SEA TURTLE VISUAL CUES

AN EVOLUTIONARY APPROACH TO ENVIRONMENTALLY SENSITIVE LIGHTING

Overview –

Human development within environmentally sensitive aquatic habitats has had significant negative impacts upon many species and, in particular, sea turtles. Tragically, adult female turtles seeking beachfront nesting areas have been constrained by physical obstacles and beach encroachment while artificial lighting interferes with visual cues used for orientation by adults and hatchlings. Although lighting guidelines have been established for full cut-off (shielded) fixtures and yellow/amber color limitations, there continue to be disorientation incidences leading to significant fatalities. Along these lines, there are studies to determine the visual acuity of sea turtles inclusive of scotopic and photopic perception. In particular, the work of D. H. Levenson, S. A. Eckert, M. A. Crognale, J. F. Deegan II, and G. H. Jacobs presented in their joint paper Photopic Spectral Sensitivity of Green and Loggerhead Sea Turtles, (Copeia, Vol. 2004, No. 4 (Dec. 15, 2004), pp. 908-914) reveals acute color sensitivity within the spectral ranges from 550nm to 650nm; green-yellow-amber. Intuitively, these findings contradict a lighting standard calling for wavelengths within the highest visual acuity and raise the serious question about potential lighting characteristics serving as visual cues for adult and hatchling turtles. An investigation of behavioral studies shows a strong potential correlation between visual cues and multi-frequency flicker as opposed to spectrum alone. This is particularly important when considering that nesting and hatching can occur at any time of the day or night. Equally important, both adults and hatchlings seem highly influenced by focused or intensely contrasted light as opposed to color and ambient lighting levels. This report provides new insight into solving various threats posed by artificial lighting and encourages further independent investigation.

Artificial Light –

The majority of lighting technology deployed in and around aquatic habitats falls into four basic categories:

1) Incandescent
2) Fluorescent
3) High intensity discharge (HID)
    a. Metal halide
    b. High pressure sodium
    c. Halogen
    d. Mercury vapor
4) Light emitting diode (LED)

Emerging technologies include light emitting plasma (LEP), organic light emitting diodes (OLED), and magnetic induction lighting (MIL). Energy efficiency standards have already foreclosed incandescent and mercury vapor lighting due to inefficiencies and environmental toxicity. Of the remaining technologies, metal halide, high pressure sodium, and halogen all have very high heat profiles. Cool bulb technologies include fluorescent, LED, and magnetic induction (MIL). Of these, LED ranks the hottest followed by fluorescent and induction.

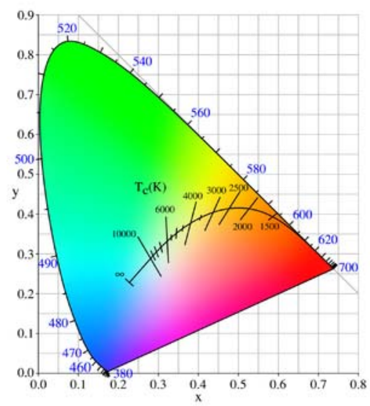
Ideally, the best artificial light for beaches and wetlands is no light at all. In the context of modernity, this is not an option. Alternatively, the next best solution is to work with the *lowest lighting levels* that provide reasonable human visual acuity where necessary.
Each of the mentioned lighting technologies displays distinct characteristics including:

- Color temperature (measured in degrees Kelvin)
- Flicker or strobe rate associated with 50 or 60 hertz
- Intensity and glare
- Diffusion/Dispersion
- Contrast
- Visibility/exposure
- Bulb and ballast heat

Taken one at a time:

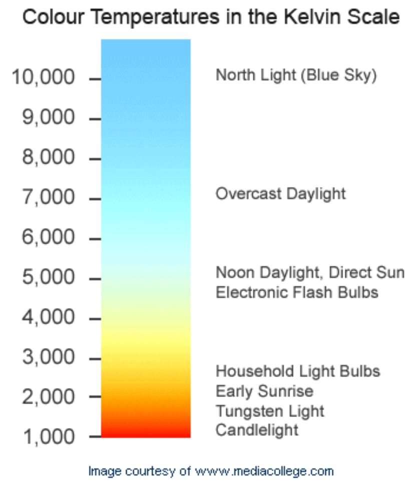
Temperature	Source
1,700 K	Match flame
1,850 K	Candle flame, sunset/sunrise
2,700–3,300 K	Incandescent lamps
3,000 K	Soft (or Warm) White compact fluorescent lamps
3,200 K	Studio lamps, photofloods, etc.
3,350 K	Studio "CP" light
4,100–4,150 K	Moonlight
5,000 K	Horizon daylight
5,000 K	Tubular fluorescent lamps or cool white/daylight compact fluorescent lamps (CFL)
5,500–6,000 K	Vertical daylight, electronic flash
6,200 K	Xenon short-arc lamp
6,500 K	Daylight, overcast
6,500–10,500 K	LCD or CRT screen
15,000–27,000 K	Clear blue poleward sky

