CONSERVATION OF THE CENTRAL GALAPAGOS RACER

(*PSEUDALSOPHIS DORSALIS*) IN THE GALAPAGOS ISLANDS, ECUADOR.

A thesis presented in partial fulfilment of the requirements for the degree of

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Figure 1. Central Galapagos racer (*Pseudalsophis dorsalis*) on Seymour Norte Island. This population exhibits several colour morphs. Photos: L. Ortiz-Catedral.

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DECLARATION

I declare that this thesis is an accurate and original account of my research and that the contents have not previously been submitted for a degree at Massey University, nor any other tertiary institution in New Zealand or overseas. Except where acknowledged, the material contained in this thesis has not been written or published by any other individual and to the extent of my knowledge, does not infringe copyright restrictions. The research presented here is part of a larger research project on Galapagos terrestrial snakes (*Pseudalsophis* spp.) developed since 2015 by my supervisor Dr. Luis Ortiz-Catedral in conjunction with the Directorate Galapagos National Park and Island Conservation. Dr. Luis Ortiz-Catedral allowed me to execute this project following approved protocols by the Ministry of Environment, Ecuador via the Directorate of the Galapagos National Park under permit PC-74-17 and PC-08-19, see Appendix A. Dr. Ortiz-Catedral and I coordinated all the logistical support necessary to complete this investigation, and also obtained the relevant permissions for accessing study sites. Dr. Ortiz-Catedral and I jointly prepared funding applications to cover the costs incurred during this investigation. Financial support for the project was obtained from the Galapagos Conservation Trust, Massey University and Auckland Zoo Conservation Fund. The ideas about the components of this thesis were discussed between my supervisor and I prior, during and after fieldtrips. Dr. Ortiz-Catedral provided all the supervision necessary for the development of this project, the analysis of results and the elaboration of the final document. I assume all responsibility for mistakes or omissions present in this document.

Harrison Edward Sollis

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GENERAL ABSTRACT

Snakes (Reptilia; Squamata) remain one of least studied vertebrate groups, in spite of recent field studies on various regions and taxa. This is due in part to logistical difficulties associated with studying these ectotherms in the field, and also the low density of some populations which prevents the collection of multi-year large datasets across large geographic areas. Island species and populations of snakes offer a unique opportunity to document aspects of diet, distribution and intra-population phenotypic variability that can inform conservation practices. In the Galapagos Islands, there are nine species of endemic terrestrial snakes, collectively known as "racers" (*Pseudalsophis spp*.). In recent years, there has been a surge in the public interest on these reptiles, which has also been accompanied with an increased need by managers to develop conservation programs for threatened populations. Unfortunately, there are still significant gaps in knowledge regarding the basic biology of these snakes. The central Galapagos racer (*Pseudalsophis dorsalis*) is one of the most widespread and variable species, with a historical distribution that includes the islands of Santa Cruz, Santa Fe, Baltra, Seymour Norte, and several islets < 100 ha in size off the coast of Santa Cruz Island. Anecdotal information suggests that the species has disappeared from most of Santa Cruz Island, possibly due to predation by introduced mammals. The Directorate of the Galapagos National Park, in collaboration with Massey University and Island Conservation has identified priority areas of research to advance the conservation of the Galapagos terrestrial snakes in general, and of the Central Galapagos racer in particular. In this thesis I provide an overview of the historical distribution of the species and an analysis of the dietary diversity of central Galapagos racers at various sites. I also present the results of a preliminary analysis of the colour variation of the Seymour Norte population and the similarities and differences in colour pattern of the Santa Fe, Baltra and Seymour Norte populations. I also describe a population of central Galapagos racers on the islet El Eden, a site where the species occurrence had not been confirmed since the 1980s.

Finally, I present a range of key knowledge gaps and recommendations for the conservation of the Central Galapagos racer and other terrestrial Galapagos snakes. The COVID-19 pandemic had a profound effect on my ability to complete data collection in the field during the 2020 field season. Nevertheless, in this thesis I present novel information that can assist the Directorate of the Galapagos National Park in its task to preserve the bio-heritage of the Galapagos Islands.

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CHAPTER 1: GENERAL INTRODUCTION, THESIS AIMS AND GENERAL FIELD METHODS.

Figure 2. Central Galapagos racer hidden among the grass, Seymour Norte. Photo: L. Ortiz-Catedral.

INTRODUCTION

Reptile biodiversity and the global biodiversity extinction crisis

The global diversity of reptiles is estimated at 10000-11000 species, of which 18.2% are threatened with extinction (IUCN, 2019). In addition, 15.4% of reptiles are classified as Data Deficient (IUCN, 2019). According to Alroy (2015) since the start of the 20th century an estimated 46 to 62 Squamate (snakes and lizards) species have become extinct, largely due to anthropogenic factors. Currently there are 28 reptile species categorised as 'Extinct' according to the IUCN Red List (IUCN, 2019). Recent reptile extinctions include iconic species like four different giant tortoises (*Chelonoidis* spp.) of the Galapagos Islands due to human overexploitation and impacts of invasive species (Froyd et al., 2014). Examples of anthropogenic causes affecting reptiles include loss of freshwater habitat for the copperbelly water snake (*Nerodia erythrogaster neglecta*) which requires a mosaic of wetland habitats for foraging (Roe, Kingsbury, & Herbert, 2004; Gibbons, 2000) or large-scale habitat modification, like the expansion of a military base in the Mojave Desert which destroyed a substantial amount of desert tortoise (*Gopherus agassizii*) habitat (Chambers group, 1990, 1991; Doak, Kareiva, Klepetka, 1994).

Other reptile habitats have been directly destroyed to harvest species for the pet trade, collectors use crowbars and hydraulic jacks that affect critical microhabitats that support rock-dwelling lizards and various non-target species (Goode, Horrace, Sredl, & Howland, 2005). Reptile populations reliance on microhabitats within a small area makes them more susceptible to habitat changes, competition becomes high and often residents will defend their territories at the expense of other individuals (Stamps, 1983). The Cobble skink's (*Oligosoma infrapunctatum*) habitat is very limited, with only a single population, the rapid erosion of their coastline habitat is so severely threatening the population that an emergency salvage into captivity was undertaken (Hitchmough, Adams, Jewell, Freeman, 2018). Human development near the shoreline has prevented access to the intertidal zone which sea turtles require for egg survival, the loss of habitat is a result of landowners attempting to stabilize shorelines using protective barriers or planting grasses that entangle and penetrate eggs (Roosenberg, 1991).

Life history traits have been directly linked with higher propensity to extinction include small population size and habitat specialization (Foufopoulos, & Ives, 1999). Islands most affected by habitat alterations have typically had the most affected reptile biodiversity. The Caribbean islands had variable levels of human interference and the islands that were more developed also had more invasive species such as mongooses which alongside habitat destruction were the causes of three Dipsadidae snake extinctions across several islands (Hileman et al., 2017). Developing conservation actions to prevent the extinction of reptile species requires an understanding of the range and intensity of threats, particularly on remnants of native habitat.

Invasive species

Introduced species have a significant effect on native reptile diversity by direct predation, destruction of habitat, or outcompeting them for resources. When species have not co-existed over ecological or evolutionary time-scales, susceptible species to invasive often are not able to adapt fast enough to combat the threats a new species introduces. Poisonous cane toads (*Bufo marinus*) were introduced to Australia without recognising they are instinctive targets for snakes, only the snakes too small to consume them and the few that have a low resistance are not under threat of extinction by them, whereas the remaining 30% of all terrestrial snake species are (Phillips, Brown, Shine, 2003). Cane toad presence is threatening other native predators like freshwater crocodiles, varanid lizards, and frogs (Letnic, Webb, Shine, 2008) (Crossland et al., 2008) (Madsen, Ujvari, 2009). South Florida has three times as many exotic lizard species than native lizards in the wild, some being large predators such as the Nile monitor (*Varanus niloticus*) which, if uncontrolled, are likely predate eggs of the endangered American crocodile (*Crocodilus acutus*) (Hardin, 2007).

Climate change

Climate change is a rapidly increasing threat to global biodiversity. Reptiles are particularly under threat of extinction if the rate of environmental change is rapid because many are reliant on temperature dependent sex ratios which would become strongly biased from the resulting extreme temperatures (Holleley, Sarre, O'Meally, & Georges, 2016). Bearded dragon (*Pogona vitticeps*) sex is strongly influenced by temperature, high temperatures during egg incubation cause phenotypic females with greater fecundity, this would benefit the reproduction via parthenogenesis but reduce genetic diversity generated by sexual reproduction (Holleley et al., 2015). A decline in reproductive success creates a genetic bottleneck regardless of whether the species can adapt to the temperature changes in future generations, forever unnaturally changing the gene pool for better or worse. Not only intergenerational threats may occur by climate change. Experimentally raised tiger snakes (*Notechis scutatus*) were found to have reduced growth rates when exposed to the increased year-to-year variation in climate and mismatches between the thermoregulatory tactics it learned at a young age, small body size leads to reduced maximum prey size and fecundity (Aubret & Shine, 2010). Inbreeding depression, climate change, and habitat fragmentation may have made snakes more susceptible to Snake Fungal Disease (SFD), it was suspected this situation occurred in New Hampshire; leading to a 50% loss of a timber rattlesnake population (*Crotalus horridus*) within 1 year (Clark, Marchand, Clifford, Stechert, & Stephens, 2011; Lorch et al., 2016).

Exploitation

Direct human exploitation of reptiles is strongly supported in countries such as Indonesia, whom initiate logging activities and establish infrastructure for access into formerly remote areas for the unregulated international pet industry and harvesting for food (Koch et al., 2013). Overharvesting of the long-necked turtle (*Chelodina mccordi timorensis*) for food is the population's greatest threat, up to 30 individuals would be collected per day by local people, the turtles are further predated by pigs and dogs but to what extent is unknown (Eisemberg, Costa, Guterres, Reynolds, & Christian, 2016). Human treatment and use of exploited reptiles are most often inhumane and unnecessary. Eastern diamondback rattlesnakes are roundup for mass killing in the US as family friendly festivals, leading to the decline of the species that is already dwindling because of habitat loss, fragmentation and automobile elimination (Means, 2009). Rattlesnake populations are particularly threatened due to repeat harvesting from the same sites over a long time and the targeting of large individuals, which provide the largest clutch sizes, is reducing the reproductive success of local populations (Means, 2009). Snakes have always been vilified by humans because of their potential harm and this has made them a target for extermination, therefore an underappreciated species to conserve.

Snake biodiversity and conservation

Snakes are a more recently evolved reptile group and are nested within Squamata, having diverged from lizards and amphisbaenians around 179 Mya (Vidal & Hedges, 2005). The global biodiversity of snakes is estimated at approximately 3500 species (Vitt and Caldwell, 2009), nevertheless new species are constantly described from south east Asia (Daltry and Wüster, 2002; David et al., 2007) south America (Passos and Fernandez, 2008; Kok, 2006); the middle east (Sindaco et al., 2006) and Australia (Ukuwela et al., 2012). The unique morphology of snakes has been their defining feature and is quickly associated with their deadly predatory abilities. The original snake ancestors were nocturnal stealth hunters of soft bodied prey in warm, well-watered and well-vegetated ecosystems (Hsiang et al., 2015). The enormous diversity of snakes has led to a variety of temperaments, distributions, morphologies and anatomies that enable them to dispatch their specific prey in their habitat. Within the past century two thirds of monitored snake populations have crashed, these seem to be primarily species with small home ranges, sedentary habits, and ambush foraging strategies that are easily disturbed by human activities (Reading et al., 2010). Many snakes have a very scattered and restricted distribution, their poor adaptability to altered habitats makes their populations highly vulnerable so preservation of their natural areas is paramount (Filippi & Luiselli, 2000).

In a changing environment, translocations have been implemented for snakes to be moved away from anthropogenic disturbances and introduced to a more natural setting. In Arkansas, hognose snakes (*Heterodon platirhinos*) that were translocated between 5 to 40 km away resulted in shorter survival than that of resident hognose snakes in the same site, it was predicted their unfamiliarity with their habitat made them more active and more obvious to predators (Plummer & Mills, 2000). A similar trend was observed in translocated tiger snakes (*Notechis scutatus*) which exhibited home ranges 6 times larger than resident snakes, often returning to suburban areas like they were translocated from, which was never observed in residents (Butler, Malone, & Clemann, 2005). In South China, white-lipped pit vipers (*Trimeresurus albolabris*) reproduction and brumation were disrupted by translocation, the males inability to brumate and increased activity led to none making it past winter, the females delayed reproduction and reduced fecundity rendered it a wasted effort (Devan-Song et al., 2016). The translocation attempts reveal the complications that can be involved in attempting to conserve snakes, making them difficult animals to protect when changes to their natural habitat commence. Translocation may be a more effective conservation technique in larger and more isolated natural areas, such as islands. Antiguan racers (*Alsophis antiguae*) translocated from Great bird Island to several other islands in Antigua had good indications of success with accelerated growth and were all alive for at least 6-10 months later, some having laid eggs within 12 months of being released (Daltry et al., 2017). Wild animal translocations have proven to be successful in North American ratsnakes (*Pantherophis obsoletus*), however less successful in snakes kept in captivity; this period should be minimised with a focus on enriching predator avoidance survival skills (DeGregorio, Sperry, Tuberville, & Weatherhead, 2017). Evidently there are snakes that prove to be adaptive and responsive species to conserve when using strategies such as translocation.

Captive rearing and breeding is a more involved conservation method that is often only implemented in dire need to prevent species extinction such as in the catastrophic declines of neotropical harlequin frogs (Bufonidae: *Atelopus*) (La Marca et al., 2005). Captive breeding reptiles have the potential to raise large stocks for the release on target times and lifecycles while limiting stress to donor populations. Captive reared common water snakes (*Nerodia sipedon sipedon*) in Indiana exhibited similar body condition and survivorship compared to resident wild snakes, with no costly naturalistic captive environments required, although resulting lower growth rates than resident snakes suggests possible foraging difficulties in the wild (Roe, Frank, & Kingsbury, 2015). There has been great success in breeding threatened snakes in zoos, such as Whitaker's boa (*Eryx whitakeri*) and King Cobra (*Ophiophagus hannah*), and even private keepers have been selected to breed species such as the broad-headed snake (*Hoplocephalus bungaroides*); which provided an important role of furthering the knowledge of this species (Lobo & Sreepada, 2015, 2018; Shine & Fitzgerald, 1989). The evident success in captive breeding snakes is comforting to ensure we do not lose species when their habitat is lost. However, such programmes can often only slow the rate of population loss as the threats continue to affect the wild populations and their habitat. Commercial snake breeding farms in China were set up to try mitigate the overexploitation of wild snakes; however, this has proven unsuccessful because the farms cannot make a profit without also exploiting wild snakes so they are almost solely storehouses (Zhou & Jiang, 2004). Captive breeding increases human awareness and accessibility to snakes and without proper education the animals can be further exploited despite initially good intentions.

Snakes are an important predator in their natural ecosystem but when they are replaced or overexploited by invasive species their population becomes unstable and to restore balance the invasive species need to be eliminated. The introduction of cane toads (*Bufo marinus*) to Australia showed how the introduction of new prey items can also threaten snake populations (Phillips, Brown, & Shine, 2003). Attempts to train the black snake (*Pseudechis porphyriacus*) to avoid toxic prey have failed, however the wild populations that live alongside cane toads have undergone a strong selection pressure to avoid toads and be more resistant to their toxins (Phillips & Shine, 2006). Understanding which native snake species are adapting to combat the effects of invasive species is important so the least adaptable species can be prioritised for conservation efforts. Introduced cats (*Felis* catus) are one of the greatest threats to reptiles in Australia, they are known to predate snakes from the families: Typhlopidae, Boidae, Colubridae, and Elapidae being targeted most often (Woinarski et al., 2018). Monitoring of elapids revealed that over three active seasons 14% of the monitored population were killed; four by humans, three by feral cats, and one by a raptor (Whitaker & Shine, 2000). Cats are the main predators of native rodents in Australia, which are important natural prey for snakes, it has been found cats are less abundant in areas of high shrub density so the reduction of large herbivores and implementation of fire reduction can create a larger area for native rodents and snakes to thrive with reduced feline interference (Davies et al., 2017). Direct control of cats has proven most effective, using management methods such as; Poison baiting, shooting, and trapping to reduce them in areas or remove them completely within isolated sanctuaries

(Doherty et al., 2017). Similarly, a poison bait programme has been used on invasive black rats (*Rattus* rattus) that were confirmed to be attacking and likely killing Antiguan racers on Great Bird Island, resulting in a substantial population increase of racers (Daltry et al., 2001). The control of invasive species allows the ecosystem to return to its natural state, allowing snakes to have adequate prey, mate availability, genetic variation, and offspring success to maintain their healthy population sizes.

Snakes on Islands

Islands are natural laboratories to understand evolution and speciation. The isolation, climate, biodiversity, and select resources on islands can have a significant effect on the evolution of species. Snakes on islands tend to be smaller than their mainland counterparts. The majority of modern extinctions have occurred on islands, their restricted populations of low abundance make them highly susceptible to anthropogenically caused extinction (Stork, 2009). To compensate for a smaller gene pool within island snake populations they have a greater influence on developmental plasticity so they can easily adapt to environmental pressures such as fluctuations in their prey availability and size (Aubret, Shine, & Bonnet, 2004). Florida cottonmouths (*Agkistrodon piscivorus conanti*) vary greatly in their diet, method of feeding, water availability, colouration, and behaviour between island and mainland populations however they have yet to evolve a significant metabolic differences, perhaps because separation between populations have not been long enough (McCue & Lillywhite, 2002). It is likely the Florida cottonmouths have a high level of developmental plasticity that has allowed many changes in their new environment that are yet to affect them genetically, however may occur over successive generations.

