Marine and Freshwater Behaviour and Physiology
Vol. 41, No. 2, June 2008, 79–91

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Visual spectral sensitivity of hatchling loggerhead (*Caretta caretta* L.) and leatherback (*Dermochelys coriacea* L.) sea turtles, as determined by single-flash electroretinography

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(*Received 14 August 2007; final version received 1 April 2008*)

Electroretinographic recordings were made from hatchling loggerhead and leatherback sea turtle eyecup preparations to generate dark-adapted spectral sensitivity curves. Both species were maximally sensitive to wavelengths between 500 and 540 nm, with a secondary peak near 380 nm. The spectral sensitivity curve for leatherbacks was attenuated at the long wavelength end of the spectrum relative to that of the loggerheads. This difference may reflect adaptations to lighting available at the relatively shallow (loggerhead) *versus* deeper (leatherback) sites where each species forages. The broad spectrum of wavelengths detected by both species (near UV to yellow–orange) indicates that vision is likely mediated by more than one photopigment, potentially rendering these turtles capable of color vision.

Keywords: marine turtles; vision; spectral sensitivity; electroretinogram; hatchling turtles; leatherback; loggerhead

Introduction

Aquatic environments vary in spectral transmission and downward irradiance as a function of water depth and clarity (Jerlov 1976). Near the surface of clear oceanic waters, a broad range of light wavelengths is available for vision. As depth increases, the shorter and longer wavelengths (above and below ~475 nm) are selectively absorbed and scattered, restricting available light to the blue–green wavelengths (Lundgren and Hojerslev 1971). Even in clear oceanic waters, light intensity diminishes by a factor of 10 for every 75 m of depth. Thus with increasing depth, vision becomes increasingly photon-limited and, at depths exceeding 900 m, downwelling daylight is absent altogether (Denton 1990).

In the less clear coastal marine and freshwater habitats, spectral transmission changes both with depth and the concentration of particulates and dissolved organic matter (Gelbstoff) (Partridge 1990). Light transmitted in such environments not only fails to penetrate as deeply as in clear ocean water, but also shifts to the longer (yellow, red) wavelengths (Clarke and James 1939; Forward et al. 1988). Thus, both the

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ISSN 1023–6244 print/ISSN 1029–0362 online

DOI: 10.1080/10236240802106556
http://www.informaworld.com

intensity of light at any depth, as well as its spectral composition, varies for aquatic organisms depending upon the specific habitat and depth where they are found (Partridge 1990).

Turtles living in different aquatic habitats vary accordingly in their spectral sensitivity (Granda 1979). Freshwater turtles, such as the red-eared slider (*Pseudemys scripta*), are most sensitive to the longer (orange, red) wavelengths typically transmitted best in ponds, lakes and rivers, whereas the strictly marine green turtle (*Chelonia mydas*), found in clear, tropical waters is broadly sensitive to the blue, green and yellow wavelengths (Granda and O'Shea 1972). The two species also differ in their photopigments (vitamin A_1 – rhodopsin – in the green turtle; A_2 – porphyropsin – in the slider) and in the color and abundance of their accessory (oil droplet) pigments. Oil droplets are red (most abundant), orange and clear in the slider, and orange (most abundant), yellow and clear in green turtles (Liebman and Granda 1971; Granda, 1979). Both the photopigment absorption and oil droplet complement contributing to the unique spectral sensitivities shown by each species (Liebman and Granda 1971).

Less information is known about how spectral sensitivity varies among species of marine turtles. In a recent paper, Levenson reported that the spectral sensitivity of adult green turtles and loggerheads (*Caretta caretta*) peaked at about 580 nm (Levenson et al. 2004). Green turtles were somewhat more sensitive to the shorter wavelengths than loggerheads, but neither species was very sensitive to wavelengths below 440 nm as measured in these experiments. However, behavioral studies showed that hatchling green turtles and loggerheads oriented most strongly towards the shorter wavelengths, including the near UV (360 nm) (Witherington and Bjorndal 1991).

In this study, we compared the photoreceptor spectral sensitivity of hatchling loggerhead to hatchling leatherback (*Dermochelys coriacea*) marine turtles. Neither of the species at this stage of development has been previously studied electrophysiologically. Our purpose was to determine whether these two carnivores, which feed on different prey in different oceanic habitats (Bjorndal 1997; Bolten 2003), differ in spectral sensitivity. Our results provide support for this hypothesis.