Color Spectrum and Temperature –



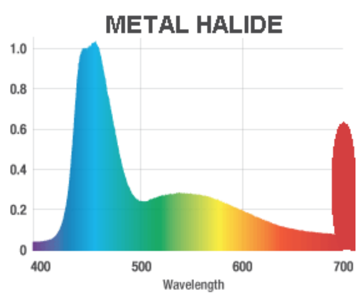
Color – In lighting, color refers to the Kelvin scale representing the ideal “black-body radiator” that generates a particular hue or spectrum. An analogy would be a heated piece of iron that begins to glow red hot. As the iron is heated it changes from red to yellow and at its hottest point before melting it becomes white hot; meaning whitish blue. Oddly, the highest Kelvin temperature is considered cool or cooler light whereas the lower Kelvin is warm or warmer. The measurement is on the Planklan Locus as seen in the graph. The table to the left identifies the general reference categories for the Kelvin scale from a match flame to the sky on a clear day viewed toward the North or South Pole. The range from 4,100K to 4,150K may be of particular interest since it is associated with moonlight. However, this is not an accurate representation of the moon’s color spectrum because it centers around the rising temperature or “red moon” as opposed to a full moon above the horizon.

Daylight takes on different color temperatures relative to time, season, direction, and atmospheric conditions. A bright clear sunny day may register 10,000K whereas a bright overcast day might drop to 6,500K. A great deal of attention has been paid to “full spectrum” lighting that mimics sunlight at sea level. Unfortunately, there is no standard for a full spectrum delineation and the color temperature of such light sources can widely vary. There is a consensus that 6,500K represents the most ideal color temperature for a full spectrum categorization.

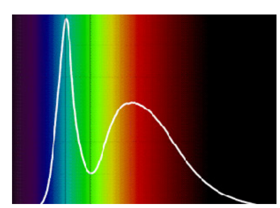


Sunsets and sunrises move into the yellow/orange and orange/red temperatures from 2,500K and down. Dusk and moonlight represent unique lighting falling into the monochromatic grays and blue-grays.

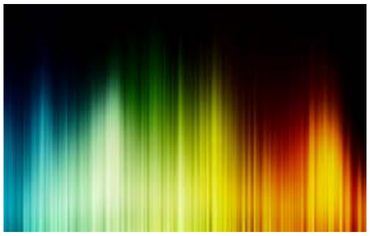
Understanding color temperature is important because it is believed to be one of the mechanisms used by sea turtles to locate beaches and water. A majority of nesting and hatching takes place during the evening. If color temperature and associated spectral output plays a role in orientation, avoiding certain wavelengths may serve to mitigate some of the adverse artificial lighting effects.



Metal halide lighting exhibits distinct spectral bias with significant light in the violet and near ultraviolet (UV) range and equally large amounts of output in the red and infrared range. These ranges have advantages based upon research to determine the photopic sensitivity of sea turtles that falls in the mid ranges of yellow and orange. However, this same sensitivity is exhibited by humans. In order to adequately light areas for human activities, higher overall intensities are required; i.e. greater power and lumen output.



Newer LEDs display a spectral bias in the UV and blue range. Like metal halide, the implication is that the lower sensitivity to short wavelengths will be less obtrusive. Although LEDs can be combined or filtered to produce various color temperatures, the nature of LED technology is to exhibit more output in the shorter wavelengths. Since LEDs are not as hot as metal halide, there is very little output in the infrared range. LEDs are considerably more efficient in producing usable light that falls within the visual acuity of human vision. The dramatic dip in green/yellow is similar to metal halide and coincides with the findings of D. H. Levenson, S. A. Eckert, M. A. Crognale, J. F. Deegan II, and G. H. Jacobs.