In the Gulf of California, islands where rodents are scarce but small lizards are prolific, rattlesnakes are smaller than their mainland counterparts, therefore the size of the most available prey has a strong influence on snake size (Case, 1978). Climate on islands is also predicted to affect the size of snakes, dwarf rattlesnakes (*Crotalus viridus caliginus*) were found to be smaller than the mainland subspecies because of the cold and foggy climate forcing them to be largely diurnal so they are warm enough to hunt lizards, whereas the mainland snakes are crepuscular and target larger rodents (Case, 1978; Klauber, 1949). Snakes on islands typically differ in diet from their mainland counterparts, there are several examples of this within species. The Taiwanese Bamboo Viper (*Trimeresurus stejnegeri*) on Green and Orchid Islands have a diet that contains fewer amphibians; due to the islands topology and microclimate being unsuitable for a large percentage of frogs, therefore the snakes have a heavier reliance on more reptilian prey (Creer, Chou, Malhotra, & Thorpe, 2002). Prey availability is a significant limiting factor for snakes on islands, it is beneficial for them to accept a wide range of prey items. It is also beneficial for island snakes to have phenotypic plasticity so they can accommodate different prey items into their diet. Tiger snakes (*Notechis ater*) on offshore islands in southern Australia have completely changed their diet which has had a direct correlation to their size differences between other populations (Schwaner, Grigg, Shine, & Ehmann, 1985; Schwaner & Sarre, 1988).

When analysing captive reared European grass snakes (*Natrix natrix*) it was concluded that island populations had smaller body sizes than mainland populations as a result of low food availability and smaller prey item size on the island, these snakes grew more slowly and stopped growing at smaller sizes (Madsen & Shine, 1993). Evidently diet is an important part of the divergence and speciation between mainland and island populations. Island size can dictate how similar the species composition is in relation to the mainland, this has the potential to significantly affect genetic drift in snake populations, leading to speciation. Snakes on the Izu Islands in Japan have similarly undergone adaptations in body size variation different to the mainland populations as a result of their diet, however on a larger island closest to the mainland; one species (*Elaphe climacophora*) has had little change in body size from the mainland population (Hasegawa, 2003). It was found that diet was also directly related to the size of these snakes, with prey size strongly correlated with snake size (Hasegawa, 2003; Hasegawa & Moriguchi, 1989). This same trend was observed in Tiger snakes with strong selection pressure to optimise body size when the size range of natural prey items was reduced, leading to dwarfs or giants evolving independently in different islands with different prey sizes (Keogh, Scott, & Hayes, 2005). The dietary changes of snakes on islands has had a clear effect on their body morphology as the most efficient body sizes in these new environments are selected for. Thus, island snakes exhibit plasticity in a range of characters and life-history traits that enables them to colonise insular environments. However, this plasticity does not necessarily protect island snake species from the effects of introduced predators.

Galapagos terrestrial snakes

The Galapagos Islands is home to nine species of terrestrial snakes (Fig. 3) and one species of sea snake (Arteaga et al., 2019). It is estimated the Galapagos racer snakes (*Pseudalsophis sp.*) shared their most recent common ancestor on the mainland at 6.9 Ma, then began to radiate in the Galapagos Archipelago at 4.4 Ma (Zaher et al., 2018). Considering todays islands emerged less than 5 Ma these snakes had to quickly adapt to a very harsh, new environment with changes to the climate, landscape, vegetation, prey, and predators (Rassmann, 1997). *Pseudalsophis elegans* is the only known species within the genus that exists outside the Galapagos islands, this is a mainland counterpart that is naturally distributed in the western Andes along the coastal deserts from southern Ecuador to Chile (Myers, 1974). Today the variety of habitats across the Galapagos archipelago has allowed for the diversification of these snakes into nine species spread across all major islands and islets apart from the northern islands of Marchena, Darwin, Wolf, Genovesa, and Pinta (Zaher et al., 2018).

Figure 3. Galapagos terrestrial snakes, from top left: central Galapagos racer (*Pseudalsophis dorsalis*); Espanola racer (*P. hoodensis*); western Galapagos racer (*P. occidentalis*); Pinzon racer (*P. slevini*); painted racer (*P. steindachneri*); Thomas' racer (*P. thomasi*); Darwin's racer (*P. darwini*); eastern Galapagos racer (*P. biserialis*) and Santiago racer (*P. hephaestus*). Photos: L. Ortiz-Catedral.

Considering these snakes are isolated in small island populations, they are susceptible to most of the threats outlined earlier in this chapter. Invasive mammalian predators are a major concern in the Galapagos Islands and have led to the decline of many native reptiles. Young land iguanas (*Conolophus sp,*) were heavily predated by domestic and feral cats (*Felis catus*) and adult iguanas by dogs (*Canis familiaris*) (Kruuk, 1979). Both land iguanas and tortoises (*Chelonoides sp.*) are outcompeted by goats, and tortoise nests are destroyed by pigs (*Sus scrofa*), dogs and fire ants (*Solenopsis*), hatchlings are predated by black rats, and tortoises of all sizes were poached (Cayot, 2008). Lava lizards are the most consumed prey of feral cats; which can easily outcompete any native predators for them, such as snakes; which may also be preyed on by cats (Carrión & Valle, 2018; Christian, 2017). Snakes are likely targeted by most of these invasive species if they are accessible to them and considering how close many of the islands are these predators may soon reach other snake populations. Invasive predator incursions may also be assisted by increased amounts of fishing and tourist activity, especially during El Nino years when rats are often seen swimming offshore (Key & Muñoz Heredia, 1994). The introduction of any invasive predators can be a direct threat the snake population or their prey. Being isolated on an island would mean prey may be a limited resource so if a snake were outcompeted, they would also perish. However, if they were more reliant on transient or seasonal prey items, they may be able to handle reduced feeding for the time being. It is therefore important to understand the diet of these snakes in order to develop sound conservation plans.

The present study

I investigated aspects of the biology of the poorly known Central Galapagos racer (*Pseudalsophis dorsalis*) to assist the Directorate of the Galapagos National Park (DGNP) and the Ministry of Environment of Ecuador, in developing conservation actions for this and other species of Galapagos terrestrial snakes. Preliminary field observations by park rangers of the DGNP in 2000-2015 suggest that the diversity of terrestrial snakes in the Galapagos Islands includes a number of undescribed species and populations. Further, anecdotal information and preliminary data indicates that the Galapagos terrestrial snakes exhibit a generalist diet. DGNP and partners are considering a plan to translocate Galapagos terrestrial snakes between islands (K. Campbell, Island Conservation, pers. comm., Christian, 2017). One such translocation is the future reintroduction of the Floreana racer (*Pseudalsophis biserialis biserialis*) back to Floreana Island, using individuals from the only two remnant known populations on the islets of Champion and Gardner-by-Floreana (Christian, 2017). The Floreana racer became extinct on Floreana Island in the late 1800s (Steadman, 1986) and recent searches for the species have failed to detect individuals or signs of its presence (Jimenez-Uzcategui and Ortiz-Catedral, 2017). Another potential translocation involves the central Galapagos racer (*Pseudalsophis dorsalis*), the focal species for this study. The central Galapagos racer has disappeared from most of its range on Santa Cruz Island (Arteaga et al., 2019), however smaller islands and islets harbour populations of this species and could serve as sources for future translocations. However, very little is known about their biology, in particular their diet and morphological variability. It is important to understand the range of prey species that these snakes consume as well as their inter-population morphological variability to better assess the suitability of potential release sites, and to represent the range of phenotypic variants at release populations.

The thesis presented here is part of a larger project investigating the taxonomy, biology, and conservation status of terrestrial snakes across the Galapagos Islands led by a research group that includes my supervisor, Dr. Luis Ortiz-Catedral from Massey University (New Zealand), Dr. Danielle Edwards from UC Merced (USA), Dr. David Salazar and Dr. Monica Paez from Universidad Indo-America (Ecuador), and Dr. Juan Guayasamin from Universidad San Francisco de Quito (Ecuador). Local Ecuadorian partners include the DGNP, Island Conservation and the Charles Darwin Research Station.

The relevant permits for accessing restricted field sites, and to capture, measure and collect faecal samples from snakes are presented in Appendices I and II. All animals were handled according to the Animal Ethics guidelines outlined by the DGNP and Ministry of Environment, Ecuador. Training in the field for handling species endemic to the Galapagos Islands, was received by rangers from the DGNP and my supervisor. No Animal Ethics Approval from Massey University is required as this research took place entirely in Ecuador.

COVID-19 declaration

In 2019, I completed a preliminary assessment of the El Eden population of the central Galapagos racer (see Chapter 4). The original plan was to revisit this site in 2020 to assess the effect that black rats have on the resident snakes. I obtained funds from the Auckland Zoo Conservation Fund to complete this part of my thesis (Appendices III and IV), scheduled to start in June 2020. Additional fieldwork in 2020 would have also included further sampling on Seymour Norte and Baltra Islands (see Chapter 2). Due to the COVID-19 pandemic and the travel restrictions in place, my supervisor and I decided to abandon this research component because I would need at least another year to complete my thesis as travel restrictions are lifted, and field operations in the Galapagos Islands resume. As a result, I could not complete this component of my thesis as originally envisaged. The COVID-19 pandemic and the resulting lockdown in New Zealand from March to June 2020 has affected my ability to develop my thesis. Following conversations with my supervisor, we decided to optimise the content of my thesis so I could complete my degree in 2020. Therefore, some research components could not be explored thoroughly owing to limited samples available.

THESIS AIMS

1. Characterise the diversity of the dietary composition of eight species of Galapagos terrestrial snakes on 11 populations across the Galapagos Islands with particular emphasis on the central Galapagos racer.
2. Describe the colour variation of the widespread central Galapagos racer on four populations.
3. Evaluate the status of central Galapagos racer populations on islets > 1.5 ha in size near Santa Cruz Island.
4. Identify significant gaps in research for future studies on Galapagos terrestrial snakes.

STUDY SITES

The analyses presented in this thesis are based on samples collected over two years, on 21 localities on 16 islands and islets across the Galapagos Islands (Table 1). I conducted sampling and field observations on 17 localities and 14 islands and islets, however due to the scale of sampling, different teams visited different localities and I could not be personally present on all of them. Nevertheless the same field protocols were followed. In this section, I provide a description of the study areas, and study sites. Further descriptions of the areas and sites are provided in chapters 2 and 4. In addition to these, I also had the opportunity to visit six other islands and islets to collect the information presented in chapter 3. Most of these visits were short in duration, lasting 58 man hours on average. All sites were accessed aboard the "El Pirata", one of the four approved research vessels in the Galapagos Islands. During each fieldtrip I was supported by two to three rangers of the Directorate of the Galapagos National Park and one to two volunteers. My supervisor also assisted in most fieldtrips. Due to the scale of the sampling, the capture of snakes and collection of samples was done in teams, therefore I was unable to be present during the sampling of some localities, for instance Fernandina in June 2018 and Pinta and Santiago in August 2019. The relevant permits to conduct this research including boat access are presented in Appendices I and II. During 2017-2019 I had the opportunity to visit these field locations on a multi-island trip, departing from Santa Cruz Island and visiting a total of 10 localities. The direction of the boat trip and locations visited are presented in Fig. 3. The locations visited are shown in Fig. 4.

Figure 4. Direction of fieldtrips described in this thesis. Purple = December 2017; Yellow = June 2018; Red = July 2019; Black, Green and White = August 2019.

Figure 5. Locations sampled during 2017-2019 in the Galapagos Islands, Ecuador.

Each trip aboard the El Pirata consisted of visits for two to four days on localities where park rangers had observed snakes or from where key museum specimens were collected (see Thomas, 1997). Strict quarantine and biosecurity protocols during each visit were followed according to field protocols and permits by the Directorate of the Galapagos National Park (see Appendices I and II).

Baltra Island (0° 25’ 30” S, 90° 5’ 13.6” W) 2619.6 ha (Snell et al., 1996).

Baltra Island is located north of the central island of Santa Cruz. It is inhabited by members of the Ecuadorian Army and it is also one of the points of access to the Galapagos Islands as it holds the largest airport. Baltra is predominantly flat. The vegetation consists predominantly of palo santo (*Bursera graveolens*), prickly pear (*Opuntia echios var. echios*) and palo verde (*Parkinsonia aculeata*) (Fig. 4). Baltra was visited twice, once in 2017 and once in 2019. The locality visited in 2017 is known as Salinas, an area of approximately 93 ha. In 2019, searches were conducted at El Basurero, an area of approximately 40 ha. A team of six surveyed both areas for a total of 120 man-hours (Table 1). Two species of Galapagos terrestrial snake are found on Baltra Island and occur in sympatry: the central Galapagos racer (*Pseudalsophis dorsalis*) and the painted racer (*Pseudalsophis steindachneri*).

El Eden (0° 33’ 41” S, 90° 32’ 11.2” W) 23 ha (Snell et al., 1996).

El Eden is a small islet located west of the central island of Santa Cruz. It is very close to the shore of Santa Cruz, separated by a mere 293 m gap. During low tide, numerous rocks are exposed making this separation temporarily narrower. El Eden is a remnant hillside, the highest point is approximately 65 m. The vegetation consists predominantly of palo santo, prickly pear and muyuyo (*Cordia lutea*) (Fig. 4). Snakes were surveyed in a 10ha area. A team of six surveyed the area for a total of 37.5 man-hours (Table 1). The central Galapagos racer is the only species found there. This population is discussed in detail in Chapter 4.

Espanola (1° 22’ 30” S, 89° 40’ 30” W) 6048 ha (Snell et al., 1996).

Espanola is a large island and the southernmost in the archipelago approximately 45 km from San Cristobal. I visited two sites: Playa Gardner and El Manzanillo, both near the shore and with similar features. The vegetation consists predominantly of shrubby chala (*Croton scouleri*), algarrobo (*Prosopis julliflora*) and Espanola prickly pear (*Opuntia megasperm var. orientalis*) and muyuyo (*Cordia lutea*) (Fig. 4). Only one species of snake inhabits Espanola, the Espanola racer (*Pseudalsophis hoodensis*). A team of five surveyed a total area of 139 ha (Table 1).

Fernandina (0° 22’ 0” S, 91° 31’ 20” W) 64248 ha (Snell et al., 1996).

Fernandina island is large, and the westernmost in the archipelago. I did not visit Fernandina for this study, but my supervisor and two park rangers surveyed an area of 30 ha in Cape Douglas during the month of June 2018, for 48 man-hours (Table 1). Two species of snakes are found here: the very common western Galapagos racer (*Pseudalsophis occidentalis*) and the elusive Darwin’s racer (*Pseudalsophis darwinii*). Only samples of the former were collected. The vegetation in Cape Douglas consists of montesalado (*Cryptocarpus pyriformis*) (Fig. 4).

Pinzon (0° 36’ 30” S, 90° 39’ 57” W) 1815 ha (Snell et al., 1996).

Pinzon is located west of Santa Cruz. A team of four, including myself surveyed an area of 45 ha for 96 man hours in December 2017 (Table 1). A single species of snake is found on Pinzon, the Pinzon racer (*Pseudalsophis slevini*). The vegetation of the area surveyed consists mostly of algarrobo and prickly pear (*Opuntia galapageia*) (Fig. 4).

Santa Cruz (0° 36’ 30” S, 90° 39’ 57” W) 98555 ha (Snell et al., 1996).

Santa Cruz is located in the centre of the archipelago. It is a large island with a variety of vegetation types and a complex topography. Two species occur here, the central Galapagos racer and the painted racer, however reports of the former are very rare (see also Chapter 5). I searched for snakes at two sites, Las Ninfas in Puerto Ayora, the largest town in the Galapagos Island on the south of the island, and on the northern part of the island, at the Canal the Itabaca. In Puerto Ayora, a team of three conducted searches for painted racer in an area of 10 ha for 16 man-hours (Table 1). The area surveyed is a residential area with some native plant species like chala, palo santo, palo verde, prickly pear (*Opuntia echios*) (Fig. 4). On the northern part of Santa Cruz a team of five searched for snakes in an area of eight ha, for 10 man-hours (Table 1) (Fig. 5).

Santa Fe (0° 49’ 0” S, 90° 3’ 30” W) 2413 ha (Snell et al., 1996).

Santa Fe is located south-east of Santa Cruz. A single species of snake occurs here, central Galapagos racer. A team of five searched an area of 10 ha for 30 man-hours (Table 1). The area surveyed is covered predominantly with prickly pear (*Opuntia echios* var. *barringtonensis*) (Fig. 5).

Santiago (0° 15' 30" S, 90° 43' 30" W) 58465 ha (Snell et al., 1996).

Santiago is located north-east of Santa Cruz. It is a large island with complex topography and various vegetation assemblages. A team of five surveyed a combined area of 121 ha at two sites: Bucanero and Puerto Nuevo. Two species of snake occur at both sites, Thomas' racer (*Pseudalsophis thomasi*) and the Santiago racer (*Pseudalsophis hephaestus*). Both species were seen, but only individuals of Thomas' racer were successfully captured. The predominant vegetation at both sites is composed of palo santo and prickly pear (Fig. 5).