Materials and methods

Because both species are endangered worldwide, our permit required us to use hatchling loggerhead and leatherback turtles remaining inside the nest for 72 h after the majority of the turtles had emerged. These subjects would not survive without human intervention. All were collected during daylight hours between July and September 2002, from nests in Palm Beach and Broward Counties, Florida, USA. The turtles were stored in a covered Styrofoam cooler in a dark, air-conditioned laboratory. A shallow layer of moist sand or a wet paper towel was placed inside the cooler to prevent desiccation. They were sacrificed for experiments within 12 h after capture. Although the hatchlings were incapable of leaving the nest, their eyes seemed fully developed and they showed consistent responses to the visual stimuli we presented.

Retinal preparations

Hatchlings were anesthetized in an ice water bath for ~20 min, or until they reached a state of torpor, decapitated at the cervical junction, and pithed according to accepted protocols (American Veterinary Medical Association 2001). For the experiments on all eight of the

loggerhead and two of the leatherback eyes, an eye was removed under a dissecting microscope (10–25×) using dim, indirect illumination, and the cornea, lens and vitreous humor were removed, leaving a retinal eyecup (Perlman et al. 1990). The eyecup was placed in a shallow depression carved into the upper surface of a Plexiglas® block inside the Faraday cage (Figure 1). A ground-wire coated with a mixture of EKG cream and turtle ringers was placed on the outside of the eyecup. The preparation and a micromanipulator for controlling electrode position were positioned inside a small PVC square frame, covered with clear plastic sheeting, which formed a ''tent''. Fully humidified air mixed with 95% oxygen continuously flowed into the tent. The preparation was dark-adapted for 20 min before light stimuli were presented (a period of time showed that preliminary experiments gave stable responses to low-level light flashes). This will be referred to as the *in vitro* preparation.

In an effort to reduce preparation time and promote longevity of the eyecup preparation, the remaining five leatherback eyes were not removed from the head. Rather, the eyecup was prepared *in situ*. The eyecup was then filled with perfluoro FC-77 (Acrōs Organics) to prevent desiccation and promote oxygen diffusion to the retina.

Recording and stimulation equipment

For the *in vitro* preparations, recordings were made with a cotton wick electrode filled with agar and a 3% NaCl solution placed on the edge of the retina, out of the path of stimulating light source. For the *in situ* preparations, a chloridized silver wire loop was placed around the peripheral retina. In both cases, we confirmed that there were no responses to the light flashes arising from the electrodes themselves. We expected that these changes in experimental procedure would have no measurable effects on the recorded photoreceptor responses, other than (perhaps) the duration for which the preparation remained viable. This expectation was confirmed by comparisons between the two *in vitro* and the five *in situ* leatherback preparations. Both provided similar results.

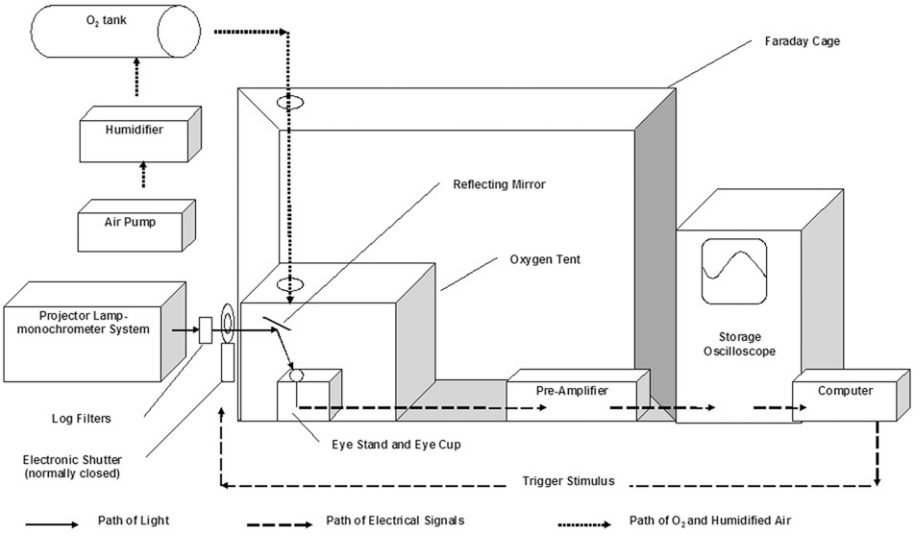

Figure 1. Diagram of the experimental set-up.

