

Evolution and maintenance of female alternative reproductive tactics in *L. olivacea*

Intellectual Merit: Alternative reproductive tactics (ARTs) are phenotypically distinct reproductive strategies that achieve approximately equal fitness (different fitness peaks). As a model system for studying the evolution of variation¹, ARTs of males have been extensively studied, characterized by color and/or size, morphology, behavior (i.e. territorial vs. sneaker males), etc.¹. By contrast, female ARTs are poorly studied. Female ARTs occur in oviposition site selection, mating behavior, and ontogenetic shifts in female size and fecundity, but many open questions remain^{1,2}: What selective factors cause divergent female behavior and/or morphology? Are they driven by predator avoidance, developmental limitations, physiology, or did they evolve in other functional contexts, for example, trophic niches¹? Have morphological and reproductive behavioral differences evolved as correlated responses to sexual selection, which then impact other life history aspects, such as feeding? Or does natural selection cause feeding dimorphisms that in turn shape morphological and reproductive behavioral differences¹? My research will explore phenotypic variation and ecological niches as underlying mechanisms of female alternative reproductive tactics in a novel, model system.

Model System: Olive ridley sea turtles (*Lepidochelys olivacea*) exhibit strikingly divergent female reproductive tactics (Table 1). In the same population, some nest synchronously (SYN) *en masse* (>10,000 individuals) on a few, distinct, beaches whereas others nest solitarily (SOL) on multiple beaches over thousands of kilometers of coastline³. *L. olivacea* are the only sea turtle species to exhibit these ARTs, which were not formally recognized until 2002. Virtually nothing is known about why or how the ARTs occur³.

I hypothesize that these alternative reproductive tactics are a result of an ecological dimorphism. SYN nesters migrate throughout the E. Pacific and aggregate to mate offshore of SYN nesting beaches to ensure copulation³. **I predict** SOL nesting females are neritic foragers, allowing them to nest more frequently and find mates more often making SYN aggregations unnecessary. I will sample females at 2 SYN and 3 SOL study site (6 if logistics permit).

Table 1: Known characteristics of <i>L. olivacea</i> divergent reproductive tactics		
Characteristic	Synchronous nesters (SYN)	Solitary nesters (SOL)
Inter-nesting period ⁴	28 days	14 days
Nesting phenology ³	Rainy season	All year
Site fidelity ⁴	High	Low
Female body & clutch size ³	Larger	Smaller
Eco-morphology	AIM 1	AIM 1
Spatially explicit foraging ecology ³	Nomadic, pelagic; AIM 2	AIM 2

AIM 1: DEFINE THE MORPHOMETRICS OF SOL AND SYN NESTING *L. OLIVACEA*. Morphological differences are common attributes of ARTs¹. There is some evidence that SYN are larger than SOL nesters³ but basic morphology of these divergent ARTs is unknown. Using morphometric tools I will test my **hypothesis** that **there are significant differences in size, shell depth, shell shape and flipper morphology between the two tactics**. Morphological differences relating to foraging behavior are known in other sea turtle species⁵⁻⁷. Ecological dimorphisms have been shown in three populations of *Caretta caretta*^{6,7} where small females forage in pelagic habitats and larger in neritic habitats. In *Chelonia mydas*, a pelagic population has larger flippers than a neritic one⁵. **Methods:** I have defined 10 flipper landmarks related to underlying skeletal and muscle structure. These landmarks and standard sea turtle body measurements⁸ (i.e. shell width & length, body depth & mass) will be quantified. I will use principal components analysis to test

for morphological differences, and if found, to evaluate which attributes drive the variation. I estimated from a power analysis⁹ (F-test, $p = .05$, 10% effect size) that a sample of 100 females per study site ($N=500$) will provide a power of 89% to detect a difference.

