diversity

MDPI

Article

Long-Term Variation in Survival of A Neotropical Freshwater Turtle: Habitat and Climatic Influences

Mario F. Garcés-Restrepo [1], John L. Carr [1,2,*] and Alan Giraldo [1]

[1] Grupo de Investigación en Ecología Animal, Sección de Zoología, Departamento de Biología, Facultad de Ciencias Naturales y Exactas, Universidad del Valle, A.A. 25360 Cali, Colombia; mariofgarces@gmail.com (M.F.G.-R.); alan.giraldo@correounivalle.edu.co (A.G.)

[2] Department of Biology, University of Louisiana at Monroe, Monroe, LA 71209-0520, USA

* Correspondence: carr@ulm.edu

Received: 11 May 2019; Accepted: 17 June 2019; Published: 20 June 2019

check for updates

Abstract: Few long-term demographic studies have been conducted on freshwater turtles of South America, despite the need for this type of inquiry to investigate natural variation and strengthen conservation efforts for these species. In this study, we examined the variation in demography of the Chocoan River Turtle (*Rhinoclemmys nasuta*) based on a population from an island locality in the Colombian Pacific region between 2005 and 2017. We calculated survival, recapture, and transition probabilities, and the effects of stream substrate and El Niño–Southern Oscillation (ENSO) phases (El Niño, Neutral, La Niña) on these variables using a multi-state model. We found differences in survival probabilities between ENSO phases, likely as a consequence of an increase in flood events. In addition, we found support for survival being greater in muddy streams than rocky streams, possibly because it is easier to escape or hide in mud substrates. Recapture probabilities varied by life stages; differences in the probability of recapture between size classes were associated with the high fidelity to territories by adults. The present increases in frequency and severity of El Niño and La Niña may exacerbate the consequences of climatic regimes on natural populations of turtles by increasing the mortality caused by drastic phenomena such as floods.

Keywords: El Niño; Chocoan River Turtle; *Rhinoclemmys nasuta*; multi-state model; survival; recapture; transition

1. Introduction

In recent decades, many turtle species have shown declines in population size [1,2]. The most recent overview estimates that 54% of all turtle species are threatened, exceeding the threat levels of other vertebrate groups such as parrots, primates, or frogs, which are considered as examples sensitive to extinction [3]. There are a variety of causes that affect population viability among chelonians, including habitat loss and degradation, introduction of invasive species, environmental pollution, disease, and human exploitation [4,5]. These threats are intensified by factors inherent to the biology of turtles, such as the slow recovery of populations after declines and delayed sexual maturity [6,7].

Extreme climatic variation and climate warming have been identified as other factors that potentially affect turtle populations [8–10]. With respect to temperature, warming may skew sex ratios in populations of the many turtle species that have temperature-dependent sex determination [11–14], as well as alter the phenology of nesting and nest emergence [9,10]. On the other hand, variation in precipitation can change net primary productivity (NPP), thereby affecting the food supply, body condition, and reproductive output in populations of different species [15], including turtles and tortoises [16,17]. Changes in temperature, precipitation, NPP, and sea level will also modify habitats and are projected to alter the geographic ranges of a significant number of turtle species under various scenarios [18–20]. The slow life history of turtles makes it necessary for long-term demographic research to generate information relevant to their conservation [21–23]. Long-term studies have been relatively common in the north temperate zone, including data of up to three decades' duration on threatened species [24–26]. For South America, this kind of long-term research is rare; only the research of Martins and Souza on *Hydromedusa maximiliani* has included data collected for longer than a decade [27].

With 27 species of terrestrial and freshwater turtles, Colombia is considered the seventh most species-rich country in the world, and third at the level of South America behind Brazil and Ecuador [28]. Despite this great diversity, turtles are far from being one of the best-studied animal groups in Colombia; many aspects of their basic biology remain unknown, and long-term research is almost nonexistent or just beginning to be published [29,30]. Among the freshwater turtles recorded in Colombia, the Chocoan River Turtle, *Rhinoclemmys nasuta* (Geoemydidae), is found only in Colombia and Ecuador [31], and its conservation status is categorized as near-threatened (NT) globally [3], NT in Colombia [32], and endangered (E) in Ecuador [33]. As a consequence of the threatened status of this species, we began studying an island population of *R. nasuta* in 2005 on Isla Palma, Bahía Málaga, in the central Pacific coastal region of the Department of Valle del Cauca in Colombia [31,34].

Using information recorded on *R. nasuta* during the sampling efforts conducted between 2005 and 2017 on Isla Palma, this research has the goal of evaluating the long-term variation in survival, recapture, and transition probabilities. We employed multi-state models that allow calculating the probabilities for individuals that vary by size class over the course of the study, and evaluate the effects of habitat type and climate on these probabilities. We hypothesize that survival and recapture probabilities will be lower in hatchlings because predators at this site are relatively small and limited to smaller prey, and these small turtles do not appear to have established home ranges. Isla Palma has a depauperate mammal fauna that lacks the typical mesopredators and large carnivores found on the mainland, as well as crocodilians [35]. The only known or suspected *R. nasuta* predators found on the island are the opossums, plus some large snakes [31,34]. We predict that the characteristics of the substrate of the streams inhabited by this species on the island will affect the probability of recapture and survival because, in the muddy streams, capture and predation are more difficult because individuals are able to hide more effectively than in streams with a rocky substrate. Based on multiple field observations of individuals found on the beaches after big storms, we predict that during the La Niña phase of El Niño–Southern Oscillation (ENSO), the probability of recapture and survival will be lower than during the El Niño or Neutral phases, due to the increase in precipitation. Finally, we predict that the probability of transition from hatchling to juvenile will be higher than the probability of transition from juvenile to adults since the growth rate is greater for hatchlings than for juveniles.