Signals from the retina were fed to a modified WPI DAM-6 preamplifier (gain: 1000×; band pass: 1 Hz–1 kHz), or a DAM 50 amplifier (similar settings). The preamplified electroretinographic (ERG) signal was monitored on a storage oscilloscope and sent to one channel of a 16-bit A/D card that allowed acquisition of the data on a laptop computer. ERGs were digitized at 1000 samples per second. A 50 Hz, low-pass FIR (finite impulse response) filter was applied to the data by the computer program. The filtered response was displayed on the computer screen.

Stimulus light was provided by a projector lamp (Fiber-Lite High Intensity Illuminator, Series 180) outside of the Faraday cage, and passed through a monochromater (FOCI Fiber Optic Communications, # 127842) with 20 nm bandwidth limiting slits and sideband filters to select the stimulus wavelength (UV Corning # 7–74, blue–green Corning # 4–96, yellow–red Corning # 3–67). The output from the monochrometer then passed through one or more neutral-density filters to set stimulus intensity. An electronic shutter (Uniblitz, Model # 310), controlled by the computer, was used to regulate stimulus duration at 20 ms.

An Ocean Optics S-2000 spectrometer was used to confirm wavelength (340–700 nm) purity. A UDT radiometer (model S351A, uniform response between 400 and 700 nm) was used to measure light intensity in $\mu W\,s^{-1}\,cm^{-2}$. These values were converted to photons $s^{-1}\,cm^{-2}$ to determine the spectral sensitivity curves.

Stimulation and recording procedures

Data were collected at 20 nm wavelength increments and 0.5 log unit intensity steps between 340 (the shortest wavelengths we could present with our equipment) and 700 nm. For the *in vitro* recordings, stimuli were presented in four sets of wavelength ranges: 340–400, 400–500, 500–600 and 600–700 nm. For the *in situ* recordings, three sets (340–460, 460–580, 580–700 nm) were used. Partitioning data collection into subsets of the entire range insured that at least a partial set of data would be collected from each eyecup in the event that the preparation deteriorated over time.

Stimuli were presented by having the computer specify the wavelength and intensity settings to be used and, once the experimenter indicated that these settings had been made, present a 20 ms flash and begin digitizing the recorded signal at a 1 kHz sampling rate for 0.5 s.

For a given set of wavelengths, data collection started with a determination of approximate response threshold for each of the wavelengths within the set. This was done by starting the computer at a subthreshold intensity and then increase the intensity in 0.5 log unit steps until a response was observed, based on visual examination of the digitized signal or the signal trace stored on the oscilloscope. Once threshold had been determined for each wavelength, formal data acquisition began. Starting at the shortest wavelength in the set, the computer presented a series of stimuli, spaced 45 s apart, starting at threshold and incrementing in intensity until either 2.5 log units of intensity had been covered, or the maximum intensity stimulus available at that wavelength had been presented. The wavelength was then incremented by 20 nm, and the process was repeated. This continued until the entire range of wavelengths in the range had been covered. The sequence was then repeated, starting with the longest wavelength and proceeding to the shortest. For example, if the subset being tested covered 400–500 nm, an intensity series at 400 nm was presented, followed by a series at 420 nm, and so on up to 500 nm. Then the intensity sequence at 500 nm was presented again, followed by 480 nm, and

so on down to 400 nm. Thus, each wavelength–intensity combination within a set was presented twice in a temporally balanced fashion. Stability of the recordings within a wavelength set was confirmed by comparing the first and second responses to each stimulus. Examination of preliminary data showed that a 45 s delay between stimuli produced stable responses to presentations of light of a given intensity and wavelength.

After data collection for a given set of wavelengths was completed, the eye was dark adapted for 20 min before the next range was tested. The order in which the sets were presented varied randomly between preparations. The end points of the wavelength sets overlapped, to allow comparison of responses to these common values between the different sets. Data collection terminated when either all the sets had been tested, or the responses indicated that the preparation was deteriorating (i.e., there was a noticeable drop in the responses to either the common endpoint wavelength from a previously tested wavelength set or a decrease in the response to a given wavelength within a set during the repeat test).

