Antipredator response of free-roaming Aldabra giant tortoise (*Aldabrachelys gigantea*) with implications for responsible wildlife tourism in the Seychelles islands

Ben Walton & Richard P. Baxter
Fregate Island Private, Seychelles *eco@fregate.com*

Address for correspondence:
Powburn, Elvaston Park Road, Hexham,
Northumberland NE46 2HL, U.K.
benjwalton1@gmail.com

Abstract: I investigated the responses of Aldabra giant tortoises (*Aldabrachelys gigantea*) to human approach. Sex and ambient temperature were not found to have a significant effect on the distance at which tortoises became alert to human approach or the distance at which they initiated their characteristic head withdrawal response. Larger tortoises (measured by curved carapace length) became alert to human approach at greater distances, however there was no relationship between size and head withdrawal distance. I recommend that buffer zones of at least five meters should be implemented where human-tortoise contact is high, to reduce unnecessary stress and minimise effects on their behaviour. I also discuss the possible impacts of tourism on the ecosystem-restoration potential of Aldabra giant tortoises.

Introduction

The distance at which animals respond to an approaching threat is of interest to both behavioural ecologists and conservation practitioners. In most studies the parameter used to measure this is flight distance (FD) (Ydenberg & Dill 1986), the distance at which an animal flees.

Behavioural ecologists have focused on the optimisation of flight distances. Animals are expected to optimise the trade-off between chances of survival and the costs of disturbance, for example, through reduced foraging opportunities and energy expenditure. This tradeoff was first formally described by the Ydenberg and Dill model (Ydenberg & Dill 1986), which models how animals should flee when the cost of remaining is greater than the costs of fleeing.

As well as varying between species, flight distances can also vary within a species due to a range of variables. Studies across taxa have shown that flight distance can be influenced by temperature (e.g. Cooper 2003; Blamires 1999), distance to refuge (eg. Dill & Houtman 1989; Bonenfant & Kramer 1996), approach speed (e.g. Cooper 2003, 2005, 2006), sex (e.g. Guay *et al.* 2016), and body mass (e.g. Gotanda *et al.* 2009).

Flight distances in response to human approach have also been used by wildlife managers to set guidelines for mitigating human disturbance on wild animals by setting buffer zones and maximum approach distances (e.g. Rodgers & Smith 1995; Giese 1998). Tourism has been shown to have negative effects on a range of taxa, for example, increasing offspring mortality (Müllner *et al.* 2004) and corticosteroid level (an indicator of physiological stress) (Ellenberg *et al.* 2007). Therefore it is important that evidence based recommendations for buffer zones are made in order to reduce such effects. Flight distances should be treated as a minimum for any recommendations as behaviour is likely to change well before this point. However, it provides a useful scientific justification for such guidelines.

I investigated the responses of Aldabra giant tortoises (*Aldabrachelys gigantea,* Schweigger 1812) to human approach. Tortoises are sedentary in nature, and their first response when threatened is not to flee. Tortoises are heavily armoured and their initial response to threat is to withdraw their head under their carapace. Therefore, in this study I measured not FD, but two parameters; (1) Alert Distance (AD), the distance at which the tortoise becomes alert to the approaching human, and (2) Head Withdrawal Distance (HWD), the distance at which the tortoise initiates the characteristic head withdrawal response. Measuring the AD is useful for setting guidelines about human approach, as it can be used as an indicator for the distance at which humans are detected by the tortoises and therefore their behaviour affected. Here it is assumed that the HWD is the point at which significant stress is experienced by the tortoise. There are currently no guidelines for human approach to Aldabra giant tortoises, despite significant tourism on many of the islands inhabited by free ranging tortoises.