2. Materials and Methods

2.1. Study Area

Isla Palma is located at the entrance of Bahía Málaga in the central Pacific region of Colombia in the Department of Valle del Cauca (ca. 3.9°N, 77.3°W) (Figure 1). This locality belongs to the Chocó biogeographic region. The island is uninhabited, and was incorporated into a national park during the study (2010)—Parque Natural Nacional Uramba Bahía Málaga. Isla Palma has an area of 138 ha and is covered in natural vegetation classified as lowland, very moist tropical forest [35]. The island is surrounded by uniformly distributed hard-rock cliffs, with sandy beaches only exposed at low tide, and with an elevation that varies from 6 to 15 m. Due to the high rainfall and rugged topography, there are numerous freshwater streams draining to the sea [34,35]. Based on the primary substrate, we categorized the streams as rocky or muddy.

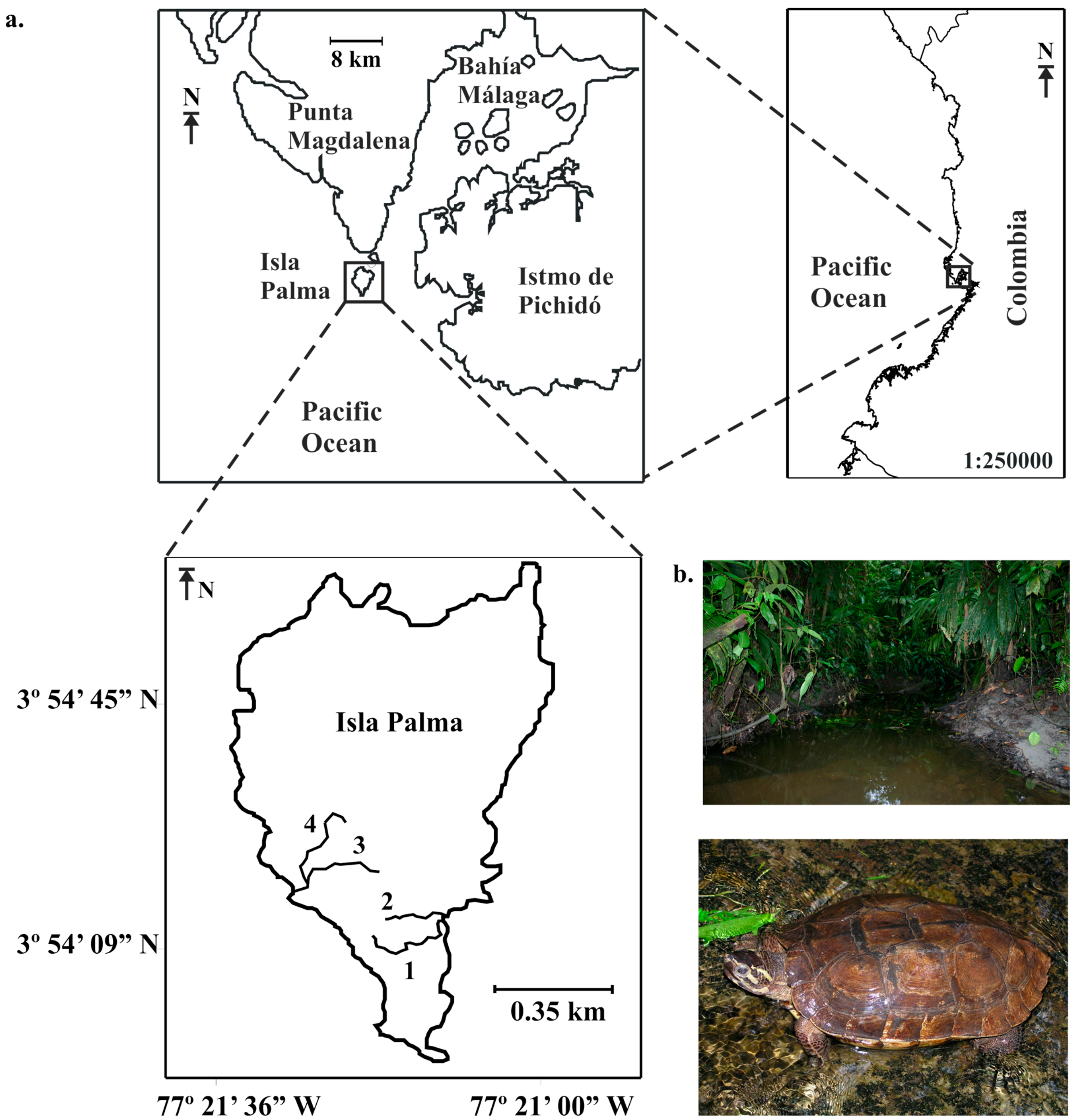

Figure 1. (**a**) Map showing the location of Isla Palma along the Colombian Pacific and the four study streams on the island, (**b**) photos of an island stream and an adult female *Rhinoclemmys nasuta* (photos by the authors).

The study site is within one of the wettest continental areas on the planet, coinciding with landfall of the Intertropical Convergence Zone (ITCZ) in the eastern Pacific [36,37]. Average climatic factors are equable with high amounts of precipitation, between 7200 to 8500 mm annually, high mean relative humidity of approximately 90%, and a mean annual temperature of 23.5 to 25.7 °C [38]. Despite this, the area is subject to the climatic phenomenon El Niño–Southern Oscillation (ENSO), which differentially affects weather conditions along the Colombian Pacific coast [39,40]. During the warm phase of ENSO (El Niño), positive anomalies in the sea surface temperatures (SSTs) of the Pacific Ocean lead to a deficit of precipitation affecting the central zone of the Colombian Pacific coast. On the other hand, during the cold phase of ENSO (La Niña), the SSTs have negative anomalies and an excess of precipitation is recorded in the central zone of the Colombian Pacific coast [40]. The third phase of ENSO (Neutral) is when SSTs are near average, as are precipitation amounts in the region. El Niño and

La Niña represent environmental changes that are extreme in intensity and duration, so all flora and fauna associated with the coastal and continental areas are affected [41–45].