Data analysis

Responses to the stimuli presented were plotted separately for each wavelength as shown in Figure 2. Our original intention was to measure the peak amplitude of the initial photoreceptor response (the negative A-wave). At lower intensities, it was generally possible to do so. However, the presence of a post-synaptic, positive going B-wave that started before the A-wave reached its peak in many of the preparations at higher intensities (Figure 2) made this impossible.

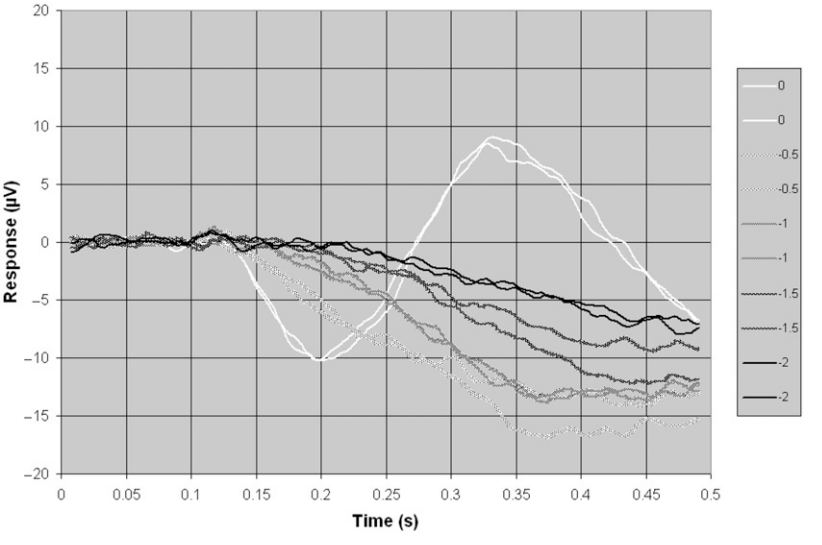

Figure 2. Electroretinographic responses from a leatherback hatchling eyecup in response to pairs of stimuli at different intensities. A 20 ms, 460 nm light flash was presented 100 ms after the beginning of each trace. Relative intensities range from 0 (brightest) to −2.0 (logarithmic scale, in 0.5 log unit steps). Note the large, positive-going B-wave responses starting before the end of the negative-going, photoreceptor A-wave responses at the highest intensity (0) and the beginning of a B-wave response to one of the −0.5 flashes.

To circumvent this problem, three approaches were tried. Response latency tended to decrease with increasing stimulus amplitude; however, this change in latency was not consistent and often not evident at lower light intensities. Measuring response amplitude at a fixed time after stimulus onset proved unsatisfactory, as it was a function of both A-wave amplitude (in those cases where a B-wave was not present) and response latency. The approach we chose to use was to look at the slope of the initial, linear portion, of the photoreceptor response. This slope increased with increasing stimulus intensity, independent of whether or not a visible B-wave response was present (Figure 2). This is equivalent to looking at the amplitude of the response at a fixed time after onset, but fitting a straight line to the response curves and using the slope of this line helped to eliminate noise fluctuations in the signal from affecting the measurement.

The response slopes *versus* stimulus intensity on log-log coordinates for all wavelengths for each preparation were plotted (Figure 3a). For a given preparation, the slopes of the individual segments of these response curves (equivalent to the exponent of a defining power function for the curves) were determined and averaged. The individual response curves were then fit to individual power functions with a least-squares procedure using this average exponent. This produced a set of parallel response curves (Figure 3b). The intercepts of these curves along the relative intensity axis for a fixed response level were then used to estimate relative sensitivity at each of the tested wavelengths. Since the curves were parallel, the results did not depend on the actual response criterion selected.

Given the intensities of the light flashes used, and our method of fitting the input–output (I/O) curves, we expected that the calculated response curves would be dominated by contributions from cone photoreceptors. However, to see if there was a significant contribution from rod receptors at low intensities, the loggerhead data were analyzed after responses to low-intensity flashes were eliminated from the data sets. This did not produce any statistically significant change in the population spectral sensitivity curve – the only hint of a change being a slight difference in the relative sensitivities at the two shortest wavelengths, points with the smallest number of observations and highest standard deviations. Therefore, the results presented here are based on the entire data set.