As well as trying to establish approach distance guidelines, I also investigated whether responses to human approach varied with any environmental or individual variables. As large-bodied ectotherms, temperature affects many aspects of Aldabra giant tortoise behaviour (Swingland & Fraizer 1980) so it might be expected that ambient temperature affects their response to human approach. Research in other reptiles has given mixed results for the effects of temperature on FD, with some allowing closer approach when cooler (e.g. Blamires 1999) and others when warmer (e.g. Rocha & Bergalo 1990). However, as these reptiles rely on different anti-predator strategies (normally crypsis or flight) explanations relating temperature to FD in other reptiles are unlikely to be appropriate for tortoises. Mass may also affect the response to human approach as smaller tortoises are more vulnerable to predation (Arnold *et al.* 1979). The effect of sex on response was also investigated to see whether there was any difference between males, females and tortoises for which sex could not be identified in their response to human approach.

Methods

Study Site **-** Research was conducted between the 02/07/2018 and the 02/09/2018 on Fregate Island, Seychelles, between 1600 and 1800 hours. Fregate Island is one of the inner granitic islands of the Seychelles and has an area of 219 ha. It has the second largest population of free ranging Aldabra giant tortoises, after Aldabra atoll. Based on a recent census, the population on the island is estimated to be approximately 3,500 individuals (R. Baxter, pers. comm.). Fregate Island is privately owned and is currently managed primarily as a high end tourist resort and is permanently occupied by staff and guests. Guests regularly touch and feed tortoises. However, only a small number of tortoises show any evidence of habituation to humans.

Approach Responses - Tortoises were selected for study at random when encountered in the field. Habituated tortoises which spontaneously approached humans or showed other evidence of habituation were omitted from the study. Tortoises were approached where there was a clear approach to the front of the tortoise and the line of sight from the tortoise to the experimenter was not obscured by vegetation. Tortoises were only approached when feeding, so that it was clear when the approacher had gained the attention of the tortoise. Tortoises were approached head on, at no more than a 45 degree angle to the direction they were facing. Tortoises were approached at a pace of ~75cm (one pace) per second. The distance from the experimenter's chest to the tortoise's head was measured when: (a) the tortoise lifted its head up, looked at the experimenter and did not return to feeding (AD), and (b) when the tortoise initiated the characteristic head withdrawal response (HWD). I recorded curved carapace length (CCL), ambient temperature and sex for each tortoise. Tortoises were sexed based on size, plastron shape, carapace shape and tail length, according to recommendations by J. Gerlach ("Island Biodiversity", 2019). Smaller individuals, likely to be juveniles, who could not be easily sexed were put into a third category, sex unknown (U).

Tortoises were then individually marked using correction fluid with a two or three digit code to prevent pseudo-replication. Previous use of correction fluid to mark tortoises had shown that the markings can last more than 6 months (pers. obs.) and codes were re-applied when previously marked tortoises were encountered in the field. In total 75 tortoises were studied, 32 females, 31 males and 12 tortoises for which sex could not be determined.

Analysis - The data collected were analysed to establish whether there was any relationship between AD or HWD and sex, CCL and ambient temperature. A one-way ANOVA was used to see if there was any significant difference in AD or HWD between males, females and tortoises for which sex is unknown. The relationships between CCL and ambient temperature and AD and HWD were analysed using a linear regression analysis.

Results

Female CCL ranged in size from 74.8cm to 119.0cm. Male CCL ranged from 91.0cm to 172.0cm. Unsexed tortoises ranged in CCL from 12.2 to 73.0 cm. (Figure 1). There was no significant difference in either AD or HWD between males, females and tortoises for which sex was unknown (one-way Anova, $p=0.09$ and $p=0.38$ respectively, Figure 2). There was no significant relationship found between ambient temperature and AD or HWD (linear regression analysis, $p=0.07$ and $p=0.76$ respectively, Figure 2). There was no significant relationship found between CCL and HWD (Linear regression analysis, $p=0.10$, Figure 2). There was a significant relationship between CCL and AD (Linear regression analysis, $p=0.025$, Figure 2).

The distribution for AD and HWD for all tortoises approached is shown in Figure 3. The majority of tortoises had HWD of less than 5m (>97%). For AD, >97% of tortoises were undisturbed over 15m, >80% were undisturbed at 10m, and >42% of tortoises were undisturbed at 5m.

