COASTAL ROADWAY LIGHTING MANUAL

A HANDBOOK OF PRACTICAL GUIDELINES FOR MANAGING STREET LIGHTING TO MINIMIZE IMPACTS TO SEA TURTLES

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USER'S GUIDE

This section briefly describes the intent of the Coastal Roadway Lighting Manual, provides an overview of its content, and directs users to those sections of the manual that may be of greatest immediate use and/or interest. **PLEASE TAKE A FEW MOMENTS TO READ THROUGH THE QUESTIONS BELOW BEFORE PROCEEDING TO THE BODY OF THE DOCUMENT!**

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1. What is the Intent of the Coastal Roadway Lighting Manual?

Florida's beaches serve as important nesting habitat for several species of threatened and endangered sea turtles. Artificial light on or near nesting beaches can negatively affect the nesting process by interfering with normal nocturnal behaviors of sea turtles. Street lights contribute to this problem.

The impetus for the Coastal Roadway Lighting Manual was an accumulating record of impacts to sea turtles from street lights and an apparent lack of understanding and/or resources needed by lighting custodians to implement effective solutions. By providing practical guidelines and identifying resources needed to reduce impacts to sea turtles, this manual is designed to facilitate and standardize light management efforts along coastal roadways in Florida.

2. Am I Required to Take Any Action as a Result of This Manual?

The Coastal Roadway Lighting Manual does not impose any new regulations nor does it establish time frames for bringing street lights into compliance with applicable lighting regulations. It is merely a tool to assist interested parties in resolving identified street lighting problems.

3. Why Should I Be Concerned About Street Lights That Shine on the Beach?

Lights shining on the beach have the potential to interfere with the natural nesting and/or sea-finding ability of sea turtles and may be in violation of local, state and/or federal laws and regulations. The party responsible for the operation of lights causing problems for sea turtles could be subject to fines and other penalties. Good faith implementation of appropriate light management techniques, as presented in the Coastal Roadway Lighting Manual, should substantially reduce exposure to this liability.

4. *Must I Compromise Roadway Safety To Protect Sea Turtles?*

Fortunately, street lighting can generally be managed in a manner that minimizes the potential for impacts to sea turtles while still providing for adequate nighttime highway safety. Technological advances presented in the Coastal Roadway Lighting Manual provide flexibility in accommodating various street lighting interests under different local highway conditions and environmental settings.

5. *Who is This Manual Intended to Serve?*

The Coastal Roadway Lighting Manual was developed with the following audiences in mind:

- Utility customer service representatives,
- Utility field personnel,
- Traffic planners and engineers,
- Environmental planners and managers,
- Regulators,
- Code enforcement officers,
- Conservationists, and
- Others involved in roadway light management.

6. *Do I Need a Background In Sea Turtle Biology to Use This Manual?*

The Coastal Roadway Lighting Manual is intended to serve those with no prior experience dealing with lighting issues as they relate to sea turtles. The manual contains basic information on how light affects both adult and hatchling sea turtles, but an understanding of that process is not essential to achieving effective light management. Step-by-step guidelines are provided for determining if a light is likely to be a problem for sea turtles and for resolving previously and newly identified problems.

6. *I Don't Have Time to Read the Entire Manual Right Now! Where Should I Start?*

The Coastal Roadway Lighting Manual includes a step-by-step approach to effective light management. A variety of background and supporting information is also included. This supporting information may not be of immediate interest to all users. The index below helps guide users to those sections of the manual of greatest immediate need or interest.

7. *Who Can I Contact if I Have Questions Regarding the Content of This Manual?*

For information regarding the preparation or content of the Coastal Roadway Lighting Manual contact:

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8. *How Can I Obtain Additional Copies of the Coastal Roadway Lighting Manual?*

Copies of the Coastal Roadway Lighting Manual, as well as periodic updates, may be obtained electronically from the Florida Department of Environmental Protection through their web site at:

http://www.fmri.usf.edu

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The City of Hollywood
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●
The City of St. Augustine Beach
●
The City of Venice
●
Manatee County
●
Palm Beach County
●
Sarasota County
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St. Johns County
●
Volusia County

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CHAPTER 1

INTRODUCTION

Purpose

In Florida, many important arterial roadways are located near the shore. These roads provide beach access to millions of residents and tourists as well as scenic routes between coastal towns and cities.

Florida's beaches provide important nesting habitat for five species of threatened or endangered sea turtles (Meylan et al., 1995). Activities that directly harm sea turtles, interfere with their essential nocturnal behaviors, or degrade nesting habitat are prohibited by law under the U.S. Endangered Species Act (ESA) of 1973 and Florida Statutes.

The proximity of lighted roadways to sea turtle nesting beaches presents an environmental dilemma in Florida. Normal behavior of adult nesting female and hatchling sea turtles can be altered by artificial light sources near the beach. This can lead to reduced nesting by adults and an inability of hatchlings to properly orient to the sea after leaving the nest. Both effects are undesirable. Interference with the sea-finding ability of hatchlings is of particular concern, because it can result in increased mortality of these threatened and endangered species.

Under increasing pressure from the U.S. Fish and Wildlife Service (USFWS) and the Florida Department of Environmental Protection (FDEP), local communities are searching for ways to minimize lighting impacts to sea turtles. To date, street lighting problems have been dealt with on a case-by-case basis. Different solutions have been developed independently for similar problems in geographically distant locations. Some solutions have been effective, while others have not. The intent of this manual is to provide a standard and practical approach to light management on Florida’s coastal roadways. The guidelines and resources contained herein will facilitate the timely selection and implementation of lighting modifications that, when properly applied, can reasonably be expected to reduce the potential for future impacts.

Approach

Guidelines and alternative lighting recommendations contained in this manual were the collaborative effort of a **Technical Working Group** (TWG). Participants on the TWG (Appendix A) consisted of lighting experts, traffic engineers, public safety personnel, utility customer service managers, biologists, and regulatory agency personnel representing the following:

- Florida Power & Light Company (FPL),

- FDEP,
- USFWS,
- Florida Department of Transportation (FDOT),
- Delray Beach Police Department,
- General Electric Lighting Systems, Inc., and
- Ecological Associates, Inc. (EAI).

The TWG considered public safety, economic, social, and conservation issues as it evaluated potential lighting solutions. Rather than advocating a single solution for all lighting problems, the focus was on providing a suite of lighting alternatives to provide flexibility in dealing with unique local conditions. Both existing and new technologies were reviewed and evaluated.

A **Steering Committee** was formed to support the TWG (Appendix B). This committee was comprised of representatives from county and municipal governments with interests in the development of effective solutions for street lighting problems in their communities. Members of the committee assisted in identifying issues of local concern, reviewed and provided recommendations on work products, served as liaisons between the TWG and their respective governing bodies, and contributed to the cost of manual production.

Because of the complexity of issues involved with street lighting and the diverse social and environmental settings around the state, satisfactory resolution of roadway lighting and endangered species conflicts can, at times, be difficult. This manual does not offer a panacea for all lighting problems. Rather, it provides a practical approach to addressing problem lights in a manner that is likely to reduce the potential for impacts. In most cases, recommended management techniques will completely eliminate a lighting problem. However, in other situations, additional light management efforts may be needed if the "corrected" problem light continues to interfere with the behavior of sea turtles.

Misconceptions abound as to what constitutes a satisfactory "fix" for lights causing problems for sea turtles. The involvement of recognized experts in the fields of roadway lighting and sea turtle conservation was intended to lend authority to the guidelines and alternative solutions presented in the manual. All members of the TWG and Steering Committee had an opportunity to review and comment on previous drafts.

When properly applied, the light management strategies contained in this document are endorsed by FDEP and USFWS, the regulatory agencies responsible for sea turtle conservation and recovery programs in Florida and the U.S., respectively.

Objectives

There are many types of lights, other than street lights, that cause problems for sea turtles on Florida's beaches. Clearly, all sources of artificial light near the beach must be properly managed. A recent publication by Witherington and Martin (1996), *Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches*, provided an in-depth look at this broader issue and offered practical solutions for effective light management. However, street lights differ from most other types of public and private lights, in that they perform a unique public function. Complex issues of highway safety, regulatory constraints, and liability are involved in the satisfactory resolution of associated lighting problems. Thus, street lighting management requires a special understanding and approach that was not previously articulated. That is the reason for this manual. It is intended to serve as a companion document to the Witherington and Martin (1996) publication.

The primary objectives of the TWG during development of the Coastal Roadway Lighting Manual were to:

1) Review the various public safety, social, regulatory, economic, and environmental issues related to street lighting,

2) Review and evaluate existing, as well as new and innovative, technologies for resolving street lighting problems,

3) Establish clear and concise guidelines for effective street light management using best available technology, and

4) Within the framework of the controlling issues identified in No. 1 above, prepare a manual that provides a practical and standard approach to addressing coastal roadway lighting problems in Florida endorsed by USFWS and FDEP.

This manual is intended to serve a variety of users, including but not limited to:

- Utilities (field personnel and customer service representatives).
- Road departments (traffic planners and engineers).
- Municipalities (code enforcement and environmental managers).
- Regulatory agencies.
- Conservation groups.

The previous lack of basic guidelines for street light management often resulted in duplication of effort, inadequate resolution of identified problems, delays in implementation of effective solutions, and/or unnecessary expense. These situations were extremely frustrating and frequently led to an adversarial climate between those requiring that lighting be modified and those responsible for affecting a solution. This project is intended to foster a more cooperative working relationship among lighting customers, lighting custodians, regulators, and conservationists.

CHAPTER 2

SUMMARY OF EFFECTS OF COASTAL LIGHTING ON SEA TURTLES

Many animals, including sea turtles, rely on celestial light for visual orientation and/or the timing of periodic behavior. Artificial light that interferes with these essential behavioral systems is termed photopollution (Verheijen, 1985). Unlike chemical pollutants, errant artificial light is not toxic. Nevertheless, it can have profound effects on the survival of animals that rely on accurate light information to initiate or guide critical biological activities (Witherington, 1997).

Light cues figure prominently in the reproductive behavior of sea turtles. Errant lighting on or near nesting beaches introduces misinformation to turtles during vital phases of the reproductive process (Witherington and Martin, 1996; Lohmann et al., 1997).

Effects on Adults

Sea turtles in Florida nest almost exclusively at night. This adaptive behavior protects the female from would-be predators and from over heating.

In summarizing our current scientific understanding of how artificial light affects sea turtles, Witherington and Martin (1996) concluded that the most clearly demonstrated effect of artificial lighting on adults is to deter nesting females from emerging from the ocean. In field experiments at undeveloped nesting beaches, both loggerhead and green turtles showed a significant tendency to avoid stretches of brightly illuminated beach (Witherington, 1992). Additionally, many researchers have noted a relationship between the amount of lighted beach development and sea turtle nest densities. For example, Mattison et al. (1993) noted that emergences of nesting turtles in Broward County, Florida were reduced in areas where lighted piers and roadways were near the beach. In areas where a glow of artificial light is present behind the dune, loggerhead turtles prefer to nest in the darker areas silhouetted by tall buildings and dune vegetation (Salmon et al., 1995).

Effects on Hatchlings

Although there is a tendency for turtles to prefer dark beaches, many do nest on lighted shores. As noted by Witherington and Martin (1996), in doing so, they place the lives of their hatchlings at risk. That is because artificial lighting can impair the ability of hatchlings to properly orient to the ocean once they leave their nests.

Hatchling sea turtles exhibit a robust sea-finding behavior. A direct and timely migration from the nest to sea may be vital to their survivorship. Although the cues involved in sea finding are complex, hatchlings rely primarily on vision for proper orientation (Witherington and Martin, 1996; Lohmann et al., 1997). A combination of light and shapes is thought to be responsible. The extent to which one or the other drives the process may be a function of the relative strength of each stimulus.

Hatchlings have a tendency to orient toward the brightest direction. There are two mechanisms that would permit this type of orientation, the simplest of which is known as phototropotaxis (a turning and movement toward light). Hatchlings turn first in one direction and then in the other until the perceived light intensity is balanced between both eyes. When light balance is achieved, they will be facing the brightest direction. A more complex mechanism, telotaxis (fixation on and movement toward a target stimulus), allows instantaneous integration of light stimuli from many directions to establish brightest direction.

On natural undeveloped beaches the brightest direction is almost always away from elevated shapes (e.g., dune, vegetation, etc.) and their silhouettes and toward the broad open horizon of the sea. On developed beaches, the brightest direction is often away from the ocean and toward lighted structures. Hatchlings unable to find the ocean, or delayed in reaching it, are likely to incur high mortality from dehydration and predators. Hatchlings lured into lighted parking lots or toward street lights are often crushed by passing vehicles (McFarlane, 1963; Philibosian, 1976; Peters and Verhoeven, 1994; Witherington and Martin, 1996).

When artificial lighting is strongly attractive, hatchlings move in a highly directed but incorrect path away from the ocean. This behavioral anomaly is termed **misorientation**. Less attractive lighting may prevent hatchlings from orienting in a constant direction either toward or away from the sea. Hatchlings, crawling erratically are said to be **disorientated**. Throughout the remainder of this manual, **both types of misdirected crawling will be referred to as disorientation**, as that is the term most frequently used by sea turtle conservationists in describing events where hatchlings do not crawl directly from the nest to the ocean.

How Hatchling Sea Turtles Perceive Light

To reduce the effects of artificial lighting on sea turtles, it is first essential to understand how sea turtles perceive light in their environment. First, and most importantly, strategies to resolve lighting problems must recognize that man's common notions of brightness and color do not apply, because sea turtles and humans perceive light quite differently.

Both the color (wavelength) and relative brightness of light sources are important in the sea-finding capabilities of hatchling sea turtles (Witherington and Martin, 1996; Lohmann et al., 1997). Green turtles are strongly attracted to light in the near-ultraviolet to yellow region of the visible spectrum (360 to 600 nm) but are relatively indifferent to light in the yellow-orange to red region (630 to 700 nm; Figure 1). Loggerhead turtles are also strongly attracted to short wavelength light, but unlike green turtles, have an aversion to bright light in the green-yellow to yellow spectrum (560 to 600 nm); loggerheads are only moderately attracted to longer wavelength light in the orange and red spectra. The relatively high sensitivity of turtles to short wavelengths is not surprising considering that they live in a medium, the ocean, that selectively filters out long wavelength colors.

The relative attractiveness of hatchlings to different colors is a function of brightness. Relatively low intensities of ultraviolet to green light (short wavelengths) are needed to elicit an orientation response in loggerhead hatchlings, whereas much higher intensities of long wavelength light would be required to elicit a similar response (Witherington and Martin, 1996). It is important to note that hatchlings can be attracted to even long wavelength red light at very high intensities.

Most light sources are composed of many wavelengths, each representing a different color. However, we are unable to distinguish among the spectral components; we see only a single color. The same is true for sea turtles. But, because of differences in spectral sensitivities, the color emitted by a particular light source may not appear the same to humans as to sea turtles. Similarly, two light sources appearing very similar in color to humans may appear dramatically different to sea turtles. This can have important implications for effective light management. For example, a source emitting monochromatic (single wavelength) yellow light is unattractive or only weakly attractive to hatchlings. Yet, another source, which also appears yellow to humans but contains both green and red spectral components, can be highly attractive to hatchlings because of the green wavelengths present. Consequently, we cannot rely solely on color when determining whether or not a light is likely to attract hatchlings.