Seymour Norte (0° 23' 30" S, 90° 17' 0" W) 183.88 ha (Snell et al., 1996).

Seymour Norte is located north of Baltra, and exhibits a largely homogeneous vegetation. The predominant species is palo santo, with an understory of Seymour Norte prickly pear (*Opuntia echios* var. *zacona*) (Fig. 5). Two species of snake occur here, the central Galapagos racer and the painted racer. Two areas were sampled, La Plataforma on the northern side of the island and the Zona Turistica, on the south-west. Snakes were only found at the former locality. A team of seven searched for snakes in an area of 32.5 ha for 306.5 man-hours (Table 1).

Venecia (0° 15' 30" S, 90° 43' 30" W) 13.79 ha (Snell et al., 1996).

Venecia is a small islet separated from Santa Cruz on high tide by a mere 30 m gap. The vegetation consists of palo santo stands, prickly pear understory and black mangrove (*Avicennia germinans*) fringes near the coast that can extend several meters inland (Fig. 5). Searches for central Galapagos racer and painted racer were in an area of 8 ha, known as the

Zona de Anidacion, an area of loose terrain were land iguanas (*Conolophus subcristatus*) nest every year. Only individuals of the painted racer were found (Table 1).

Champion (0° 14’ 7” S, 90° 23’ 8” W) 9.5 ha (Snell et al., 1996).

Champion is an offshore islet near the coastline of Floreana in the south of the archipelago. At low tide the distance to the coastline is 730 m. The islet is a small eroded volcanic cone. The predominant vegetation consists of Floreana prickly pear (*Opuntia megasperma megasperma*), Candelabro (*Jasminocereus thouarsii*), muyuyo and palo verde (Fig. 6). The only snake species found here is the Floreana racer (*Pseudalsophis biserialis biserialis*) (Table 1.)

Bowditch (0° 31’ 57.7” S, 90° 31’ 1.7” W) 3 ha (Snell et al., 1996).

Bowditch is a small islet, only 270 m from the coastline of Santa Cruz island at low tide. The predominant vegetation is prickly pear (*Opuntia echios*) and an understory of chala (Fig. 6). There are no confirmed records of snakes here, but the two potential species include the central Galapagos racer and the painted racer.

Guy Fawkes 4 (0° 30’ 45” S, 90° 31’ 39” W) 3.4 ha (Snell et al., 1996).

This islet is a highly eroded volcanic cone with sparse herbaceous vegetation (Fig. 6). There are no confirmed records of snakes on this islet, however park rangers have reported lava lizards and geckos. Due to its proximity to Santa Cruz (2000 m), the potential two snake species are the central Galapagos racer and the painted racer (Table 1).

Pinta (0° 35’ 18” N, 90° 45’ 17” W) 5940 ha (Snell et al., 1996).

Pinta is a large island covered in scrubby vegetation, muyuyo and Pinta prickly pear (*Opuntia galapageia*) (Fig. 6). There are no confirmed records of snakes from Pinta, however park rangers have reported a sighting of a snake near the coastline. It is unclear whether Pinta supports populations of snakes, and a three day expedition took place to survey the area, however, no evidence of snakes was found (Table 1).

Plaza Norte (0° 34’ 36” S, 90° 09’ 32” W) 8.8 ha (Snell et al., 1996).

Plaza Norte is a small islet off the coast of Santa Cruz Island, covered in thick vegetation that includes palo verde, prickly pears and herbaceous vegetation (Fig. 6). the potential two snake species are the central Galapagos racer and the painted racer (Table 1). Due to the proximity (ca. 300 m) to Plaza Sur, both islands are commonly referred to “Plazas”.

Plaza Sur (0° 34’ 56” S, 90° 09’ 57” W) 12 ha (Snell et al., 1996).

Plaza Sur is a small islet off the coast of Santa Cruz Island, covered in sparse vegetation due to the presence of a high-density population of Galapagos land iguana (Fig. 6). The potential two snake species are the central Galapagos racer and the painted racer (Table 1).

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Figure 4. Landscape photographs of field sites samples during this research. Top row from left: Baltra, El Eden and Espanola.

Bottom row from left: Fernandina, Pinzon, Puerto Ayora (Santa Cruz).

Figure 6. Landscape photographs of field sites samples during this research. Top row from left: North Santa Cruz, Santa Fe and Bucanero (Santiago). Bottom row from left: Puerto Nuevo (Santiago), Seymour Norte and Venecia.

Figure 7. Landscape photographs of field sites samples during this research. Top row from left: Guy Fawkes 4, Champion, Bowditch.

Bottom row from left: Pinta, Plaza Norte, Plaza Sur. Photos: L. Ortiz-Catedral.

Table 1. Localities and snake species surveyed during this research.

Locality	Island	Species	Search area (ha)	Search effort (Man-hours)	Individuals caught	Faecal samples obtained
Salinas	Baltra	*Pseudalsophis steindachneri*	93	72	1	1
		Pseudalsophis dorsalis	93	72	0	0
El Basurero	Baltra	*Pseudalsophis steindachneri*	40	48	11	2
		Pseudalsophis dorsalis	40	72	7	1
El Eden	El Eden	*Pseudalsophis dorsalis*	10	37.5	8	3
Playa Gardner	Española	*Pseudalsophis hoodensis*	38	80	5	5

Locality	Island	Species	Search area (ha)	Search effort (Man-hours)	Individuals caught	Faecal samples obtained
Manzanillo	Espanola	*Pseudalsophis hoodensis*	31	59	8	5
Cape Douglas	Fernandina	*Pseudalsophis occidentalis*	15	48	100	66
		Pseudalsophis darwinii	15	48	0	0
El Estadio	Pinzón	*Pseudalsophis slevini*	45	96	14	14
Las Ninfas	Santa Cruz	*Pseudalsophis steindachneri*	10	16	4	4
Canal de Itabaca		*Pseudalsophis steindachneri*	8	10	0	0

Locality	Island	Species	Search area (ha)	Search effort (Man-hours)	Individuals caught	Faecal samples obtained
Canal de Itabaca	Santa Cruz	*Pseudalsophis dorsalis*	8	10	0	0
Las Tunas	Santa Fe	*Pseudalsophis dorsalis*	10	30	4	4
Bucanero	Santiago	*Pseudalsophis thomasi*	61	144	3	3
		Pseudalsophis hephaestus	61	144	0	0
Puerto Nuevo		*Pseudalsophis thomasi*	60	28.5	8	8
		Pseudalsophis hephaestus	60	28.5	0	0

Locality	Island	Species	Search area (ha)	Search effort (Man-hours)	Individuals caught	Faecal samples obtained
La Plataforma	Seymour Norte	*Pseudalsophis dorsalis*	24	297.5	77	0
		Pseudalsophis steindachneri	24	297.5	3	3
Zona Turistica		*Pseudalsophis dorsalis*	8.5	9	0	0
		Pseudalsophis steindachneri	8.5	9	0	0
Zona de Anidacion	Venecia	*Pseudalsophis dorsalis*	8	15	0	0
		Pseudalsophis steindachneri	8	15	2	2

Locality	Island	Species	Search area (ha)	Search effort (Man-hours)	Individuals caught	Faecal samples obtained
Bowditch	Bowditch	*Pseudalsophis dorsalis*	2	8	0	0
		Pseudalsophis steindachneri	2	8	0	0
Champion	Champion	*Pseudalsophis biserialis*	9	20	4	4
Embarque	Pinta	*Pseudalsophis sp.*	200	40	0	0
Plaza Norte	Plaza Norte	*Pseudalsophis dorsalis*	7	6	0	0
		Pseudalsophis steindachneri	7	6	0	0

Locality	Island	Species	Search area (ha)	Search effort (Man-hours)	Individuals caught	Faecal samples obtained
Plaza Sur	Plaza Sur	*Pseudalsophis dorsalis*	7	12.5	0	0
		Pseudalsophis steindachneri	7	12.5	0	0
Guy Fawkes 4	Guy Fawkes 4	*Pseudalsophis dorsalis*	1	2	0	0
		Pseudalsophis steindachneri	1	2	0	0

STUDY SPECIES

In the course of this research, I collected samples of eight species of Galapagos terrestrial snakes, however the emphasis is on the central Galapagos racer (*Pseudalsophis dorsalis*). This species is one of the most widespread in the archipelago, and exhibits a complex taxonomic history. At present, it is managed as a single species, but it is likely that the different populations represent distinct undescribed taxa. For example in the course of this research the populations of Santiago and Rabida Island were described as distinct new species, Thomas' racer (*Pseudalsophis thomasi*) (Zaher et al., 2018). The taxonomy followed here is consistent with Arteaga et al. (2019). Thus, the populations sampled in this study might well represent distinct species. There are molecular studies underway at the University of California, Merced at the Edwards Herpetology Lab that might clarify the current situation of the central Galapagos racer in coming years. One of the priorities for snake conservation outlined by the Galapagos National Park in the Annual Operations Plan 2017 is to identify populations of the central Galapagos racer on outlying islets of Santa Cruz, which might serve as sources of individuals for subsequent translocations in coming years (see Chapter 4). Therefore, my research focuses on this species. Descriptions of the other species discussed in this thesis can be found in Zaher et al. (2018) and Arteaga et al. (2019).

Central Galapagos Racer *Pseudalsophis dorsalis* (Steindachner, 1876) (Fig. 7).

Medium to large-sized colubrid, ventral scales > 210, post-ocular scale series usually 2, rarely 3, dorsal colouration variable light grey, light brown, pale yellow, pale green or pale pink . Colour pattern spotted or stripped, sometimes both morphs occurring in the same population, head with pattern visible (Thomas, 1997). Stripes distinct for the entire length of the body. Type locality "Santa Cruz", collected in 1868 (Steindachner, 1876).

Figure 8. Type specimen of central Galapagos racer at the Vienna Museum, Austria. Photo: G. Gassner.

There are no details about the exact locality of collection of the type specimen of the central Galapagos racer. The general consensus among researchers on the group is that, most likely the collection was near the coast of Puerto Ayora. Since the mid 1800s this has been the centre of human activity and the busiest port in the Galapagos Islands (Lundh, 2001), where explorers and traders were lodged while visiting the islands. Later collections by the California Academy of Sciences in 1905 indicate snakes were common in Santa Cruz, with Slevin stating "saw more snakes on this island than any other so far" (Slevin, Fritts and Fritts, 1982). There are also at least four specimens of central Galapagos racers collected in Academy Bay, Puerto Ayora collected by Van Denburgh at the American Museum of Natural History (Thomas, 1997).

Field guides, local scientists and park rangers have mentioned that the "culebras moteadas" (spotted snakes) used to be common in Puerto Ayora but since the 1970s sightings are rare and mostly in areas with low feral cat density as well as islets (Ortiz-Catedral, pers. comm). Local photographer and naturalist, Tui de Roy, mentioned in 2017 that she had seen and photographed central Galapagos racer on El Eden islet in the 1980s (de Roy, pers. comm.). Local herpetologist Alizon Llerena suggested that offshore islets might still harbour significant populations of central Galapagos racers (A. Llerena, pers. comm.) however, visits in the last 10-15 years by park rangers have not noticed snakes on these islets. The fragmented information about the current status of the central Galapagos racer on Santa Cruz Island, the type locality, indicates that numbers of this snake have reduced, however no systematic survey has attempted to verify this. The species is still common on nearby islands to Santa Cruz: Baltra, Seymour Norte and Santa Fe (Fig. 8) (see also Chapters 3 and 4).

GENERAL FIELD METHODS

Galapagos terrestrial snakes exhibit a bi-modal pattern of activity (Altamirano, 1991; Christian, 2017). Previous research on the Floreana racer and preliminary surveys in 2016-2017 indicate that snakes are active from 5:30 a.m. to 10:00 a.m. and from 5:30 p.m. to 6:30 p.m. (Ortiz-Catedral, pers. comm.). However, snakes could be found actively hunting outside these main periods, for instance on Fernandina Island (R. Wollocombe, pers. comm.). Searches were conducted by teams of two to seven trained volunteers and park rangers during the main activity periods. Whenever a snake was located, it was captured by hand and placed in a cotton bag for later examination. The locality of each capture was registered in a GPS, however the fine scale geographic distribution of the snakes captured for this research falls outside the scope of my research and it is therefore not discussed in subsequent chapters. If captured early in the morning, snakes were measured and photographed within 1.5 to 2 hours of capture as per specifications of research permits, or if captured in the evening, released the morning after at exactly the same location where they were found. The following measurements were recorded: snout-vent length (SVL), tail length (T), total length (TL), mass, head width (HW), and head length (HL). Measurements were taken from drawn silhouettes on a plastic box (Fig. 9) as this method is faster and less intrusive than hand-measuring. Standard scale series were also registered (see Christian, 2017). Snakes were photographed against a white background with a reference Spydercheckr ® colour card.

Faecal samples were obtained from individual snakes using the palpation technique. I was trained in the field on this method by my supervisor. This method is moderately intrusive to snakes and has been used to successfully obtain samples from a range of snake species, including Galapagos terrestrial snakes (Daltry et al., 1996; Williams et al., 2016; Ortiz-Catedral et al., 2019). In brief, each snake is held firmly around the mid-body, then gentle pressure is applied alongside the intestinal tract in the direction of the cloaca until faecal is expelled. In numerous cases, it was not necessary to palpate snakes as these will defaecate during handling, or in the cotton bag. Faecal samples were collected in 2 ml micro-centrifuge tubes and fixed in 0.5-1.5 ml of 96 % ethanol until examination for contents. An alternative to study the diet of snakes consists in forced regurgitation (Drummond and Garcia, 1989; Manjarrez et al., 2013), nevertheless this method is more intrusive and only successfully if the snakes have ingested prey recently. In contrast, faeces can remain in the intestinal tract for longer, thereby providing information on range of prey consumed over various days in some cases.

Faecal samples were examined and photographed using a Celestron handheld digital microscope Pro. Faeces contained highly fragmented remains of prey. I recognised 29 general categories of prey remains found in faecal samples (Table 2). In most cases, prey could be identified to species level by comparison with reference voucher specimens at the Invertebrate and Vertebrate Collection Labs of the Charles Darwin Research Station in Puerto Ayora, Santa Cruz, Ecuador. A full catalogue of voucher specimens can be accessed via darwinfoundation.org/en/datazone. After examination, samples were returned to plastic tubes and deposited at the Directorate of the Galápagos National Park.

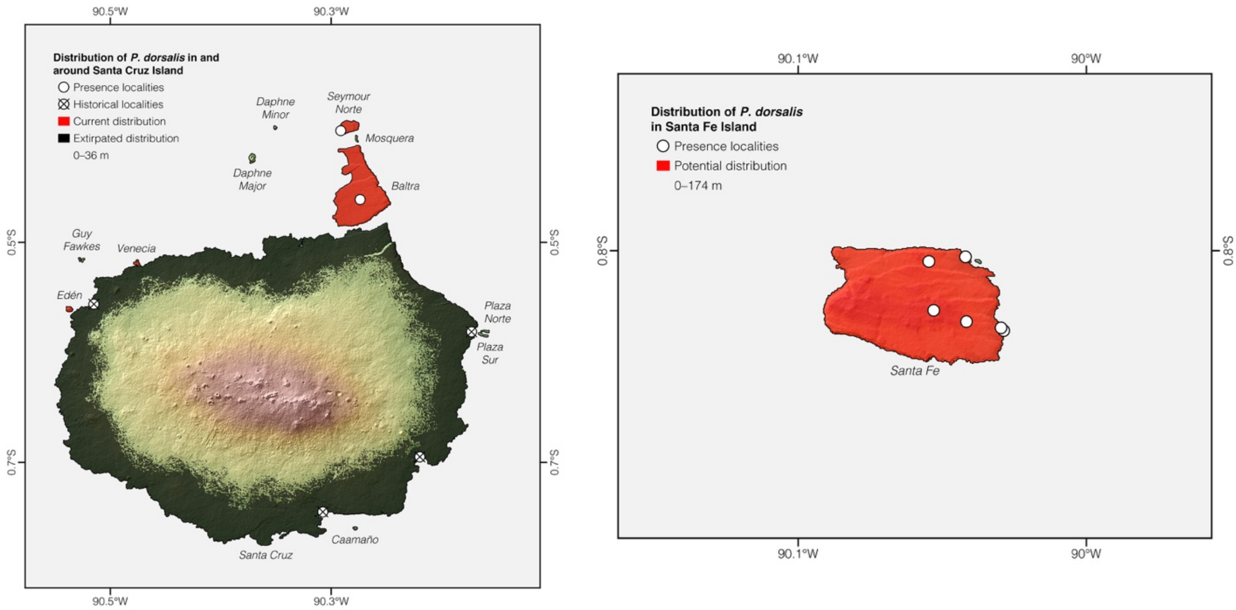
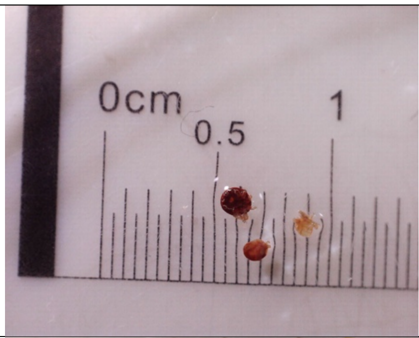
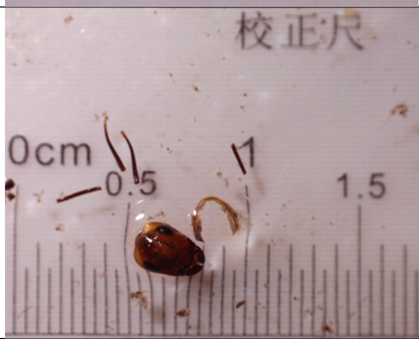
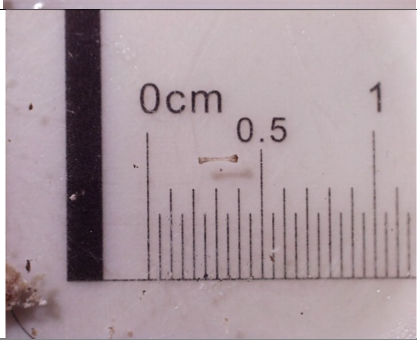
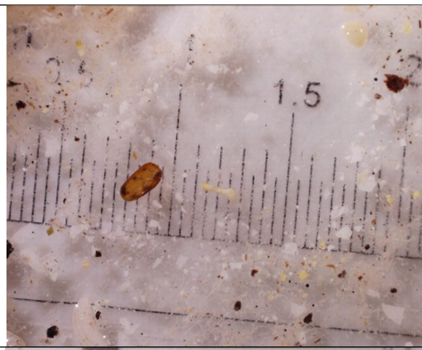
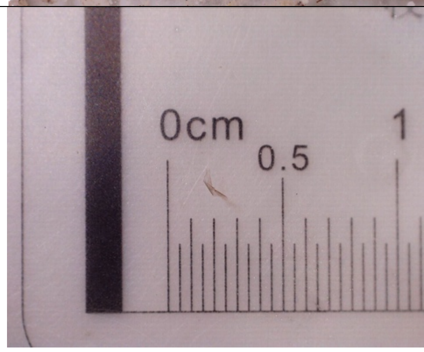
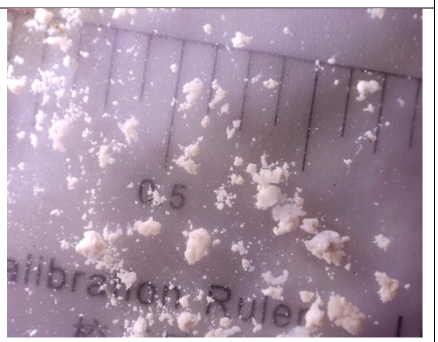