AIM 2: DEFINE THE FORAGING ECOLOGY OF SYN AND SOL NESTING *L. OLIVACEA*. Stable nitrogen ($\delta^{15}\text{N}$) and carbon ($\delta^{13}\text{C}$) isotope ratios, coupled with satellite telemetry, have proven to be effective tools for defining sea turtle ecological dimorphisms in 3 of the 6 other species^{7, 10, 11}. I will utilize these tools to test my ***hypothesis*** that ***SYN nesters are nomadic, pelagic (open ocean) foragers with no localized foraging ground, whereas SOL nesters are neritic foragers with distinct neritic foraging grounds.*** **Methods:** Skin and dorsal shell samples will be taken to provide recent (skin) and multi-year (shell) foraging histories¹². Samples will be taken during early, mid and late nesting season to account for migrations from various foraging grounds and will be collected, prepared and analyzed using established methods¹². The power analysis demonstrated that a sample size of 35 turtles per sample period, per site, for skin and shell tissue (105 per site, total $N=524$) is sufficient. To examine spatially explicit foraging ecology I will attach satellite tags to randomly assigned females sampled for stable isotopes (10 at each study site, total $N=50$). Implementing robust state space modeling, I will analyze the data using established protocols¹³. Sampling from multiple sites and using spatial statistical analyses will account for the possibility of pseudoreplication (spatial autocorrelation in this system).

This is the first detailed morphological analysis of *L. olivacea* ARTs and the first examination of ecological niches as an underlying mechanism driving them. Both aims are **feasible**; the methods have been successful in other sea turtle studies, I have tested them in the field and I have support of **international collaborators**. My results will **contribute to a meta-analysis** creating a stable isotope landscape for the E. Pacific Ocean, headed by a NSF GRF. I am organizing the first *L. olivacea* working group to address the unknown life history traits, which will have important management applications for this vulnerable species. My field season includes fall semester and at least two are needed. This fellowship is crucial in allowing me to be decoupled from campus and will greatly increase my capacity to do fieldwork.

Broader Impacts: Communicating my research is an important part of my career path and professional development. Using social media I share my research and discuss science issues with scientists and lay people. Working with Texas Sea Grant I am **developing STEM educational materials**, using charismatic sea turtles as flagship species to promote watershed education in K-12 classrooms. I will **develop a network of graduate students** across Texas to speak with classes about their adventures in pursuit of higher STEM education.

I will **assemble and train** undergraduates (**including those in the Texas A&M, NSF-funded, Louis Stokes Alliance for Minority Participation program**), Costa Rican community members and personnel from NGOs and national parks to assist in my research. Participants will receive a hands-on opportunity to learn about experimental design, fieldwork, data analyses and ethics of working with animals all while engaging in cultural exchange. I will continue to disseminate my work to the scientific community via presentations and peer-reviewed papers.

This fellowship is key in allowing my work to impact the evolutionary understanding of ARTs, life history of an understudied species and a wide nonscientific audience through education and collaboration. **References:** ¹Oliveria et al. 2008 *Alt Repro Tactics*. ²Henson & Warner 1997. *Annu Rev Ecol Syst* 28:571-92. ³Plotkin 2007. *Biol and Conserv of Ridley Sea Turtles*. ⁴Kalb 1999. Ph.D. Diss. ⁵Balazs et al. 1997. *Proc Ann Sea Turtle Symp*. ⁶Hawkes et al. 2006. *Curr Biol* 16, 990-5. ⁷Hatase et al. 2002. *Mar Ecol-Prog Ser* 233:273-281. ⁸Wyneken. 2001 *The Anatomy of Sea Turtles*. ⁹Cohn 1988. *Stat Power Analysis for the Behav Sci*. ¹⁰Hatase et al. 2006. *Oecologia* 149:52-64. ¹¹Caut et al. 2008. *PLoS One* e1845. ¹²Reich & Seminoff 2010. *Proc Ann Sea Turtle Symp*. ¹³Block et al. 2011. *Nature* doi:10.103/nature10092.