In addition to their spectral sensitivity, hatchling sea turtles also are sensitive to the directional component of light (Witherington and Martin, 1996; Lohmann et al., 1997). As hatchlings assess the brightest direction, they integrate light through a broad, relatively flat cone of acceptance (Figure 2). For loggerhead turtles, the cone of acceptance is about 180° wide and only from about 10° to 30° above the ground. This implies that light reaching the hatchling (illuminance) from all sources combined is more important in influencing orientation than is the brightness of light emanating from a particular source (luminance). Furthermore, light near the horizon plays the greatest role in determining orientation direction. Thus, color, brightness, proximity to the beach, and broadcast characteristics combine to determine the relative attractiveness of a light source to a hatchling.

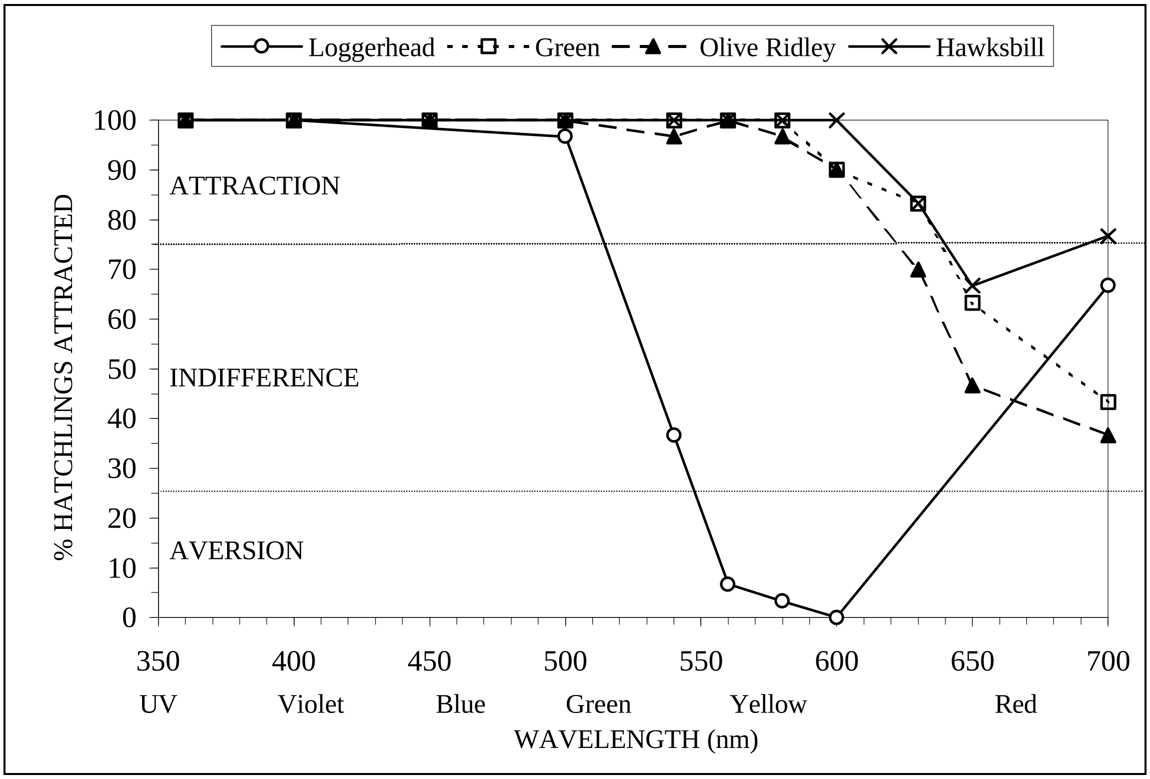


Figure 1. Orientation responses of four species of sea turtle hatchlings to colored light sources. Responses were measured as the proportion of hatchlings that chose an illuminated window over a similar but darkened window. Aversion indicates that hatchlings preferred the dark window to the lighted window. Indifference is the statistically random choice of windows according to a binomial probability test at $\alpha = 0.05$. Figure taken from Witherington, 1997, with permission.

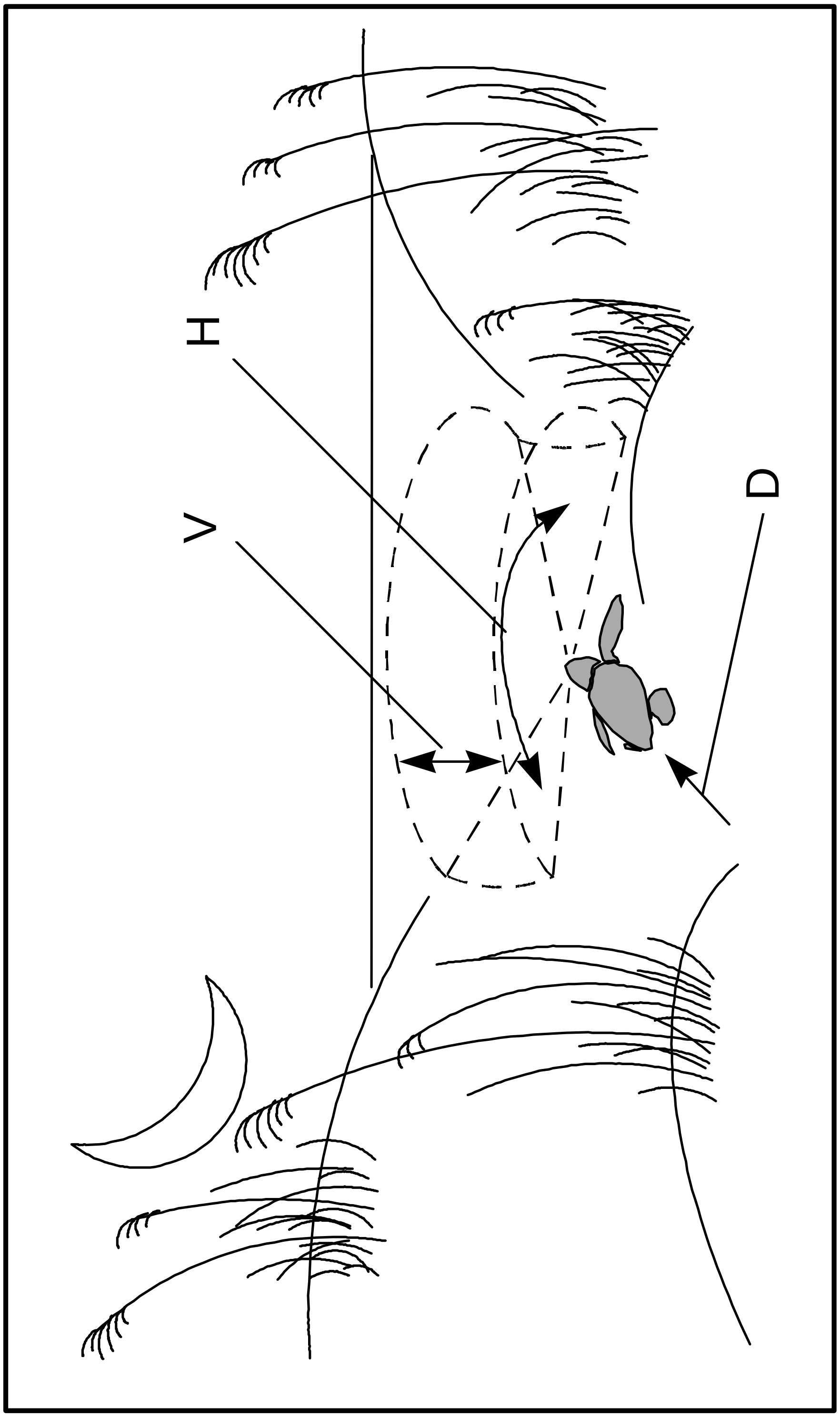


Figure 2. A hypothetical cone of acceptance that describes how a sea turtle hatchling measures brightest direction The vertical component of the cone (V) is approximately 10-30° from the horizon, and the horizontal component of the cone (H) is approximately 180°. Light sources within this cone of acceptance are thought to be integrated into an assessment of brightness for the direction D. Figure taken from Witherington, 1997, with permission.

Questions frequently arise as to why a light source near the beach has any more influence over a hatchling's orientation than does a full moon. Although celestial light sources are very bright, they are also very distant. As light travels from these sources to earth, it is scattered by the atmosphere and reflected off the ocean and features on land. As a result of these moderating influences, by the time celestial light reaches the beach, it is only moderately directed. From a hatchling's perspective, celestial light does not make one direction appreciably brighter than another. On the other hand, artificial light sources, although not as bright as celestial sources, are relatively close to the beach. Light reaching the beach from these sources is highly directed. From a hatchling's perspective one direction (the one towards the artificial light source) is often much brighter than all others, and this typically will be the direction in which the hatchling will choose to orient.

Although a bright moon does not interfere with hatchling orientation, it may diminish the extent of disruption caused by nearby artificial lights. By illuminating broad areas of the beach, moon light diminishes the directivity of nearby artificial light fields. Consequently, artificial lights typically are more disruptive to hatchling orientation on nights around a new moon than on nights around a full moon.

Based on the above information, it is apparent that most commercially available light meters would prove inadequate in determining whether or not a light source is likely to be disruptive to sea turtles. First, hatchlings show a preference for short wavelength light and respond to light (e.g., ultraviolet) that we cannot even see. Second, illuminance is "measured" by hatchlings through a broad flat cone which is dissimilar to the acceptance cones utilized in most light meters. Third, light meters measure light from all sources, not just that emitted from detrimental artificial sources. Thus, when measuring the amount of light reaching the beach from a particular artificial light source, the value obtained may vary considerably from one night to another depending on sky conditions and the amount of ambient (celestial) light present. Finally, the low intensity of light needed to elicit orientation behavior for certain wavelengths may be below the detectable limits of many light meters.

For these reasons, the best available illuminance meters are the hatchlings themselves. If hatchlings emerging from a nest are disoriented, there is typically a disruptive artificial light source nearby. However, rather than waiting for a disorientation event to occur, we should adopt a proactive posture and attempt to identify and remedy potential problem lights before hatchlings are negatively impacted. Later chapters of this manual present guidelines for determining if a light is likely to cause a problem and discuss alternative lighting options for resolving identified problems.

For a more thorough review and assessment of lighting impacts on sea turtles and other nocturnal animals refer to Witherington and Martin (1996), Lohmann et al. (1997), and Witherington (1997). (For complete references to these reviews, see the Literature Cited section beginning on Page 60 of this manual.)

CHAPTER 3

SUMMARY OF ISSUES RELATED TO COASTAL ROADWAY LIGHTING

As in most conflict-resolution cases, a variety of issues other than sea turtles must be considered when proposing changes to street lighting. "Satisfactory" resolution of street lighting problems implies that all relevant public interests have been accommodated to the greatest extent practicable.

Rarely is a street light whimsically placed along a coastal roadway. It has a purpose, based on public need, and must be permitted, positioned and operated in a manner that fulfills that purpose. Clearly, the simplest and most effective way of preventing lighting impacts is to turn off the offending light(s). However, public safety must also be considered. Costs are also an issue. It is unlikely that an exorbitantly priced lighting alternative will be popular with local officials or the constituents they serve. To be sure, there are compelling reasons for correcting problem lights and potential consequences for failing to do so. Nevertheless, proposed solutions must be sensitive to the purpose of, and public need for, street lighting. The criteria used by the TWG in framing acceptable lighting solutions are presented below.

<u>Sea Turtles</u>

The impetus for a Coastal Roadway Lighting Manual was an accumulating record of impacts to hatchling sea turtles from street lights in Florida. In Chapter 2 (Summary of Effects of Coastal Lighting on Sea Turtles), we discussed why these impacts occur. Reasons for addressing the impacts are presented here.

Importance of Florida's Nesting Beaches

The vast majority of nesting by sea turtles in the continental United States occurs in Florida. Three species regularly nest on Florida's sandy shores: the loggerhead turtle (*Caretta caretta*), the green turtle (*Chelonia mydas*), and the leatherback turtle (*Dermochelys coriacea*). Two others, the hawksbill (*Eretmochelys imbricata*) and Kemp's ridley (*Lepidochelys kempii*), have also been reported to nest here, although they do so infrequently.

Over 97 percent of nesting in Florida is by the loggerhead turtle (Meylan et al., 1995). The nesting population of Florida loggerheads is the second largest in the world and accounts for about a third of all nesting by this species worldwide (NMFS and USFWS, 1991a). Florida's nesting green turtle population is one of the largest remaining in the Caribbean Sea and Western Atlantic (Meylan et al., 1995). No other state in the continental United States supports regular nesting by the leatherback. Thus, Florida's beaches are of national, regional, and in some cases global, importance to the survival of sea turtles.

Regulations Protecting Sea Turtles

All species of sea turtles occurring in Florida are protected by the U.S. Endangered Species Act (ESA) of 1973 and Florida Statutes (Chapter 370.12 FAC). The loggerhead turtle is listed federally as a threatened species, while all other species in Florida are listed as endangered.

Section 9 of the ESA prohibits the “ of any threatened or endangered species of plant or animal. Take, as defined by the ESA, means “to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct.” Obvious examples of take are those activities that cause direct injury or death to a listed species or remove it from its habitat. However, more subtle impacts, such as harm and harass, also fall under the definition.

Harm includes acts that significantly modify or degrade habitat to such an extent as to kill or injure wildlife by impairing essential behavioral patterns. Harass is “an intentional or negligent act or omission that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering.” Thus, by degrading nesting habitat, interfering with essential reproductive behavior, and contributing to the death of hatchlings, problem street lighting constitutes take under the ESA. Similar definitions are contained in Florida’s Marine Turtle Protection Act (370.12 Florida Statutes).

Recovery plans for U.S. sea turtle populations place considerable emphasis on preserving, and where possible improving, the quality of Florida’s beaches as nesting habitat (NMFS and USFWS, 1991a; NMFS and USFWS, 1991b; NMFS and USFWS, 1992). Management of artificial light near the beach is critical to this effort.

Two agencies are responsible for the conservation and recovery of sea turtle populations on their nesting beaches in Florida, USFWS and FDEP. USFWS (the Service) is responsible for enforcing the provisions of the ESA. When take of hatchlings occurs, this agency has the authority to pursue civil penalties against the owners of the responsible light and/or refer the case to the Department of Justice to pursue criminal penalties. Typically enforcement action is initiated only after the offending party has been notified about the problem and fails to take appropriate corrective action to prevent future occurrences (i.e. additional take).

The USFWS feels that if recommendations contained in this manual are followed, take of sea turtles is unlikely to occur. Nevertheless, it cannot ignore additional take that may occur if a selected light management option proves ineffective. However, as long as the party responsible for resolving the problem puts forth a good faith effort and works cooperatively with the Service to achieve an effective solution, it will not recommend prosecution under the ESA (see statement from USFWS in Appendix C). Although the lighting custodian (typically a municipal or private utility) plays an important role in helping to select and implement an appropriate lighting modification, the party ultimately responsible to the USFWS for resolving the problem is the person or entity paying for the lighting service (i.e. utility customer/rate payer). The rate payer must, therefore, determine which of numerous corrective actions, including non-use, is acceptable for their specific street lighting situation and direct the lighting custodian accordingly.