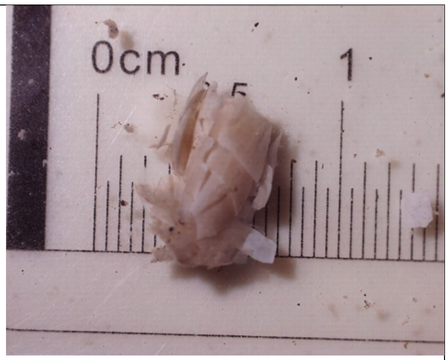
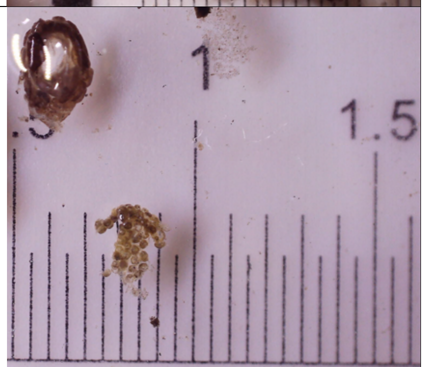
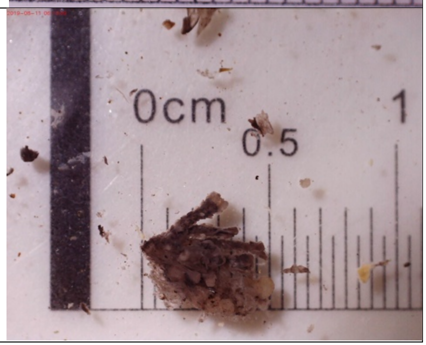
Figure 9. Distribution of central Galapagos racer on Santa Cruz and nearby islands (left) and Santa Fe (right). Distribution maps from Arteaga et al. (2019).

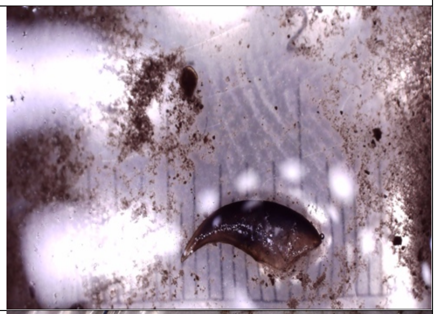
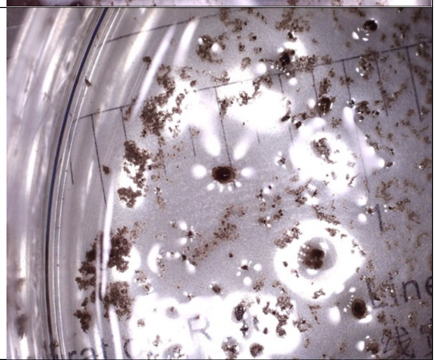
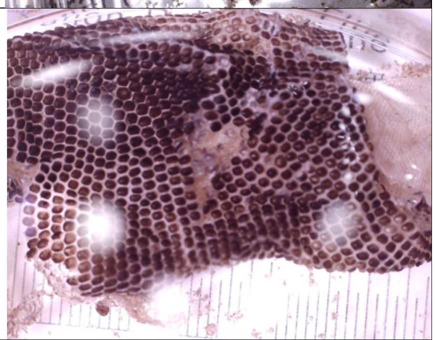
Figure 10. Measuring and photographing snakes in the field. Top row: snakes are placed inside a plastic box and a piece of foam pressed carefully to hold them in place. Bottom row: after measuring, individual snakes are photographed on a white background. Photo: L. Ortiz-Catedral.

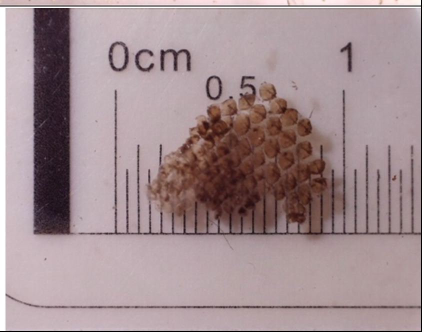
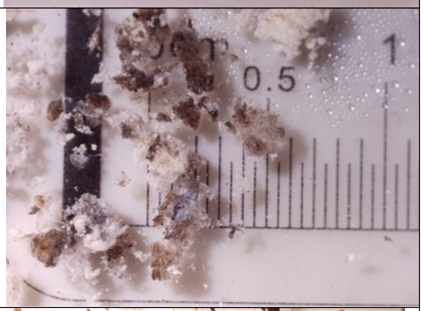
Table 2. Prey categories used to classify material found on 133 faecal samples of Galapagos terrestrial snakes.

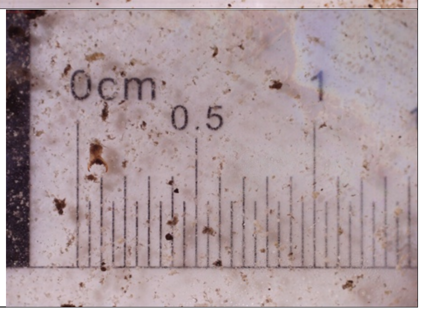
Prey category	Description	Reference image
Acari	Whole acari, tick or mite.	
Ants	Whole ant body or ant head.	
Spider	Whole spider or body fragment.	
Bone fragment	Whole bones or fragmented bones.	

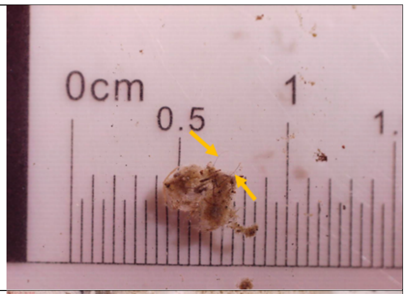
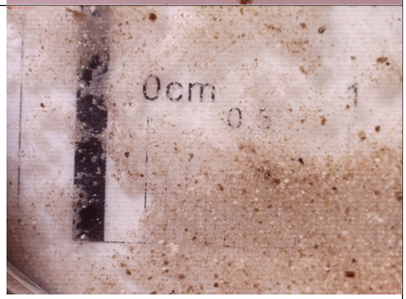
Beetle elytron	Individual coleopteran elytron.	
Fly wing	Individual dipteran wing.	
Faecal ground mass	Tightly packed white or pale-yellow granules consisting of uric acid and calcium (Doherty, 2005).	
Feather	Whole feathers, afterfeathers or loose barbs.	

Gecko eggshell	Brittle white or pale-yellow eggshell fragments.	
Gecko foot	Whole or fragmented foot.	
Gecko skin	Section of skin with scales attached.	
Gecko toes	Whole or fragmented toes or pads.	

Grit	Small rocks.	
Iguana claw	Loose claws.	
Iguana scales	Individual scales.	
Iguana skin	Section of skin with scales attached.	
Lava lizard claw	Loose claw.	

Lava lizard foot	Whole or fragmented foot.		
Lava lizard scales	Individual scales.		
Lava lizard skin	Section of skin as opposed to individual scales.		
Lava lizard tail	Whole or fragmented tail with scales attached. Scales more or less rectangular.		
Plant material	Any plant material including flowers, leaves, seeds etc.		

Sand	Sand.		
Seashell fragments	Small seashell fragments found in sand.		
Snake skin	Section of skin as opposed to individual scales.		
Snake teeth	Maxillary, pterygoid, palatine or dentary teeth.		
Termite mandible	Whole or fragmented mandible.		

Unidentified hair	Mammalian hair.	
Unidentified organic matter	Pale brown to white soft mass without distinguishable fragments. Not composed of granules like faecal ground matter.	

THESIS OUTLINE

The present thesis consists of five chapters, three prepared in the standard format for a thesis chapter, and two prepared as research papers. At the time of submission of this thesis, these papers have been submitted for review. Below I present a description of the contents of each chapter.

CHAPTER 1

This chapter includes a general introduction to the current state of reptile conservation worldwide and the main knowledge gaps identified in the recent literature, with emphasis on snakes. I also present a description of the different study sites and present a description of the general field methods and contents of each chapter in this thesis.

CHAPTER 2

In this chapter I describe the prey type and prey species consumed by seven species of Galapagos terrestrial snakes. I also discuss the relevance of these findings for the conservation of populations of snakes in the archipelago, and document for the first time, evidence of cannibalism among conspecifics.

CHAPTER 3

In this chapter I investigate the colour and pattern variability of the central Galapagos racer (*Pseudalsophis dorsalis*). The central Galapagos racer is one of the most widely distributed species, in the archipelago. This variability has been interpreted as either the result of high phenotypic plasticity in the species, or a cluster of different taxa not clearly differentiated in current taxonomic studies. Further, the species occurs on islands with and without introduced predators. I conducted the first field study aimed at characterising the variability in colouration and colour pattern of Central Galapagos racers, and to conduct a preliminary assessment of to assist the DNGP in developing a management plan for the species.

CHAPTER 4

Here I present a preliminary assessment of a recently rediscovered population of the central Galapagos racer (*Pseudalsophis dorsalis*) on El Eden, a small islet off the coast of Santa Cruz Island. The central Galapagos racer was first reported from El Eden in 1923 by William Beebe. The last confirmed sighting of the species prior to this study was in in 1980s by photographer and conservationist Tui de Roy, who photographed a single individual. In 2019 I had the opportunity to visit El Eden and assess the current status of the central Galapagos racer population. I captured and measured eight individuals over 38 man-hours. I describe the generalities of the snakes at this site and discuss priority conservation actions that need to take place on this small islet.

CHAPTER 5

In this chapter I describe some of the most important gaps in knowledge to advance the conservation of the Galapagos terrestrial snakes in general and of the central Galapagos racer in particular. I present potential alternatives for field research and their relevance to the current conservation status of the Galapagos terrestrial snakes.

CHAPTER 2: DIET COMPOSITION AND EVIDENCE OF CANNIBALISM AMONG GALAPAGOS TERRESTRIAL SNAKES *PSEUDALSOPHIS SP.* (REPTILIA: COLUBRIDAE), ECUADOR

Paper draft for submission to Herpetology Notes

Central Galapagos race (*Pseudalsophis dorsalis*) in its habitat on Seymour Norte. Photo: L. Otiz-Catedral.

ABSTRACT

Detailed information on the trophic relationships of snakes in animal communities is pivotal to developing conservation and management actions. We investigated the diet of eight species of Galapagos terrestrial snakes on 11 populations over a two-year period (2018-2019), by examining 133 faecal samples obtained in the field using the palpation technique. We identified prey species by examining scales, bones, teeth and exoskeleton remains found in faecal samples, under a microscope and comparing these to voucher reference specimens. The most common prey type consumed were lava lizards (*Microlophus* spp.) (26.98%) followed by geckos (*Phyllodactyllus*) (7.94%), birds (4.76%), gecko eggs (3.17%) and possibly rodents (1.59%). I encountered a total of 140 snake teeth on 25 samples from ten populations ranging in number from one to 56 (mean = 12). While small numbers of teeth in faeces might result from the continuous replacement of teeth in snakes, large numbers of these indicate instances of cannibalism. In support of this explanation I also encountered a section of snake skin corresponding to the left side of the head, and an ocular scale in one sample, and a maxillary snake tooth still attached to tissue in another sample. Field observations prior to this study confirm instances of attempted cannibalism on Fernandina Island. The widespread occurrence of snake teeth and scales found in faecal samples in this study suggests that cannibalism among Galapagos terrestrial snakes has been underestimated. I also encountered hair in two samples, possibly belonging to native rice rats (*Aegiolamys* and *Nesoryzomys*). Finally, I report the first instance of predation of Galapagos shearwater chicks (*Puffinus subalaris*) based on numerous feathers in two samples. This study confirms that the dietary spectrum of Galapagos terrestrial snakes is broader than previously considered and provides information that can help better conserve species and populations of snakes present in the archipelago.

INTRODUCTION

The Galapagos Islands are renowned for their naturally undisturbed coastal and marine biodiversity (Bustamante, Collins, & Bensted-Smith, 2000), and unique terrestrial species such as Galapagos tortoises (*Chelonoidis sp.*) and Darwin's finches (subfamily: Geospizinae) (Jackson, 1994). Another diverse animal group present on the archipelago are Galapagos terrestrial snakes (*Pseudalsophis sp.)* (Zaher et al., 2018) which represent one of the least studied groups of terrestrial vertebrates. One of the main threats to island faunas worldwide, including the Galapagos Islands are introduced species (Holmes et al., 2019). Introduced species can affect native and island endemics by predation or competition for resources (Russell et al., 2017). Islands free of introduced predators can act as refuges for vulnerable native species. In New Zealand native fauna are highly threatened by introduced mammalian predators, however some of its offshore islands have maintained healthy populations of vulnerable species as a result of a lack or low abundance of predators and effective pest management programmes (Boessenkool, Taylor, Tepolt, Komdeur, & Jamieson, 2007). Offshore refuges for native and endemic species can serve as sources to translocate individuals and reintroduce species into their historical ranges. For instance, following the eradication of introduced black rats (*Rattus rattus*) and mongoose (*Herpestes javanicus*) from 14 islands in the Caribbean, a reintroduction program for Antiguan racers (*Alsophis antiguae*) has seen the return of the snakes to four predator-free islands, bringing the global population from a mere 51 individuals to over 1,100 (Daltry et a., 2017).

For Galapagos terrestrial snakes, introduced species have reduced the number of populations and geographic distribution of at least three species (Christian, 2017; Arteaga et al, 2019). Fortunately, small offshore island populations of these species still exist (Christian, 2017; Zaher et al., 2017; Arteaga et al., 2019) opening up the possibility of reintroducing species into their historical ranges. Prior to developing a reintroduction strategy we need to understand their trophic interactions. Zipkin et al. (2020) demonstrated that declines in vertebrate prey diversity are directly correlated with declines in the abundance and diversity of their snake predators. Galapagos terrestrial snakes depredate or consume a high diversity of prey items that includes: Lava lizards (*Microlophus spp.*), Geckos (*Phyllodactylus spp.*), Marine iguanas (*Amblyrhynchus cristatus*), Galapagos racer snakes (*Pseudalsophis*), Invertebrates, myctophid fish (*Bolinichtys* spp.) and birds (Ortiz-Catedral et al., 2019; Merlen and Thomas, 2013). Therefore, understanding the interaction of predators and their prey in the Galapagos Islands can assist in the development of conservation management plans. Island species often evolve from a small gene pool, and the majority of all recorded extinctions are on islands impacted by humans (Stork, 2009).