Results

Spectral sensitivity curves for both species (Figure 4) showed peak sensitivity between 520 and 540 nm, with a secondary peak in the UV portion of the spectrum (340 nm was the shortest wavelength our equipment was able to produce). While neither species was particularly sensitive to the red end of the spectrum, the leatherback eyes proved to be significantly less sensitive to wavelengths above 520 nm than the loggerhead eyes (binomial test, $p < 0.01$).

Discussion

The retinas of loggerhead and leatherback hatchlings are especially sensitive to wavelengths near those best transmitted through relatively clear oceanic and coastal waters (480–520 nm) (Jerlov 1976), with loggerheads more sensitive than leatherbacks to longer (540–700 nm) wavelengths (Figure 4). A secondary peak in sensitivity exists for both species in the near UV (380 nm), consistent with UV sensitivity found in many fishes

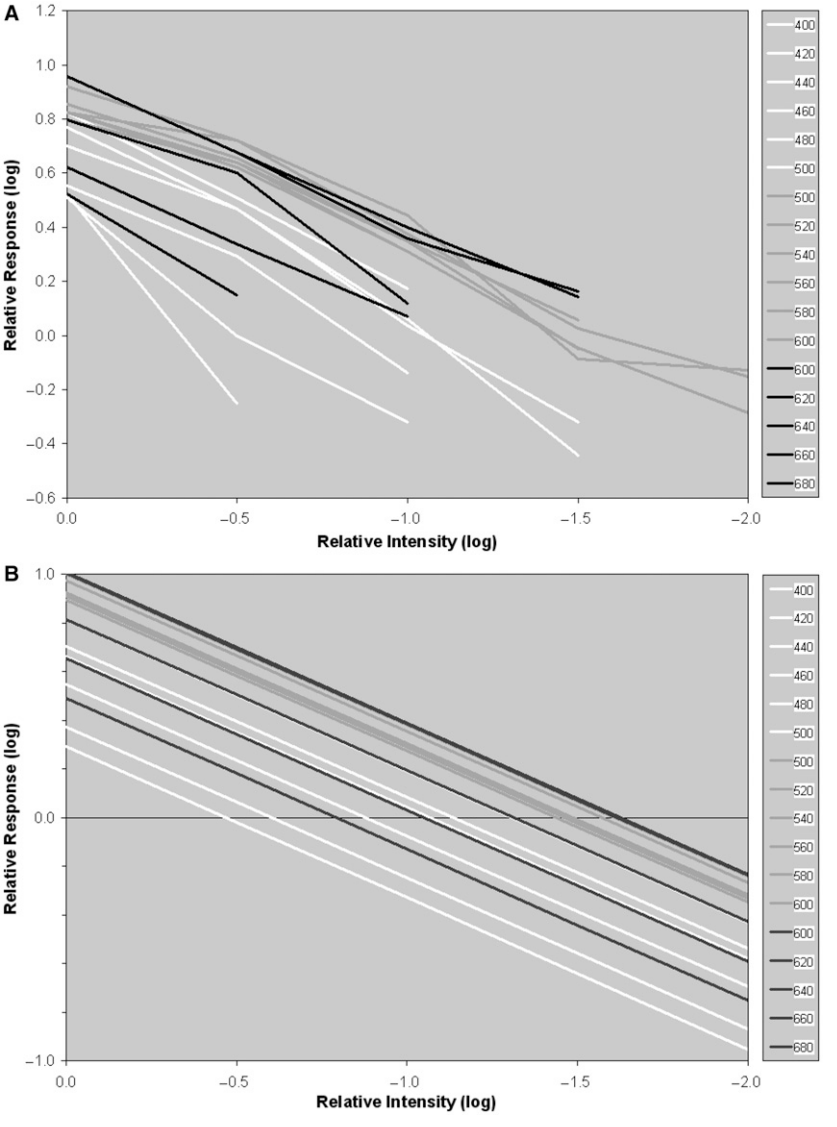

Figure 3. (a) I/O curves from a loggerhead hatchling (animal 6) for three frequency range sets. Logarithms of the slopes of the initial A-wave responses *vs*. the relative intensity of the light flashes are plotted on a log scale. The three different sets of data are indicated by different shadings. Each wavelength-intensity pair was presented twice in a time-balanced fashion within a set. (b) Least-squares fits to the data shown in (a), using a fixed slope equal to the average of the segmental slopes of the curves in (a). Relative sensitivities were determined using the values where these lines crossed the log Relative Response = 0.0 axis.

and reptiles (including some freshwater turtles) (Arnold and Neumeyer 1987; Ventura et al. 1999; Loew and Govardovskii 2001).