FDEP is responsible for administering Florida's Marine Turtle Protection Act and for assisting with national sea turtle recovery efforts through a cooperative agreement with USFWS. One of the major roles of FDEP is the permitting of qualified individuals to conduct hands-on sea turtle conservation activities on Florida's nesting beaches. These activities include daily monitoring of nesting activities, nest protection, and documentation of factors adversely affecting the reproductive cycle.

Each morning throughout the nesting season, permit holders and their designees survey beaches around the state for signs of nesting. Frequently nest sites are marked and monitored for signs of hatching. Whenever hatchling tracks emanating from a nest show obvious signs of disorientation, a standard reporting form is completed and sent to FDEP. The form identifies the species of turtle involved, the geographic location of the nest, the approximate number of hatchlings disoriented, the general direction of their travel, and potential light sources that may have been responsible. If a lighting ordinance is in effect, either the permit holder or FDEP typically furnishes a copy of the report to the local code enforcement department for action. If no lighting ordinance is in effect, the property owner is usually notified directly and advised of the problem.

Most coastal communities adjacent to sea turtle nesting beaches in Florida have adopted beachfront lighting regulations. When a local government learns of a problem light, they typically notify the responsible party and advise them that the light is in violation of code. Ideally, they are able to provide proper guidance in resolving the problem. At all levels of government, voluntary compliance with local ordinances and a cooperative spirit in resolving identified problems are preferable to heavy-handed enforcement. However, if this approach fails, code enforcement action may be necessary. Records of persistent lighting problems are furnished to USFWS by FDEP for federal prosecution under the ESA.

Basic Approach to Roadway Light Management

Based on behavioral responses of sea turtles to artificial lighting, there are three principal tenets of effective street light management:

1) Design or modify lights in such a manner that the light is confined to the roadway and is prevented from straying onto the beach,

2) Reduce the total luminance (combination of lamp wattage and number of fixtures) of roadway lights to the minimum required for adequate traffic safety, and

3) Install or modify lights such that the quality (color) of light emitted is minimally attractive to hatchlings.

At a minimum, light management should be in place throughout the sea turtle nesting season (see below). However, it is recommended that permanent solutions be developed and light management practices be adhered to year round. This negates the need for seasonal adjustments.

The Nesting Season

Sea turtles typically begin nesting on Florida's beaches in spring and terminate this activity in late summer. There is some offset in the timing of reproductive activity among species, with leatherback turtles being the first to emerge onto area beaches and green turtles being the last. Peak nesting occurs in June and July.

It typically takes about two months for incubating eggs to hatch. Thus, eggs laid in mid-August would not hatch until mid-October. The inclusive period during which turtles are nesting and hatchlings are emerging from nests is termed the nesting season. In southeast Florida, where the majority of nesting occurs (Table 1), FDEP considers the period from March 1 through October 31 to be the official nesting season. This area includes Brevard, Indian River, St. Lucie, Martin, Palm Beach and Broward Counties. Throughout the remainder of Florida, the official nesting season runs from May 1 through October 31 each year.

Table 1

Contribution by Coastal County to Sea Turtle Nesting in Florida and Corresponding Wind Loading Criteria For Roadway Lights Mounted At A Height Of 50 Feet Or Less.

Coastal County	Percentage of Statewide Sea Turtle Nesting[1]	Wind Loading (mph)			
		70	80	90	100
Bay	0.1		X		
Brevard	39.4			X	
Broward	3.4				X
Charlotte	0.6		X		
Citrus	None Documented		X		
Collier	0.7			X	
Dade	0.6				X
Dixie	None Documented		X		
Duval	0.1		X		
Escambia	<0.1		X		
Flagler	0.4		X		
Franklin	0.1		X		
Gulf	0.1		X		
Hernando	<0.1		X		
Hillsborough	None Documented		X		
Indian River	4.6			X	
Jefferson	None Documented	X			
Lee	0.6		X		
Levy	None Documented		X		
Manatee	0.3		X		
Martin	17.0			X	
Monroe	0.2				X
Nassau	0.1		X		
Okaloosa	<0.1		X		
Palm Beach	18.0				X
Pasco	None Documented		X		
Pinellas	0.2		X		
Santa Rosa	<0.1		X		
Sarasota	2.6		X		
St. Johns	0.3		X		
St. Lucie	7.7			X	
Taylor	None Documented	X			
Volusia	2.8		X		
Wakulla	None Documented	X			
Walton	<0.1		X		

[1] Average annual nesting for all species combined, 1988-1992 (from Meylan et al., 1995)

Roadway Lighting

Regulatory Authority

Coastal roadways fall under several different jurisdictions: federal, state, county, or incorporated municipality. Most major arterial highways running along the coast, such as A1A on Florida's east coast, fall under the purview of the Florida Department of Transportation (FDOT). Although federal roads are funded by the U.S. Department of Transportation (USDOT), they are typically built, maintained, and regulated by FDOT. FDOT establishes design, maintenance, and safety standards for lighting on all public roads, even though the maintenance of the lighting systems may be delegated to the counties and municipalities within which the roads are located.

If lighting was not installed on state or federal roads during project construction, local governments may petition FDOT for use of the right-of-way for that purpose. Chapter 337, Florida Statutes, and Chapter 14-46, Florida Administrative Code (FAC), establish that all lighting on state roadways be authorized by FDOT through written permit. FDOT issues permits for the construction, alteration, operation, relocation and maintenance of utilities upon state road rights-of-way in conformity with the Department's Utility Accommodation Manual. The FDOT Plans Preparation Manual establishes minimum standards for the design of lighting systems.

Copies of the above-referenced FDOT documents can be obtained through: FDOT Maps and Publications Sales, 605 Suwannee Street, Mail Station 12, Tallahassee, Florida 32399-0450 or from FDOT's web site at http://www.dot.state.fl.us.com.

Sub-section 14-64.0011 of Chapter 14-64, FAC (Illumination of the State Highway System) indicates that no lighting system can be installed on any part of the state highway system or its associated right-of-way until "there has been executed a valid contract with the responsible local authority for that authority's maintenance, operation, and assumption of legal liability for that lighting system in those cases where the Department establishes it has no responsibility to maintain and operate the lighting system." Thus, when FDOT permits the placement of lights on state road rights-of-way, the local authority assumes liability for that lighting system.

Florida Roadway Lighting Standards

FDOT requires that lighting for systems it permits must meet minimum standards for highway safety. These include:

1. Mounting height - Mounting height is the vertical distance between the roadway surface and the center of the light source. This distance is established to provide adequate clearance for cars and trucks and to minimize glare off the roadway surface. Mounting heights vary depending on the photometric properties of the fixture and the wattage of the lamp being used.

2. Pole setback - The light pole must be a minimum distance from the edge of the travel lane to ensure adequate traffic safety. This distance is established in accordance with the Plans Preparation Manual. Setbacks vary with location and setting.

3. Wind loading - In Florida tropical storms are frequent. Consequently, the structural supports of light fixtures (e.g., poles and bracket arms) must be strong enough to withstand high winds. Wind loading criteria vary among geographic regions of the state (Table 1).

4. Illuminance - Good visibility is one of the fundamental requirements of safe driving. Street lighting enables motorists to more clearly see other vehicular traffic, pedestrians, obstructions, and signs on or adjacent to the roadway at night. It also improves nighttime visibility for other roadway users, including cyclists and pedestrians. Minimum levels of illuminance, the amount of light striking the roadway surface, are established by the FDOT.

5. Light uniformity ratio - In addition to the amount of light reaching the roadway surface, its distribution should be uniform to provide optimum driver comfort and safety. Uniform light distribution eliminates the bright-dark picket fence phenomenon (caused by widely spaced lights) that can create dangerous driving conditions.

Altering Roadway Lighting Systems

When a street lighting problem is identified, several parties have an interest in determining how the problem is resolved: the user, the custodian, and the permitting authority.

<u>User</u> - The user is the entity that is paying for the use of the lighting system. This is the utility customer or rate payer. Ultimately, it is the user's responsibility to evaluate and balance competing interests when deciding how best to resolve a lighting problem.

<u>Custodian</u> - The lighting custodian, usually an electric utility, installs and maintains street lights and provides electricity to the system. The custodian must work with the user to develop solutions appropriate to the specific lighting problem.

<u>Permitting Authority</u> - The permitting authority is the agency that authorized right-of-way usage and/or roadway lighting installation.

In the simplest cases, the user, custodian, and permitting authority are one and the same party. Typically, however, two or more parties are involved in street light management efforts.

When a street lighting problem is identified, the user, in consultation with the lighting custodian, must first consider under whose authority the light is operated and maintained before undertaking any modifications. As noted above, FDOT has oversight of state and federal roadway lighting systems as well as local roadway lighting systems funded by the state. For other systems, county or city authorities must be notified.

If a state permit was issued for right-of-way usage, the permittee (usually a local government) must contact the local FDOT maintenance office to discuss the proposed changes. Any substantive changes will be forwarded to the appropriate FDOT regional office for review and/or approval.

Deviations from established lighting standards may occur when the amount and/or distribution of light on the roadway surface is altered to protect sea turtles. Thus, variances and waivers may be needed for proposed lighting modifications, depending on the effect the modification is expected to have on highway safety. If safe operation of the highway facility is likely to be impaired by a deviation from design standards, an official variance is required under Section 120.542, Florida Statutes, and rules adopted pursuant thereto. On a case-by-case basis, FDOT may modify permits to allow flexibility in dealing with roadway lighting and protected species conflicts, provided the permittee expressly assumes liability for changes to the lighting system. Additionally, signage warning drivers of poor highway conditions may be appropriate if substantial deviations from highway safety standards are likely to result from lighting modifications.

At present, roadway lighting standards are based almost exclusively on traffic safety. It has been estimated that between 35-50% of atmospheric light pollution is caused by roadway lighting (Finch, 1978). Yet, despite our increasing understanding of the effects of light pollution on sea turtles and other wildlife, little consideration is given to this phenomenon in the design or permitting of lighting systems. Clearly, there is a need for special lighting standards along coastal roadways adjacent to sea turtle nesting beaches. The Federal Highway Administration (FHWA) has recently funded a study to establish “Sea Turtle Lighting Zones” along FDOT coastal roadways in Florida. In these zones, alternative lighting standards would be developed to reduce the potential for lighting impacts. The alternative standards would utilize the light management techniques contained in the Coastal Roadway Lighting Manual and the Witherington and Martin (1996) lighting manual. Any changes to roadway lighting standards and/or the permitting process resulting from this effort will be incorporated into future editions of the Coastal Roadway Lighting Manual.

Public Safety

There are a variety of social and economic benefits attributable to roadway lighting, including but not limited to:

1) Facilitation of traffic flow,

2) Reduction of nighttime accidents,

3) Aid to police protection,

4) Promotion of roadside businesses, and

5) Safety for pedestrians and bicyclists.

With respect to light management, perhaps one of the most fervently debated issues is that of crime and public safety. There is a strong public perception that efforts to reduce light pollution will increase crime. This is based largely on the premise that light management equates to lights out. As outlined earlier in this manual, the intent of street light management is to:

1. Confine light to the area of its intended use,

2. Reduce the amount of light emitted to the minimum required to effectively achieve its intended purpose, and/or

3. Use light sources that minimize the potential for hatchling disorientation.

Although street light management efforts may not eliminate light on coastal roadways, they may alter the amount, color, and/or distribution of that light. Reduced levels of illumination and changes in light color are often viewed as less safe. To obtain feedback on any impact these modifications might be expected to have on law enforcement activities, a questionnaire was furnished to the traffic safety departments of the 12 counties and cities represented on the Coastal Roadway Lighting Manual Steering Committee. Nine of the questionnaires were returned. Although the sample is small, the results are informative.

The preference of law enforcement personnel was unambiguous. They would like to have brightly illuminated roadways, with light that is uniformly distributed and does not distort colors. However, when asked how inferior lighting conditions would affect job performance, the responses were mixed. For example, respondents felt that it was important to be able to distinguish colors. (Low pressure sodium vapor lamps, which emit monochromatic yellow light, distort colors.) But, when asked if poor color rendition would affect job performance or place officers at risk, the importance factor was neutral (5 on a scale of 1 to 10, ranging from not important to extremely important). Similarly, respondents felt that uniform light distribution was very important in deterring crime and improving traffic safety. However, they felt that intermittent light would only moderately affect their job performance.

The above results are not a measure of the effect of light management on public safety. They merely reflect the perception that law enforcement personnel have on the effect(s) of different lighting conditions on public safety and job performance. It is not surprising that when asked to rank various combinations of brightness, distribution and color reliability, respondents ranked bright, uniformly distributed light with good color rendition as the most desirable option and no light as the least desirable.

Typically, the issue of crime arises as light management efforts are proposed. In response to questions from a county seeking input on the effects of lighting ordinances on crime, an assistant state attorney cited correspondence from several municipalities that had enacted such ordinances. In a letter to Dennis K. Bayer, Assistant State Attorney, dated July 31, 1989, the Chief of Police of the City of New Smyrna Beach (Volusia County, Florida) indicated that "criminal activity in relationship to the lighting ordinance on the beach proper was negligible at best." Following ordinance implementation, there were no increases in burglary, larcenies or vandalism other than that which would be considered normal.

As in the case of New Smyrna Beach, much of the available information on light management and crime is anecdotal. There is little hard data to allow statistical comparisons of crime before and after ordinance enactment. Nevertheless, considering that most of our current information on the effects of light management comes from those tasked with combating crime, there is no rational basis for concluding that light management programs will lead to increased crime. This does not imply that crime and public safety are not important local issues. They must certainly be considered in the selection of lighting alternatives for areas where street lights cause problems for sea turtles. The important point, though, is that an altered lighting environment may be perceived as being more detrimental to public safety than it actually is.

Regulation of Utilities

The Florida Public Service Commission (PSC) is the board that regulates utility rates and levels of service in Florida. Utilities that install and maintain roadway lights file tariffs which must be approved by the PSC. The tariffs prescribe the types of lights that can be offered and the rates charged for each.

For example, the selection and use of street lights by FPL, the state's largest electric provider, is governed by its Rate Schedule SL-1, which is a part of FPL's electric tariff on file with the PSC. Rate Schedule SL-1 currently allows FPL to use the following luminaire types for street lighting: (i) high pressure sodium vapor (HPS); (ii) mercury vapor; (iii) incandescent; and (iv) fluorescent. No changes to FPL's rate schedule may be made without approval from the PSC, after appropriate administrative proceedings.

Without such approval, the use or installation by FPL of any luminaire type not included in the rate schedule is prohibited.

Options Offered by Electric Suppliers

Utilities generally provide their customers with the following options:

- Utility-owned street lights and full maintenance service.
- Relamping of customer-owned street lights.
- Energy to customer-owned street lights.