Port-Bright™ magnetic induction lighting (MIL) is a totally new approach to artificial lighting for ecologically sensitive aquatic habitats. It works on the principle of using *substantially less power*… 70% to 80% less than metal halide and a balanced spectrum with emphasis within the visual acuity of human vision, referred to as "visually effective lumens." (VEL) The use of this type of full spectrum light source adheres to recent findings about the visual acuity of Loggerhead, Green, Leatherback, Hawksbill, and Ridley turtles. Color sensitivity declines below 440nm (Photopic Spectral Sensitivity of Green and Loggerhead Sea Turtles: Copeia, Vol. 2004, No. 4 (Dec. 15, 2004), pp. 908-914)

An empirically derived contradiction exists in the assumption that color temperature makes a difference when we observe nesting and hatching at all times during the day and night and at all phases of the moon. Adult females are able to lay eggs and navigate back to the water regardless of general lighting levels or the color temperature of ambient light. A great deal of study has been conducted to analyze moonlight that can have intensities up to 1 lux when full on a clear night. Most spectral analysis reveals a blue/white light when full and 30 degrees above the horizon. Like the sun, the moon is affected by the angle relative to the horizon and will change to an orange hue when wavelengths are extended by the Earth's atmosphere. There has been no definitive association between turtle spectral sensitivity and disorientation.

There have been "suggested" relationships between spectrum and turtle vision (The Suggested Effect of Lighting on Green Turtles Based on a Proposed V(λ) Curve: Neil Midolo, FIEAust, FIES, *Lighting Magazine*, Feb/March 2011). Evidence that turtles are tetrachromatic (4 types of cones) as opposed to trichromatic (3 types of cones) raises the question whether turtles can see in the UV range. The flicker electroretinography studies indicate the contrary despite evidence of tetrachromatic capabilities. (Ibid Copeia) An oil within the vitreous humor of Green and Loggerhead turtles is believed to filter out blue in order to provide contrast underwater. This is speculative, at best.

Absent any definitive proofs of the spectral effects upon orientation, Ultra-Tech™ Lighting tested a variety of color temperatures from 1,200K (very warm) to 15,000K (bright clear sunlight – blue sky). Contrary to current guidelines that call for amber or monochromatic light in the yellow/orange range, turtles appear unaffected by ranges from 6,500K through 12,000K. This is extremely important because color temperature can play a critical role in reflectivity off varying backgrounds. The Port-Bright™ "Turtle-Safe™" research shows that there is no single appropriate color temperature or spectrum that can generally apply to all lighting circumstance. Rather, there are appropriate spectrums for surfaces like roadway blacktop (asphalt) or white-top (concrete). There is the right spectrum for sandy white beaches versus black piers and bulkheads.

Blacktop absorbs light. The objective is to provide the least amount of contrast with the highest *above surface* visual effect. This means objects moving above the road surface (traffic) will

have high visibility within the most sensitive human visual range while the road surface will not present a contrasted "target" for turtles' focal attention. Under natural light at sunset or sunrise, blacktop has little contrast with adjacent surroundings. Under these conditions, it is rare to see hatchlings attracted to blacktop roadway surfaces. Essentially, the road blends as the light creates a more monochromatic environment. It is important to note that the light is diffused… non-focused.

Thus, the lighting level is uniform between the road surface and the land. Since the surface is light absorbing, it will likely darken in advance of other surfaces as dusk fades into more complete darkness. In contrast, a road that is artificially illuminated with typical street lamps will display a series of hot spots where each of the fixtures is located. Unlike diffused natural light that lacks contrast, undiffused artificial light inherently creates focused visual fields regardless of the backdrop. The effect of contrasted lighting is to provide a visual cue that may be similar to light reflected upon water. There is no uniformity in the presentation to suggest consistency. This is clearly a potential change from one environment, like dry land, to another that might be the sea.

This brings up observations of generalized environments and associated lighting interaction. Consideration must be given to scenarios that include:

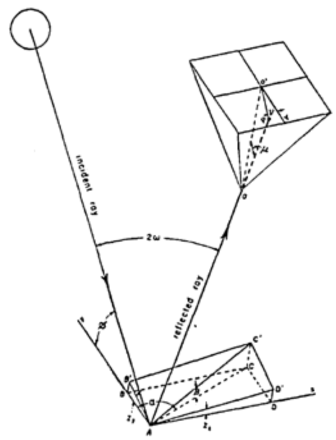
- Water against a white sandy extended beach
- Water against a truncated white sandy beach
- Water against a bulkhead
- Water against a marsh/wetlands
- Water against a roadway
- Water against a bridge or pier
- Water around a platform (oil or other)

Each of these and other scenes create different contrast dynamics that have all generated confusion for adult female turtles and hatchlings. But by the same measure, each scene has also been well negotiated by adult and hatchling turtles. To the extent that there is major diversification between the contrasted boundaries, it is difficult to draw conclusions regarding artificial lighting other that the observations than high contrast is potentially disorienting.