Discussion

Here, unlike in most studies assessing the response of an animal to human approach, flight distance (the distance at which an animal flees), is inappropriate. Therefore, I measured the distance at which the tortoise became alert (AD) and the distance at which the tortoise initiated its characteristic head withdrawal response (HWD) in order to assess the response of tortoises to human approach. There was no significant relationship between ambient temperature and either parameter measured. It may be likely that internal temperature has more of an effect on behaviour, as tortoise internal temperature has been shown to lag significantly behind ambient temperatures (Falcón *et al.* 2018). There was no significant difference found in either parameter between males, females and tortoises for which sex was unknown. This lack of difference between sexes was also found in a previous study in Galapagos giant tortoises (Hayes *et al.* 1988). Although there was no significant relationship between CCL and HWD, there was a significant positive relationship between CCL and AD. This seems odd as only smaller tortoises are vulnerable to predation (Arnold *et al.* 1979). This correlation could potentially be explained by smaller tortoises prioritising feeding over vigilance as they are undergoing more rapid relative growth. It may also simply relate to perception

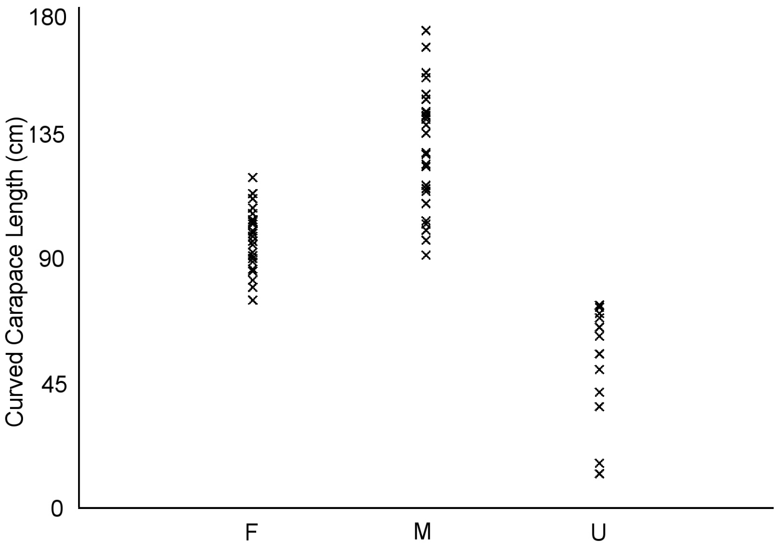

Figure 1: Curved carapace length (CCL) for female tortoises (F), male tortoises (M) and those of unknown sex (U)