If a power provider installs and maintains the lights of its customer (user), utility-specific policies may dictate which light management options are available. For example, at present FPL can perform the following modifications to lights that are disruptive to sea turtles:

1) Seasonally turn the lights off,

2) Relocate or redirect the light fixture,

3) Install a light shield,

4) Change a drop globe fixture to a cutoff style fixture,

5) Remove the fixture, and/or

6) Selectively install experimental colored lenses.

Low-pressure sodium vapor lighting (LPS) is not currently offered as an option for any FPL lighting system, because it has not been approved by the PSC. Thus, if a customer wishes to pursue this type of lighting, they must hire a private contractor. However, FPL is presently evaluating the possibility of allowing installation of customer-owned LPS lights on FPL poles.

During preparation of the Coastal Roadway Lighting Manual, several new technologies were identified or developed to aide in light management. These include new types of shields and colored lenses for light fixtures already in use by FPL. The new shields more effectively confine light to areas seaward of the beach, while the lenses filter out those wavelengths which are most disruptive to sea turtles. The colored lenses have broad appeal, because they appear to be a good substitute for LPS lighting but lack some of the undesirable properties of LPS. They are also easily adaptable to existing HPS fixtures. The lenses are being offered to utility customers as one of several alternative lighting solutions, pending results of controlled field experiments scheduled for the summer of 1998. Depending on test results, the lenses may be available on a permanent basis or may undergo additional refinements to improve their spectral properties. Other utilities may have different policies or products that may influence how light management is accomplished.

Low-Pressure Sodium Vapor (LPS) Lighting

LPS is an alternative to high pressure sodium vapor (HPS), which is the most widely used type of lamp for street lighting. Because the monochromatic properties of LPS have been shown to be minimally disruptive to sea turtles, its use is strongly advocated by sea turtle conservationists. However, most utilities have not offered LPS, citing the following disadvantages:

1) It distorts color,

2) The large fixtures required for LPS typically do not meet wind loading criteria, and the fixtures deteriorate relatively quickly in the salt-air environment of coastal roadways (i.e. higher maintenance),

3) Both initial and operational costs for LPS lights are substantially higher than for HPS lights,

4) The distribution of lighting is more difficult to control (more lights are needed for uniform distribution),

5) Replacement cycles for LPS lights are more frequent than for HPS lights (i.e. shorter operational life), and

6) LPS has environmental concerns which require special disposal procedures.

Others (e.g., see Witherington and Martin, 1996) contend that although initial costs for LPS lights are higher than for HPS lights, electricity costs are generally lower, because LPS lamps are more efficient (more lumens per watt). In practice, operational costs may vary, depending on how the lights are used in a particular utility's lighting system. Regardless of overall costs, there are some drawbacks to LPS usage. Principal among those are the large fixtures required to house the lamps. These fixtures are susceptible to damage during high winds, require more maintenance, and typically have more omni-directional broadcast properties than conventional light fixtures (i.e. more difficult to control light distribution).

Although LPS lights distort colors, the effect of this phenomenon on crime and public safety may be more a factor of public perception than of reality. In Delray Beach, Florida, where LPS lights were used in an experimental demonstration project, local law enforcement personnel reported that color distortion did not noticeably affect the performance of their duties.

Economics

Light management comes with cost. Depending on the management option(s) selected, the cost may be nominal (in the case of turning lights off) or substantial (when major system-wide changes are implemented). However, as indicated by Witherington and Martin (1996) initial implementation costs may be at least partially offset by electrical savings resulting from reduced wattage or more efficient types of lamps.

The utility customer (street light user) is ultimately responsible for shouldering the costs of light management efforts. In estimating potential costs associated with a particular lighting modification, the customer should consider the following:

1) Installation of new, or modification of existing, equipment and accessories,

2) Maintenance,

3) Product longevity (i.e. replacement frequency), and

4) Energy consumption (i.e. operational expense of the light or system).

In assessing these costs, the customer should also consider the consequences of potential regulatory agency action under the ESA, Florida Statutes, and/or local ordinances for failure to take responsible action to resolve identified lighting problems.

Approximate costs for various lighting alternatives are provided in Appendix D.

CHAPTER 4

GUIDELINES FOR IDENTIFYING PROBLEM LIGHTS

Usually, neither the user nor the lighting custodian is aware that a street light is causing harm to sea turtles until the problem is brought to their attention. There are three basic methods whereby problematic lights can be identified. One is reactive and the other two are proactive.

Disorientation Reports

The first indication of a problem is usually a report from FDEP-permitted monitoring personnel attributing a hatchling disorientation event to a nearby light. The individuals reporting the event are typically familiar with the local nighttime lighting environment and are often able to identify the responsible light based on the path taken by hatchlings leaving the nest. In cases where numerous lights are present in the area of the disorientation, it may not be possible to assign responsibility to a specific light. In those cases, all potentially disruptive lights observed in the general area are reported. Even if a light is not solely responsible for a disorientation event, it may have contributed to the problem and should be carefully evaluated.

Upon receipt of a disorientation report, FDEP and/or the local code enforcement department will notify the light user (customer/rate payer) and require that appropriate lighting modifications be made. Prior to undertaking any modifications, the user and/or lighting custodian should obtain a copy of the disorientation report and visit the site at night to evaluate the spatial extent and severity of the problem. This will facilitate selection of an effective lighting alternative (see Chapter 7, Selecting the Appropriate Alternative).

Nighttime Lighting Evaluations

Sometimes, lights may have a relatively high potential for causing problems for sea turtles but go unreported, because either no nests are laid near the light source or a disorientation event goes undetected. For this reason more proactive lighting assessments are recommended.

The most practical and conservative approach to light management is to perform visual nighttime evaluations of street lights. Lights of primary concern are those within direct line of sight of the beach, because these lights have the potential for broadcasting light directly onto the beach. Lights that directly illuminate the beach will typically cause problems for sea turtles. Indirect illumination of the beach by reflected light may also be a problem. Additionally, all light contributes to cumulative skyglow. Skyglow, particularly in urban areas, can create problems for sea turtles, especially on cloudy nights.

The evaluation should be conducted on or near the date of the new moon (i.e. dark moonless night). This is the period when problems will be most evident. View each light from numerous positions on the beach, both near the waterline and near the dune. During the evaluation, be sure to walk a reasonable distance in both directions away from the light source. Often a light may be blocked from beach view from a position due seaward of the light because of buildings or vegetation. However, it may become very conspicuous when viewed from positions farther up or down the beach.

For each light fixture visible from the beach, note the following:

1. *Can the source of light (i.e. the bulb or lamp) be seen from the beach?*

   Because sea turtles perceive light differently than humans, it is inappropriate to try to determine if a light will cause a problem based on its brightness or broadcast properties. As indicated by Witherington and Martin (1996), **an artificial light source is likely to cause problems for sea turtles if the source of light can be seen by an observer standing anywhere on the nesting beach**. This basic rule of thumb will allow light managers to easily identify potentially problematic light sources.

2. *Are there reflective surfaces on or near the fixture that broadcast light toward the beach?*

   Depending on brightness of the light source and the distance of the reflective surface from the beach, indirect lighting can be just as disruptive to sea turtles as direct lighting. A good method for determining if light is reaching the beach is to stand on the beach and hold a piece of white, rigid material (e.g., poster board, clip board, etc.) at arm's length away from the light source. This positions the observer between the light source and the material. From a standing position, slowly move the material from side to side. If you cast a shadow on the material, light is reaching the beach.

3. *How extensive is the illumination? Can you see the light from only one small area of the beach, or is the source visible from most locations?*

   The more extensive the illumination, the greater the potential for problems. Light visible from a crouching position on the beach (simulating a turtle's perspective) is likely to be more disruptive than light only visible from a standing position. Although both situations warrant remediation, the former should be given a higher priority if resources available for lighting modifications are limited.

All of the information obtained during nighttime lighting evaluations will be integral to the selection of an appropriate light management option, as discussed in subsequent chapters of this manual.

Hatchling Arena Assays

The most scientifically reliable indication of whether or not a light is likely to cause problems for hatchlings can be obtained by performing a hatchling bioassay (Salmon et al., 1995). This technique involves the introduction of hatchlings into a specific lighting environment under controlled field conditions. The bioassays are essentially staged hatchling emergences, whereby a group of hatchlings is released into the center of a circular arena drawn in the sand. As the hatchlings crawl toward the periphery of the arena, their paths are recorded and later analyzed statistically to determine if they were significantly oriented toward the sea. The lack of significant orientation or a significant orientation away from the sea would be indicative of a lighting problem.

Because of the required manipulation of hatchlings, arena assays can only be performed by experienced professionals holding a valid marine turtle permit and prior written authorization from FDEP. Consequently, they are not widely used as an evaluation technique. Nevertheless, the tests can be very instructive in situations where large numbers of street lights are located near a nesting beach. A well designed bioassay program could be used to determine if an existing or newly installed lighting system is likely to cause problems for hatchling sea turtles before an actual disorientation event occurs. In cases where there is uncertainty as to whether or not street lights are a potential problem, the bioassays may avert unnecessary modifications and expense. If, on the other hand, the tests indicate that lighting modifications are necessary, subsequent bioassays at the same location can be used to assess the effectiveness of corrective measures. Persons interested in determining whether arena assays would be appropriate for assessing their specific lighting problems should contact FDEP.

CHAPTER 5

A STANDARD APPROACH FOR MINIMIZING LIGHTING IMPACTS TO SEA TURTLES

Basic Approach to Light Management

Although each street lighting problem may be unique, the approach to its resolution should be consistent. The most critical element of light management is the selection of the lighting alternative that most effectively reduces the potential for impacts to sea turtles while accommodating other public lighting needs. When evaluating lighting alternatives, three basic guidelines should be followed:

- Keep light off the beach.
- Minimize the total amount of illumination adjacent to the beach.
- Use light sources that are minimally disruptive to sea turtles.

This manual provides the best available technology (BAT) for accomplishing these objectives (Table 2). An overview of the step-by-step approach to the implemen-tation of an effective street lighting solution is presented in Table 3 (Page 28).

Table 2

Basic Objectives of Effective Street Light Management

Light Management Strategy	Methods
Keep Light Off the Beach	Realign, modify, reposition, shield, or screen fixture from beach view
Reduce Total Luminance	Turn lights off, install fewer lights, reduce wattage
Minimize Potentially Disruptive Wavelengths	Install colored lenses that filter out short-wavelength light or use LPS lights

It is the ultimate responsibility of the light user (entity requesting and utilizing the service) to resolve identified street lighting problems. However, this usually cannot be accomplished without the cooperation and active participation of the lighting custodian (local utility or electric provider). As light managers, both users and custodians must be vigilant for potential problems and be sensitive to the needs and constraints of the other party. A balanced approach may also require consultation and cooperation among the light user, custodian, permitting authority, regulatory agencies (FDEP and USFWS), and local environmental managers (city and county).

The complexity of a lighting problem should never be used as justification for lack of action. As discussed in the following chapters, a variety of alternatives are available for managing roadway lighting. If these are fully explored and evaluated, acceptable solutions to even the most complex lighting problems are likely to be found.

Keep Light Off The Beach

The first priority of light management is to keep light from reaching the beach, regardless of the spectral properties of the light source. Some light may be less disruptive than others, but all light has the potential to cause problems for sea turtles. Furthermore, different species respond differently to the various properties of light (brightness, color, etc.). Thus, while minimizing disorientations for one species, a selected lighting option may be ineffective for others.

If the lamp or any reflective surfaces of a street light are visible from anywhere on the beach, the light is likely to cause direct illumination of the beach. Fixtures can be realigned, modified, repositioned, and/or shielded to keep light from reaching the beach.

Reflected light (light indirectly reaching the beach from a light fixture such as that reflected off a nearby building) may also cause a problem for sea turtles. If street lights are in close proximity to buildings, modifications to the fixture may be required, even if the source of light is not directly visible from the beach. Indirect lighting of the beach should be addressed in the same manner as for direct beachfront lighting. (See Chapter 4, Page 24, Item No 2 for a practical method of determining if reflected light is reaching the beach.)

Reduce Total Luminance

The second priority of light management is to reduce the total amount of luminance adjacent to the beach. Light that is cast or reflected skyward contributes to skyglow. Along the coast line, particularly on misty or cloudy nights, cumulative skyglow can cause problems for sea turtles. If lights in a street lighting system can be eliminated without sacrificing public safety, they should be turned off. A reduction in the wattage of street lamps will also reduce the potential for skyglow problems.

Table 3

Guidelines For Achieving Effective Street Lighting Solutions

1. Ascertain that a problem exists. This can be accomplished through:
   a. A proactive nighttime beach evaluation of roadway lights, or
   b. Receipt of notification of a disorientation event attributed to a particular light.

2. For each problem light, determine the following, where possible:
   a. Spatial extent of beach affected,
   b. Brightness of light reaching the beach,
   c. Approximate distance of light fixture from the beach,
   d. Height of dune and extent of vegetative buffer along the section of beach affected by the light,
   e. Type of fixture (e.g., drop globe, decorative street light, etc.),
   f. Light source (type of lamp and wattage; e.g., 150W HPS lamp),
   g. Mounting height,
   h. Roadway type and lighting requirements,
   i. Position of fixture relative to beach (e.g., facing toward or away from the beach), and
   j. Utility pole identification number.

3. Determine who owns the light (custodian) and under whose authority the light is operated (permitting authority). The local utility customer service representative (account manager) should be able to assist in this matter.

4. Considering the type of roadway being illuminated, the amount of crime in the area, pedestrian usage, etc., work cooperatively with the lighting custodian, local regulatory agencies and municipal environmental managers to select the lighting alternative that best accommodates local concerns and public interests, while providing adequate protection for sea turtles. If numerous lights within a lighting system are causing problems, prepare a plan of action to address each.

5. Based on the alternative selected, determine if a lighting variance is needed from the permitting authority, and obtain lighting modification approvals, as necessary.

6. Implement the selected light management option.

7. Assess the effectiveness of the selected alternative.

8. Make additional adjustments, as necessary (i.e. fine tune the selected option or select another option) to minimize the potential for future lighting impacts.

Minimize Potentially Disruptive Wavelengths

It is not always possible to completely keep light off the beach while satisfying other public interests. Thus, the third step of light management is to minimize the amount of potentially disruptive wavelengths reaching the beach. Fixtures emitting only long-wavelength light are particularly useful in situations where street or security lighting is needed very close to the beach. Long-wavelength light sources require less broadcast precision than conventional light sources, because they are less likely to cause problems for hatchlings. LPS lighting or colored filters applied to conventional HPS light sources should be used when it is practically impossible to keep light off the beach.

Employ Best Available Technology

A common strategy for combating many types of pollution is to implement proven and effective pollution-reduction and pollution-prevention methodologies, often referred to as best available technology (BAT). In the context of light pollution, BAT simply implies that light managers use the best available means to minimize the potential for street lighting impacts to sea turtles.

This manual contains all of the tools and guidelines needed for an informed approach to light management. Although ingenuity will undoubtedly yield some options not contained in the manual, the most effective alternatives currently available have been identified and evaluated and are presented here.