2.2. Field Data Collection

Sampling was conducted annually between June 2005 and March 2017, except for the years 2008, 2013, and 2014. Sampling was performed in four streams of first and second order (widths less than 4 m and depths less than 1.5 m), with variable lengths between 100 and 300 m; the total area for all streams was 0.36 ha. Specimens were collected between 20:00 and 00:00 by direct visual encounter in the clear water and manual investigation of crevices, overhangs, and leaf litter; the animals collected were marked at the site of capture using a triangular file. We used Cagle's [46] scute notching method to individually mark turtles, with some species-specific modifications [34]. For each individual, the carapace length was measured with a Vernier caliper as an indicator of the life stage (age) category to which it corresponds.

2.3. Data Handling and Analyses

Multi-state mark—recapture models [47] were implemented using the program MARK version 8.1 [48] to estimate annual survival, recapture (individual detectability), and transition (recruitment) probabilities for turtles in the three different life stages: hatchlings (soft plastron, carapace length < 100 mm); juveniles (carapace length > 100 mm and < 140 mm); and adults (carapace length > 140 mm) [31,49]. The capture history of each turtle is included in the Supplementary file. Model selection was based on the information theoretic approach (Akaike information criterion), with the most supported models having the lowest values [50]. We treated type of stream (rocky vs. muddy) as a categorical factor to examine the relationship of survival and transition probabilities with these types of habitats. Another factor included in the analysis was the ENSO phase—we checked the phase when the capture event occurred and treated El Niño, La Niña, and Neutral phase as a factor to test whether this climate phenomenon influenced survival or transition probability. We first evaluated a global model that included interactions among all four factors (year, ENSO, life stage, stream) for survival, recapture, and transition probabilities; however, due to limitations of the data, the program only used 69 parameters in the calculation of results and not the full 145 parameters. For this reason, we substituted the next most-inclusive model (142 parameters) as the global model with interactions among three of the factors (model 1) and a dot model where all three factors were constant (model 2). Then, maintaining a global model structure for survival and transition, we evaluated support for all single factors (year, life stage, stream, ENSO; models 3–6) and maintain recapture probability as constant (model 7). Subsequently, we selected the most supported model structure for recapture probabilities and repeated this process for transition and survival (models 8–18). In cases where the differences between models were $\Delta AIC_c < 2.0$, we tested additive and multiplicative effects between variables.

3. Results

During the 10 visits to Isla Palma, we captured 650 different individuals of *R. nasuta* (hatchlings: 170; juveniles: 142; adults: 338) 850 times. Of the set of 18 candidate models used to assess the influence of year, life stage, stream type (muddy vs. rocky), and ENSO phase on survival, recapture, and transition probabilities, the most supported models included ENSO affecting survival, and life stage determining recapture and constant transition probabilities (w = 0.47, Table 1). According to this model, annual survival probabilities were lower for La Niña phase ($\mu = 0.64$, ± CI 95% = 0.13) and Neutral phase ($\mu = 0.70$, ± CI 95% = 0.10) than El Niño phase ($\mu = 0.80$, ± CI 95% = 0.11; Figure 2a). Recapture probabilities were higher in adults ($\mu = 0.073$, ± CI 95% = 0.023), followed by juveniles ($\mu = 0.018$, ± CI 95% = 0.008), and, finally, hatchlings ($\mu = 0.005$, ± CI 95% = 0.003; Figure 2b). Transition probabilities were constant between the different stages with wide variation ($\mu = 0.449$, ± CI 95% = 0.227). Only one other model was considered competing ($\Delta AIC_c = 1.2$); in this model (15), stream type affected survival, which was lower in rocky streams ($\mu = 0.686$, ± CI 95% = 0.09) than in muddy streams

(μ = 0.799, ± CI 95% = 0.122; Figure 3). There were no additive or multiplicative effects identified among ENSO phases or stream types. In addition, we tested whether or not the differences between survival probabilities were significant in the two best models (16 and 15) using a test for confidence intervals. We found that in the first model (16), the survival probability was significantly higher in El Niño years than in La Niña years (T_{1540} = 1.950; p = 0.049); in the other two comparisons for this model we did not find significant differences (El Niño vs. Neutral; La Niña vs. Neutral; $p > 0.05$). For the second model (15), we did not detect a significant difference in the survival probabilities between streams with different substrates at $p \leq 0.05$; rather, the value lies between 0.05 and 0.10 (T_{1540} = 1.652; p = 0.099).

Table 1. Rankings of multi-state models estimating survival (Φ), recapture (p), and transition (Ψ) probabilities for the Chocoan River Turtle on Isla Palma. AIC_c = Akaike information criterion corrected for small sample sizes; K = number of parameters; w = AIC_c weight; El Niño–Southern Oscillation (ENSO) = phases (La Niña, Neutral, El Niño); stages = hatchlings, juveniles, and adults; type of stream = muddy, rocky. Models are ranked based on AIC_c. The order in which the models were computed is shown in parentheses.