The increasing colonisation and tourist activity on the Galapagos Islands has led to an abundance of invasive species incursions, habitat disturbances, and poaching of native species (Eckhardt, 1972; Márquez, Wiedenfeld, Landázuri, & Chávez, 2007; Watson, Trueman, Tufet, Henderson, & Atkinson, 2009). The increasing anthropogenic threats disrupt ecosystems and can lead to deleterious consequences on native species populations. To conserve the current biodiversity, we must engage in supporting the relationships within its ecosystems. The Galapagos Racer Snakes (*Pseudalsophis*) are one of the few strictly terrestrial predators in the Galapagos however there are few studies documenting the biology of Galapagos terrestrial snakes, whih provide information to develop conservation plans for these species (Christian, 2017; Ortiz-Catedral et al., 2019; Zaher et al., 2018). There are currently nine described species of terrestrial snakes in the Galapagos, having been recorded on all major islands and several islets except for the northern islands of Pinta, Marchena, Genovesa, Darwin, and Wolf (Zaher et al., 2018). However, there is an unconfirmed record of a snake from Pinta (J. Suarez pers. comm). With such a widespread distribution and several distinct species, it is likely they fill an important predatory role in their ecological systems. Galapagos racers are known to have interacted with several prey species. Previous studies have mentioned interactions of Galapagos racers with their prey, including: Lava Lizards (Altamirano, 1996; Cadena-Ortiz, Barahona, Bahamonde-Vinueza, & Brito, 2017; Merlen & Thomas, 2013), marine iguanas (Laurie & Brown, 1990), land iguanas (Werner, 1983), and coastal fish (Merlen & Thomas, 2013). Recently, dedicated analyses of their diet were published confirming Lava lizards (*Microlophus*) as a significant part of their diet and also noted the presence of Geckos (*Phyllodactylus*), invertebrates, and birds in the diet of six Galapagos racer species (Christian, 2017; Ortiz-Catedral et al., 2019). There are also at least three reports of attempted cannibalism among eastern racers on Fernandina Island. In June 2015, three instances of attempted cannibalism involving six different snakes was photographed at Cape Douglas, during filming for a BBC nature documentary (R. Wollocombe, pers. comm.; Appendix 5). The snake ingesting snake prey managed to grab another live snake and hold it in place for a few minutes, but no instances of full ingestion were recorded. It is unclear if snakes released their live prey due to the presence of observers. Occasionally, eastern snakes have been seen regurgitating half-eaten marine iguana hatchlings if disturbed (Ortiz-Catedral, pers. comm.). Christian (2017) reported snake teeth in faecal samples of another species, the Floreana racer (*Pseudalsophis biserialis*), however these were considered the snake's own. Snake teeth in faeces have been reported however, their presence is attributed to the continuous replacing of reptilian teeth (van Wyk, 1988).

The diet of the Galapagos racer snakes consists of endemic Galapagos species that are not available to their closest living ancestor in mainland Ecuador, the Elegant racer (*Pseudalsophis elegans*) (Zaher et al., 2018). The Galapagos racers separated from their mainland counterpart roughly 6.9 Mya, and have since radiated into nine morphologically distinct species (Zaher et al., 2018). The type and size of snake prey items have been known to have a significant effect on their morphology. Snakes on the Izu islands in Japan exhibit island gigantism on islands with colonies of sea birds and dwarfism is strongly linked to saurophagy (lizard eating), most of the island snakes exhibit either one of these trends when compared to their mainland counterparts in which their diet almost exclusively consists of frogs (Masami Hasegawa, 2003; M. Hasegawa & Moriguchi, 1989). Prey availability and size have been closely correlated with the size of Tiger snakes (*Notechis ater*) on offshore islands in southern Australia, furthermore; with sexual dimorphism on Chappell Island as a result of high seasonal availability of mutton bird chicks when female snakes are heavily gravid and inactive (Terry D. Schwaner, Grigg, Shine, & Ehmann, 1985; Terry D. Schwaner & Sarre, 1988). The elegant racer can reach an average SVL of around 430 mm, this length is roughly between that of the larger and smaller species of Galapagos racers, it is possible this size disparity from the mainland population was also a result of dietary changes (Zaher et al., 2018). It is argued that under Bergmann's rule climate may be an evolutionary driver for body size, however this rule is not strongly supported within ectotherms as most larger reptiles are closer to the equator and have slower heating rates than smaller species (Bergmann, 1847; Pincheira-Donoso & Meiri, 2013). There must be alternate factors affecting Galapagos snake body size, so investigating their target prey has the potential to reveal causational trends. It has been observed that Galapagos racers are active hunters of all their known prey items, however they have a bi-modal pattern of activity; primarily being active in dawn and dusk (Christian, 2017; Merlen & Thomas, 2013; Ortiz-Catedral et al., 2019; Zaher et al., 2018). The Galapagos racers pattern of activity is a result of their relatively small body size and warm climate that causes ectotherms with little thermal inertia to rapidly heat up (Haack, 1986; Pincheira-Donoso & Meiri, 2013). It is not known whether the different snake size classes have different periods of activity because of their thermal tolerances. The activity periods of these snakes would typically result in a missed opportunity to forage for prey items that are active during the middle of the day or at night. Understanding what prey the different populations of snakes consume could help reveal what type of prey capture behaviour they exhibit and when they are most likely to actively consume prey within their thermal inertia.

In this study our main objective was to describe the diversity of prey type and prey species consumed by eight species of snakes on various populations. The idea is that this information can help us understand what the most important prey species they interact with were for future conservation efforts such as translocations or mitigating population declines. We calculated the most important prey species on each island population to identify any differences in their required or preferred prey items. We have also analysed the snake body size in relation to their diet so we can observe any relationship between prey size and snake size to find out whether larger prey may be necessary in populations of snakes with a larger SVL, however not necessary in populations of snakes with a smaller SVL.

METHODS

Study Areas

Between December 1, 2017 to August 22, 2019 faecal samples from Galapagos racers were collected on nine different islands: Eden (0° 33’ 37” S, 90° 32’ 13” W), Venecia (0° 31’ 05” S, 90° 28’ 32” W), Baltra (0° 27’ 25.96” S, 90° 16’ 27.59” W), Seymour Norte (0° 23’ 30’’ S, 90° 17’ 0’’ W), Espanola (1° 22’ 48” S, 89° 40’ 48” W), Santa Fe (0° 49’ 0’’ S, 90° 3’ 30’’ W), Pinzon (0° 36’ 30’’ S, 90° 39’ 57’’ W), Fernandina (0° 22’ 0’’ S, 91° 31’ 20’’ W) and Santiago (0° 18’ 11’’ S, 90° 40’ 0’’ W) (see also Table 1, Fig. 3; Fig. 4). Eden is a small islet only 300m northwest off the coast of Santa Cruz and is highly vegetated with Palo Santo (*Bursera graveolens*) in most parts apart from the peaks of the island where blue footed boobies (*Sula nebouxii*) nest. Eden has a resident population of of black rats (*Rattus rattus*) however still has a population of Central Galapagos racers (*Pseudalsophis dorsalis*) (see Chapter 4). Venecia is a similar sized group of islets near to Cerro Dragon north of Eden and barely separated from Santa Cruz by a 10m body of water. The islet is highly vegetated with Tuna (*Opuntia echios*), candelabra cactus (*Jasminocerus thourasii*), palo verde (*Parkinsonia aculeata*), Palo Santo, acacia botón (*Acacia rorudiana*), and separated by small channels with dense mangroves (*Avicennia germinans*). The painted racer (*Pseudalsophis steindachneri*) is the only known species of snake on Venecia. Baltra island has a very bare landscape with little vegetation; primarily tuna, acacia botón, and thorn shrub (*Scutia spicata*). The island is quite developed with an airport, a military base, and wind energy powerplant. We had the highest snake capture rate on the northern side of the island, capturing both central Galapagos racer and painted racer within the same habitat. Seymour Norte is 1.5km north of Baltra, the island is relatively undisturbed with tourist visits restricted to its southwestern side. Snake searches were performed on the eastern side of the island, in a flat area known as 'La Plataforma'. This site was sparsely vegetated with Palo Santo and tuna, however *P. dorsalis* had a high population density and *P. steindachneri* were present in a low population density. Our searches were restricted to the south-eastern coast of Santiago island. The island has a high amount of vegetation and different cactus species, Prickly pear (*Opuntia galapageia*). Thoma's racer (*P.* thomasi) have a stable population on the island, however, are more sparsely distributed. Santiago and Pinzon island are also undisturbed apart from tourist visitors; however they aren't allowed to step foot on Pinzon. There is a tropical highland habitat on Pinzon that tortoises (*Chelonoidis duncanensis*) occupy and a lowland arid habitat; both of which support Pinzon racer (*P. slevini*). The snakes are sparsely distributed across the island. Espanola is the southernmost island in the Galapagos. The Espanola racer (*Pseudalsophis hoodensis*) was sparsely distributed across this island, with most found in coastal areas. On Fernandina island, snake searches were restricted to the shoreline of Punta Espinoza. This is a coastal habitat of primarily rock and sand with little vegetation, only low-lying shrubs and sporadic candelabra cactus. Western Galapagos racers (*P. occidentalis*) were captured in high numbers throughout the year, however we caught the most during the time of the year when marine iguana (*Amblyrhynchus cristatus*) hatchlings emerge from their eggs.

Collection of samples

The samples were collected during summer and winter, however there is no evidence to suggest a change in diet between seasons apart from western Galapagos racers, in during marine iguana hatching season (R. Wollocombe, pers. comm.). Searches of western Galapagos racer occurred when marine iguana hatchling emergence was occurring and was not occurring to avoid bias. Monitoring was performed during dawn and dusk, between the hours of 06:00am to 10:00am and 15:30am to 18:30am. Teams of between two and six actively searched for snakes by visual recognition without disturbing the environment. Snakes were captured by hand and secured in numbered cotton bags sealed with hair ties to be kept in a safe, shaded area until the time came to be analysed. With snake health and wellbeing in mind we ensured that no snake was severely injured, lost, or killed during the entirety of the sampling period. No snake was kept in a bag for more than 12 hours, snakes captured in the morning session were analysed and then released in the afternoon session, snakes captured in the afternoon session were analysed and released the next morning.

Snake analysis

The captured snakes were analysed in the field by experienced snake handlers that have been trained to accurately record locations, take measurements, determine sex, and take faecal samples. The individual snakes are identified by their corresponding numbered bag they were put in after capture. The bag number is used to identify the snake's GPS location that was taken in the field, as well as the time of capture and release. We began analysing the snake by counting its scale series on its head and body for ongoing taxonomic research. The snakes were then measured by placing them in a clear box with a foam pad tightly pressed on and around them to prevent movement while we replicate their snout-vent-length (SVL) and tail length using a piece of string that we measured. We weighed the snakes by placing them in their bags and using a hanging scale to get the precise total weight and then weighing the bag separately to find the weight of the snake alone. Snakes from populations that we monitored by mark-recapture were injected with a transponder to identify them, this included snakes on Seymour Norte and Fernandina. Finally, we attempted to take faecal samples from all the snakes using the palpation method outlined in Ortiz-Catedral et al. (2019) and Christian (2017).

Sample analysis

Faecal samples collected in the field were stored in 2 ml plastic containers and fixed in ethanol 96% and refrigerated until the time they could be analysed under a microscope. When analysing the samples, we placed them in a petri dish filled with alcohol and visually identified the contents under the microscope according to general categories (Table 1). Much of the faecal matter was too digested to identify but in some samples there were teeth, scales, feathers, bones, eggs, or body parts that remained for us to identify the snake's prey to the species level. For any body parts that we were unsure about we were able to compare them with samples from the Charles Darwin Research Station and confirm the original species the part belonged to. The faecal samples with identifiable material were photographed and all the material from each sample were recorded. The fragments from species were flattened and spread so their length and width could be measured to find the total area of each species consumed.

Statistical analysis

We wanted to test whether there is a relationship between the snake size and the presence of different types of prey in their diet. In R studio we used a logistic regression model to test for the relationships between the measurement variable: snake SVL and the prey categories. A number of prey types occurred only on a few individuals (for instance, seabirds). Logistic regression in R uses maximum likelihood estimates for logit and probit models. While these estimates work well for large sample sizes, they introduce substantial bias and derive incorrect test statistics that can inflate probabilities estimates (Merino et al., 2012). Thus, I only conducted analyses on three prey type binary outcomes (presence/absence) where at least nine samples contained identifiable prey items for lava lizard, snake, and gecko and SVL measurements. I also conducted Fisher's exact test on frequencies of prey items vs. sex of snakes across species and populations.

RESULTS

In this study, I identified eight different prey types corresponding to 16 prey remains to the species level (Table 2) The central Galapagos racer (*Pseudalsophis dorsalis*) has the highest prey diversity, closely followed by the western Galapagos racer (*P. occidentalis*) (Table 2). Table 3 shows that across 11 different islands there was between 2 to 7 prey types with Fernandina having the highest prey diversity. Most islands shared lava lizard and/or snake as a part of the diet. The prey of male and female snakes proved very similar; however, male snakes have a significantly higher frequency of lava lizards in their diet (male = 66% presence lava lizard, female = 34% presence lava lizard; Fisher's exact test = 0.055; n = 69). Faecal samples from male and female show equal frequencies of snake prey remains (male = 51% presence snake prey, female = 49% presence snake prey; Fisher's exact test = 0.99; n = 69). Similarly, faecal samples of male and female snakes showed equal frequencies of gecko remains (male = 44%, female = 55% presence gecko prey; Fisher's exact test = 0.728; n =69). For marine iguana, the difference in prey remains between sexes approached significance, with females showing higher frequency of marine iguana remains than males (male = 0%, female = 100% marine iguana prey; Fisher's exact test = 0.104; n =69), but an equally high absence of this prey type (male samples without iguana remains 54%, female 40%, Fisher's exact test = 0.104; n = 69).

I also identified four prey types not previously recorded for Galapagos terrestrial snakes: seabird chicks, snake prey, gecko eggs, and mammals (Table 2, Table 3). Snake teeth and/or scales were found in 31 samples (45%) with between one to 56 teeth (mean = 12) per sample. Snake remains were identified in all seven species and in 10 out of 11 islands surveyed indicating that cannibalism among these snakes is more prevalent than previously assumed. I encountered a section of snake skin corresponding to the left side of the head, and an ocular scale in one sample (see image on Table 1), and a maxillary snake tooth still attached to tissue in another sample. Snakes can lose teeth during predation attempts, however, my results suggest the number of instances and mass of material discovered provide enough evidence of cannibalism. Coupled with observations of attempted cannibalism on Fernandina in June 2015 (see Appendix 5) the results presented here support the idea of widespread cannibalistic behaviour on Galapagos terrestrial snakes. Feathers of seabird chicks (see Table 1) were identified on two individuals from Seymour Norte (ID 0007922B97 female; 0007923DD2 male; Appendix VI). I did not find significant differences between SVL measurements and type of prey identified in faces, however, there was a tendency towards significance for bird prey (Table 4).

Table 2. Prey species identified in faeces of seven species of Galapagos terrestrial snake.

Snake species	Prey species
Pseudalsophis occidentalis	Gecko (*Phyllodactylus galapagensis*)
	Iguana (*Amblyrhynchus cristatus*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus albermarlensis*)
	Bird (Unidentified bird species)
	Rodent (Unidentified rodent species)
	Unidentified Vertebrate
Pseudalsophis thomasi	Gecko (*Phyllodactylus maresi*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus jacobi*)
	Bird (Unidentified bird species)
	Unidentified Vertebrate
Pseudalsophis slevini	Gecko Eggs (*Phyllodactylus duncanensis)*

	Snake (*Pseudalsophis slevini*)
	Lava Lizard (*Microlophus duncanensis*)
	Unidentified Vertebrate
Pseudalsophis steindachneri	Gecko (*Phyllodactylus galapagensis*)
	Gecko Eggs (*Phyllodactylus galapagensis*)
	Lava Lizard (*Microlophus indefatigabilis*)
	Snake (*Pseudalsophis sp.*)
	Unidentified Vertebrate
Pseudalsophis dorsalis	Gecko (*Phyllodactylus galapagensis*)
	Gecko Eggs (*Phyllodactylus galapagensis*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus indefatigabilis*)
	Bird (Unidentified bird species)
	Bird (*Puffinus subalaris*)
	Rodent (Unidentified rodent species)
	Unidentified Vertebrate

Pseudalsophis biserialis biserialis	Snake (*Pseudalsophis biserialis biserialis*)
	Lava Lizard (*Microlophus grayii*)
	Unidentified Vertebrate
Pseudalsophis hoodensis	Gecko Eggs (*Phyllodactylus gorii*)
	Snake (*Pseudalsophis hoodensis*)
	Lava Lizard (*Microlophus delanonis*)
	Bird (Unidentified bird species)
	Unidentified Vertebrate

Table 3. Prey types per island on 133 faecal samples of Galapagos terrestrial snakes.