The Introduction of Strobe (Flicker) Effect –

Lacking conclusive evidence of the spectral influence upon orientation and/or visual cues, the approach taken in the development of a more appropriate artificial light has been to seek correlations between characteristics of the natural environment and observed behavior. Using this data as a reference, what artificial lighting features correlate with observations? As often happens in science, the answer is indirectly derived.

In virtually all instances of natural moonlight and sunlight upon water, there is a reflective feature often called “shimmer” or “glistening.” This occurs when the angle of the light source intersects an irregular geometric surface relative to the water’s plane. (*Measurement of Roughness of Sea Surface from Photographs of Sun's Glitter*: Charles Cox and Walter Munk, Journal of the Optical Society of America, November, 1954) Examples include reflections seen on ripples caused by light to medium wind, reflections off undulating waves, and reflections off crested and broken waves. These reflections appear as sequenced intensity differentials regardless of spectrum. Depending upon wind speed and shore configuration, the direction, angles, and appearance of light will widely vary.



The Beaufort Scale was developed by Sir Francis Beaufort in 1805 to associate water surface conditions with wind speeds. It was used by sailors to judge wind speed in the absence of anemometers. For reference:

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects
			On the Water
0	Less than 1	Calm	Sea surface smooth and mirror-like
1	1-3	Light Air	Scaly ripples, no foam crests
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps
4	11-16	Moderate Breeze	Small waves 1-4 ft. becoming longer, numerous whitecaps
5	17-21	Fresh Breeze	Moderate waves 4-8 ft taking longer form, many whitecaps, some spray
6	22-27	Strong Breeze	Larger waves 8-13 ft, whitecaps common, more spray
7	28-33	Near Gale	Sea heaps up, waves 13-19 ft, white foam streaks off breakers
8	34-40	Gale	Moderately high (18-25 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks
9	41-47	Strong Gale	High waves (23-32 ft), sea begins to roll, dense streaks of foam, spray may reduce visibility
10	48-55	Storm	Very high waves (29-41 ft) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility
11	56-63	Violent Storm	Exceptionally high (37-52 ft) waves, foam patches cover sea, visibility more reduced
12	64+	Hurricane	Air filled with foam, waves over 45 ft, sea completely white with driving spray, visibility greatly reduced

We are concerned with Force 1 through Force 5. Winds above Force 5 generally cause sea conditions that are not conducive to coming ashore to lay eggs. Higher winds would be problematic for hatchlings as well.

In all instances from Force 1-5 there will be wave amplitude and frequency. Each will influence the flicker effect generated by the water. Thus, the shape of the shoreline, water depth, subsurface features, and wind will generate different lighting from the sun, moon, and artificial sources. Timing measurements taken using a stop watch and strobe light reveal the following approximate frequencies along a shoreline:

Force	**Frequency**
1	0.7cps
2	20cps~60cps
3	5cps~10cps
4	1cps~4cps
5	0.5cps~4cps

A subset of strobe measurements shows surface ripples reflect from 30cps to as high as 160cps. Higher frequencies are identified as shimmering water.

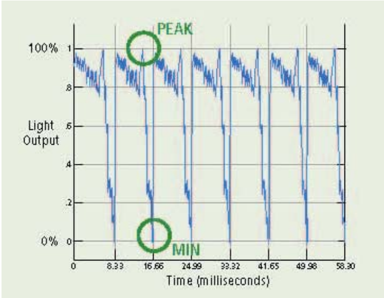
Researchers have posed the possibility that the sound of waves is used by hatchlings to find the water. Since sound is not consistent relative to the Beaufort Scale and artificial light is believed to disorient hatchlings, an empirically derived conclusion is that *the primary visual cue* for locating the water is the shimmer or vibration of light that is unique relative to the shore. Any use of sound or smell would be additive.