Model	K	AIC_c	Δ AIC_c	w
(16) Φ(ENSO), p(stage), Ψ(.)	7	108,618.42	0	0.47
(15) Φ(stream), p(stage), Ψ(.)	6	108,619.58	1.16	0.26
(13) Φ(year), p(stage), Ψ(.)	14	108,621.97	3.56	0.08
(4) Φ(year*stage*stream), p(stage), Ψ(year*stage*stream)	44	108,623.20	4.78	0.04
(12) Φ(year*stage*stream), p(stage), Ψ(.)	36	108,623.22	4.80	0.04
(17) Φ(ENSO + stream), p(stage), Ψ(.)	10	108,623.36	4.94	0.04
(14) Φ(stage), p(stage), Ψ (.)	7	108,623.49	5.08	0.04
(8) Φ(year*stage*stream), p(stage), Ψ(year)	41	108,624.92	6.50	0.02
(9) Φ(year*stage*stream), p(stage), Ψ(stage)	38	108,627.58	9.16	0.00
(10) Φ(year*stage*stream), p(stage), Ψ(stream)	41	108,631.82	13.40	0.00
(11) Φ(year*stage*stream), p(stage), Ψ(ENSO)	41	108,633.82	15.40	0.00
(18) Φ(ENSO*stream), p(stage), Ψ(.)	17	108,636.44	18.02	0.00
(5) Φ(year*stage*stream), p(stream), Ψ(year*stage*stream)	34	108,659.34	40.93	0.00
(7) Φ(year*stage*stream), p(.), Ψ(year*stage*stream)	36	108,663.82	45.40	0.00
(3) Φ(year*stage*stream), p(year), Ψ(year*stage*stream)	41	108,665.19	46.77	0.00
(6) Φ(year*stage*stream), p(ENSO), Ψ(year*stage*stream)	39	108,670.06	51.64	0.00
(2) (.)	3	108,706.48	88.06	0.00
(1) Φ(year*stage*stream), p(year*stage*stream), Ψ(year*stage*stream)	142	108,830.43	212.02	0.00

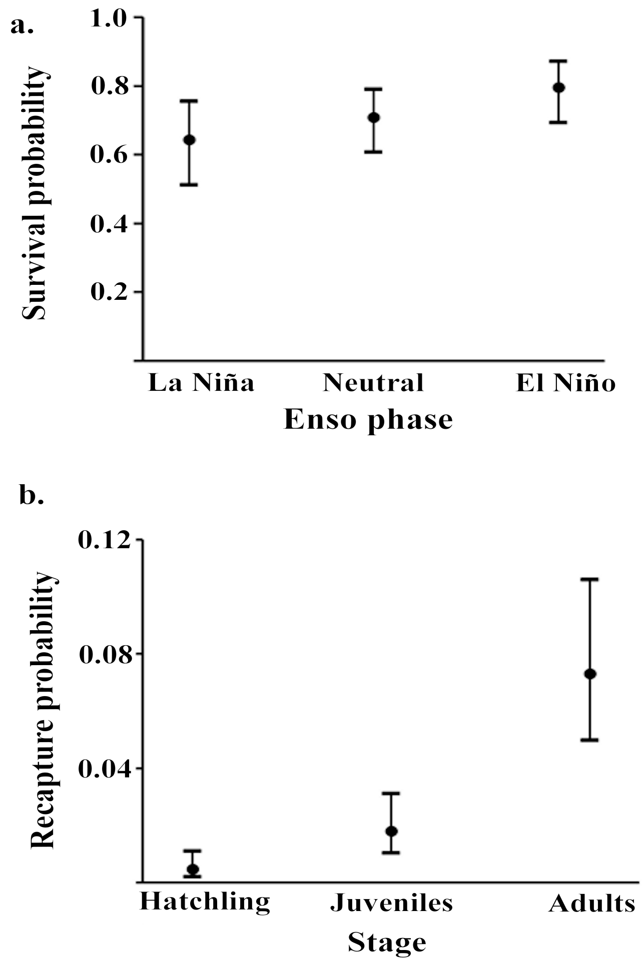

Figure 2. (**a**) ENSO phase survival probability, and (**b**) stage-specific recapture probability for the Chocoan River Turtle on Isla Palma estimated using multi-state mark-recapture models (error bars = 95% confidence interval).

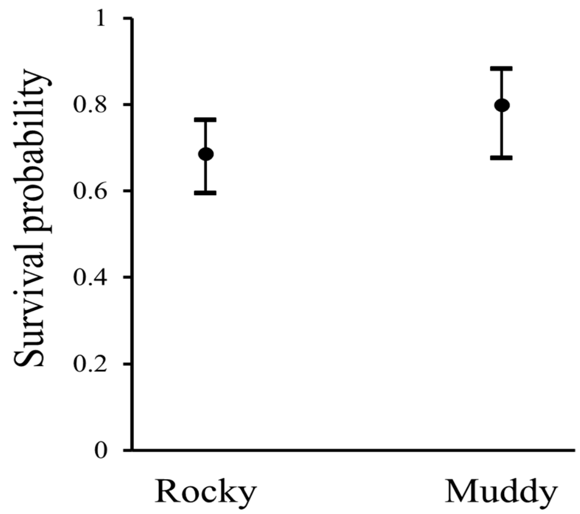

Figure 3. Survival probability in relation to stream substrate type for the second-best model for the Chocoan River Turtle on Isla Palma estimated using multi-state mark-recapture models (error bars = 95% confidence interval).

4. Discussion

Our results suggest that survival in this insular population of *R. nasuta* is more affected by the ENSO oscillations than by the type of stream this species inhabits or the variation among the different size classes. The probability of recapture, as predicted, varies among size classes, which is possibly associated with the fidelity to territory exhibited by adults [31]. The probability of transition is constant; surprisingly, the differential growth rate among size classes [31] does not seem to result in variation of this probability. It is possible that the constant transition result is affected by the few individuals that made transitions between size classes.

Previous studies have shown that climatic conditions affect the viability of turtle populations by affecting sex ratio and nesting success [51]. On the other hand, a study in the Mediterranean tortoise *Testudo hermanni* showed that this species had greater survival when precipitation increased due to the positive effects on plant growth and forage for the young tortoises [16]. In our tropical species, we found the opposite pattern because the mechanism by which the rain affects the populations is different and has nothing to do with diet. We propose that climatic conditions directly affect the survival of *R. nasuta* when catastrophic events such as floods occur, which generate the expulsion of some individuals from the streams and change the habitat structure and water dynamics of the streams; this type of effect has been related to variation in population parameters in some turtle populations [25,52,53]. Anecdotally, we have observed this ejection of individuals during sampling when some individuals were found on the beaches or in the intertidal area after strong storms, and we have seen smaller individuals being washed downstream during torrential rainstorms.

