed of carefully. However, unlike the mercury-containing high-intensity discharge lamps (*e.g.*, mercury-vapor, high-pressure sodium vapor), the contents of LPS lamps are not toxic.

Availability—Although LPS luminaires are not as readily available in retail stores as other light sources are, a wide variety of LPS fixtures are available from a number of manufacturers (see Appendices D and G).

Sea turtle nests on our beach are moved to darker areas to protect hatchlings from lighting. Are our lights still a problem?

Yes. Although it may seem that moving nests out of harm's way will solve the problem, doing so only partially solves the problem and may create new ones. In moving nests, nothing is done to prevent lighting from deterring nesting turtles and interfering with their orientation on the beach. Moving nests also has its own negative consequences that stem from the limitations of this technique:

1. In nearly every effort to find nests, some are missed. Hatchlings from missed nests will suffer the effects of beach lighting.

2. Moved clutches of eggs often have poorer hatching rates. Moving eggs kills at least some of them, and often many die, depending upon how skillfully the moving is done.

3. Putting eggs in places other than those chosen by the nesting turtle can be detrimental. A specific nest environment is critical, both for the survivorship of eggs and for the determination of the hatchlings' sex ratio.

How can the sacrifice of human safety and security to save a few sea turtles be justified?

Thankfully, no such choice is necessary. The safety and security of humans can be preserved without jeopardizing sea turtles. The goal of any program to reduce sea turtle harassment and mortality caused by lighting is to manage light so that it performs the necessary function without reaching the nesting beach. Still, some may contend that any inconvenience at all is too much and that the concerns of humans should always outweigh those for turtles. People insistent on this generalization should not ignore the large and resolute constituency that values sea turtles. Sea turtles are valuable to people both ecologically and for pure enjoyment. In many ways, the protection of sea turtles is in our own best interests.

What good are sea turtles?

Measuring the true worth of anything is difficult, but it is especially difficult to make this measurement of a common resource. Although some may appreciate sea turtles more than others, sea turtles are of value to all. Short of a thorough discussion on the ecological place of sea turtles, suffice it to say that the world would be a poorer place to live without them. We just don't know how much poorer. With regard to sacrificing the diversity of life, Aldo Leopold wrote in his *Sand County Almanac:*

> *"The last word in ignorance is the man who says of an animal or plant:* 'What good is it?'... *If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering."*

APPENDIX K

A glossary of terms.

Acceptance cone: A solid angle that describes the apex of a geometrical cone containing the range of directions from which light can be measured by a detector (or an animal).

Angle of acceptance: An angle, usually specified as horizontal or vertical, that describes the range of directions from which light can be measured by a detector (or an animal).

Anthropogenic: Originating from the actions or devices of humans.

Artificial lighting: Light sources that have been produced by humans.

Beach: Dynamic coastal areas of sedimentary deposits, usually sand, between the primary dune and the water.

Bollard lighting: Lighting fixtures within a waist-level post or bollard. Bollard fixtures are generally designed to illuminate only the immediate area around the bollard.

Brightest direction: The direction in which the perception or measurement of brightness is greatest.

Brightness: The perception or measure that describes light intensity with respect to a specific spectral sensitivity and angles of acceptance.

Bug light: An incandescent lamp that is tinted yellow in order to attenuate its emission of short-wavelength visible light and thus reduce its attractiveness to insects.

Candela: The basic, international unit for measuring luminous intensity.

Clutch: A group of eggs deposited within a nest.

Color rendering: The effect of a light source on the color appearance of an object.

Color: The sensation resulting from stimulation of the retina by light of certain wavelengths.

Cone of acceptance: *See* Acceptance cone.

Crawl: Used as a noun, the tracks and other disturbances left on a beach by a sea turtle that has attempted to nest.

Cut-off angle: The angle between a vertical line through a luminaire and the first line of sight at which the glowing elements of the luminaire are no longer visible.

Diffuser: Made of translucent material, the part of a luminaire through which light is diffused. One of the elements of a luminaire that appears to glow. Also called a lens or globe.

Direct lighting: A luminaire provides direct lighting if any of the glowing elements of the luminaire are visible to an observer on the beach.

Directional lighting: A luminaire that can be aimed so that its light reaches only specific areas.

Disorientation: Loss of orientation. Being unable to maintain constant directional movement.

Downlighting: Generally canister- or cylinder-shaped lighting fixtures that direct light predominately downward and that possess light baffles to reduce lateral light.

Efficiency: For a lamp, the ratio of light output (lumens) to electrical power (watts) consumed.

Electroretinography (ERG): A method to determine spectral sensitivity in which the relative electrical potential is measured across retinas exposed to light at specific wavelengths and intensities.

ERG spectrum: Measured by electroretinography, the spectral sensitivity of an animal.

False crawl: An aborted nesting attempt (emergence onto a beach) by a sea turtle.

Fixture: The device that holds, protects, and provides the optical system and power connections for a lamp.

Floodlighting: High-intensity lighting that can be directed at various angles to illuminate large areas or objects.

Fluorescent: An electric-discharge lamp containing argon, neon, mercury, and in some cases krypton, which is coated inside with phosphors that determine color appearance (most commonly, white) when lighted.

Footcandle: The English unit for measuring illuminance; the illumination of a surface uniformly one foot from a point source of one candela; one lumen per square foot; equal to 10.76 lux.