Clearly controlled experimentation is required. Still, the associated behavior appears supportive while anecdotal evidence is logged in observations made through all lighting conditions; natural and artificial. This raises the question, “What does artificial lighting have in common with the potential correlation?” Intriguing evidence emerges from shared characteristics of common artificial light and, most notably, fluorescent and LED sources.

Alternating current (AC) in the United States operates at 60Hz. In other countries it is either 60Hz or 50Hz. This produces an inherent flicker between 60cps and 120cps in all fluorescent and LED lighting. While incandescent lights can exhibit flicker, it is usually not as pronounced and occurs when lights are dimmed. Flicker is found in high pressure sodium and metal halide fixtures as well.

When a beach is backlit from the land (opposite the water), turtles appear unaffected. The characteristic of such light… regardless of spectrum and color temperature… is its uniformity and lack of flicker. The fact that such light, even when sharply contrasted against the shoreline, does not disorient hatchlings or obscure the beach from adults is a basis for concluding that flicker may play the dominant role. The 60cps to 120cps flicker inherent in LED and fluorescent lighting coincides with the frequency of reflection off water at Force 2 winds, however, there is a superset of reflection observed from Force 2 through Force 5 (Ibid Cox & Munk).

Flicker perception in turtles may be more acute than for humans and other land mammals. Flicker has been shown to disrupt distance perception for birds of prey. A strobe light stops perceived action and interferes with the brain’s visual interpolation. We can speculate that there are equally dramatic effects upon turtles. The problem of flicker in LEDs is so pronounced that the IEEE Standards Working Group, IEEE PAR1789 is "Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers." This process has been put in place to advise the lighting industry, ANSI/NEMA, IEC, EnergyStar and other standards groups about the emerging concern over flicker in LED lighting.



Measured peak to trough, the dip in lighting intensity can be considerable. The coincidence of frequency to potential visual cues used by hatchlings establishes a precedent for avoiding all lighting subject to strobe effect or flicker. This effectively excludes fluorescent, LED, most metal halide and sodium that have ballast frequency modulation.

Magnetic induction lighting is not subject to flicker because drivers (ballasts) operate at frequencies exceeding 150,000cps. The principle of spinning high energy atoms within an induction loop (field) creates a constant light. There are no electrodes to vibrate nor does induction rely upon excited gases. It is the energy transferred from the atoms to the phosphorous. Port-Bright™ Turtle-Safe™ design relies upon a zero flicker rate to remove the possible confusion generated by conflicting visual cues. Port-Bright™ operates up to 350,000cps with silent drivers to avoid disturbing sound sensitive wildlife like bats.

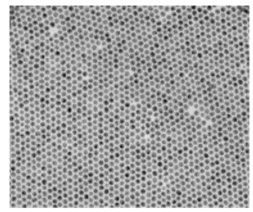
Intensity and Glare –

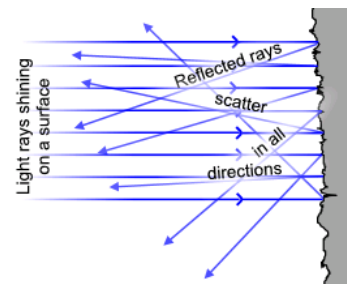
Behavioral observations reveal most sea turtle spicies can be directed using flashlights on a dark night. There are numerous films of hatchling rescue operations where turtles were oriented towards the sea with various types of high intensity directed (focused) light. Using flashlights to direct sea turtles provides evidence that intense singular light sources will act as visual cues; particularly for hatchlings. There appears to be no difference in response when using standard incandescent flashlights with color temperatures under 4,000K or newer LED flashlights with temperatures above 7,500K. Clearly, it is the singular intensity that attracts.

There are flashlights that use a red LED source which have are certified safe by the Imperiled Species Management section of the Florida Fish & Wildlife Commission. The assumption is that turtles are undisturbed by the longer wavelength. Yet, these same flashlights have been used to guide hatchlings under certain circumstances. By the same standard, white lights used to film nesting females and hatchlings at night have not interrupted normal and expected behavior. A noticed difference between light used by professional camera crews and flashlights is the dispersion pattern and use of "scrims" and filters. These light reducing techniques are used to obtain correct exposure. In the process, they reveal a potentially critical element of turtle-safe illumination. Filmed from emergence through the "frenzy" movement into the water, camera lighting above 5,000K has consistently failed to disoriented hatchlings. It may not be a coincidence that camera and video lighting specifically uses *non-flickering* light sources to insure smooth frame transitions without strobe. When flashlights are used to guide hatchlings, they are frequently waved back and forth in a way that might mimic undulating water.