In addition to climatic factors, it has been amply demonstrated that freshwater turtles exhibit a preference for particular habitats [54–56] and that variation in survival probability can be produced by differences in predation levels [57,58]. The differences found at the level of survival in this population in streams with different substrates may be associated with the fact that the muddy substrates afford a reduction in predation risk because it is easier to escape or hide in mud, a pattern that has been reported in other species of freshwater turtles [59,60]. It may also be the case that the muddy substrates afford some protection from the scouring action of the torrential rains during the wetter ENSO phases—we have observed juveniles and adults that dug their own body pits in mud along the margins of the streams.

In general, the capture rate of turtle hatchlings in demographic studies is very low because typical turtle capture methods, such as trapping, are not effective with small individuals [61,62]. However, in our Isla Palma study streams, the method of capture is manual and the *R. nasuta* population exhibits a high percentage of hatchlings [63]—they are not missing. Differences in the recapture probability between size classes may be associated with the high fidelity to relatively small territories by adults, in particular, the females [31,34]. Another possibility is that, merely based on size, there are more small spaces to hide and more small, wet depressions where hatchlings and juveniles can evade detection [64]. Due to the lack of a pattern in variation of the transition probabilities, it is difficult to draw conclusions. The low proportion of individuals that made a transition (6.3%) may be the cause of large variation and the lack of a pattern. This low transition rate is probably associated with the low annual growth rate in this species, with growth rates in juveniles of about 5 mm per year [31]. This means that for an individual to move from hatchling to juvenile it would need, on average, 7.5 years. However, it is possible that the low recapture probability during hatchling or juvenile stages did not allow for the frequent detection of transitions.

The IPCC has identified basic aspects of climate change that are expected to impact biodiversity, such as the global warming trend, extremes of temperature, drying trends, and precipitation, as well as two geographic areas of particular concern, namely, terrestrial ecosystems in the tropics and northern latitudes [65]. As has been suggested, it may not be changes in average climatic conditions that may be determinative of a species geographic range and, presumably, its likelihood of extinction, but, rather, the extreme climatic events to which it is exposed [66]. Climate projections for the probability of extreme weather events, like floods and droughts, are greater than the projections of change in average conditions [67]. Although a flooding event has previously been suggested to influence reproduction in turtles by impacting survival [68], there appears to be no previous suggestion of an association in turtles between a documented climatic fluctuation, such as ENSO and survival, something that has been predicted for fishes [69].

Current research shows that in turtle populations where human disturbance and the rate of depredation are low, they are nevertheless affected by climatic changes. The increase in the severity of El Niño and La Niña may exacerbate the consequences of climatic regimes on natural populations of turtles in the tropics as this study suggests. The proximate cause of the increased mortality appears to be extreme climatic phenomena, in this case, floods associated with extreme rainfall during the wettest phases of ENSO.

Supplementary Materials: The following are available online at http://www.mdpi.com/1424-2818/11/6/97/s1, Turtle survival encounter data will be deposited in the Dryad Digital Repository.

Author Contributions: Conceptualization, M.F.G.-R., J.L.C. and A.G.; Data curation, M.F.G.-R.; Formal analysis, M.F.G.-R.; Funding acquisition, J.L.C. and A.G.; Investigation, M.F.G.-R., J.L.C. and A.G.; Methodology, M.F.G.-R., J.L.C. and A.G.; Visualization, M.F.G.-R. and A.G.; Writing—original draft, M.F.G.-R., J.L.C. and A.G.; Writing—review & editing, M.F.G.-R., J.L.C. and A.G.

Funding: The Universidad del Valle, the Grupo de Investigación en Ecología Animal of Univalle, and COLCIENCIAS, as well as the Chelonian Research Foundation and the University of Louisiana at Monroe, partially financed this work.

Acknowledgments: We thank the Dirección General Marítima (DIMAR) for permission to work on Isla Palma, a research permit from the Special Administrative Unit of the Sistema de Parques Nacionales Naturales (Res-0134) dated 11 September 2015, and Authorization No. 001 of 2017 associated with the Framework Permit for Collection granted to the Universidad del Valle with Resolution No. 1070 of 28 August 2015 from the National Environmental Licenses Authority (file AUR DTPA 001-17).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Gibbons, J.W.; Scott, D.; Ryan, T.; Buhlmann, K.; Tuberville, T.; Metts, B.S.; Greene, J.; Mills, V.; Leiden, Y.; Poppy, S.; et al. The global decline of reptiles, déjà vu amphibians. *BioScience* **2000**, *50*, 653–666. [CrossRef]
2. Turtle Taxonomy Working Group (TTWG). Turtles of the World, 7th Edition: Annotated checklist of taxonomy, synonymy, distribution, and conservation status. *Chelonian Res. Monogr.* **2014**, *5*, 329–479. [CrossRef]
3. Rhodin, A.G.; Stanford, C.B.; Van Dijk, P.P.; Eisemberg, C.; Luiselli, L.; Mittermeier, R.A.; Hudson, R.; Horne, B.D.; Goode, E.V.; Kuchling, G.; et al. Global conservation status of turtles and tortoises (Order Testudines). *Chelonian Conserv. Biol.* **2018**, *17*, 135–161. [CrossRef]
4. Mittermeier, R.A.; Carr, J.L.; Swingland, I.R.; Werner, T.B.; Mast, R.B. Conservation of amphibians and reptiles. In *Herpetology: Current Research on the Biology of Amphibians and Reptiles*; Adler, K., Ed.; Society for the Study of Amphibians and Reptiles Publication: Oxford, OH, USA, 1992; pp. 59–80.
5. Klemens, M.W. (Ed.) *Turtle Conservation*; Smithsonian Institution Press: Washington, DC, USA, 2000; ISBN 1-56098-372-8.
6. Congdon, J.D.; Dunham, A.E.; Sels, R.V.L. Demographics of common snapping turtles (*Chelydra serpentina*): Implications for conservation and management of long-lived organisms. *Am. Zool.* **1994**, *34*, 397–408. [CrossRef]
7. Heppell, S.S. Application of life-history theory and population model analysis to turtle conservation. *Copeia* **1998**, *1998*, 367–375. [CrossRef]
8. Mitchell, N.J.; Janzen, F.J. Temperature-dependent sex determination and contemporary climate change. *Sex. Dev.* **2010**, *4*, 129–140. [CrossRef]
9. Janzen, F.J.; Hoekstra, L.A.; Brooks, R.J.; Carroll, D.M.; Gibbons, J.W.; Greene, J.L.; Iverson, J.B.; Litzgus, J.D.; Michael, E.D.; Parren, S.G. Altered spring phenology of North American freshwater turtles and the importance of representative populations. *Ecol. Evol.* **2018**, *8*, 5815–5827. [CrossRef]