If an existing technique for light management is not presented in this manual, it has probably been rejected as not meeting the criteria of BAT. For example, long-pass (dichroic) filters have been advocated as a method for attenuating harmful short-wavelength light (Witherington and Martin, 1996). These laminate filters can easily be applied to the inside of the glass lenses of existing fixtures. Unfortunately, under normal application they greatly diminish the efficiency of the fixture. Furthermore, they are only effective in filtering short-wavelength light that strikes the lens perpendicularly. At more oblique angles, the filtering properties diminish. For this reason, long-pass filters are not recommended for use adjacent to sea turtle nesting beaches.

Short-cuts to light management, such as painting or attaching aluminum foil to the seaward face of a fixture, are impermanent, ineffective, and may be unsafe. Half-way measures result in unnecessary effort and expense and delay resolution of the lighting problem. This delay may potentially result in additional take of sea turtles.

As new and innovative lighting alternatives are developed, they will be evaluated for effectiveness. Those that are demonstrated to be good alternatives will be included in future updates of this manual.

Evaluate the Selected Alternative

The final step in the light management process is to evaluate the effectiveness of the selected alternative. If possible, walk onto the beach and examine the light before and after the light management option is applied. Does it appear that the application has kept light off the beach or, at least, considerably reduced the amount of illumination reaching the beach? Can other options be applied to further reduce the potential for lighting impacts? A small adjustment or application of additional hardware before leaving the work site may eliminate the need for a return trip. This important final step will reduce the overall effort, expense, and/or aggravation associated with light management.

Planning and Design of New Street Lighting Systems

As with most environmental problems, the time and expense required to combat light pollution could be eliminated or considerably reduced through proper system design. Although the focus of this manual is on problem solving, it also provides an excellent opportunity for incorporating preventive measures into the design of new lighting systems. The basic objectives of light management presented in this chapter, as well as the alternative methods for managing light presented in Chapter 6, serve as appropriate design criteria. Potential lighting impacts should be considered in the planning and design of the following:

- New roadway lighting systems within direct line-of-sight of the beach.
- Renovation of existing lighting systems within direct line-of-sight of the beach.
- Construction of new bridges near the coast.

The design criteria for new lighting systems is contained in the FDOT Plans Preparation Manual, a document authorized under section 334.044(2), Florida Statutes. When a lighting system is incorporated into a roadway improvement project, the FDOT Project Design Engineer refers to the Plans Preparation Manual for information on how to justify and design the system to applicable safety standards. Design elements include distance between poles, pole height, light source, wattage and illuminance. The proximity of proposed lighting systems to environmentally sensitive areas is not always considered. However, there is a mechanism whereby the Project Design Engineer can request a design exception if variances from minimum safety standards are needed to reduce the potential for lighting impacts to sea turtles. This requires coordination with the Federal Highway Administration. Guidelines for seeking design exceptions and variances are contained in the Plans Preparation Manual, Volume I, Chapter 23.

Copies of FDOT's Plans Preparation Manual can be ordered from: FDOT Maps and Publications Sales, 605 Suwannee Street, Mail Station 12, Tallahassee, Florida 32399-0450 or from FDOT's web site at http://www.dot.state.fl.us.com.

The FDOT Plans Preparation Manual provides guidance in the design and construction of municipal lighting systems located on FDOT rights-of-way. As in the case of state lighting systems, variances and waivers to minimum safety standards can be granted in the permitting of these systems. To obtain these variances, the applicant must demonstrate a hardship in complying with design standards. Presumably, in the case of lighting impacts to sea turtles, conformance to minimum lighting standards causes undo hardship because of conflicting regulations regarding the protection of federally protected species. Section 120.542, Florida Statutes, describes the process for seeking variances and waivers.

Through a combination of careful light placement and best available lighting technology, it may be possible to design new coastal roadway lighting systems that meet minimum safety standards yet pose minimum risk to sea turtles on adjacent nesting beaches. Directional lights placed on the seaward side of coastal roadways and aimed away from the beach, utilization of existing light barriers (buildings, vegetation, etc.), reduced (compressed) transverse light distribution, lower mounting heights, light filtering mechanisms, and construction of vegetated dune buffers used independently or in combination may satisfactorily minimize the potential for lighting impacts without any compromise to highway safety. Coastal roadways in Florida also provide an excellent opportunity to test new technologies such as light-emitting diodes (LED) imbedded in the roadway surface. These and other advances may one day supplant conventional roadway lighting adjacent to important nesting beaches.

<u>Reasons for Managing Lights Rather Than Manipulating Eggs and Hatchlings</u>

Questions frequently arise as to why lights must be modified to protect sea turtles. Why can't we simply move the nests to darker areas of the beach? There are numerous, sound reasons why state and federal agencies responsible for sea turtle conservation and recovery programs discourage manipulative programs as a substitute for light management.

Nest relocation has been utilized in the past to manage lighting impacts to marine turtle hatchlings. Relocation of eggs to a controlled hatchery or to darker areas on the beach is no longer authorized by FDEP. The few communities with exceptions to this restriction are working to improve light management and reduce the number of nests relocated annually. Relocation programs are time-consuming, costly, and ultimately may not be in the best interests of sea turtle conservation. Because it is not possible to find and relocate every nest, particularly by 9 AM as required by FDEP, some turtle hatchlings will still be vulnerable to lighting impacts, and thus, there is a probability that take will occur. In addition, poor light management reduces the frequency of emergences by nesting females onto the beach. This constitutes take under the ESA, because it interferes with essential breeding behavior. Light pollution diminishes the suitability of available nesting habitat and may force turtles to utilize less appropriate nesting sites (Murphy, 1985).

The process of egg relocation poses risks; mortality occurs if eggs are broken or developing embryos are disrupted during movement (Limpus et al., 1979). Data from several nesting beaches in Florida suggest that the percentage of hatchlings emerging from the nest (emerging success) is reduced for relocated nests when compared to nests left in place (Moody, In press). Those nests that are relocated to a centralized hatchery are susceptible to natural catastrophes, such as storms, that could destroy a disproportionately large percentage of a beach's annual reproductive output. Eggs and hatchlings in a centralized location are also more susceptible to disease, parasites, and predators. There are also potential sub-lethal effects, such as disruption of critical cues imprinted by hatchlings while still in the nest and/or during their migrations from the nest to offshore habitats. Best available scientific data support the long-held belief that female sea turtles return to their natal beaches to lay their eggs (Bowen and Karl, 1997). Manipulation of eggs and hatchlings could potentially interfere with these imprinting mechanisms.

Another management technique that has been used to protect hatchlings from lighting impacts is caging. Screen cages are placed over the nests as they near hatching and checked periodically during the night. Hatchlings confined by the cage are collected and released at a dark beach. This too has its drawbacks. Excessive crawling by confined hatchlings prior to their release expends valuable energy needed during their offshore migrations. As for nest relocation, some nests are likely to be missed during morning surveys, and hatchlings from these nests are at risk from light pollution. Similarly, nest caging does not resolve the issue of nesting habitat degradation caused by artificial lighting.

Nest relocation and caging can only be performed by qualified individuals holding a valid marine turtle permit and written authorization from FDEP. The circumstances that warrant manipulative protective measures and the conditions attached to the FDEP authorization for such measures are detailed in guidelines issued to the permit holder.

Because of the potential liabilities associated with nest relocation and caging, current conservation philosophy advocates light management as the best strategy for minimizing lighting impacts to sea turtles. Effective light management can be practically implemented in most coastal settings. When properly applied, the techniques contained in this manual will substantially reduce, if not eliminate, the need for manipulative programs allowing nests to be left in place and the reproductive process to occur naturally without human intervention.

CHAPTER 6

ALTERNATIVES FOR MANAGING EXISTING ROADWAY LIGHTING

Management of roadway lighting can be more complicated than managing beachfront lighting on private property because of the various issues and parties potentially involved. However, effective light management is not technically difficult nor is it necessarily expensive. Simple, inexpensive solutions are often very effective.

Because of the complexity of social needs and environmental settings throughout coastal areas, no specific lighting option is likely to be appropriate for every problem. In this chapter, a variety of alternatives for reducing street lighting impacts to turtles are presented (Table 4). Table 5 shows the relative effectiveness of different lighting alternatives in addressing various street lighting issues.

Some alternatives may effectively resolve a lighting problem when used independently, while other problems may require a combination of alternatives. Some alternatives may be adequate as temporary solutions, while other more complex and permanent solutions are under evaluation.

An important consideration to keep in mind is that any modification to street lights may alter the amount and distribution of light on the roadway. This may require an approval from the authority that has permitted the lighting system. The criterion used by FDOT in assessing whether a variance or waiver from lighting standards is required is the affect the modification is expected to have on highway safety (see Chapter 3, Page 16 *Altering Roadway Lighting Systems).* Because the combination of lighting environments, highway usage patterns, and lighting alternatives is so variable, there are no clear tests that can be offered to determine if a selected alternative will or will not require a variance. This can only be determined through consultation with the permitting authority.

Table 4

List of Options[1] That Can be Used Independently or in Combination to Reduce Street Lighting Impacts to Sea Turtles

- Realign the fixture (change angle of mounting arm or rotate fixture head) so the source of light is not directly visible from the beach.
- Apply a shield to a drop globe fixture.
- Change an open bottom or drop globe fixture to a cutoff fixture.
- Apply a shield to a cutoff fixture.
- Reduce the mounting height of the fixture.
- Reduce the lamp wattage.
- Change the lamp socket position in the fixture to compress the lighting footprint.
- Change to a fixture with a different type of reflector providing a more favorable lighting footprint.
- Install a flat acrylic amber lens in a cutoff fixture with an HPS lamp of 70 watts or less (e.g., GELS 70W M250).
- Install a flat Lexan® polycarbonate lens in a cutoff fixture with an HPS lamp of 100 watts or less.
- Install a stained amber flat glass lens in a cutoff fixture with an HPS lamp of 150 to 400 watts (e.g., GELS 250W M400).
- Install a prismatic acrylic amber lens in a drop globe fixture with an HPS lamp of 150 watts or less (e.g., GELS 150W M250).
- Install a stained amber prismatic glass lens in a drop globe fixture with an HPS lamp of 150 to 400 watts (e.g., GELS 250W M400).
- Install a prismatic Lexan® polycarbonate lens in a drop globe fixture with an HPS lamp of 250 watts or less.
- Turn the light off.
- Remove the fixture.
- Relocate the fixture to block light from beach view.
- Move the fixture to the ocean side of the roadway.
- Change to an LPS fixture.
- Create a vegetated dune buffer.
- Erect an artificial light shield between the light and the beach.

[1] Not listed in any particular order.

Table 5

Relative Effectiveness[1] of Lighting Alternatives (Used Independently) in Accommodating Various Street Lighting Interests

Lighting Alternative (Used Independently of Other Alternatives)[2]	Sea Turtle Protection	FDOT Lighting Standards	Traffic & Public Safety	Color Rendition	Ease of Application	Initial Cost	Operating Costs	Maintenance Costs
Remove Fixture	Best	Worst	Worst	Poor	Poor	Poor	Best	Best
Turn Off Light	Best	Worst	Worst	Poor	Best	Best	Best	Best
Shielded Cutoff Fixture	Good	Fair	Fair	Best	Good	Good	Fair	Good
Shielded Drop Globe Fixture	Poor	Good	Good	Best	Good	Good	Fair	Good
Install Cutoff Fixture	Fair	Fair	Fair	Best	Fair	Fair	Fair	Good
Alter Transverse Light Distribution	Fair	Fair	Good	Best	Fair	Fair	Fair	Good
Reduce Fixture Height	Poor	Poor	Fair	Best	Fair	Fair	Fair	Good
Realign Arm Bracket	Worst	Fair	Good	Best	Fair	Good	Fair	Good
Reposition Fixture Behind Structure	Good	Good	Good	Best	Worst	Worst	Fair	Good
Orient Fixtures Away from Ocean	Good	Best	Best	Best	Worst	Worst	Fair	Good
Reduce Wattage	Fair	Poor	Poor	Best	Fair	Fair	Good	Good
Cutoff Fixture with Acrylic Lens	Good	Fair	Fair	Fair	Good	Good	Fair	Fair
Drop Globe with Stained Glass Lens	Fair	Good	Fair	Fair	Good	Good	Poor	Fair
LPS Lighting	Good	Fair	Poor	Worst	Poor	Poor	Worst	Worst
Install Light Barrier	Good	Best	Best	Best	Worst	Worst	Fair	Good

Best/Most Effective   Good   Fair   Poor   Worst/Least Effective

[1] A "best" and "worst" are listed for each category. However, unlisted alternatives may rank higher or lower than those listed.
[2] Unless otherwise stated, the alternative is used in conjunction with conventional HPS lighting.

1. Selectively Eliminate the Light Source

The simplest and most certain way to eliminate the potential for street lighting impacts to sea turtles is to eliminate the light source. Depending on social needs associated with a particular light, the following options are available:

a. If a light can be eliminated without appreciable social impact, remove the fixture. This will ensure that the light is not inadvertently turned on during the nesting season.

b. If seasonal lighting is desirable, turn the light off during the sea turtle nesting season. This allows roadway lighting during the fall and winter months, the period of heaviest traffic in many coastal areas of Florida, while protecting turtles during the spring and summer months.

c. If the light is critical to year-round traffic safety, turn the light off during the period that nearby nests are expected to hatch. This approach is the least desirable, because it:

    - Does not address lighting effects on nesting turtles.
    - Requires coordination with sea turtle monitoring personnel to identify periods when the light should be turned off.
    - Requires an assessment as to what constitutes a “nearby” nest (i.e., What is the spatial extent of influence of the light in question? Each lighting situation is unique and therefore there is no standard guideline.).
    - Does not provide protection to hatchlings emerging from missed nests.
    - Requires that the lighting custodian is available and can be responsive to user requests for assistance. In cases where a roadway lighting system includes a large number of potential problem lights, the selective turning off and on of lights near nests may not be feasible.

Elimination of as many sources of light as possible along the coast is a desirable goal for sea turtle conservation. However, the location and numbers of lights to be eliminated must be determined on a community-by-community basis with consideration given to local social needs. Typically, lights are turned off or the fixtures eliminated when:

a. The fixture is very close to the beach and there is little vegetative dune buffer to keep the light off the beach.

b. Other lighting options prove ineffective.

2. Shield the Light Source

A relatively simple solution to lighting problems is to modify the fixture to shield the light source (bulb, lamp, etc.) from beach view. A variety of commercial shields are available for this purpose. When determining which type of shield to use consider the following:

a. The shield should be deep and wide enough to prevent the light source from being visible from anywhere on the beach. Often, shields are effective in preventing light from reaching the beach due seaward of the fixture, but the light source can still be seen from locations farther up or down the beach. A shield having an arc of 180° and a depth of 8 inches will resolve most lighting problems.

b. Shields attached to fixtures can add increased stresses to the fixture and bracket during high winds. They should withstand winds of up to 50 MPH (to minimize loss and maintenance costs), yet should break free in stronger winds without damaging the fixture.

Shielding of light fixtures is typically effective by itself when lights are a considerable distance from the beach or when a light source is only visible from a few areas near the dune. As the distance of the fixture from the beach decreases, shields are often used in combination with other alternatives.