The spectral sensitivity curves for the two species appear too broad to be explained by the presence of only a single visual pigment. Rather, the curves are consistent with the presence of at least three visual pigments, based on our ability to closely match the observed spectra by fitting them to a trio of photopigment templates (Dartnall 1953;

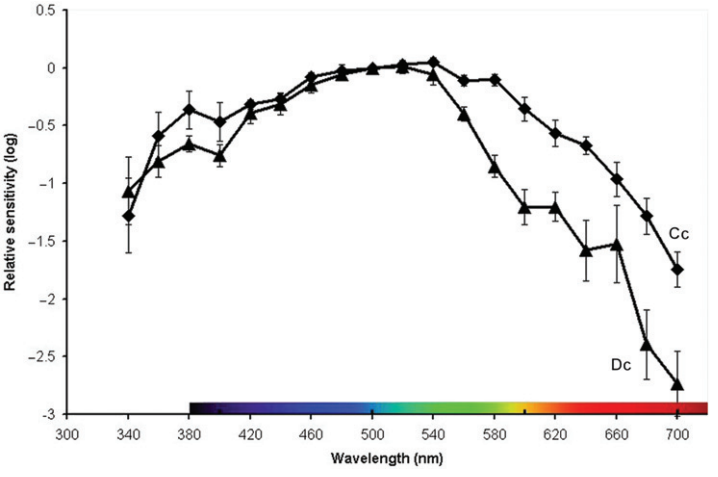

Figure 4. Average (±SE) visual spectral sensitivity curves for loggerhead (Cc, $n = 8$) and leatherback (Dc, $n = 7$) hatchling sea turtles. Not all wavelengths were tested in all animals. The sensitivity curve for each animal was normalized to its value at 500 nm prior to taking the group average.

Govardovskii et al. 2000; Horch et al. 2002). These curve fits are not presented here as we do not have adequate information about the nature of the photopigment (A_1 *vs.* A_2) and the oil droplets in these hatchlings to provide a definitive statement about the likely λ_{max} values of the constituent pigments. Green turtles are known to have three cone pigments with peak absorption in the visible wavelengths (Liebman and Granda 1971). A fourth visual pigment, with peak sensitivity in the UV, is hypothesized to occur in green turtles (Mäthger et al. 2007) that, like loggerheads, can detect UV light (Witherington and Bjorndal 1991). This pigment cone may be associated with a clear oil droplet that transmits UV light (Mäthger et al. 2007). The presence of multiple pigments suggest that marine turtles are potentially capable of color vision.

The data we obtained were derived from intact retinas. As such, they reflect both absorption by the cone visual pigments and their properties as modified by oil droplets (Vorobyev 2003). Differences in spectral sensitivity between the species may be a function of the number and absorption properties of their photoreceptors, the composition of their oil droplets, or (most likely) species-specific associations between those elements. Determining the mechanism(s) involved was beyond the scope of this study, but remains an important objective for future investigation. Our goal here was to determine whether species differences in spectral sensitivity existed and, if they did, to highlight correlations between those differences and visual ecology.

Visual ecology of hatchling and adult marine turtles

Six of the seven species of marine turtles have life histories that include a multiyear pelagic stage of development in the open ocean for the youngest individuals (Bolten 2003). Young turtles feeding on their own (referred to as ''neonates'', ''posthatchlings'' or ''juveniles'') cannot dive deeply, probably because they lack sufficient blood volume (and oxygen storage capacity) required for a prolonged dive (Lutcavage and Lutz 1997).

Posthatchling loggerheads are behaviorally specialized for life at the surface – they are attracted to flotsam (in the Atlantic Ocean basin, mats of *Sargassum*)

where they remain largely inactive, find food and shelter and probably are hidden from predators (Carr 1986; Carr 1987; Witherington 2002). Recent field observations (Witherington, pers. comm.) and laboratory experiments (Smith and Salmon, submitted) indicate that young green turtles also rest in flotsam, even though their counter shaded body coloration suggest that they may temporarily leave these habitats to feed in open water (Musick and Limpus 1997).