10. Gibbons, J.W.; Lovich, J.E. Where has turtle ecology been, and where is it going? *Herpetologica* **2019**, *75*, 4–20. [CrossRef]
11. Janzen, F.J. Climate-change and temperature-dependent sex determination in reptiles. *Proc. Natl. Acad. Sci. USA* **1994**, *91*, 7484–7490. [CrossRef]
12. Shine, R.; Elphick, M.J.; Donnellan, S. Co-occurrence of multiple, supposedly incompatible modes of sex determination in a lizard population. *Ecol. Lett.* **2002**, *5*, 486–489. [CrossRef]
13. Valenzuela, N.; Literman, R.; Neuwald, J.L.; Mizoguchi, B.; Iverson, J.B.; Riley, J.L.; Litzgus, J.D. Extreme thermal fluctuations from climate change unexpectedly accelerate demographic collapse of vertebrates with temperature-dependent sex determination. *Sci. Rep.* **2019**, *9*, 4254. [CrossRef] [PubMed]
14. Jensen, M.P.; Allen, C.D.; Eguchi, T.; Bell, I.P.; LaCasella, E.L.; Hilton, W.A.; Hof, C.A.; Dutton, P.H. Environmental warming and feminization of one of the largest sea turtle populations in the world. *Curr. Biol.* **2018**, *28*, 154–159. [CrossRef] [PubMed]
15. Madsen, T.; Shine, R. Rain, fish and snakes: Climatically driven population dynamics of Arafura filesnakes in tropical Australia. *Oecologia* **2000**, *124*, 208–215. [CrossRef] [PubMed]
16. Fernández-Chacón, A.; Bertolero, A.; Amengual, A.; Tavecchia, G.; Homar, V.; Oro, D. Spatial heterogeneity in the effects of climate change on the population dynamics of a Mediterranean tortoise. *Glob. Chang. Biol.* **2011**, *17*, 3075–3088. [CrossRef]
17. Hedrick, A.R.; Klondaris, H.M.; Corichi, L.C.; Dreslik, M.J.; Iverson, J.B. The effects of climate on annual variation in reproductive output in Snapping Turtles (*Chelydra serpentina*). *Can. J. Zool.* **2018**, *96*, 221–228. [CrossRef]
18. Ihlow, F.; Dambach, J.; Engler, J.O.; Flecks, M.; Hartmann, T.; Nekum, S.; Rajaei, H.; Rödder, D. On the brink of extinction? How climate change may affect global chelonian species richness and distribution. *Glob. Chang. Biol.* **2012**, *18*, 1520–1530. [CrossRef]
19. Agha, M.; Ennen, J.R.; Bower, D.S.; Nowakowski, A.J.; Sweat, S.C.; Todd, B.D. Salinity tolerances and use of saline environments by freshwater turtles: Implications of sea level rise. *Biol. Rev.* **2018**, *93*, 1634–1648. [CrossRef] [PubMed]
20. Hamilton, C.M.; Bateman, B.L.; Gorzo, J.M.; Reid, B.; Thogmartin, W.E.; Peery, M.Z.; Heglund, P.J.; Radeloff, V.C.; Pidgeon, A.M. Slow and steady wins the race? Future climate and land use change leaves the imperiled Blanding's turtle (*Emydoidea blandingii*) behind. *Biol. Conserv.* **2018**, *222*, 75–85. [CrossRef]
21. Cooley, C.R.; Floyd, A.O.; Dolinger, A.; Tucker, P.B. Demography and diet of the Painted Turtle (*Chrysemys picta*) at high-elevation sites in southwestern Colorado. *Southwest. Nat.* **2003**, *48*, 47–53. [CrossRef]
22. Daigle, C.; Jutras, J. Quantitative evidence of decline in a southern Quebec wood turtle (*Glyptemys insculpta*) population. *J. Herpetol.* **2005**, *39*, 130–132. [CrossRef]
23. Cayuela, H.; Akani, G.C.; Hema, E.M.; Eniang, E.A.; Amadi, N.; Ajong, S.N.; Dendi, D.; Petrozzi, F.; Luiselli, L. Population dynamics and age-dependent mortality processes in tropical reptiles. *BioRxiv* **2019**, 575977:1–575977:25. [CrossRef]
24. Nichols, J.T. Data on size, growth and age in the box turtle, *Terrapene carolina*. *Copeia* **1939**, *1939*, 14–20. [CrossRef]
25. Schwartz, C.W.; Schwartz, E.R. *The Three-Toed Box Turtle in Central Missouri: Its Population, Home Range, and Movements (No. 5)*; Missouri Dept. of Conservation: Jefferson City, MO, USA, 1974.
26. Doroff, A.M.; Keith, L.B. Demography and ecology of an ornate box turtle (*Terrapene ornata*) population in south-central Wisconsin. *Copeia* **1990**, *1990*, 387–399. [CrossRef]
27. Martins, F.I.; Souza, F.L. Demographic parameters of the Neotropical freshwater turtle *Hydromedusa maximiliani* (Chelidae). *Herpetologica* **2009**, *65*, 82–91. [CrossRef]
28. Turtle Taxonomy Working Group (TTWG). Turtles of the world: Annotated checklist and atlas of taxonomy, synonymy, distribution, and conservation status (8th ed.). *Chelonian Res. Monogr.* **2017**, *7*, 1–292.
29. Páez, V.P.; Lasso, M.A.; Mora, C.A.C.; Bock, O.V. *Biología y Conservación de las Tortugas Continentales de Colombia*; Instituto de Investigación de Recursos Biológicos Alexander von Humboldt: Bogotá, Colombia, 2012; ISBN 978-958-8343-77-8.
30. Forero-Medina, G.; Páez, V.P.; Garcés-Restrepo, M.F.; Carr, J.L.; Giraldo, A.; Vargas-Ramírez, M. Research and conservation priorities for tortoises and freshwater turtles of Colombia. *Trop. Conserv. Sci.* **2016**, *9*, 1–14. [CrossRef]