If external commercial shields are inadequate or are not available for a particular style of fixture, consider fabrication of specially designed shields. These can be fashioned of aluminum to meet specific attachment, depth and/or arc requirements. However, this should be done only in consultation with the lighting custodian. Electric providers may have policies against installation of non-conforming equipment/materials to fixtures in their roadway lighting systems. Shields should be firmly attached to the fixture so they are not blown off during storms, and periodically inspected to ensure that they are functioning properly.

In cases where decorative, carriage-style fixtures are used along streets, internal sleeves can be applied. These can be custom made at relatively little expense out of PVC. As for external shields, the sleeve should be of sufficient arc and height so the light source is not visible from anywhere on the beach. The lighting custodian must be consulted in the design and application of this fixture modification.

Several alternatives to shielding have been used in the past. These include painting the seaward face of the fixture or placing aluminum foil or other opaque material in the interior seaward face of the fixture. Neither is recommended.

Some colors of paint allow light of undesirable wavelengths to pass through. Even black paint is not completely opaque. Paints deteriorate over time and thus require routine maintenance. During periods when the paint chips or cracks, potentially detrimental light may reach the beach and cause take of sea turtles.

Materials placed inside fixtures may alter the performance of the fixture or cause over heating. Metal sleeves placed inside the seaward side of open-bottom fixtures are typically inadequate to resolve lighting problems unless the fixture is a considerable distance from the beach.

3. <u>Change or Modify the Fixture</u>

Several adjustments can be made to fixtures to minimize their potential for causing direct illumination of the beach. These include:

Compress the Lighting Footprint

The better light is confined to the area of its intended use, the less likely it is to cause problems for sea turtles. The photometric properties of a street light (geometric pattern of light on the ground and variation in brightness within the pattern, hereafter referred to as lighting footprint) can be improved by replacing an open bottom or drop globe fixture with a cutoff or hooded fixture. This compresses the lighting footprint by concentrating light on the roadway, thereby reducing the amount of light reaching the beach. Cutoff fixtures include both shoe box and designs. Shields attached to these fixtures further confine the lighting footprint.

Cutoff fixtures are typically effective in managing light from fixtures located a block or more away from the beach. They may also be appropriate for street lights closer to the beach, if the lights are only visible from a few locations near the dune.

A combination of cutoff fixture and shield will usually resolve all but the most serious of lighting problems. For lights very close to the beach, additional modifications may be necessary.

Alter the Light Distribution

Another method of affecting the lighting footprint is by changing the fixture to one with a different type of reflector or changing the lamp socket position within the existing fixture. The type of reflector used and the position of the lamp in relation to the reflector affect the way light is distributed away from the source, both longitudinally and transversely. Longitudinal distribution refers to the amount of light cast up and down the street (i.e. perpendicular to the mounting arm of the fixture). Typically, a medium longitudinal pattern is used to maximize the spacing between fixtures, while maintaining good uniformity of light distribution on the roadway surface. If uniformity of light distribution can be compromised, fixtures having a long longitudinal pattern will require fewer lights to illuminate the street.

The transverse distribution of light refers to how far light travels across the roadway (i.e. parallel to the mounting arm of the fixture). Fixtures with Type I, II, and III reflectors have relatively narrow transverse properties (Figure 3). For street lights facing the ocean, this is preferable to the broad transverse footprints produced by other types of reflectors.

With a Type I reflector, light distributions on the street side and back side of the fixture are identical; with Type II and III reflectors, light is offset towards the street side (Figure 3). Having good back side cutoff properties is ideal for street lights located on the seaward side of roadways. Depending on their distance from the beach and mounting height, utilization of Type II or III reflectors in fixtures facing away from the ocean may be sufficient to prevent direct illumination of the beach.

Use Non-Reflective Interior Surfaces

Adding an internal shield, a dark non-reflective material, to a fixture may substantially reduce the size of the lighting footprint and thereby minimize the amount of light cast toward the beach. Only internal shields approved by the fixture manufacturer should be used, as these may affect the operational safety and performance of the fixture.

Realign the Fixture

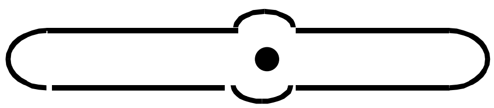
Often times the realignment of a fixture may be sufficient to prevent light from reaching the beach. This can be accomplished by altering the mounting angle of the fixture on the mounting arm so light is directed down or away from the beach. If the fixture is parallel to the roadway surface or bent at a slight angle toward the road, the potential for light reaching the beach is less than if the fixture were at an obtuse angle. Realignment of fixtures is generally most effective for fixtures relatively distant from the beach.

Reduce the Mounting Height

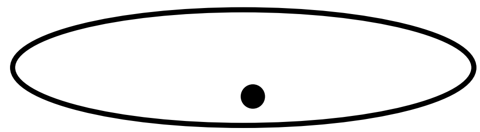
The higher a light is mounted above the roadway surface, the greater the potential for lighting problems. A reduction in mounting height alone will often resolve problems for fixtures relatively distant from the beach. For serious lighting problems near the beach, a reduction in mounting height should be the first consideration in a combination of light management efforts. This alternative must be carefully reviewed by the lighting custodian and regulators for conformance to roadway safety standards.

FIGURE 3.

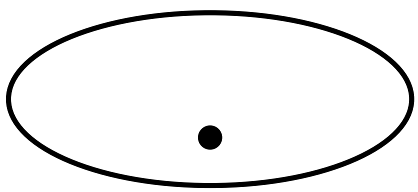
LIGHT DISTRIBUTION PATTERNS (LIGHTING FOOTPRINTS) FOR STREET LIGHTS WITH DIFFERENT TYPES OF REFLECTORS



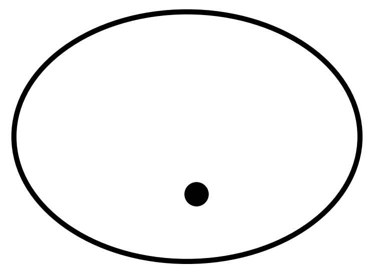
Type I - Narrow beam pattern.
Identical distribution
on both sides of light.



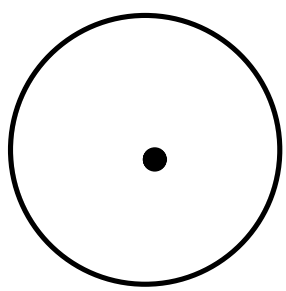
Type II - Narrow beam pattern.
Distribution offset towards
street side of light.



Type III - Mid-size beam pattern.
Distribution offset towards
street side of light.



Type IV - Broad beam pattern.
Distribution offset towards
street side of light.



Type V - Circular beam pattern.
Non-directional.

4. Relocate the Light Source

In some instances light can be better controlled by moving the fixture to another location. Light management can be effectively achieved by:

a. Moving the fixture to a location where buildings or other light barriers shield the light from beach view.

b. Moving the fixture a greater distance from the beach, so the seaward edge of the lighting footprint is moved off the beach.

c. Moving the fixture to the ocean side of the roadway. This often permits better light management because many shields and fixtures are designed for light cut off on the back side of the street light. Additionally, the fixture head can be tilted to move the seaward edge of the lighting footprint further away from the beach. Light that is directed away from the beach typically will cause fewer problems than light directed toward the beach.

Because of the expense and effort involved, relocation of street lights is typically a measure of last resort for resolving the most serious lighting problems. However, light positioning should be a high priority in the planning of new installations and in the retrofitting of existing systems as they become obsolete. If repositioning of light poles is to occur seaward of the Coastal Construction Control Line (CCCL), FDEP must be consulted prior to any construction activities.

5. Reduce Total Illumination

Where sea turtles are concerned, less light is better. An overall reduction in levels of luminance (lumens) can be achieved by:

a. Reducing the wattage in fixtures used for coastal roadway lighting, and

b. Reducing the total number of lights used in the system to those that are absolutely essential.

6. Change Spectral Qualities of Light Source

Fixtures that emit light that is minimally disruptive to sea turtles are preferred over broad spectrum light sources. This can be accomplished through the use of the following:

Filtering Lenses

Amber colored acrylic and glass lenses filter out most short-wavelength light emitted by HPS street lamps. Unlike other types of long-pass filters (e.g., dichroic filters), the angle at which the light strikes the lens has relatively little effect on its filtering properties. Because these lenses do not produce monochromatic light, there is much less color distortion than with LPS light.

Currently, three types of lenses are available and are under evaluation (Table 6):

- Flat and molded (prismatic) acrylic.

Two types of acrylic products are being assessed. Atohaas 2422™ is a sheet product, about 1/8 inch thick, used to fashion flat lenses which can be applied to Cobrahead cutoff fixtures with low wattage lamps (e.g., GELS 70W M250). Atohaas 938™ is a molding pellet product that can be formed into prismatic refractor lenses which can be applied to drop globe fixtures with higher wattage lamps (e.g., GELS 150W M250).

- Lexan® polycarbonate sheeting.

Lexan® (#4158 sheet product) is a polycarbonate material that can be formed into either a flat lens for cutoff fixtures or a molded drop globe for standard fixtures.

- Stained glass.

Glass treated with an inorganic stain (e.g., SC-V55 available through GELS) may also be used in either flat or prismatic applications. Glass is advantageous for relatively high wattage applications, because the acrylic and polycarbonate lenses tend to warp or discolor with increasing heat.

Filtering lenses have broad appeal, because they are relatively inexpensive, are easy to install and maintain, and can be applied to existing HPS fixtures. All three types of lenses are available from FPL on a demonstration basis. Although these filters are certain to reduce the potential for hatchling disorientations, they may require additional modifications to optimize their performance. In controlled field experiments (see Chapter 4, Page 25, Hatchling Arena Assays) scheduled for the summer of 1998, hatchlings will be introduced to light filtered by each of the various amber lenses. If the hatchlings are able to orient properly to the ocean in the presence of the filtered light, the test lens will be offered to utility customers on a permanent basis. If a lens does not perform well (i.e., has an unacceptable level of attractiveness to hatchlings), it may be modified to improve its spectral properties, or it may be removed from the list of available options. A summary of test results and any advances in lens development will be included in future editions of this manual. Specifications, ordering information, and costs for all prototype lenses offered by FPL are provided in Appendix D.

Low-pressure Sodium Vapor (LPS) Light Fixtures

LPS lamps emit monochromatic yellow light. At high luminance levels, loggerhead turtles have an aversion to this type of light. At lower levels, it is weakly attractive to all species. Advantages and disadvantages of LPS have been discussed elsewhere (see Chapter 3, Page 21).

Table 6

Typical Application of Colored Filtering Lenses

Style	Material	Applicability Fixture Style	Wattage
Flat	Atohaas 2422™ amber acrylic	Cobrahead cutoff	70 W
	Stained amber glass	Cobrahead cutoff	150-400 W
	Lexan® #4158	Cobrahead cutoff	70-100 W
Drop Globe	Atohaas 938™ amber acrylic	Standard Cobrahead	70-150 W
	Stained amber glass	Standard Cobrahead	150-400 W
	Lexan® #4158	Standard Cobrahead	70-150 W

7. <u>Plant Vegetative Buffers</u>

Keeping light off the beach is the number one priority of light management. The installation of light barriers should, therefore, be a high priority in those areas where coastal roadways run immediately adjacent to the beach and there is no dune or vegetation to block light. Removal or substantive trimming of existing dune vegetation should be strongly discouraged by local governments. Dune restoration and revegetation projects should be a key element of new roadway design. Establishment of natural light barriers should also be considered in those areas with long-term shoreline protection/beach preservation programs. All beach nourishment projects should incorporate this element into project design. A good vegetative dune buffer will eliminate many lighting problems. Synthetic light barriers may be appropriate in those situations where aesthetics is not an important consideration and light management is extremely difficult. Any construction, including the establishment of vegetative or synthetic light barriers seaward of the Coastal Construction Control Line (CCCL), must be approved by FDEP.

8. <u>Implement Other Technologies</u>

Other new and innovative street lighting technologies may become available after this manual is initially distributed. Those proven to be effective in further reducing impacts to sea turtles should be added to the alternatives presented in this chapter. To the greatest extent practicable, updates of the manual will be made available to all interested parties electronically through the Florida Department of Environmental Protection’s web site at :

http://www.fmri.usf.edu

The manual is designed such that obsolete pages can be easily removed and new information substituted in its place. Periodically, subscribers should check the FDEP web site to determine if they are using the most recent version.

CHAPTER 7

SELECTING THE APPROPRIATE ALTERNATIVE

The principal that has been applied to the alternative selection process in this manual is to begin with the most basic and simplest solutions and progress to more complex and difficult solutions. For example, if a light fixture a considerable distance from the beach is identified as a problem, the first step would be to realign or shield the light. If that proves ineffective, then the fixture should be replaced with a cutoff style fixture. That too may require shielding. If the light is very bright and mounted high on a pole to meet roadway lighting standards, an amber filter may be needed in addition to the other adjustments. With experience, the lighting custodian should be able to determine the extent of modifications necessary to effectively resolve the problem, without having to return several times to make additional modifications. Local, state, and/or federal environmental managers should be used as a resource in developing effective solutions.

In evaluating and selecting lighting alternatives, some general guidelines are offered for achieving light management goals. The potential for lighting impacts to sea turtles is reduced as the:

1. Distance of the street light from the beach increases,

2. Mounting height of the light fixture decreases,

3. Luminance (brightness) of the lamp decreases,

4. Total number of fixtures used in the street lighting system decreases (cumulative impact),

5. Photometric properties of the light fixture are altered to reduce the size of the lighting footprint,

6. Extent of natural or man-made shielding (light blocking) increases,

7. Fixture is rotated to face away from the beach, and

8. Amount of short-wavelength light emitted decreases (by using colored lenses, filters, or LPS lights).

Below is a basic guide to the selection of a light management alternative for most standard roadway lighting problems. Each light management option should be evaluated after modifications have been made to ensure that the selected option is effective.

Is the Light Visible From the Beach?

Both direct and indirect illumination of the beach may cause disorientation of sea turtle hatchlings, and both types of lighting problems must be addressed. Although street lights that cause direct illumination of the beach are typically the most serious of the two, both can be addressed by implementing one of the lighting alternatives offered in this section.

A conservative approach is to consider that a light is causing direct illumination of the beach, if the source of light or any reflective surfaces of the fixture can be seen from anywhere on the beach. Chapter 4, Page 24 (Item No 2) presents a practical method for determining if reflected light is reaching the beach. For direct lighting, modifications are directed toward keeping the light from shining onto the beach. The objective of modifications to reduce indirect beach illumination is to keep light off nearby reflective surfaces.

If a street lighting system consists of many lights within direct line of sight of the beach, even if none of the lamps is directly visible from the beach, an overall reduction in luminance is recommended. This will reduce the potential for cumulative lighting impacts such as skyglow. An overall reduction in the amount of light adjacent to the beach can be accomplished by reducing the wattage of lamps within the lighting system and/or by reducing the total number of lights turned on.

Distance of Light From the Beach

The intent of light management is to confine light landward of those areas where sea turtle nests are deposited. The landward extent of nesting habitat is usually the line of permanent dune vegetation. In the absence of a well defined dune system, nesting may occur anywhere where sufficient areas of open sand are present. Along beaches where erosion control structures are present (e.g., seawalls, rock revetments, etc.), the structure itself usually establishes the upland boundary for nesting. In the context of light management, beach is used to denote the spatial extent of sea turtle nesting habitat.