With the exception of Witherington's study (Witherington 2002), little is known about the behavior or the visual ecology of other species. We reared posthatchling green turtles and leatherbacks in the laboratory, then released them in the open ocean and observed their swimming and diving behavior during 30 min trials. Turtles were released at 2 week intervals during their first 10 weeks of development. Each turtle towed a tag that recorded its diving depth and duration. With increases in size and age, green turtle dives became longer in duration but failed to change significantly in depth. However, as leatherbacks increased in mass their most extreme dives became both deeper and longer (Salmon et al. 2004). The routine dives of both species did not exceed 20 m.

Collectively, then, these studies suggest that pelagic-stage green turtles, loggerheads and leatherbacks spend most of their time near to the ocean surface where they should be exposed to a relatively broad spectrum of light wavelengths (Jerlov 1976). For that reason, it is reasonable to expect that they would be sensitive to light spectra from the near UV to the yellow–orange wavelengths (620 nm). Our data indicate that they are. The broad spectral sensitivities of juvenile green turtles (Granda and O'Shea 1972) present a similar pattern but, unfortunately, the turtles in that study were not exposed to UV light (Granda 1979).

As adults, loggerheads and leatherbacks show differences in where they feed, the nature of their prey and in their diving behavior. Our results suggest that these differences are reflected in the spectral sensitivities shown even by their hatchlings.

Adult loggerheads typically feed in shallower waters than adult leatherbacks and should therefore routinely be exposed to a broader range of light wavelengths. Maximum depth for loggerhead dives is 211–233 m, with routine dives ranging between 9–22 m (Lutcavage and Lutz 1997). Adults are primarily benthic invertebrate predators feeding on bivalves (*Anadara*, *Pinna*, *Solen*, *Mytilus*), gastropods (*Busycon*), crabs (*Libinia*, *Cancer*, *Ovalipes*, *Pagurus*), horseshoe crabs (*Limulus*), as well as sea pens (*Virgularia*), sea pansies, whip corals, anemones, sea horses (*Hippocampus*), mantis and penaeid shrimp and marine plants found in continental shelf waters (Bjorndal 1997). Stomach contents also reveal that adults occasionally feed in the water column on jellyfish and salps, though this tendency is most prevalent among the younger (pelagic phase) life history stages. Foraging sites for populations range from the tropics (coral reefs) to temperate habitats during the warmer summer months. Though feeding occurs both during the day and at night, loggerheads forage primarily during the day.

Adult leatherbacks are the most pelagic and deepest diving of the marine turtles (>1000 m), though their routine dives are typically shallower: 50–84 m (Lutcavage and Lutz 1997). Most feeding and diving occurs in the open ocean, especially at locations where their prey (jellyfishes, salps, and other gelatinous organisms) are abundant – near convergence zones between current boundaries (Bjorndal 1997). The turtles also feed opportunistically near the surface of continental shelf waters where there are jellyfish blooms (Grant and Ferrell 1993). In the open ocean, diving also occurs at night when gelatinous prey in the deep-scattering layer migrate closer to the surface (Eckert and Eckert 1989; Eckert 1992). Some of these are bioluminescent (ctenophores, medusae, siphonophores) species that emit light at wavelengths between 440–506 nm (Haddock and Case 1999).

The emissions by species found at shallower depths contained somewhat longer wavelengths within that range. Leatherbacks might use these emissions to locate their prey (Davenport 1988), either during their deeper diurnal dives (Eckert 1992) or during their shallow dives at night.

Ontogenetic change in spectral sensitivity – does it occur in marine turtles?

Several studies have shown that the eyes of marine invertebrate and vertebrate organisms undergo major changes in structure, function and physiology associated with the transition between juvenile and adult forms (Partridge 1990; Cronin and Jinks 2001). Somewhat less radical changes occur among coral reef fishes, and fishes that migrate between fresh and salt water, growing to maturity in one habitat and breeding in the other (Partridge 1990). These include changes in the photopigments mediating vision and, presumably, changes in spectral sensitivity.