Island	Prey species
Fernandina	Gecko (*Phyllodactylus galapagensis*)
	Iguana (*Amblyrhynchus cristatus*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus albermarlensis*)
	Bird (Unidentified bird species)
	Rodent (Unidentified rodent species)
	Unidentified Vertebrate
Santiago	Gecko (*Phyllodactylus maresi*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus jacobi*)
	Bird (Unidentified bird species)
	Unidentified Vertebrate
Pinzon	Gecko Eggs (*Phyllodactylus duncanensis)*

	Snake (*Pseudalsophis slevini*)
	Lava Lizard (*Microlophus duncanensis*)
	Unidentified Vertebrate
Santa Cruz	Snake (*Pseudalsophis sp.*)
	Unidentified Vertebrate
El Eden	Snake (*Pseudalsophis dorsalis*)
	Lava Lizard (*Microlophus indefatigabilis*)
Venecia	Gecko (*Phyllodactylus galapagensis*)
	Unidentified Vertebrate
Baltra	Gecko Eggs (*Phyllodactylus galapagensis*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus indefatigabilis*)
Seymour Norte	Gecko (*Phyllodactylus galapagensis*)
	Gecko Eggs (*Phyllodactylus galapagensis*)
	Snake (*Pseudalsophis sp.*)
	Lava Lizard (*Microlophus indefatigabilis*)

	Bird (*Puffinus subalaris*)
	Unidentified Vertebrate
Santa Fe	Snake (*Pseudalsophis dorsalis*)
	Lava Lizard (*Microlophus indefatigabilis*)
	Rodent (Unidentified rodent species)
	Unidentified Vertebrate
Champion	Snake (*Pseudalsophis biserialis biserialis*)
	Lava Lizard (*Microlophus grayii*)
	Unidentified Vertebrate
Espanola	Gecko Eggs (*Phyllodactylus gorii*)
	Snake (*Pseudalsophis hoodensis*)
	Lava Lizard (*Microlophus delanonis*)
	Bird (Unidentified bird species)
	Unidentified Vertebrate

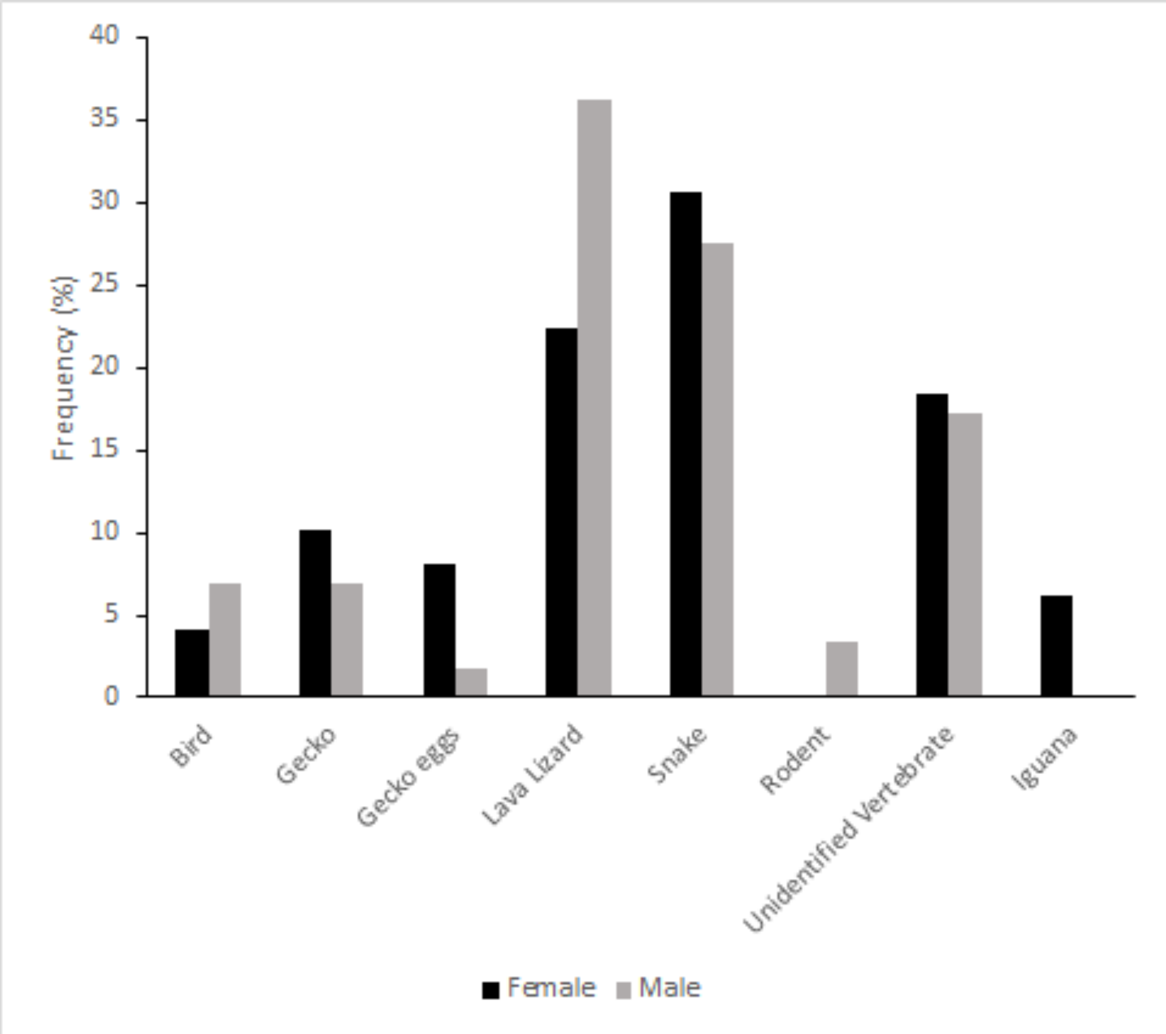


Figure 11. Proportion of prey type consumed by male and female Galapagos terrestrial snakes (n= 133).

Table 4. Results of logistic regression models for SVL vs. Prey type.

Prey type (n)	Z-value	P-value
Bird (6)	1.698	0.08946
Gecko (9)	-0.283	0.777
Gecko eggs (5)	-1.846	0.0649
Lava lizard (32)	-1.561	0.119
Snake (31)	0.542	0.588
Rodent (2)	0.251	0.802
Iguana (3)	2.003	0.0451

DISCUSSION

Understanding the trophic dynamics of animal communities is essential to develop appropriate management and conservation plans. Snakes, including Galapagos terrestrial snakes are predators that can indicate the health of animal communities. Any significant changes to the diet of snakes may indicate a change in the population abundance or distribution of either predator or prey. Weatherhead and Madsen (2009) explain how valuable understanding snake diet can be to interpreting population fluctuations, responses to invasive species, and predicting how changes in prey communities could affect snake populations. There are currently several methods of obtaining critical dietary information. Direct observation can be a time consuming or opportunistic method to record dietary information as it occurs, this proved very effective in this project to receive a photographic conformation of snake cannibalism. This was the result of much networking and collaboration, it is rarely a reliable method for a team gathering dietary information for statistical analysis under a time constraint. Stomach flushing or forced regurgitation are useful methods when individuals consume prey on a regular basis, however, this was not the case for most of our snakes captured (Dorcas, 2009). Stable isotope analysis does not need individuals to feed recently and has proven the most effective and less intrusive method for analysing the diet of hog-nosed snakes (*Heteradon nasicus*) (Durso & Mullin, 2017). This isotope analysis also identified prey that may be digested at a faster rate, a known drawback of faecal sample analysis. However, faecal sample analysis can be performed only moderately intrusively in the field to quickly obtain results when transportation of samples is not allowable, such as in our permit.

Although the faecal sample analysis has some disadvantages, it has proven highly successful in this study on Galapagos racers by the increased number of known prey type and prey species. Of interest is the confirmed ingestion of snake prey. This behaviour has been suggested for Galapagos terrestrial snakes but no direct or indirect evidence was available.

Other colubrids are known to eat snakes (Göçmen, Werner, & Elbeyli, 2008; Mitchell, 1986). These records are not restricted by the size of snake as juveniles have a high chance of encountering siblings and in adults have a larger number of snakes they can physically consume, this may serve to reduce intraspecific competition (Göçmen, Werner, & Elbeyli, 2008). Snakes may also consume prey snakes of equal size to them, as observed by kingsnakes (*Lampropeltis getula californiae*) forcing their prey's vertebrae to bend in waves to fit, while African snakes have been seen still with their preys tail hanging out their mouth during digestion (Jackson, Kley, & Brainerd, 2004; Schönland, 1895). Galapagos terrestrial snakes are generalists so will feed opportunistically; this may have been beneficial to them in island environments. Cannibalism may be the result of low prey availability or an opportunistic behaviour which they may have resorted to in a harsh island environment. Sudden changes in prey availability could change their trophic relationships. Florida cottonmouth snakes (*Agkistrodon piscivorous* and *A. conanti*) on Seahorse Key expressed cannibalistic behaviour following the abandonment of avian rookeries and a scarcity of alternative prey on this island (Sheehy III, Sandfoss, & Lillywhite, 2017). Competition with introduced species could also mean the loss/reduction of different prey types and a reliance on cannibalism which may not be sustainable.

In addition, we were able to identify Galapagos shearwater (*Puffinus subalaris*) in the diet of the central Galapagos racer population on Seymour Norte, this is the first instance in any Galapagos racer diet. I also discovered strands of hair in two samples which indicated the first recorded predation of mammals, most likely rodents. These were found in samples from Fernandina and Santa Fe, they are possibly from native rice rats (*Aegiolamys* and *Nesoryzomys*). Although the resulting predation on these prey types was too low to explore statistically. Gecko eggs were found in faecal samples from four island populations and three distinct gecko species. This type of prey requires active searching which we observed on several occasions with the snakes poking their heads into rock crevices, this was also observed by Christian (2017). Florida cottonmouth snakes on Seahorse Key share a similar feeding style as they scavenge for fish carrion (Sheehy III, Sandfoss, & Lillywhite, 2017).

With the use of DNA based methods of faecal analysis, we could gain a more accurate understanding of the Galapagos terrestrial snakes' prey range and preferences. Using PCR Brown, Ebenezer, and Symondson (2014) was able to identify the complete list of species consumed by the rare smooth snake (*Coronella austriaca*) without having any bias to digestion rate of material. Using this method increases the potential sample size and allowed them to make predictions more confidently with their prey types. DNA sequencing can also be used to accurately identify to the species level which is not typically possible using visual methods when there is multiple possible prey of the same genera. Using specific primers Berry et al. (2017) was able to identify important commercial fishing species as a part of Australian sea lion (*Neophoca cinera*) diet, however their opportunistic feeding style bodes well for the survival of the species. Understanding whether Galapagos terrestrial snakes frequently consume a wide range of prey would give us more confidence in whether they could cope with the loss/reduction of their most important prey species.

Although the analysis presented here is limited by sample size, my results suggest that lava lizards are the most important prey item for Galapagos terrestrial snakes, closely followed by snakes. The discovery of snakes as a significant prey species and the additional findings of gecko eggs and rodents give us confidence that these snakes have high plasticity in regards to diet.

CHAPTER 3: COLOUR VARIATION IN A POPULATION OF CENTRAL GALAPAGOS RACER (*PSEUDALSOPHIS DORSALIS*) ON SEYMOUR NORTE.

Paper draft for submission to Herpetology Notes

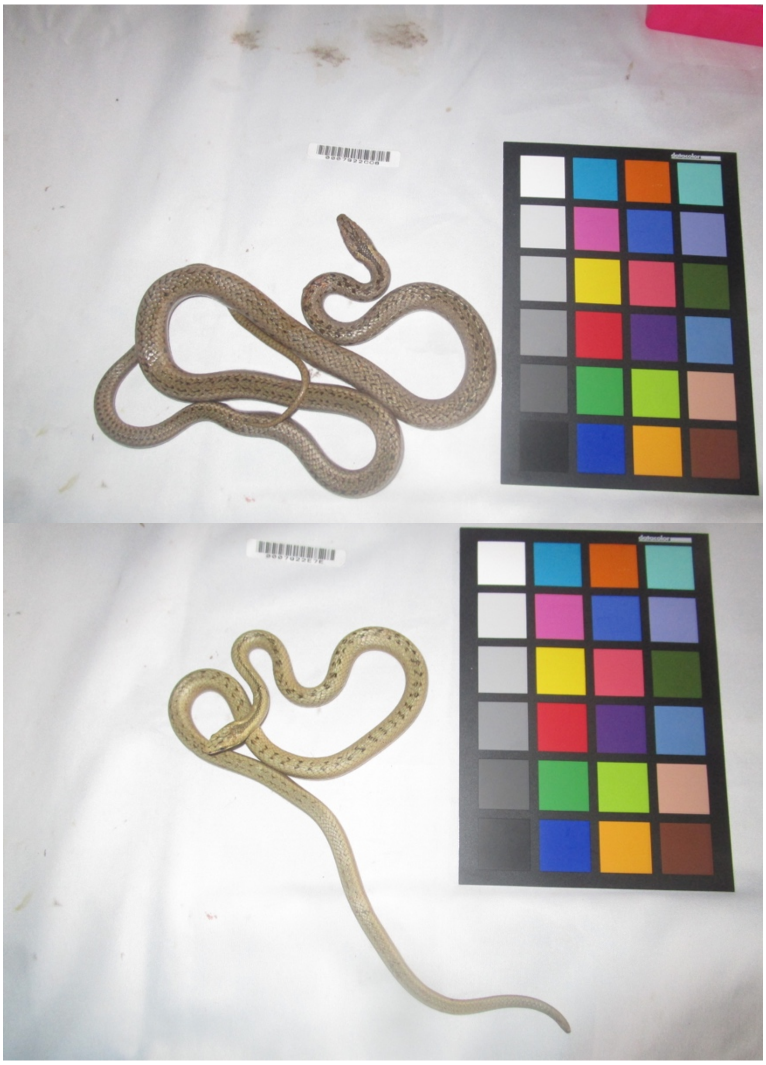


Figure 12. Examples of colour variation in a population of Central Galapagos racer (*Pseudalsophis dorsalis*) on Seymour Norte. Photos. H. Sollis and E. Montcreiffe.

ABSTRACT

The Galapagos terrestrial snakes exhibit a complex, unresolved taxonomy largely due to the lack of field studies that address the colour and morphological variability between species and populations. The central Galapagos racer is a species with variable colouration and colour patter across its range. The spectrum of colouration and colour pattern for the species is underrepresented in museum collections due to changes in colouration as a result of fixation of material. The most variable population known to date is on Seymour Norte, where the species exhibits between nine and ten distinguishable background dorsal colourations. Historically widespread, the species is now restricted to islands and islets free of introduced mammals that exhibit distinguishable patterns of colour and colour pattern variation, and that might correspond to different taxa. In order to better understand the colour and colour pattern variation of the species and intra and inter-population variability, I compared body colouration of 62 individuals from four populations, encompassing most of the current distribution of the species. I identified nine colour morphs based on dorsal background colouration, and two general types of pattern: stripped and spotted, with seven colour morphs. A single dorsal background colouration morph occurs on Baltra, two on El Eden and Santa Fe and nine on Seymour Norte, despite no distinguishable scaling or measurement differences between populations. It is possible that this high phenotypic variability is related to camouflage and future studies should address this. Future translocations of the species back to historical ranges need to consider the current inter-population variability of the central Galapagos racer, in order to preserve phenotypic variability and to maximise survival of founders on heterogeneous environments.

INTRODUCTION

The Galapagos terrestrial snakes, or “racers” area a group of 10 of recently diverged (6.9 Mya), visually distinct Colubrids that in the genus *Pseudalsophis* (Zaher et al., 2018). With the exception of a single continental species, the Elegant racer (*Pseudalsophis elegans*), all species are endemic to the Galapagos Islands. The genus has a complex taxonomy that spans over 150 years of numerous revisions by Steindachner (1876), Van Denburgh (1912), Mertens, (1960), Slevin et al., (1982), Thomas (1997) and most recently Zaher et al. (2018). The majority of taxonomic studies have focused on the morphology of preserved museum specimens, predominantly from the large collections by Slevin during the 1905-1906 California Academy of Sciences expedition to the Galapagos Islands (Thomas, 1997). Only recently, Zaher et al. (2018) included field observations and notes in their analysis of taxonomic boundaries among Galapagos terrestrial snakes, nevertheless, the same study relied largely on museum specimens for obtaining information on morphological traits. One trait that preserves poorly in museum specimens is colouration (Doucet and Hill, 2009). Fixative agents can alter the colouration of specimens (Pisani, 1973) limiting thus the inclusion of colour variation among populations and species as traits for taxonomic analysis, and making it difficult to characterise intra and inter-population variability in this trait.

The colouration of Galapagos terrestrial snakes is generally light brown to grey, however, a population of the Central Galapagos racer (*Pseudalsophis dorsalis*) on Seymour Norte, exhibits several visually distinct colour morphs, noticed during a field trip in 2015 (Ortiz-Catedral, pers. comm.). While intra-population colour variation is common among snakes, populations of Galapagos terrestrial snakes appear more or less consistent. The first field study of the Floreana racer (*Pseudalsophis biserialis biserialis*) was conducted in 2015-2016 (Christian, 2017), 155 years after the original description of the species. The same study revealed previously unavailable information on scalation and colour variability on the species, including pale grey and dark brown individuals. Zaher et al. (2018) describe a yellow morph for Thomas' racer (*Pseudalsophis thomasi*). The basis of colour variation among Galapagos terrestrial snakes is unknown. Polymorphism is colouration and colour pattern have been reported in island Colubrids such as the radiated ratsnake (*Elaphe subradiata*) which shoes considerable morphological variation across its distribution in the Lesser Sunda Islands (How, Schmitt & Suyanto, 1996). It is hypothesised that polymorphic species indicate active speciation, as lineages evolve toward monomorphism and non-adapted colour variants go extinct, which explains why polymorphic species are so rare (Hugall & Stuart-Fox, 2012; Roulin & Wink, 2004). From a management perspective, it is important to understand the variability in colouration among reptiles, in particular when conducting translocations of cryptic species (Baling et al. 2016). Different colour variants have different survival rates across different habitat types, Shore skinks (*Oligosoma smithi*) had a higher proportion of predation rates in more conspicuous colour morphs when translocated to a new habitat that differed in substrate and colour (Baling, Stuart-Fox, Brunton, & Dale, 2016).