Lights More than 300 Feet From Beach (see Table 7A, Page 55)

The farther the light is located from the beach the greater the flexibility in addressing the problem. For lights greater than 300 feet from the beach, simple solutions will most likely prove effective. Sometimes, a fixture might only have to be realigned (tilted down or to the side) to completely eliminate the problem. Shields applied to any type of fixture should take care of most remaining problems at this distance. If the light is particularly high or bright or if there is little in the way of dune buffer to shield it from beach view, a cutoff fixture may be required. If the problem light is already a cutoff fixture, apply a shield and/or amber lens.

For distant lights along urban streets, where traffic flow, pedestrian safety and/or crime are a major concern, it may not be possible to reduce the level of luminance. In these cases install an amber prismatic (drop) lens in a drop globe fixture and/or apply a shield. The shield must be deep enough and have a sufficiently broad arc so the light source is not visible from anywhere on the beach.

Lights 100 to 300 Feet From Beach (see Table 7B, Page 56)

At intermediate distances (200 to 300 feet), many of the techniques referenced above still apply. The alternative selected will depend largely on how much illumination is reaching the beach. If relatively little light is visible from the beach, shielded cutoff fixtures are probably all that is required. As either the mounting height and wattage of the fixture increase or the amount of dune vegetation buffer decreases, amber lenses should be added. Prismatic amber drop lenses in shielded drop globe fixtures may still be used at this distance to accommodate roadway lighting standards and public safety, as long as the amount of beach illumination is minimal. However, if large areas of beach are being illuminated, a reduction in mounting height and lamp wattage may be required along with a change out of drop globe fixtures to shielded cutoff fixtures.

Between 100 and 200 feet from the beach, fewer lighting options will be effective, and some major modifications may be required. However, if a good dune buffer is present, changing to a shielded cutoff fixture may be sufficient. Where high wattage lamps are mounted high on the pole, first attempt to reduce the wattage and mounting height before undertaking any other adjustments. Then try either a shield or a combination of shield and cutoff fixture. Where considerable light is reaching the beach, the lighting distribution may be improved by changing the fixture to one with a different type of reflector or by adjusting the lamp socket position within the fixture. Light directed away from the beach is usually easier to keep off the beach than light directed toward the beach. If there is sufficient room on the seaward side of the highway and little or no dune buffer is present, relocation of the fixtures to the seaward side of the street may greatly improve the light management effort. In any case where lights are fairly close to the beach, the application of shielded cutoff fixtures with amber lenses is recommended.

Lights Within 100 Feet of Beach (see Table 7C, Page 57)

At distances closer than 100 feet from the beach, difficult choices sometimes have to be made. Depending on the local setting, turning the light off may be the only way to ensure that lighting impacts will not occur. If turning the light off is not an option, it becomes increasingly important to modify the spectral properties of the light being emitted, because it may not be possible to prevent all light from reaching the beach. Any light that reaches the beach should be minimally disruptive to sea turtles.

It is important to remember that the principal objective of light management is to keep light off the beach. Even if colored filtering lenses or LPS light are used to alter spectral properties, the fixtures should be shielded or modified to confine the lighting footprint landward of the primary dune. For example, consider a HPS lamp in a drop globe fixture located at the end of a road terminating only 50 feet from the beach. If by changing the fixture to a shielded cutoff fixture with a compressed lighting footprint, we could keep all light from reaching the beach, this would be preferable over allowing short-wavelength light to illuminate the beach. In other words, changing the spectral properties of a light source should never be used as a substitute for keeping light off the beach. However, if the lighting modifications described above continue to allow some light to reach the beach, then we would want to implement spectral quality modifications as well.

The distributional properties of LPS light are more difficult to manage than those of conventional HPS fixtures. For this reason amber filtering lenses in directional street lights (e.g., Cobrahead cutoff fixtures) are preferable for those cases where modifications will largely, but not completely, confine the lighting footprint landward of the beach. However, the spectral properties of LPS light are superior to those of filtered light. Thus, in those cases where a street light is very close to the beach and lighting modifications cannot effectively maintain the lighting footprint landward of the dune, LPS would be a superior choice.

Establishment of a thick vegetated dune buffer along those sections of beach in close proximity to a lighted roadway is one of the most effective long-term light management options for keeping light off the beach. The worst lighting problems typically occur in those areas where there is little or no dune vegetation. Temporary light screens set up between nearby street lights and nests ready to hatch can also be used if coastal aesthetics are not an issue. These screens are typically constructed of a double layer of shade cloth (used by plant nurseries) secured to a line of tall posts placed along the dune crest. FDEP and local approvals must be obtained prior to construction of either natural or synthetic light barriers to ensure that these systems are properly planned, constructed, and maintained.

Type of Fixture

The more control a light manager has over the photometric properties of a fixture, the better he/she will be able to keep light off the beach. Cutoff fixtures are better than open bottom or drop globe fixtures in confining the lighting footprint. The combination of fixture style and photometric properties selected will depend on the orientation of the street and street light relative to the ocean. If a street runs perpendicular to the beach longitudinal light distribution will be more important than transverse distribution. The opposite applies to streets that run parallel to the ocean. Light can be better controlled if a fixture is directed away from the beach. Cutoff fixtures become increasingly important in light management as the distance of the fixture to the beach decreases.

Mounting Height and Wattage

In order to maintain an acceptable level of light on the roadway and keep the number of fixtures to a minimum, increased mounting height and higher lamp wattages are typically used in roadway lighting designs. Unfortunately, as mounting heights and wattages increase, the potential for beachfront illumination increases. Thus, a first step in addressing a lighting problem is to determine whether a reduction in mounting height and wattage can be undertaken without compromise to an acceptable level of highway safety. Where it is not possible to alter the lighting configuration, a combination of amber lenses and shields may be an acceptable alternative. If the subject lights are relatively close to the beach, installation of light screens or establishment of natural dune barriers may be required to keep the light off the beach.

Extent of Beach Illumination

The amount of effort required to resolve a lighting problem is directly related to the amount of light reaching the beach and the spatial extent of illumination. If a street light is only visible from a few locations near the dune, simple shielding may be effective. In other cases a combination of cutoff fixture and shield may be required. If the light is very close to the beach, even if only visible from a few locations, the addition of an amber lens would be appropriate. This will offer additional protection, in the event that dune characteristics change (e.g., vegetation dies, beach profile changes, etc.).

If a street light is visible from numerous locations both near the dune and the waterline, a combination of shielded cutoff fixture with amber lens will probably be required. Depending on the distance of the fixture from the beach a reduction in mounting height and wattage may also be appropriate.

In the most extreme cases where bright lights are very close to the beach and there is little dune buffer, large sections of beach may be brightly illuminated. In these cases, the lights must either be turned off, the spectral qualities altered, or artificial light barriers erected. Establishment of a natural vegetated dune buffer would probably allow for the use of shielded cutoff fixtures with amber lenses instead of LPS.

Summary of Lighting Options

As indicated above, there are a number of factors involved in determining which alternative is appropriate for resolving a particular lighting problem. It is impractical to list all of the potential combinations of variables that could be considered in the selection of a lighting solution.

- Table 4 lists the available options that can be used either independently or in combination to resolve identified lighting problems.

- Table 5 indicates the effectiveness of each lighting alternative, when used independently, in addressing various street lighting issues.

- Table 7 summarizes the alternative selection process and provides examples of appropriate solutions for selected lighting conditions.

Table 7

The Alternative Selection Process

<u>Explanation of Table</u>

This table is designed to assist in the selection of a lighting modification that is ***likely*** to resolve your street lighting problem. In selecting one of the alternatives, there are two important considerations:

1. ***The recommended modification may not be 100% effective for your specific lighting problem.*** Each lighting situation is unique depending on the purpose of the light, the type of fixture, the wattage of the lamp, the distance of the fixture from the beach, the linear extent and height of natural barriers and buildings between the light and the beach, etc. While the alternative selected from the table will undoubtedly *reduce* the potential for lighting impacts to sea turtles on adjacent beaches, it is not guaranteed to be 100% effective for every lighting problem. For that reason, it is important to evaluate your problem light after the modifications have been made to ensure that the selected option has adequately achieved light management objectives. (See Chapter 4, Page 23 for guidelines for performing nighttime lighting evaluations).

   Light management objectives have been achieved if:

   - The source of light (bulb, lamp, etc.) is no longer directly visible from the beach.
   - Light is not indirectly reaching the beach from reflective surfaces near the light source.
   - The total amount of luminance adjacent to the beach has been reduced to the minimum required to comply with highway safety standards.
   - Any light reaching the beach has spectral properties that are minimally disruptive to sea turtles.

2. ***The recommended modification may be more involved than is necessary for your specific lighting problem.*** The recommended modifications in the table are conservative. They were developed to ensure that an effective solution will ***likely*** be achieved. In many cases, depending upon the specific lighting situation, a simpler, less expensive alternative may be just as effective as the recommended modification(s). Therefore, prior to undertaking a modification, a site-specific assessment of the lighting environment should be made (see Table 3, Item No. 2, Page 28). This, together with consultations with local environmental managers and/or lighting experts, may reduce the effort and expense associated with implementation of an effective solution.

How to Use the Table

Step 1. Determine how far the problem light is from the beach and go to the appropriate sub-table to select a lighting alternative.

As indicated throughout this manual, there are a number of variables that will determine which modifications will be most effective for your particular lighting situation. In this table, distance from the beach is the first principal determinant. Lights that are very close to the beach will require considerably more effort to correct than those farther inland. The distances selected for the table are somewhat arbitrary, but should provide a relative gauge of the effort that is likely to be required to achieve light management objectives.

a. Light fixture more than 300 feet from the beach ….. Use Table 7A
b. Light fixture 100-300 feet from the beach ………… Use Table 7B
c. Light fixture within 100 feet of the beach …………. Use Table 7C

Step 2. Go to the section of the table that best characterizes the community setting where the light is located (rural or urban).

Typically there is more flexibility in addressing lighting problems in rural areas than in more urbanized settings where there may be greater concerns about pedestrian safety.

Step 3. Under the appropriate community setting, go to the section of the table that is closest to the mounting height and lamp wattage of the fixture being modified.

The higher the light is off the ground and the brighter the lamp, the greater the potential for causing problems for sea turtles. Bright lights mounted relatively high will require more modifications than dimmer lights closer to the ground. The minimum mounting height for street lights is usually 25 ft. At that height, 150 w HPS lamps are typically used. Table 7 assumes these minimum standards. However, reductions may be possible and should be considered, particularly with respect to lamp wattage.

Step 4. Consult with the lighting custodian and permitting authority (see Chapter 3, Page 16, *Altering Roadway Lighting Systems*) to determine if the mounting height and/or lamp size can be reduced. Go to the appropriate section of the table (*Is Lighting Configuration Adjustable?*) in response to that determination.

If the mounting height and/or lamp size can be reduced, light management objectives will be easier to achieve. It is assumed that in many urban settings, where traffic flow and pedestrian safety are of paramount concern, the mounting height and lamp size cannot be adjusted, because it would result in unacceptable deviations from the photometric properties of the roadway lighting design. If adjustments are acceptable, select an alternative from the rural section of the table.

Step 5. Determine if the lamp is mounted within a drop globe or cutoff fixture and go to the appropriate section of the table.

Light from cutoff fixtures will be easier to manage than light from other styles of fixtures.

Step 6. Assess the linear extent and height of the dune and vegetative buffer between the light source and the beach, and select the option in the table that most closely characterizes the environmental setting at the site.

The better the vegetative buffer between the beach and the light, the better able you will be to implement an effective modification. Man-made barriers, such as buildings and artificial light screens, are just as effective as dune vegetation and should be considered in this step.

If light is visible over a broad section of beach from both near the dune and near the waterline, consider the dune buffer as *Poor*. If light is visible from only one or a few narrow sections of beach near the dune, consider the dune buffer as *Good*.

Step 7. Select the recommended modification that is most appropriate to your specific lighting problem.

Recommendations for effective light management are represented by numbers corresponding to **modifications listed in Table 7D** (Page 59). Several recommendations are provided for each lighting situation. Each recommendation is enclosed in parentheses. Some recommendations consist of only a single modification, while others involve a combination of modifications. The first of the listed recommendations is usually the simplest. The last of the listed recommendations is usually the most complicated and/or costly, but it is the one that has the highest probability of achieving light management objectives.

Example 1.

A 150W Cobrahead drop globe street light, mounted at a height of 25 feet, is located about 200 feet from the beach in an urban area, and there is a poor dune buffer between the light and the beach. The recommended modification from Table 7B (100-300 feet from the beach) is (7 & 2 & 4). This modification would consist of changing to a cutoff style fixture (7) and then applying a shield (2) and an amber lens (4).

Example 2.

A 250W cutoff fixture, mounted at a height of 30 feet, is located about 80 feet from the beach in a rural setting, and a good dune buffer is present between the light and the beach. After consulting with the lighting custodian and permitting authority, it is determined that the light fixture and wattage can be changed. The recommended modification from Table 7C (within 100 feet from the beach) is (6 & 2 & 4). This modification would consist of reducing the mounting height and wattage of the light (6) and then applying a shield (2) and amber lens (4). If it was determined that the mounting height and wattage could not be changed, one of two recommendations are provided. One (5 & 2 & 4) involves adjusting the light distribution by changing the socket position of the lamp (5) and then applying a shield (2) and an amber lens (4). The other (8 & 2 & 4) involves changing the fixture to one with a different style of internal reflector (8) and then applying a shield (2) and an amber lens (4).