31. Carr, J.L.; Giraldo, A. Rhinoclemmys nasuta (Boulenger 1902)—Large-nosed wood turtle, Chocoan river turtle. In *Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group*; Rhodin, A.G.J., Pritchard, P.C.H., van Dijk, P.P., Saumure, R.A., Buhlmann, K.A., Iverson, J.B., Mittermeier, R.A., Eds.; Chelonian Research Foundation: Lunenburg, MA, USA, 2009; pp. 5, 34:1–34:6.
32. Morales-Betancourt, M.A.; Lasso, C.A.; Páez, V.P.; Bock, B.C. *Libro Rojo de Reptiles de Colombia*; Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH) & Universidad de Antioquia: Bogotá, Colombia, 2015; ISBN 978-958-888-980-1.
33. Carrillo, E.; Aldás, S.; Altamirano, M.; Ayala-Varela, F.; Cisneros-Heredia, D.; Endara, A.; Márquez, C.; Morales, M.; Nogales-Sornosa, F.; Salvador, P. *Lista Roja de los Reptiles del Ecuador*; Fundación Novum Milenium, UICN-Sur, UICN-Comité Ecuatoriano; Ministerio de Educación y Cultura, Serie Proyecto Peepe: Quito, Ecuador, 2005.
34. Giraldo, A.; Garcés-Restrepo, M.F.; Carr, J.L.; Loaiza, J. Tamaño y estructura poblacional de la tortuga sabaletera (*Rhinoclemmys nasuta*, Testudines: Geoemydidae) en un ambiente insular del Pacífico colombiano. *Caldasia* **2012**, *34*, 109–125.
35. Giraldo, A.; Garcés-Restrepo, M.F.; Quintero-Angel, A.; Bolívar-García, W.; Velandia-Perilla, J.H. Vertebrados terrestres de Isla Palma (Bahía Málaga, Valle del Cauca, Colombia). *Bol. Cient. Mus. Hist. Nat.* **2014**, *18*, 183–202.
36. Poveda, G.; Mesa, O.J. On the existence of Lloró (the rainiest locality on Earth): Enhanced ocean-land-atmosphere interaction by a low-level jet. *Geophys. Res. Lett.* **2000**, *27*, 1675–1678. [CrossRef]
37. Quinto-Mosquera, H.; Moreno-Hurtado, F. Precipitation effects on soil characteristics in tropical rain forests of the Chocó biogeographical region. *Rev. Fac. Nac. Agron. Med.* **2016**, *69*, 7813–7823. [CrossRef]
38. Rangel-Ch, J.O.; Arellano-P, H. Clima del Chocó Biogeográfico/costa pacífica de Colombia. In *Colombia Diversidad Biótica IV: El Chocó Biogeográfico/Costa Pacífica*; Rangel-Ch, J.O., Ed.; Instituto de Ciencias Naturales, Universidad Nacional de Colombia: Bogotá, Colombia, 2004; pp. 39–82.
39. Poveda, G.; Mesa, Ó.J. Las fases extremas del fenómeno ENSO (El Niño y La Niña) y su influencia sobre la hidrología de Colombia. *Tecnol. Cienc. Agua* **2015**, *11*, 21–37.
40. Bravo, G.N.; Enriquez, O.; Arroyo, A.G. Distribución de la precipitación en el municipio de Buenaventura (Valle del Cauca-Colombia) entre 1994 y 1996. *Rev. Estud. Hemisféricos Polares* **2016**, *7*, 22–43.
41. Bendix, J.; Trachte, K.; Palacios, E.; Rollenbeck, R.; Göttlicher, D.; Nauss, T.; Bendix, A. El Niño meets La Niña—Anomalous rainfall patterns in the "Traditional" El Niño region of southern Ecuador. *Erdkunde* **2011**, *65*, 151–167. [CrossRef]
42. Corlett, R.T. Impacts of warming on tropical lowland rainforests. *Trends. Ecol. Evol.* **2011**, *26*, 606–613. [CrossRef] [PubMed]
43. Jiménez-Muñoz, J.C.; Mattar, C.; Barichivich, J.; Santamaría-Artigas, A.; Takahashi, K.; Malhi, Y.; Sobrino, J.A.; Van Der Schrier, G. Record-breaking warming and extreme drought in the Amazon rainforest during the course of El Niño 2015–2016. *Sci. Rep.* **2016**, *6*, 33130. [CrossRef] [PubMed]
44. Cavaleri, M.A.; Coble, A.P.; Ryan, M.G.; Bauerle, W.L.; Loescher, H.W.; Oberbauer, S.F. Tropical rainforest carbon sink declines during El Niño as a result of reduced photosynthesis and increased respiration rates. *New. Phytol.* **2017**, *216*, 136–149. [CrossRef] [PubMed]
45. Fan, F.; Dong, X.; Fang, X.; Xue, F.; Zheng, F.; Zhu, J. Revisiting the relationship between the South Asian summer monsoon drought and El Niño warming pattern. *Atmos. Sci. Lett.* **2017**, *18*, 175–182. [CrossRef]
46. Cagle, F.R. A system of marking turtles for future identification. *Copeia* **1939**, *1939*, 170–173. [CrossRef]
47. White, G.C.; Kendall, W.L.; Barker, R.J. Multistate survival models and their extensions in Program MARK. *J. Wildl. Manag.* **2006**, *70*, 1521–1529. [CrossRef]
48. White, G.C.; Burnham, K.P. Program MARK: Survival estimation from populations of marked animals. *Bird Study* **1999**, *46*, S120–S139. [CrossRef]
49. Giraldo, A.; Garcés-Restrepo, M.F.; Bolívar-García, W.; Carr, J.L. First report of hatching of the Chocoan River Turtle *Rhinoclemmys nasuta* (Boulenger 1902) (Testudines: Geoemydidae). *Bol. Cient. Mus. Hist. Nat.* **2013**, *17*, 153–159.
50. Burnham, K.P.; Anderson, D.R. *Model Selection and Multimodel Inference: A Practical Information-theoretic Approach*, 2nd ed.; Springer: New York, NY, USA, 2002; ISBN 0387953647.