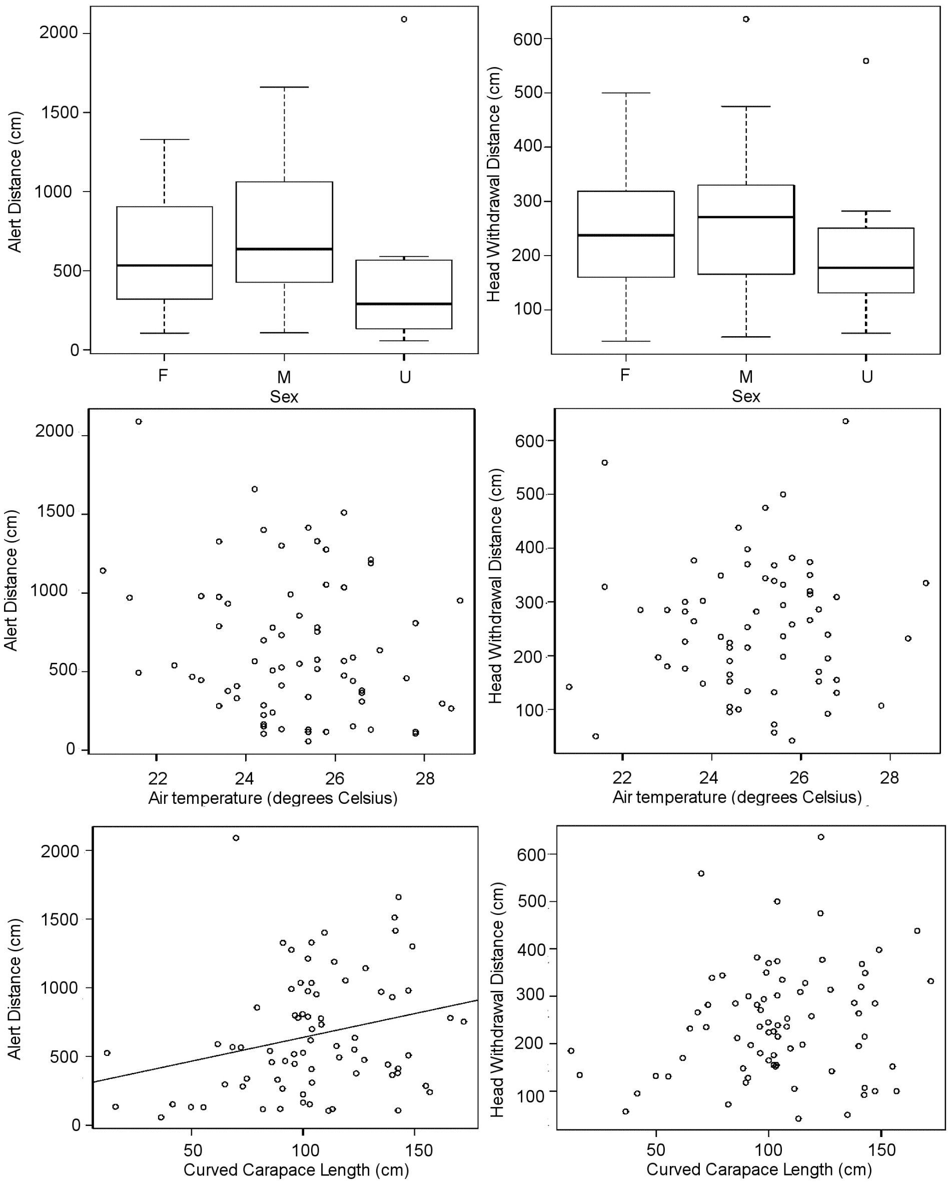

Figure 2: Graphs showing the relationship between Alert Distance (AD) and Head Withdrawal Distance (HWD) and sex, air temperature and Curved Carapace Length (CCL)

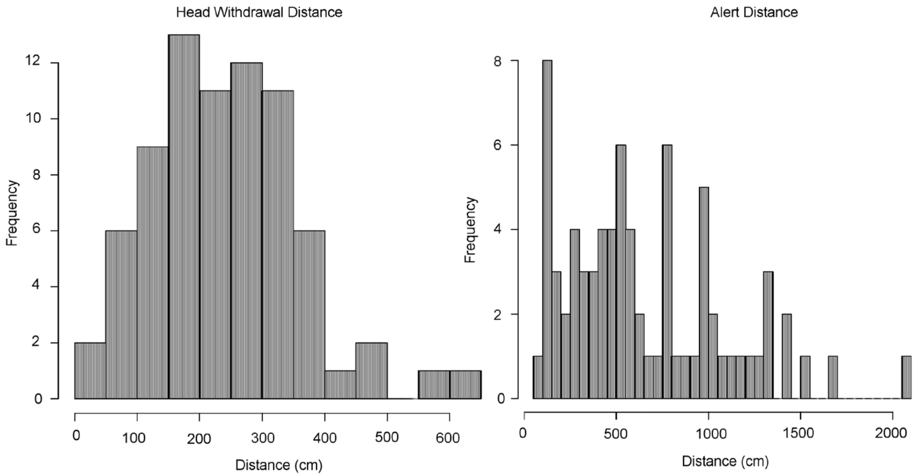

Figure 3: Histogram of Head Withdrawal Distances (HWD) and Alert Distances (AD) for Aldabra giant tortoises in response to human approach

ability, which could explain why head withdrawal distance is non-significant whereas alert distance is; smaller tortoises may be poorer at perceiving approaching threat, either due to lack of experience or differing fields of view. However, this result should be interpreted with caution, especially as there was no significant relationship between CCL and HWD. A previous study in Galapagos giant tortoises found no relationship between size and response to human approach (Hayes *et al*. 1988).