Hatchling loggerheads and green turtles, tested in a maze, crawl preferentially towards monochromatic near-ultraviolet (360 nm), violet and blue-green lights over a standard light of constant intensity and color (Witherington and Bjorndal 1991). These behavioral responses demonstrate that UV light is detected and suggest that the shorter wavelengths may play an important role in seafinding (hatchling orientation from the nest to the sea). However, adult green turtles and loggerheads were reported by Levenson to show peak sensitivities at 580 nm, with more modest responses between 520–640 nm (Levenson et al. 2004). These sensitivity profiles (with their shift towards the yellow–orange wavelengths) resemble those of some freshwater turtles living in habitats where only the longer wavelengths are transmitted through water. Levenson et al. (2004) attribute their results to an age-related decline in the transmission of the shorter light wavelengths by the cornea and/or lens to the retina. Such changes occur in humans (Weale 1988) and in some (but not all) fishes (Bowmaker and Kunz 1987; Losey et al. 1999, 2000, 2003).

There is so far no evidence that wavelength transmission through the eye of marine turtles changes as a function of age, though direct measurements have been made only on juvenile green turtles. In that species, wavelengths between 350 and 700 nm are transmitted uniformly through the cornea and vitreous of juvenile (estimated age: 10–30 years) turtles. The lens somewhat limits short wavelength transmission (T_{50} of 325 nm) but not sufficient to eliminate near- UV light from impinging upon the retina (Mäthger et al. 2007).

Three classes of cones have been described for juvenile green turtles exposed to visible light wavelengths: those that absorb maximally at 440 (deep blue), 502 (blue–green) and 562 nm (green–yellow), respectively (Liebman and Granda 1971). The spectral sensitivities reported by Levenson for adults indicate that responses were obtained primarily from one (562 nm) cone receptor (Levenson et al. 2004). The light flashes they used, in combination with an adapting light, may have depressed short-wavelength sensitivity, perhaps by saturating the cones that mediate those responses. Granda and O'Shea found that brighter light flashes depressed sensitivity to wavelengths below 520 nm in both dark- and light-adapted subjects (Granda and O'Shea 1972). We avoided this problem by using single flashes presented initially at levels just above threshold. We also allowed our preparations to dark-adapt for 45 s between successive (and increasingly more intense) stimulus presentations.

Additional experiments will be required to resolve this issue.

Sensitivity to UV light

In most shallow water marine habitats, UV light is quickly attenuated by Gelbstoff (Partridge 1990) but where waters are clear, UV can penetrate to greater (> 100 m) depths (Smith and Baker 1981; McFarland 1986). UV sensitive visual pigments are best known among vertebrates in freshwater fish (roach, Japanese dace; goldfish) that live in shallow water (Avery et al. 1983; Harosi and Hashimoto 1983; Harosi 1985; Hawryshyn and Beauchamp 1985). However, recent studies show that many coral reef fishes have eyes capable of detecting UV light (Losey et al. 1999), and that it may play an important role in communication (Losey 2003; Siebeck et al. 2006).

Pelagic stage loggerheads (and green turtles), as they grow larger, are known to feed at shallow depths in the water column, and away from flotsam. So, as well, do posthatchling leatherbacks (Salmon et al. 2004). All three species feed on pelagic coelenterates (siphonophores, scyphomedusae, ctenophores and hydromedusae), some of which are transparent to humans (Bjorndal 1997). An intriguing possibility is that these prey may be rendered visible to the turtles feeding near the surface, either by absorbing UV light, which would make them darker than their surrounding environment (Bowmaker and Kunz 1987; Losey et al. 1999), or by reflecting it, which would make them appear brighter than their surroundings (Lythgoe 1988). In either case, sensitivity to the near-UV wavelengths we report here for hatchlings has potential utility for older turtles in several behavioral contexts (e.g. detection of prey and predators; orientation and/or navigation; communication), especially when turtles are active near the ocean surface. How marine turtles might exploit these capacities remains to be determined.

Acknowledgements

This study was completed by J.P. Gocke as a Masters thesis at Florida Atlantic University and was supported by the Nelligan Fund. We thank T. Cronin (University of Maryland) for using his equipment, J. Cohen (Eckert College) for comments on an earlier draft, the anonymous reviewers of this manuscript and R. Normann (University of Utah) for training in the eyecup preparation technique. Permits to carry out this project were obtained from the U.S. Fish and Wildlife Service (TE087169-0), the Florida Fish and Wildlife Conservation Commission (TP # 173), and the Florida Atlantic University Institutional Animal Care Committee (A02-22).

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