Table 7A - Light Fixture More Than 300 Feet From the Beach

Type of Roadway and Usage	Mounting Height and Lamp Size	Is Lighting Configuration Adjustable?	Fixture Style	Extent of Vegetated Dune Buffer	Recommended Modification See Table 7D
Rural, No Sidewalks, Little Pedestrian Traffic	≤ 25 ft ≤ 150 watts	No	Drop Globe	Good	(2) or (2 & 3)
				Poor	(2 & 3) or (7) or (7 & 2)
			Cutoff	Good	(2)
				Poor	(2) or (2 & 5)
	> 25 ft > 150 watts	Yes	Drop Globe	Good	(7) or (7 & 2)
				Poor	(6 & 2) or (6 & 7) or (6 & 7 & 2)
			Cutoff	Good	(2) or (6 & 2)
				Poor	(6 & 2) or (6 & 2 & 5)
		No	Drop Globe	Good	(7 & 2) or (7 & 2 & 5)
				Poor	(7 & 2 & 5) or (7 & 2 & 8)
			Cutoff	Good	(2) or (2 & 5) or (2 & 8)
				Poor	(2 & 5) or (2 & 8) or (2 & 4 & 5) or (2 & 4 & 8)
Urban, Sidewalks Present, Heavy Pedestrian Traffic	≤ 25 ft ≤ 150 watts	No	Drop Globe	Good	(2) or (2 & 4)
				Poor	(7) or (7 & 2)
			Cutoff	Good	(2)
				Poor	(2) or (2 & 5)
	> 25 ft > 150 watts	No is assumed (If yes; select an alternative from the rural section above)	Drop Globe	Good	(7 & 2) or (7 & 2 & 5) or (7 & 2 & 8)
				Poor	(7 & 2 & 5 & 4) or (7 & 2 & 8 & 4)
			Cutoff	Good	(2 & 5) or (2 & 8)
				Poor	(2 & 4 & 5) or (2 & 4 & 8)

Table 7B - Light Fixture 100-300 Feet From the Beach

Type of Roadway and Usage	Mounting Height and Lamp Size	Is Lighting Configuration Adjustable?	Fixture Style	Extent of Vegetated Dune Buffer	Recommended Modification See Table 7D
Rural, No Sidewalks, Little Pedestrian Traffic	≤ 25 ft ≤ 150 watts	No	Drop Globe	Good	(7)
				Poor	(7 & 2) or (7 & 2 & 5) or (7 & 2 & 8)
			Cutoff	Good	(2) or (2 & 5) or (2 & 8)
				Poor	(2 & 5 & 4) or (2 & 8 & 4)
	> 25 ft > 150 watts	Yes	Drop Globe	Good	(7 & 2 & 5) or (7 & 2 & 8)
				Poor	(6 & 7 & 2 & 5) or (6 & 7 & 2 & 8)
			Cutoff	Good	(2 & 5) or (2 & 8)
				Poor	(6 & 2 & 5) or (6 & 2 & 8)
		No	Drop Globe	Good	(7 & 2 & 4)
				Poor	(7 & 2 & 5 & 4) or (7 & 2 & 8 & 4)
			Cutoff	Good	(2 & 4)
				Poor	(2 & 4 & 5) or (2 & 4 & 8)
Urban, Sidewalks Present, Heavy Pedestrian Traffic	≤ 25 ft ≤ 150 watts	No	Drop Globe	Good	(2 & 4)
				Poor	(7 & 2 & 4)
			Cutoff	Good	(2 & 4)
				Poor	(2 & 5 & 4) or (2 & 8 & 4)
	> 25 ft > 150 watts	No is assumed (if yes; select an alternative from the rural section above)	Drop Globe	Good	(7 & 2 & 5) or (7 & 2 & 8)
				Poor	(7 & 2 & 5 & 4) or (7 & 2 & 8 & 4)
			Cutoff	Good	(2 & 4)
				Poor	(2 & 4 & 5) or (2 & 4 & 8)

Table 7C - Light Fixture Within 100 of the Beach

Type of Roadway and Usage	Mounting Height and Lamp Size	Is Lighting Configuration Adjustable?	Fixture Style	Extent of Vegetated Dune Buffer	Recommended Modification See Table 7D
Rural, No Sidewalks, Little Pedestrian Traffic	≤ 25 ft ≤ 150 watts	No	Drop Globe	Good	(7 & 2 & 4)
				Poor	(7 & 2 & 5 & 4) or (7 & 2 & 8 & 4)
			Cutoff	Good	(2 & 4)
				Poor	(2 & 5 & 4) or (2 & 8 & 4)
	> 25 ft > 150 watts	Yes	Drop Globe	Good	(6 & 7 & 2 & 4)
				Poor	(6 & 7 & 2 & 5 & 4) or (6 & 7 & 2 & 8 & 4)
			Cutoff	Good	(6 & 2 & 4)
				Poor	(6 & 2 & 5 & 4) or (6 & 2 & 8 & 4)
		No	Drop Globe	Good	(7 & 2 & 5 & 4) or (7 & 2 & 8 & 4)
				Poor	(7 & 2 & 5 & 4) or (7 & 2 & 8 & 4) or (7 & 2 & 4 & 10) or (7 & 2 & 11) or (1)
			Cutoff	Good	(5 & 2 & 4) or (8 & 2 & 4)
				Poor	(2 & 4 & 5) or (2 & 4 & 8) or (2 & 4 & 11) or (2 & 4 & 10) or (1)

Table 7C - Light Fixture Within 100 of the Beach (Continued)

<table>
<tr><th>Type of Roadway and Usage</th><th>Mounting Height and Lamp Size</th><th>Is Lighting Configuration Adjustable?</th><th>Fixture Style</th><th>Extent of Vegetated Dune Buffer</th><th>Recommended Modification See Table 7D</th></tr>
<tr><td rowspan="8">Urban, Sidewalks Present, Heavy Pedestrian Traffic</td><td rowspan="4">≤ 25 ft
≤ 150 watts</td><td rowspan="4">No</td><td rowspan="2">Drop Globe</td><td>Good</td><td>(7 & 2 & 4)</td></tr>
<tr><td>Poor</td><td>(7 & 2 & 5 & 4)
or
(7 & 2 & 8 & 4)</td></tr>
<tr><td rowspan="2">Cutoff</td><td>Good</td><td>(2 & 4)</td></tr>
<tr><td>Poor</td><td>(5 & 2 & 4) or
(8 & 2 & 4)</td></tr>
<tr><td rowspan="4">> 25 ft
> 150 watts</td><td rowspan="4">No is assumed (if yes; select an alternative from the rural section above)</td><td rowspan="2">Drop Globe</td><td>Good</td><td>(7 & 2 & 5 & 4)
or
(7 & 2 & 8 & 4)</td></tr>
<tr><td>Poor</td><td>(7 & 2 & 5 & 4)
or
(7 & 2 & 8 & 4)
or
(7 & 2 & 4 & 10)
or
(7 & 11)
or (1) or (9)</td></tr>
<tr><td rowspan="2">Cutoff</td><td>Good</td><td>(5 & 2 & 4)
or (8 & 2 & 4)</td></tr>
<tr><td>Poor</td><td>(2 & 4 & 5) or
(2 & 4 & 8) or
(2 & 4 & 10)
or (1) or (11)
or (9)</td></tr>
</table>

Table 7D - List of Lighting Modifications for Use in Tables 7A-C.

The following list of alternative lighting modifications progresses from the easiest and least expensive to the most difficult and expensive. Go to the corresponding page number for more information about the alternative.

1. Turn the light off (Page 36).

2. Apply a shield to the seaward portion of the fixture (Page 37).

3. Adjust the light distribution by aiming the fixture down and/or away from the beach (Page 39).

4. Install an amber filtering lens (Page 42).

5. Adjust the light distribution by changing the lamp socket position (Page 38).

6. Reduce the mounting height and/or wattage of the light (Page 39).

7. Change the fixture to a cutoff style fixture (Page 38).

8. Adjust the light distribution by changing the fixture to one with a different style of reflector (Page 38).

9. Install shielded LPS lighting (Page 43).

10. Install a vegetative or synthetic light barrier (Page 43).

11. Move the fixture behind a building or other structure to block its view from the beach (Page 41).

LITERATURE CITED

Bowen, B.W., and S.A. Karl. 1997. Population genetics, phylogeography, and molecular evolution. Pages 29-50 *in* Lutz, P.L., and J.A. Musick (eds.), The Biology of Sea Turtles. CRC Press.

Finch, D.M. 1978. Atmospheric light pollution. Journal of the IES, 7(2).

Limpus, C.J., V. Baker, and J.D. Miller. 1979. Movement induced mortality of loggerhead eggs. Herpetologica, 35(4): 335-338.

Lohmann, K.L., B.E. Witherington, C.M.F. Lohmannn, and M. Salmon. 1997. Orientation, navigation and natal beach homing in sea turtles. Pages 107-136 *in* Lutz, P.L., and J.A. Musick (eds.), The Biology of Sea Turtles. CRC Press.

Mattison, C., C. Burney, and L. Fisher. 1993. Trends in the spatial distribution of sea turtle activity on an urban beach (1981-1992). Pages 102-104 *in* Schroeder, B., and B. Witherington (eds.), Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-341.

McFarlane, R.W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia, 1963:153.

Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Research Institute Technical Report No. 52. 51 p.

Moody, K. In Press. The effects of nest relocation on hatching success and emergence success of the loggerhead turtle (*Caretta caretta*) in Florida. *In* Proceedings of the Sixteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum.

Murphy, T. M. 1985. Telemetric monitoring of nesting loggerhead sea turtles subject to disturbance on the beach. Paper presented at the 5th Annual Sea Turtle Research Workshop, February 13-16, 1985, Waverly, Georgia.

NMFS (National Marine Fisheries Service) and USFWS (U.S. Fish and Wildlife Service). 1991a. Recovery Plan for U.S. Population of Loggerhead Turtle. National Marine Fisheries Service, Washington D.C. 64 p.

NMFS and USFWS. 1991b. Recovery Plan for U.S. Population of Atlantic Green Turtle. National Marine Fisheries Service, Washington D.C. 52 p.

NMFS and USFWS. 1992. Recovery Plan for Leatherback Turtles in the U.S., Caribbean, Atlantic and Gulf of Mexico. National Marine Fisheries Service, Washington D.C. 65 p.

Peters, A., and K.J.F. Verhoeven. 1994. Impact of artificial lighting on the seaward orientation of hatchling loggerhead turtles. Journal of Herpetology, 28:112-114.

Philibosian, R. 1976. Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights. Copeia, 1976:824.

Salmon, M., R. Reiners, C. Lavin, and J. Wyneken. 1995. Behavior of loggerhead sea turtles on an urban beach. I. Correlates of nest placement. Journal of Herpetology 29(4):560-567.

Verheijen, F.J. 1985. Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. Experimental Biology, 44:1-18.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48(1): 31-39.

Witherington, B.E. 1997. The problem of photopollution for sea turtles and other nocturnal animals. *In* Clemmons, J.R., and R. Buchholz (eds.), Behavioral Approaches to Conservation in the Wild. Cambridge University Press, Cambridge England.

Witherington, B.E., and R.E. Martin. 1996. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. FMRI Technical Report TR-2, Florida Marine Research Institute, St. Petersburg, Florida. 73 p.

APPENDIX A

TECHNICAL WORKING GROUP CONTACT LIST
Coastal Roadway Lighting Manual

APPENDIX A

TECHNICAL WORKING GROUP CONTACT LIST
Coastal Roadway Lighting Manual

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APPENDIX A
(Continued)

TECHNICAL WORKING GROUP CONTACT LIST
Coastal Roadway Lighting Manual

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APPENDIX B

STEERING COMMITTEE CONTACT LIST
Coastal Roadway Lighting Manual

APPENDIX B

STEERING COMMITTEE CONTACT LIST
Coastal Roadway Lighting Manual

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APPENDIX C

STATEMENT FROM USFWS REGARDING GOOD FAITH EFFORTS TO RESOLVE STREET LIGHTING PROBLEMS

EXCERPT FROM LETTER SIGNED BY
Sandra L. MacPherson, Sea Turtle Recovery Coordinator, US Fish and Wildlife Service

August 20, 1997

Mr. Robert G. Ernest
Ecological Associates, Inc.
P.O. Box 405
Jensen Beach, Florida 34958

Dear Bob:

This letter is in response to your August 1, 1997, telephone request for information on how the Service would proceed if sea turtle disorientations are attributed to lights corrected in a manner recommended in the coastal lighting management plan/manual being developed by the Technical Work Group convened by the Florida Power & Light Company.

As a member of the Technical Work Group, I foresee that only those recommendations that the U.S. Fish and Wildlife Service and Florida Department of Environmental Protection, which is also represented on the Technical Work Group, have approved will be included in the manual as roadway lighting problem solutions. Assuming this is the case and problem lights are corrected in the recommended manner, then I would anticipate that take of federally listed sea turtles would not occur as a result of the corrected lights. However, if take is attributed to the corrected lights, the Service would recognize that a good faith effort had been made and would continue to work with the party responsible for the lights to eliminate the take. Under these circumstances, the Service would not recommend prosecution under the Endangered Species Act as long as the responsible party continues to act in good faith to correct the problem.

I hope this information is helpful. Please contact me at 904/232-2580 (extension 110) if you have any questions or require additional information.

Sincerely,

Sandra L. MacPherson
Sea Turtle Recovery Coordinator

APPENDIX D

TECHNICAL SPECIFICATIONS AND APPROXIMATE COSTS OF LIGHT MANAGEMENT OPTIONS

Technical Specifications and Approximate Costs of Light Management Options

Name of Product	Eff. Date	Order No. FPL	Supplier Order No.	Application	Expected Life	Cost Of Product			Applicable FPL Fixture	
						Per Unit	Installation Cost	Operational Cost	Description	FPL M&S #
Turtle Cutoff Refractor Lens - Lexan	Mar-98	By Description	35-420695B01 (General Electric)	GE M250 Luminaire 100W Max.	5 Years	$ 30.00	Job Specific (varies)	Job Specific (varies)	120V, 70W, Cobra C/O 120V, 100W, Cobra C/O	170-92400-5 170-92401-3
Turtle Drop Globe Refractor - Lexan	Mar-98	By Description	35-232406B08 (General Electric)	GE M250 Luminaire 150W Max.	10 Years	$ 30.00	Job Specific (varies)	Job Specific (varies)	120V, 70W, Std Cobra 120V, 100W, Std Cobra 120V, 150W, Std Cobra 480V, 150W, Std. Cobra	170-92204-5 170-92201-1 170-92202-9 170-92203-7
Turtle Cutoff Refractor Lens - Stained Glass	Mar-98	By Description	35-232543B02 (General Electric)	GE M400 Luminaire	20 Years	$ 30.00	Job Specific (varies)	Job Specific (varies)	120V, 200W, Cobra C/O 480V, 400W, Cobra C/O 120V, 400W, Cobra C/O 480V, 400W, Cobra C/O	170-96000-1 170-96500-3 170-94000-1 170-95000-6
Turtle Drop Globe Refractor - Stained Glass	Mar-98	By Description	35-231137B02 (General Electric)	GE M400 Luminaire	20 Years	$ 30.00	Job Specific (varies)	Job Specific (varies)	120V, 200W, Std. Cobra 480V, 400W, Std. Cobra 120V, 400W, Std. Cobra 480V, 400W, Std. Cobra	170-91000-4 170-91001-2 170-90000-9 170-90200-1
Turtle Shield for Streetlight with Cutoff Optics	1997	By Description	ELS-M2RC002 (General Electric)	GE M250 Luminaire	20 Years	$ 12.00	Job Specific (varies)	Job Specific (varies)	120V, 70W, Cobra C/O 120V, 100W, Cobra C/O 120V, 150W, Cobra C/O 480V, 150W, Cobra C/O	170-92400-5 170-92401-3 170-92402-1 170-92403-0
Turtle Cutoff Refractor Lens-Acrylic	Apr-98	By Description	35-420695B02 (General Electric)	GE M250 Luminaire 70W Max.	15-20 Years	$ 22.00	Job Specific (varies)	Job Specific (varies)	120V, 70W, Cobra C/O	170-92400-5
Turtle Drop Globe Refractor - Acrylic	Apr-98	By Description	35-232406B09 (General Electric)	GE M250 Luminaire 150W Max.	15-20 Years	$ 22.00	Job Specific (varies)	Job Specific (varies)	120V, 70W, Std Cobra 120V, 100W, Std Cobra 120V, 150W, Std Cobra 480V, 150W, Std. Cobra	170-92204-5 170-92201-1 170-92202-9 170-92203-7