Translocation of species to former historical areas is part of the overall management approach by the Directorate of the Galapagos National Park (Gibbs et al., 2008). For Galapagos terrestrial snakes, translocation is currently being discussed for the Floreana racer (Christian, 2017) and potentially for the central Galapagos racer (*Pseudalsophis dorsalis*) (see Chapter 4). Natural predators can have a strong influence on the gene pool and may be the cause for colour polymorphism. Potential native predators of Galapagos Racers are Barn Owls (*Tyto alba punctatissima*), Short-eared Owls (*Asio flammeus galapagoensis*), Galapagos Hawks (*Buteo galapagoensis*), and members of the family Aredeidae such as Lava herons (*Butorides sundevalli*), Yellow-crowned night-heron (*Nyctanassa violacea*), green heron (*Butorides virescens*), Great blue heron (*Ardea herodias*) and introduced Cattle egrets (*Bubulcus ibis*). Although direct predation events of Galapagos terrestrial snakes by herons and egrets has been recorded in the literature, both species consume prey within the size range of these snakes(Fig. 11). Also, both species occur within the current distribution of the central Galapagos racer, and could therefore prey on these snakes.

Until recently Galapagos Hawks were present on Santa Cruz however have now been extirpated, primarily as a result of human activities (De Groot, 1983; Faaborg, 1984; Whiteman, Matson, Bollmer, & Parker, 2006). Colour polymorphism is known to occur under disruptive selection in species where their prey can distinguish and learn the colour morph of unsuccessful attackers then flee when that colour morph is identified, so an individual with an alternate colour morph has a delayed detection by their prey (Roulin & Wink, 2004). Different colour morphs may also benefit depending on daylight periods: black sparrowhawks (*Accipiter melanoleucus*) with darker or lighter colourations are more cryptic when hunting at different times of the day (Tate, Bishop, & Amar, 2016). If the central Galapagos racer population on Seymour Norte is benefitting from their colour polymorphism then it may be maintained by this form of selection rather than speciating into a single morph.

Figure 13. Blue heron (top) and cattle egret (bottom) feeding on marine iguana hatchling and adult lava lizard.

The relationship between the environmental substrate colouration and the colour of the central Galapagos racer could be the reason for success in survivability or predation. Colour polymorphism is thought to be maintained in snakes by two selective forces acting in opposite directions. Melanistic European Adders (*Vipera berus*) are less camouflaged in their habitat, however have more effective thermoregulatory properties to grow and mate faster (Forsman & Ås, 1987). European adders are hereditarily melanistic, however, they have a wide array of colour morphs that exhibit intermediate forms and exhibit ontogenic and sex determined colour change with brown juveniles typically becoming grey as males or remaining brown as females (Terhivuo, 1990). The benefits of a melanistic morph are also observed in western whip snakes (*Coluber viridiflavus*), which showed this morph improved the female fecundity and overall size of both sexes (Luiselli, 1995). Sex and ontogenically linked traits such as these may be why we see such obvious colour differences in central Galapagos racer. Considering females and males undergo different selection pressures in different species there may be a trend for female or male *P. dorsalis* to grow larger at a faster rate that can be achievable with darker colour morphs. However, a contrast to this trend is the lack of selective difference is seen in striped and melanistic morphs of Lake Erie area Garter snakes which show no obvious size advantage of colour polymorphism (King, 1988). It is suspected that benefits of thermoregulation or crypsis may still affect these snakes gene pool, with random genetic drift causing monomorphic colouration in small populations (King, 1988). Random genetic drift is most influential on small populations however may still occur in any population that lacks gene flow from other populations. The abilities to survive longer to reproduce more times or to have access to more mates with a higher predation risk both successfully contribute to the population gene pool to maintain or constrain colour polymorphism. In our study we will catalogue the extent of this colour polymorphism and investigate whether it has a relationship with the snake's habitat, sex, or age/class size.

METHOD

Study Area

On Seymour Norte, sampling took place within the roughly 0.33 km^2 area known as 'La Plataforma', aptly named for being a flat area, on the eastern side of the 1.9km^2 Seymour Norte. Seymour Norte is 1.5 km north of Baltra with Mosquera Islet in the middle with roughly 500 m of ocean separating it from on each island. Seymour Norte is open to tourist visitation with day trips restricted to a 2 km trail along the rocky southern cliff and western beach. 'La Platatforma' is isolated from tourists and undisturbed by human activity, it is sparsely vegetated with Palo Santo (*Bursea graveolens*), Tuna (*Opuntia echios*), and patches of Espino (*Scutia spicata var. pauciflora*). 'La Plataforma' has a hill of large rocks that separates it from the rest of the island, there a far fewer rocks on the flat area, however the dirt substrate is popular with burrowing land iguanas (*Conolophus subcristatus*). The iguanas were not historically present on the island and were translocated from Baltra Island in 1933, some have since been relocated back to Baltra and recently translocated to Santiago island (Banning, 1933; Cayot & Menoscal, 1992; Kumar, 2019). We observed lava lizards (*Microlophus indefatigabilis*) and snakes make use of tunnels dug by land iguanas which are abundant in the large area of dirt substrate. I also analysed background colour and colour pattern on central Galapagos racers from El Eden, Santa Fe and Baltra, encompassing the current general area of distribution of the species.

Sampling

From August 6 to August 8 of 2019 we captured 45 Central Galapagos racer snakes and photographed 37 of them at the site of capture. Snake searches were performed during dawn and dusk, between the hours of 06:00 am to 10:00 am and 15:30 am to 18:30 am. Teams of between 2 to 6 actively searched for snakes during their most active periods of activity (see Chapter 1). To have a representation of the snake's specific habitat we had a 0.56 m^2 frame used to photograph the snake in its habitat, with the snake as the centre of the frame. When snakes were spotted, they were either left as they were and poles were placed around them to photograph them, or if the snake tries to escape it was carefully captured by hand and then placed back where it was first seen to be photographed. A colour chart was placed next to the snakes to compensate for changes in lighting within the photograph taken. Snakes were then placed into cotton bags and sealed with hair ties to be kept safe and shaded until they were later analysed.

Snake analysis

All snakes were analysed by experienced snake handlers trained on how to accurately record locations, take measurements, determine sex, and identify colouration. Analysis is performed the same as we outlined in the previous chapter except with the addition of noting the colouration of the snakes and taking their photo alongside a colour chart on a white sheet. Snake photos were later compared with photos in the field to identify any significant changes in colouration as a result of their different environment and temperature.

Colour classification

I classified individual snakes according to their background dorsal colouration and pattern colouration (Fig. 12). Snakes on Seymour Norte were photographed twice, once in a white standard background and once in the wild in the location where they were found (Appendix X). I used an online recreation of the 1821 Werner's nomenclature of colours for plants, animals and minerals (c82.net/werner/). Modern analysis of coloration of photographed live animals uses RGB colour space analysis (Smith et al., 2016). However, Werner's classification of colours remains useful in taxonomic studies, scientific illustration and palaeontology. Unlike modern colour reference charts, Werner's was developed specifically for zoologists and botanists (Simonini, 2018) and in widespread use in the 19th century, therefore many taxonomic descriptions during the golden era of exploration and species discoveries, use the colour labels coined by Werner. The updated version available online, uses the same classification but updates the colours to be comparable on digital media, making the comparison of digital photographs and Werner's colours easier.

For snakes photographed in the wild, I recognise three background substrates according to their composition:

- Rock and grass /areas with boulders or large rocks, with grass growing in between rocky substrate.
- Dirt and grass / areas of loose soil with grassy cover
- Vegetation / areas under. Shrub, on top of a shrub or adjacent to a prickly pear (*Opuntia echios* var. *zacana*)

See also Appendix X.

Statistics

We used a logistic regression model in R to measure whether there was a significant relationship between the different colour morphs and their body SVL to observe any ontological changes in colouration as they grow. We then used Pearson's Chi-squared test to measure the relationship between the different colour morphs and their sex. We looked at each colour morph individually and grouped the silver/brown morphs separately to the yellow/green/gold morphs then compared the two with their corresponding sexes.

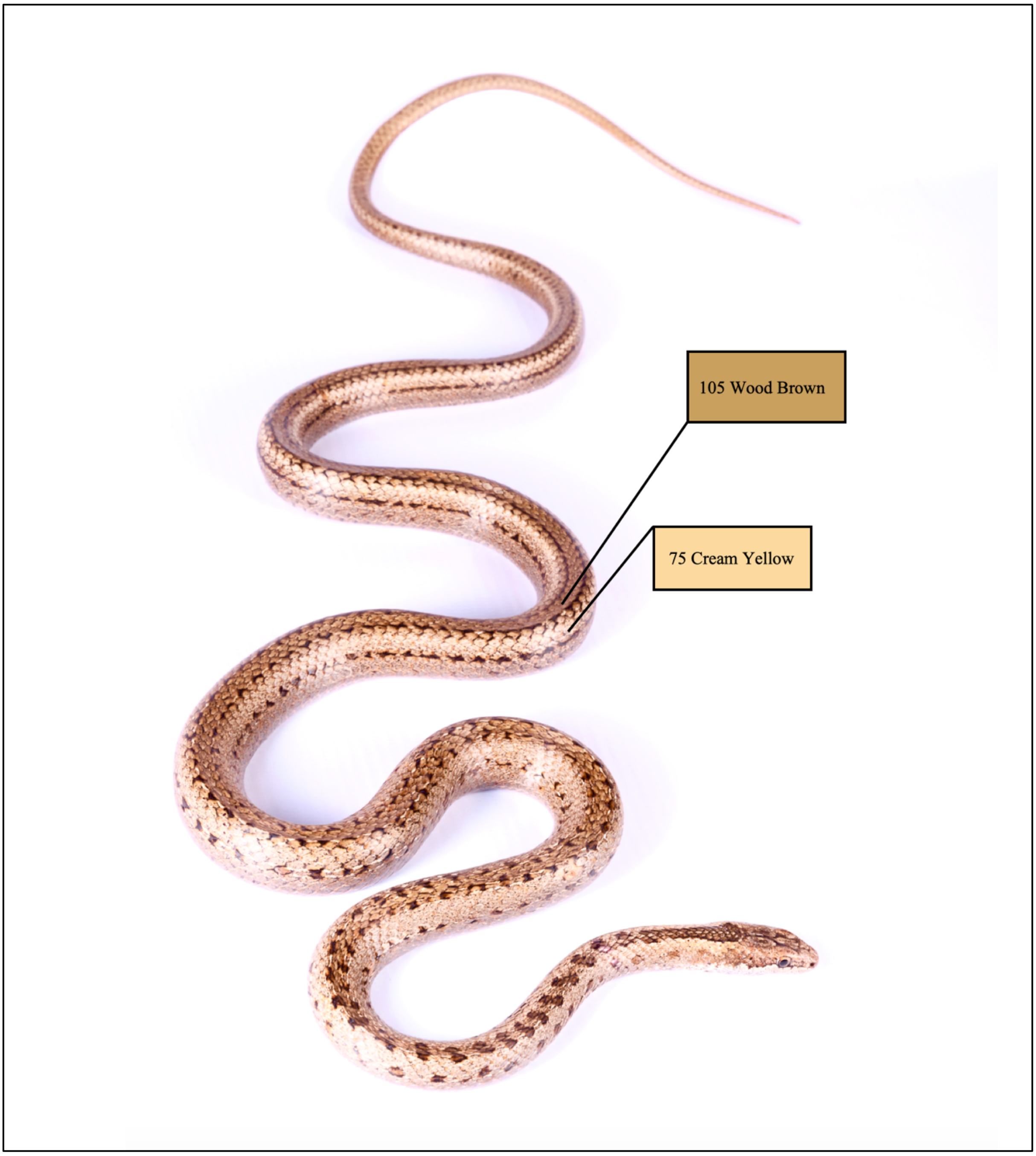


Figure 14. Classification of dorsal background colouration and pattern colouration on a central Galapagos snake according to Werner's colour system. Photo: D. Quirola.

RESULTS

I recognise nine different dorsal background colour morphs across populations in the central Galapagos racer (Fig. 13). Within those, I also recognise six colour pattern variants (Fig. 14). Dorsal background colour morphs were not significantly associated to a particular size class with one exception (Table 5).

Figure 15. Dorsal background colouration of central Galapagos racers. A) Wine yellow, B) wax yellow, C) pistachio green, D) oil green, E) chestnut brown, F) broccoli brown, G) smoke grey, H) yellowish grey, I) greyish black.

Figure 16. Pattern colouration of central Galapagos racers. A) velvet black, B) greyish black, C) chestnut brown, D) deep reddish brown, E) yellowish brown, F) blackish brown.

The greyish black morph was significantly associated with individuals with a SVL 63.32 ± 6.61, Z = -2.227, P = 0.0259). Dorsal colour morphs did not differ significantly between males and females in all but one cases (Table 6), the broccoli brown morph appear to be significantly more common among males than females (75% males; 25% females, X^2 = 4.4648, P = 0.0346). The colour of patterns however, did not differ significantly between males and females (Table 7).

Table 5. Logistic regression values for SVL vs dorsal background colour.

Dorsal background colouration	Z-value	P-value
Broccoli brown (12)	0.252	0.801
Chestnut brown (2)	1.515	0.130
Greyish black (11)	-2.227	0.0259*
Oil green (11)	0.415	0.678
Pistachio green (1)	-0.082	0.935
Smoke grey (3)	0.584	0.559
Wax yellow (2)	1.190	0.234
Wine yellow (1)	1.067	0.286
Yellowish grey (2)	-1.235	0.217

Table 6. Chi-squared results for contrast of dorsal colour morph frequency between sexes.

Background colouration	Male (%)	Female (%)	X-squared	P-value
Broccoli brown (12)	0.75	0.25	4.4648	0.0346*
Chestnut brown (2)	0.50	0.50	0.0010	0.9743
Greyish black (11)	0.63	0.36	0.9140	0.3390
Oil green (11)	0.54	0.45	0.0687	0.7932
Pistachio green (1)	0	1	0.9783	0.3226
Smoke grey (3)	0.66	0.33	0.3113	0.5769
Wax yellow (2)	0.50	0.50	0.0010	0.9743
Wine yellow (1)	0	1	0.9783	0.3226
Yellowish grey (2)	0.50	0.50	0.0010	0.9743

Table 7. Results of logistic regression of pattern colour vs sex in central Galapagos racer.

Pattern vs sex

Pattern colouration	Z-value	P-value
Blackish brown (18)	-0.596	0.551
Chestnut brown (1)	-1.014	0.310
Greyish black (19)	0.943	0.346
Deep reddish brown (3)	1.433	0.152
Velvet black (3)	-1.593	0.111
Yellowish brown (1)	0.75	0.453

The distribution of dorsal colour morphs between populations was inconsistent. All nine dorsal colour morphs were found on Seymour Norte, two morphs on Eden and Santa Fe, and a single one on Baltra (Fig. 15). Colour pattern was also more variable on Seymour Norte than on El Eden, Baltra and Santa Fe (Fig. 16). Only spotted patterns were found on Seymour Norte. In contrast, only stripped patterns on Baltra, while on El Eden population central Galapagos racers exhibited either spotted or stripped pattern (Fig. 17; Appendices VI-IX). Finally, the broccoli brown dorsal background colour morph was the only type found on all three substrate categories (Table 8).

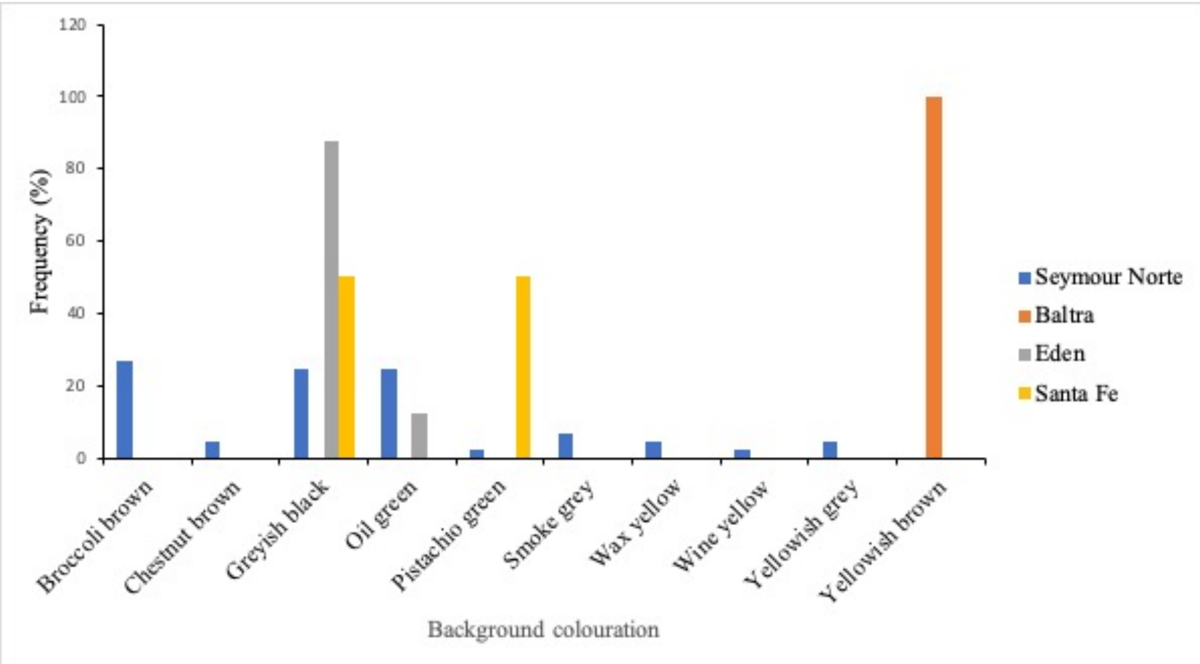


Figure 17. Dorsal background colour morphs between four populations of the central Galapagos racer.