Globe: A diffuser, usually hemispherical, of a luminaire. One of the elements of a luminaire that appears to glow.

Hatching success: The proportion of eggs in a nest that produce living hatchlings.

Hatchling: A newly hatched sea turtle.

High-pressure sodium vapor (HPS) lamp: An electric discharge lamp containing an amalgam of sodium and mercury, and rarefied xenon, that appears whitish golden or peach-colored when lighted.

High-intensity discharge (HID) lamp: Referring to a group of light sources that include high-pressure sodium-vapor, mercury-vapor, and metal-halide lamps.

Illuminance: The density of luminous flux on a surface. Luminous flux includes only visible light. Measured in footcandles or lux.

Incandescent: A lamp that produces light by means of an electrically heated glowing metal filament and that appears white when lighted. Includes quartz tungsten halogen (or simply tungsten halogen) sources. May be tinted to vary color (*e.g.*, yellow bug lights).

Indirect lighting: A luminaire provides indirect lighting if its light is visible to an observer on the beach only after it is reflected by objects near the beach or scattered by mist.

Irradiance: The density of radiant flux on a surface. Radiant flux may include light throughout the spectrum.

Lamp: The source of light within a luminaire.

Lens: *See* Diffuser.

Light: 1) Visible or near-visible radiant energy. 2) A term often used in place of "luminaire" or "light fixture."

Light color: *See* Color.

Light fixture: *See* Fixture.

Light shield: Any opaque material fastened to a luminaire that makes the luminaire produce more directional lighting.

Light meter: A detector used to measure levels of visible light, typically luminance or illuminance.

Light pollution: The introduction of artificially produced detrimental light into the environment. Similar to light trespass: the emission of light into areas where it is unwanted.

Louver: A series of light-blocking baffles used to direct light coming from a luminaire.

Low-pressure sodium vapor (LPS) lamp: An electric discharge lamp that contains sodium, neon, and argon and that appears amber yellow when lighted.

Lumen: A unit of light output or flux, equal to the amount of light flow from one candela through a unit solid angle.

Luminaire: A complete unit that artificially produces and distributes light. An artificial light source, including fixture, ballast, mounting, and lamp(s).

Luminance: The luminous flux from a surface or light source, per unit area of the surface. Luminous flux includes only visible light.

Lux: The metric unit for measuring illuminance; the illumination of a surface uniformly one meter from a point source of one candela; one lumen per square meter; equal to 0.0929 footcandle.

Mercury-vapor lamp: An electric-discharge lamp that contains mercury and argon and is sometimes coated with phosphors; appears whitish when lighted.

Metal-halide: An electric-discharge lamp that contains mercury, argon, sodium iodide, scandium iodide, and scandium; appears white when lighted.

Misorientation: Orientation in the wrong direction. For hatchling sea turtles on the beach, travel in any direction other than the general vicinity of the ocean.

Monochromatic: The description of a light source emitting a very narrow set of wavelengths (*i.e.*, a single color).

Mounting height: The vertical distance between a luminaire and the surface to be lighted.

Nest: The area of disturbed sand on a beach where a sea turtle has buried a clutch of eggs.

Nesting success: The proportion of nesting attempts by a sea turtle (emergences onto the beach) that result in eggs being deposited.

Photometer: *See* Light meter.

Photopigments: The light-absorbing chemicals within the rod and cone cells of the retina.

Photopollution: *See* Light pollution.

Phototropotactic: Pertaining to phototropotaxis.

Phototropotaxis: Directional movement governed by a weighing of sensory excitation from stimuli received by separate light-sensing structures.

Primary dune: Coastal areas of elevated sandy deposits closest to the water; generally has well-established vegetation if it has not been artificially cleared.

Radiance: The radiant flux from a surface or light source, per unit area of the surface.

Radiometer: An instrument for measuring radiant energy (*e.g.*, visible light).

Recessed: A term describing a luminaire mounted within a ceiling opening in such a way that the glowing elements of the luminaire are hidden from view.

Reflector: An element of a luminaire that directs light from the luminaire by reflection.

Retina: The surface within the vertebrate eye that contains the pigmented cells (rods and cones) that are sensitive to light.

Sea-finding behavior: The tendency to move in the direction of the ocean.

Sex ratio: The proportion of females to males. Sex ratios of sea turtle hatchlings are determined by the environmental conditions (mostly temperature) under which the eggs incubate.

Shield: *See* Light shield.

Skyglow: The glow of light scattered by mist and clouds over densely lighted areas.

Spectral light: Light composed of specific wavelengths.

Swash zone: The beach zone where advancing waves wash up the beach and recede.

Tier lighting: Small light fixtures with louvers that restrict light to the immediate area around the fixture. These fixtures are generally mounted at ground level.

Up-lighting: Lighting fixtures that are directed upward, usually onto objects (flags, monuments, signs, buildings, *etc.*).

Urban skyglow: *See* Skyglow.

Visible spectrum: The range of wavelengths visible to humans, generally between 380 (violet) and 760 (red) nanometers.

Wavelength: The property of a photon of light that determines its energy and color, usually expressed in nanometers (nm, billionths of a meter).

Xanthophobia: The tendency to orient away from sources rich in yellow light. A type of orientation seen in loggerhead hatchlings.