Diffusion/Dispersion –

Given these observations, Port-Bright™ lighting uses a large format bulb that disperses light over a greater area than single light sources like metal halide, halogen, and sodium sources. The intensity at the source is substantially reduced, yet the overall luminance remains high within the spectrally tuned range. To further decrease glare and act more like natural light, Port-Bright™ incorporates a nano-particle reflector that is tuned for the spectral properties of the bulb/driver set. The effect is to scatter light as it emerges from the full cut-off fixture geometry. The more diffused the light, the less obtrusive it appears to be to both adults and hatchlings. Such light substantially reduces contrast between different surfaces; i.e. beach, roads, and water. By precisely shaping the reflector geometry, extraordinarily wide dispersion and uniform diffusion prevents over intensity and excessive glare.





Consider that sunlight bounces off a multitude of irregular surfaces and colors. The combinations and permutations of reflective angle, surface characteristics, and colors produce homogenized full spectrum light. Although the sun's angle to an object produces a shadow, the overall lighting appears uniform on a clear day or if there is a consistent overcast. The nano-particle diffusion reflector acts like the variety of surfaces in the typical outdoor setting and represents a departure from lighting norms. When the sun acts as a singular light source over water, the reflection angle invokes shimmer that can be the visual cue used even as hatchlings emerge in broad daylight.

Port-Bright™ 60-watt dispersion floods can be used to observe hatchlings with no apparent disturbance or disorientation. Singular narrow dispersion light sources distribute light in inverse proportion to the distance from an object. This represents the fundamental physics of light. The strict physics does not necessarily coincide with visual perception which is both interpretive and interpolated. Experiments among all species including humans shows that the eye captures intermittent data that is constructed in "real time" by the brains optical processing. This means that higher contrast between objects will create a greater impression and emphasis in the interpretive and interpolative processes.

Contrast –

This brings up the importance of contrast. How are hatchlings able to distinguish between the dark water, light sandy beach, and dark trees or vegetation inland from the beach? Based upon observation, the reflection off water is characteristically different from the inland absorption. Thus, there is powerful visual contrast between potential cues. In all instances other than urban proximity, three contrasting surfaces exist. Even the black volcanic sands of Hawaii provide a contrast against the water. The simmer on the water is unmistakable. This occurs throughout the angular orientation of the sun, moon, or artificial light source; i.e. the sun rises in the east and sets in the west. The water will be illuminated from its horizon or from the shoreline.

A previously mentioned, there are combinations and permutations of surfaces that can present challenges to adults and hatchlings.

- Water against a white sandy extended beach
- Water against a truncated white sandy beach
- Water against a bulkhead
- Water against a marsh/wetlands
- Water against a roadway
- Water against a bridge or pier
- Water around a platform (oil or other)

Each will respond differently to different spectrums depending upon the inherent colors and topology. Each will also present different contrasts under the same light. Notice the consistency in the direction of hatchlings during the day with a clear sky and bright sun. What is the distinguishing contrast? Since there is no spectral selection under sunlight, the visual cue must be unrelated to color. We see strong contrast between the uniform and *unmoving sand* against the moving and brighter water. Keep in mind that the color difference between the sand that is white/gray and water that is white/blue is reasonably subtle.

At night, the contrast is equally apparent. The higher reflectivity of water consistently provide contrast even under minimal lighting. Indirect and direct moonlight have the same contrasting impact, distinguishing the water from the land. Again, it is the contrast rather than the color spectrum that differentiates surfaces and is likely to be the critical visual cue for finding the water. This implies that appropriate artificial lighting should provide the least delineable contrast distortion, preserving the natural aspects of surface transition as much as possible. Unfortunately, aspects of lighting contrast have not been sufficiently studied to create a reliable knowledge base. For example, certain forms of artificial lighting from the shoreline that might be assumed to disrupt orientation appear to have little to no effect. One example is a light source that seems to mimic the moon on the water. In such a case, the assumed visual cue and contrast are preserved. The picture of lighting that illuminates the water provides an example.

Regardless of the contradiction, prudence dictates that such lighting *be avoided* because the particular case may be an anomaly.

The adverse impact of roadway lighting represents another exercise in contrast versus color.