51. Schwanz, L.E.; Spencer, R.J.; Bowden, R.M.; Janzen, F.J. Climate and predation dominate juvenile and adult recruitment in a turtle with temperature-dependent sex determination. *Ecology* **2010**, *91*, 3016–3026. [CrossRef] [PubMed]
52. Williams, E.C., Jr.; Parker, W.S. A long-term study of a box turtle (*Terrapene carolina*) population at Allee Memorial Woods, Indiana, with emphasis on survivorship. *Herpetologica* **1987**, *43*, 328–335.
53. Converse, S.J.; Iverson, J.B.; Savidge, J.A. Demographics of an ornate box turtle population experiencing minimal human-induced disturbances. *Ecol. Appl.* **2005**, *15*, 2171–2179. [CrossRef]
54. Mahmoud, I.Y. Comparative ecology of the kinosternid turtles of Oklahoma. *Southwest. Nat.* **1969**, *14*, 31–66. [CrossRef]
55. DonnerWright, D.M.; Bozek, M.A.; Probst, J.R.; Anderson, E.M. Responses of turtle assemblage to environmental gradients in the St. Croix River in Minnesota and Wisconsin, USA. *Can. J. Zool.* **1999**, *77*, 989–1000. [CrossRef]
56. Donaldson, B.M.; Echternacht, A.C. Aquatic habitat use relative to home range and seasonal movement of Eastern Box Turtles (*Terrapene carolina carolina*: Emydidae) in eastern Tennessee. *J. Herpetol.* **2005**, *39*, 278–284. [CrossRef]
57. Dodd, C.K. *North American Box Turtles: A Natural History*; University of Oklahoma Press: Norman, OK, USA, 2001; ISBN 0806135018.
58. Neto, H.J.F.; Ayub, M.; de Freitas, G.; Oliveira, T.; Berger, G.; Colli, G.R. Demography of *Acanthochelys spixii* (Testudines, Chelidae) in the Brazilian Cerrado. *Chelonian Conserv. Biol.* **2011**, *10*, 82–90. [CrossRef]
59. Froese, D. Habitat preferences of the Common Snapping Turtle, *Chelydra s. serpentina* (Reptilia, Testudines, Chelydridae). *J. Herpetol.* **1978**, *12*, 53–58. [CrossRef]
60. Kaufmann, J. Habitat use by Wood Turtles in central Pennsylvania. *J. Herpetol.* **1992**, *26*, 315–321. [CrossRef]
61. Pike, D.A.; Pizzatto, L.; Pike, B.A.; Shine, R. Estimating survival rates of uncatchable animals: The myth of high juvenile mortality in reptiles. *Ecology* **2008**, *89*, 607–611. [CrossRef] [PubMed]
62. Souza, F.L. Uma revisão sobre padrões de atividade, reprodução e alimentação de cágados Brasileiros (Testudines-Chelidae). *Phyllomedusa* **2004**, *3*, 15–27. [CrossRef]
63. Garcés-Restrepo, M.F.; Giraldo, A.; Carr, J.L. Population ecology and morphometric variation of the Chocoan river turtle (*Rhinoclemmys nasuta*) from two localities on the Colombian Pacific coast. *Bol. Cient. Mus. Hist. Nat.* **2013**, *17*, 160–171.
64. Garcés-Restrepo, M.F.; Rivera-Domínguez, N.; Giraldo, A.; Carr, J.L. Reproductive aspects of the Chocoan River turtle (*Rhinoclemmys nasuta,* Geoemydidae) along the Colombian Pacific coast. *Amphib. Reptil.* **2017**, *38*, 351–361. [CrossRef]
65. Settele, J.; Scholes, R.; Betts, R.; Bunn, S.; Leadley, P.; Nepstad, D.; Overpeck, J.T.; Taboada, M.A. Terrestrial and inland water systems. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability: Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK, 2014; pp. 271–359.
66. Zimmermann, N.E.; Yoccoz, N.G.; Edwards, T.C.; Meier, E.S.; Thuiller, W.; Guisan, A.; Schmatz, D.R.; Pearman, P.B. Climatic extremes improve predictions of spatial patterns of tree species. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 19723–19728. [CrossRef] [PubMed]
67. IPCC (Intergovernmental Panel on Climate Change). Summary for policymakers. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*; A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change; Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach, K.J., Plattner, G.K., Allen, S.K., et al., Eds.; Cambridge University Press: Cambridge, UK, 2012; pp. 3–21.

68. Tucker, J.K.; Filoramo, N.I.; Janzen, F.J. Size-biased mortality due to predation in a nesting freshwater turtle, *Trachemys scripta*. *Am. Midl. Nat.* **1999**, *141*, 198–204. [CrossRef]
69. Meyers, E.M.; Dobrowski, B.; Tague, C.L. Climate change impacts on flood frequency, intensity, and timing may affect trout species in Sagehen Creek, California. *Trans. Am. Fish. Soc.* **2010**, *139*, 1657–1664. [CrossRef]