Although responses differed greatly between individuals, responses were broadly within the same range. Most of the parameters measured did not affect response to human approach, therefore it is reasonable to suggest that any guidelines generated from this data can be applied to all Aldabra giant tortoises. Based on these data I would recommend buffer zones of five meters as a minimum. Only two tortoises (less than three percent of the sample) showed a head withdrawal response at a greater distance. Furthermore, nearly half (>42%) of tortoises showed no awareness of humans at this distance. Tortoises that became alert at the largest distances probably became alert by senses other than sight, such as scent or ground vibrations, as tortoise eyesight is relatively poor (J. Gerlach, pers. comm.). Indeed scent may well play a significant role in the detection of human approach. However, this does not affect the validity of buffer zone recommendations based on these data. Buffer zones of five meters would avoid stress and significantly decrease any effects on behaviour.

Beyond causing stress, tourism has the potential to impact the behaviour of tortoises in other ways. This is important to consider where such changes in behaviour can affect the potential of the tortoises to act as agents of ecological restoration, widely used as the justification for their (re)introduction onto many Mascarene Islands (Griffiths *et al.* 2010; Gerlach *et al.* 2013). Tortoises regularly fed by humans may restrict their activity and dispersal to those areas where they are fed. This was observed with a few individuals on Fregate Island, and although anecdotal, this does indicate that humans can change patterns of tortoise movement. If tortoises are encouraged to stay in one place this reduces their capacity to distribute native seeds, change vegetation structure through herbivory and act as disturbance agents. Even if feeding does not affect movement it may affect quantity or choice of vegetation consumed. Therefore, I would recommend that feeding is also discouraged and that further research is undertaken into the impacts of tourism on tortoises and their ability to act as agents of ecological restoration.

Acknowledgements

We would like to thank Frégate Island Private for facilitating this research by providing accommodation and equipment. We would also like to thank J. Gerlach for his valuable comments on the manuscript.

References

Blamires, S.J. (1999). Factors influencing the escape response of an arboreal agamid lizard of tropical Australia (*Lophognathus temporalis*) in an urban environment. *Canadian Journal of Zoology* **77**(12), 1998–2003. doi:10.1139/z99-166

Bonenfant, M., & Kramer, D.L. (1996). The influence of distance to burrow on flight initiation distance in the woodchuck, *Marmota monax. Behavioral Ecology* **7**(3): 299–303. Retrieved from http://dx.doi.org/10.1093/beheco/7.3.299

Cooper, W.E.J. (2005). When and how do predator starting distances affect flight initiation distances? *Canadian Journal of Zoology* **83**(8): 1045–1050. doi:10.1139/z05-104

Cooper Jr, W.E. (2006). Dynamic Risk Assessment: Prey Rapidly Adjust Flight Initiation Distance to Changes in Predator Approach Speed. *Ethology* **112**(9): 858–864. doi:10.1111/j.1439-0310.2006.01240.x

Cooper Jr., W.E. (2003). Risk factors affecting escape behavior by the desert iguana, *Dipsosaurus dorsalis*: speed and directness of predator approach, degree of cover, direction of turning by a predator, and temperature. *Canadian Journal of Zoology* **81**(6): 979–984. doi:10.1139/z03-079

Dill, L.M., & Houtman, R. (1989). The influence of distance to refuge on flight initiation distance in the gray squirrel (*Sciurus carolinensis*). *Canadian Journal of Zoology* **67**(1): 233–235. doi:10.1139/z89-033