Even with orange sodium lamps that are believed to be less obtrusive than metal halide, hatchlings make their way onto roads. Here, the problem may be the lack of a full cut-off fixture than presents distracting glare. Additionally, the spacing of lighting intensity on the roadway can cause confusion in immature special processing. Hatchlings have been exposed to light for only minutes before they must gain orientation. Instinctive inborn navigation is obvious.

When approaching any lighting challenge there must be elements of intuitive design used in constructing and conducting experiments. The environments are dynamic and do not lend themselves to perfect controls. This means street traffic cannot be isolated from an active causeway. Lamp fixtures cannot be swapped back and forth in an active environment. The challenge is significant.

Visibility/Exposure –

Along the lines of contrast is lighting visibility and exposure. Without question, experiments with flashlights demonstrates that intense singular non-diffused light sources will attract hatchlings. Although still light in actual experiment data, preventing high visibility light from an undesired direction is a critical standard. Whenever possible, lighting should be directed away from direct view to avoid attracting or confusing hatchlings and adults.

Port-Bright™ fixtures are designed with full cut-off features to prevent "bleed" or generalized light pollution. This is the standard for aquatic environments. The lighting industry has adopted a new standard called the BUG rating; an acronym for Behind, Up, Glare. This rating is a composite of measurements for light bleed behind an intended target area, above (skyward), and the glare intensity. Port-Bright™ lights achieve zero values for backlighting (B) and up-lighting (U). The full diffusion reflector and large bulb format minimize glare (G) readings.

To be sure, there is little that can be done to combat human encroachment onto and into environmentally sensitive aquatic environments. Still, there may be ways to make such encroachment as complimentary as possible. Efforts to blend lighting in nonintrusive ways can be supported by using diffused light in the right spectrum to provide reasonably minimal contrast disruption. At a minimum, illuminating buildings using diffused light will reduce contrast and glare.

Heat –

Hot lighting has been known to stall adults in a trancelike state. Since turtles are coldblooded, a warm light source can attract them. This is a common observed behavior in tanks and aquarium settings where incandescent bulbs are used. Turtles will move under the light as if to tan themselves. This may be temporarily pleasant, but it disrupts the natural progression in the nesting process.

Metal halide and sodium bulbs are extremely hot and lamp design often radiates heat as a way to extend lamp life. If placed too close to the ground, the radiated heat may be sensed by turtles and cause attraction.

Port-Bright™ lights have negligible heat and are only warm to the touch. Thus, any heat-related issues are eliminated.

The Human Interface –

In direct contrast to guidelines and ordinances designed to protect marine life, the Occupational Hazard and Safety Administration (OSHA) has enacted minimum lighting requirements that are virtually *impossible to satisfy* in conjunction with ordinances such as Florida's 2009-040 inclusive. For example, according to United States Coast Guard (33 CFR 126.15(1) and (n), and 33 CFR 154.570), general construction area lighting for working and walking areas shall be illuminated with a minimum of *5 foot candles on the ground* for ports and marine terminals involved in cargo transfer. Until the development of Port-Bright™ lighting, the only lamps that could meet OSHA and Coast Guard requirements were those banned by Florida's Ordinance 2009-040.

The obvious objective is to provide a safe working environment. By the same standard, any lighting is designed to provide an effective human interface. Port-Bright™ addresses this by accentuating visually effective lumens (VEL) rather than overall lumens. Power is reduced along with unnecessary light intensity because human photopic acuity is more important that intensity alone.

Human performance and visual perception is adversely influenced by flicker. Port-Bright™ addresses this problem to present a positive proposition for retrofitting offending lighting. Rather than create an adversarial and confrontational debate, Port-Bright™ achieves a complimentary process where goals are aligned. With energy savings exceeding 70% over metal halide and 40% to 50% over fluorescent, the economics are sufficient incentive to prompt a positive decision. There is no dispersed mercury in Port-Bright™, making them environmentally safe. The extraordinary operating lifecycle of 100,000 hours represents up to 600% in maintenance savings and less waste in landfills.

Conclusion –

This paper is designed to be provocative in explaining the position of Port-Bright™ lighting and related research. There is a body of evidence suggesting that spectrum is not the defining characteristic in providing visual cues. The use of monochromatic long wavelength light could be a self defeating standard. Field work supports the use of a full spectrum light with color temperatures matched to the characteristics of the illuminated surface. Feedback is encouraged and appreciated.

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