Ellenberg, U., Setiawan, A.N., Cree, A., Houston, D.M., & Seddon, P.J. (2007). Elevated hormonal stress response and reduced reproductive output in Yellow-eyed penguins exposed to unregulated tourism. *General and Comparative Endocrinology* **152**(1): 54–63. doi:10.1016/J.YGCEN.2007.02.022

Falcón, W., Baxter, R.P., Furrer, S., Bauert, M., Hatt, J.-M., Schaepman-Strub, G., Hansen, D.M. (2018). Patterns of activity and body temperature of Aldabra giant tortoises in relation to environmental temperature. *Ecology and Evolution* **8**(4): 2108–2121. doi:10.1002/ece3.3766

Gerlach, J. (2019) *Island Biodiversity*. Retrieved from https://islandbiodiversity.com

Gerlach, J., Rocamora, G., Gane, J., Jolliffe, K., & Vanherck, L. (2013). Giant Tortoise Distribution and Abundance in the Seychelles Islands: Past, Present, and Future. *Chelonian Conservation and Biology* **12**(1): 70–83. doi:10.2744/CCB-0902.1

Giese, M. (1998). Guidelines for people approaching breeding groups of Adélie penguins (*Pygoscelis adeliae*). *Polar Record* **34**(191): 287-292. doi:10.1017/S0032247400025973

Gotanda, K.M., Turgeon, K., & Kramer, D.L. (2009). Body size and reserve protection affect flight initiation distance in parrotfishes. *Behavioral Ecology and Sociobiology* **63**(11): 1563–1572. doi:10.1007/s00265-009-0750-5

Griffiths, C.J., Jones, C.G., Hansen, D.M., Puttoo, M., Tatayah, R.V, Müller, C.B. & Harris, S. (2010). The Use of Extant Non-Indigenous Tortoises as a Restoration Tool to Replace Extinct Ecosystem Engineers. *Restoration Ecology* **18**(1): 1–7. doi:10.1111/j.1526-100X.2009.00612.x

Guay, P.-J., Lorenz, R.D.A., Robinson, R.W., Symonds, M.R.E. & Weston, M.A. (2013). Distance from Water, Sex and Approach Direction Influence Flight Distances Among Habituated Black Swans. *Ethology* **119**(7), 552–558. doi:10.1111/eth.12094

Hayes, F.E., Beaman, K.R., Hayes, W.K., & Lester E. Harris, J. (1988). Defensive Behavior in the Galapagos Tortoise (*Geochelone elephantopus*), with Comments on the Evolution of Insular gigantism. *Herpetologica* **44**(1): 11–17. Retrieved from http://www.jstor.org/stable/3892193

Müllner, A., Eduard Linsenmair, K. & Wikelski, M. (2004). Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). *Biological Conservation* **118**(4): 549–558. doi:10.1016/J.BIOCON.2003.10.003

Arnold, E.N. (1979). Indian Ocean giant tortoises: their systematics and island adaptations. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences* **286**(1011): 127–145. doi:10.1098/rstb.1979.0022

Rocha, C.F.D. & Bergallo, H.G. (1990). Thermal biology and flight distance of *Tropidurus oreadicus* (Sauria Iguanidae) in an area of Amazonian Brazil. *Ethology Ecology & Evolution* **2**(3): 263–268. doi:10.1080/08927014.1990.9525411

Rodgers Jr., J.A. & Smith, H.T. (1995). Set-Back Distances to Protect Nesting Bird Colonies from Human Disturbance in Florida. *Conservation Biology* **9**(1): 89–99. doi:10.1046/j.1523-1739.1995.09010089.x

Swingland, I.R., & Frazier, J.G. (1980a). The Conflict between Feeding and Overheating in the Aldabran Giant Tortoise. *A Handbook on Biotelemetry and Radio Tracking,* 611–615. doi:10.1016/B978-0-08-024928-5.50079-8

Ydenberg, R.C. & Dill, L.M. (1986b). The Economics of Fleeing from Predators. *Advances in the Study of Behavior* **16**: 229–249. doi:10.1016/S0065-3454(08)60192-8