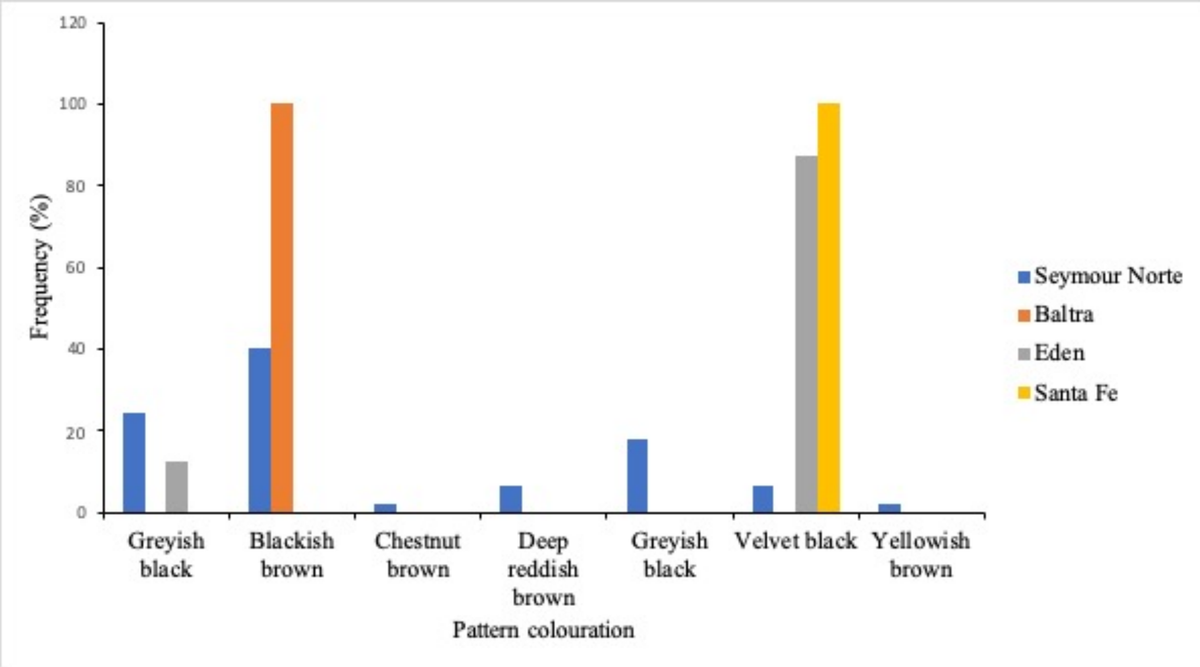


Figure 18. Colour pattern variability between four populations of the central Galapagos racer

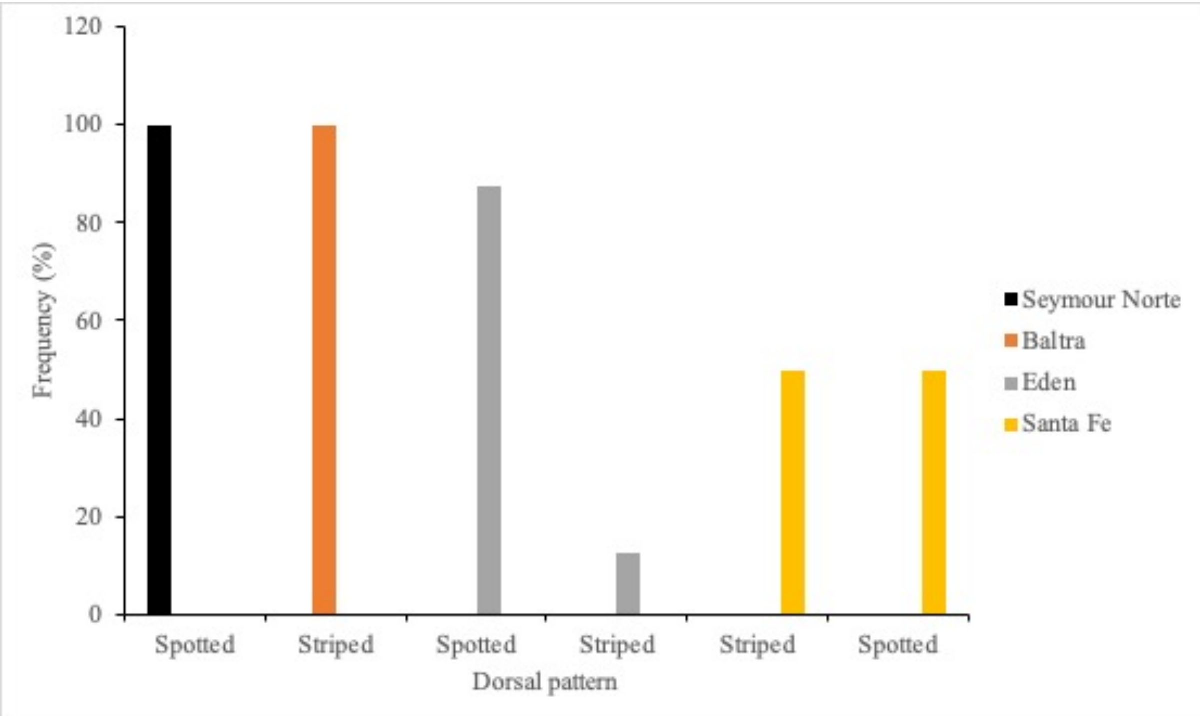


Figure 19. Distribution of spotted and stripped patterns on four populations of central Galapagos racer.

Table 8. Distribution of dorsal background colouration among substrate types on Seymour Norte.

Dorsal background colouration	Dirt/grass	Rocks/grass	Vegetation
Broccoli brown (12)	6 (50%)	3 (25%)	3 (25%)
Chestnut brown (2)	1 (50%)	1 (50%)	0
Greyish black (11)	5 (45%)	6 (55%)	0
Oil green (11)	5 (45%)	6 (55%)	0
Pistachio green (1)	0	1 (100%)	0
Smoke grey (2)	1 (50%)	1 (50%)	0
Wax yellow (2)	0	2 (100%)	0
Wine yellow (1)	0	0	1 (100%)
Yellowish grey (2)	2 (100%)	0	0

DISCUSSION

Colour polymorphisms in snakes are the result of environmental and genetic factors that are subjected to natural and sexual selection. In species such as the Chinese cobra (*Naja atra*), colour morphism is displayed between two genetically and geographically isolated populations which have either black or white ventral colouration (Lin, Li, Fong, & Lin, 2008). European adders (*Vipera bereus)* and asps (*Vipera aspis*) also display colour polymorphism but within the same population, there was a substantial presence of melanistic morphs that persists when the thermoregulatory benefit outweighs the cost of predation pressure (Andrén & Nilson, 1981; Broennimann et al., 2014). Antiguan racers (*Alsophis antiguae*) are another example of island snakes with variable colour polymorphism, however, this is strictly the result of sexual dimorphism (Daltry et al., 2001). The central Galapagos racer has four extant island populations, but the dorsal background colouration and colour pattern are not homogeneous across populations. The Seymour Norte population includes nine distinguishable colour morphs, all with a spotted colour pattern. The population of El Eden exhibit a spotted pattern with two background and pattern colour morphs. Santa Fe exhibit stripped and spotted patterns with two background colour morphs and one pattern colouration. The Baltra population exhibits only stripped patterning and only and a single colour morph for both background and pattern.

Based on preliminary observations on other populations and species of Galapagos terrestrial snakes (2015-2017, Ortiz-Catedral, pers. obs.) it appears that the Seymour Norte population of central Galapagos racers has the greatest variability of dorsal background colour. Unlike the example above, involving the Antiguan racer, this high diversity of colouration is not sex-related, with males and females except pistachio green and wine yellow which were only present on females (Table 6) in the current dataset. Nevertheless, these are represented by single individuals, and therefore there is a possibility that upscaling sampling would reveal whether males also aoccur in these colours. Both sexes of the central Galapagos racer display all of the background colour morphs we found more than one of, with only broccoli brown having significantly more males than females. A similar colour polymorphism was investigated in Malagasy snakes (*Mimophis mahfalensis*) which also was not strictly related to sex or ontogeny and may have geographically impeded gene flow to these polymorphic populations (Ruane et al., 2018). However, the trend observed in broccoli brown central Galapagos racers may express a greater benefit of this colouration for males, similar to melanism in European grass snakes (*Natrix natrix*) which was suggested to have a greater benefit to males for its positive impact on immunity (Bury, Mazgajski, Najbar, Zając, & Kurek, 2020; Saad & Shoukrey, 1988). As previously mentioned in my introduction, the central Galapagos racers' polymorphic colouration may be currently subjected to selection pressures that result in monomorphism or perhaps sexual polymorphism. The central Galapagos racers on Seymour Norte have no geographic barrier between the colour morphs to create separate gene pools, therefore the persistence of this colour polymorphism is determinate on natural selection.

According to my results, there is a significant trend of an SVL range associated with the greyish black morph. The aforementioned range is roughly the median size of snakes and is not related to their maximum potential size or adolescent size. Ontogenetic colour polymorphism is typically present between snakes in their adolescence and when they reach maturity, such as in the European adder (Terhivuo, 1990). The presence of different colour morphs throughout the range of size classes we analysed leads me to conclude the colouration is not related to ontogeny. Batesian mimicry of patterning in the viperine snake (*Natrix maura*) was similarly proven to not be the result of sex or ontogeny, but the habitat structure as the differences in vegetation better concealed the two morphs from predators (Santos et al., 2018). My investigation into the habitat of the racer population on Seymour Norte, did not show a separation of morphs in each substrate type, however, the habitat for the central Galapagos racer on Seymour Norte is less variable than those described for that of the viperine snake in Santos et al. (2018). The low detection of snakes on a substrate with vegetation was both the result of a low density of vegetation on Seymour Norte and the bias of difficulty to observe and capture snakes in the dense, sharp vegetation. To effectively measure the difference between open and densely vegetated habitat the vegetation would need to be removed, however with the little amount of vegetation present this would severely impact many species that rely on it, including racer snakes. We often captured snakes moving toward or away from vegetation patches in open areas, so it is highly likely the snakes are not restricted to vegetation patches.

The high amount of variation of colour morphs and patterns across the central Galapagos racer populations is unlike any other known snake species in the Galapagos. The uniform differences in both colouration and patterning between Seymour Norte and Baltra populations, separated by only 1.5 km is evidence of their long-term genetic isolation of central Galapagos racer populations which may now be considered separate species or sub-species. Recent investigations into Galapagos racer species complex have resulted in the separation of new species (R. A. Thomas, 1997; Zaher et al., 2018). This is not the only recent instance of a large restructuring of island snake taxonomy, such as that of blind snakes in Hispaniola and Cuba (R. Thomas & Hedges, 2007). Only after identifying these new species populations we may begin implementing measures to conserve them individually. Morphological differences presented in this project are consistent with those observed in the newly described taxa, therefore warrant further investigation. My project is a part of a larger collaborative project that is currently working on DNA analysis of the different populations to understand the genetic differences. We may then report our findings and recommendations to the Directorate of the Galapagos National Park so they can decide how to best conserve the populations.

Understanding the factors that may affect this colour variation can help us manage it more effectively. Factors such as changes in the number of both native and introduced predators on Seymour Norte may affect the proportion of different colour morphs in the racer population. Baling, Stuart-Fox, Brunton, and Dale (2016) showed the different levels of vulnerability Shore skinks have to predation depending on how conspicuous they are in their habitat, and how some conservation actions like translocations can be deleterious to colour morph variation. Despite Seymour Norte having a suitable population for translocations, there are many considerations when planning to reintroduce the central Galapagos racer to nearby islands that are currently devoid of snakes. Having a genetically representative founding population is important for reintroductions but if predators more easily targeted individuals with more conspicuous colouration it could risk losing a large proportion of the population's genetic diversity. It was found that shore skink populations would lose a significant amount of genetic diversity when translocated to inappropriate habitats. Sustaining measures to prevent pest reinvasion and further research into determining the cause of colour variation are recommended before allowing any interference to the populations.

CHAPTER 4: PRELIMINARY ASSESSMENT OF A REMNANT POPULATION OF THE CENTRAL GALAPAGOS RACER (*PSEUDALSOPHIS DORSALIS*) ON EL EDEN, SANTA CRUZ ISLAND.

Figure 20. Aerial view of El Eden Islet, off the coast of Santa Cruz Island, Galapagos Islands, Ecuador.

ABSTRACT

The central Galapagos racer (*Pseudalsophis dorsalis*) type locality is Santa Cruz, in the middle of the Galapagos archipelago, however sightings of the species there have decreased significantly since the 1980s, possibly due to depredation by cats, rodents and feral dogs. Offshore satellite islets free of predators are considered valuable strongholds for a range of endemic species, including the central Galapagos racer, however the status of the species on these satellite islands has not been investigated in recent years. In July 2019 I visited five islets off the coast of Santa Cruz to determine whether the central Galapagos racer is still present and to identify potential threats. I also visited the north of Santa Cruz island, an area of low feral cat density to assess whether these snakes still occur there. I encountered a remnant population of central Galapagos racers on El Eden, 293 m off the coast of Santa Cruz, including a very young individual indicating local recruitment. I did not find evidence of live snakes, or skins on Bowditch Islet, Guy Fawkes Four or the north of Santa Cruz Island. Within seven months of concluding my field season in Galapagos, park rangers from the Directorate of the Galapagos National Park encountered two dead specimens of central Galapagos racer, on the road to Granillo Rojo and at Los Gemelos, within 12 km south of the area surveyed in Santa Cruz. These sightings indicate the existence of a remnant population of central Galapagos racer in Santa Cruz island. During field work on El Eden I also encountered introduced black rats (*Rattus rattus*) which are common on Santa Cruz and can easily move between El Eden and the coast of Santa Cruz at low tide. Park rangers from the Directorate of the Galapagos National Park applied a pulse of rodenticide as per standard protocols. However, to ensure the long-term persistence of the central Galapagos racer further work is required to identify the level of predation intensity etc. I prepared a project to address this issue, and was awarded funds to conduct it by the Auckland Zoo, however due to COVID-19 I was unable to complete this component of my research.

INTRODUCTION

Introduced species on island systems have shown the potential to drastically reduce the population size and geographic distribution of vulnerable taxa. For instance, in a review of over 200 global cases, Medina et al. (2011) found that introduced feral cats have significantly reduced population size and number of populations of at least 175 vertebrates. The same study concluded that introduced feral cats, are responsible for nearly 14% of modern extinctions of birds, mammals and reptiles predominantly on islands. The effects of other introduced species are less understood. For instance, the Indian Mongoose (*Herpestes edwardsi*) introduced to the Antilles in the 1800, has caused the extinction of at least three endemic species of snakes on Jamaica, Hispaniola and Saint Croix, yet closely related snake species persist on other, smaller mongoose-free islands despite the presence of other introduced predators (Tolson and Henderson, 2011). For reptiles, disentangling the effects of introduced species can be particularly challenging as some island species are difficult to survey and exhibit secretive behaviours.

An emphasis on archipelagos around the world is to maintain significant populations of endemic taxa free of the effects on introduced species, either by preventing the arrival of introduced species to remnant populations, or by actively managing populations of these. For instance, in the Galapagos Islands, two remnant populations on islets some 25 km apart represent the last stronghold for the endemic, critically endangered Floreana mockingbird (*Mimus trifasciatus*) (Ortiz-Catedral, 2014). Strict bio-security protocols are in place to maintain these islets free of introduced species with the vision that one day, they could serve as sources of individuals to repopulate the historical range of the Floreana mockingbird (Hoeck et al., 2010). Another example is the rediscovery of a remnant population of South Island Takahe (*Porphyrio hochstetteri*) in the Murchinson Mountains, New Zealand (Clout & Craig, 1995). Following decades of predator control on a range of sites, the current management of

South Island Takahe involves the movement of numerous individuals between dozens of subpopulations across New Zealand, within and outside historical range of the species (Hegg, et al., 2012; Grange et al., 2014).

Isolated islands have proven particularly useful as sources of relic populations which have not been exposed to the same threats as mainland populations. When these threats are no longer abundant we have observed species naturally recolonizing in their historical habitat, such as the return of the Kermadec parakeet (*Cyanoramorphus novaezelandiae cyanurus*) to Raoul Island (Ortiz-Catedral et al. 2009; Bellingham et al., 2010). However, in cases where self-recolonising is very slow or impossible, some restoration projects have opted for conservation translocations, such as the successful introduction of South Island Takahe described above, or the current management of the Kakapo (*Strigops habroptila*) on at least four islands across New Zealand (Stone et al., 2017). The Duvaucel's gecko (*Hoplodactylus duvaucelii*) is another species that disappeared from most of its historical habitat throughout New Zealand, however, relic populations on offshore islands have been successfully used for translocations and a captive breeding programme that assists the long-term persistence of the species (Van Winkel, 2008). Thus, a priority for field conservationists is to identify remnant or relic populations of endangered taxa due to their potential in assisting the recovery of the target species.

The central Galapagos racer (*Pseudalsophis dorsalis)* was historically distributed throughout the coastal areas on Santa Cruz and adjacent islands and islets (Fig. 8). The increasing human population and development on Santa Cruz has resulted in the introduction of various invasive species that have in part contributed to the decline in geographic distribution of the central Galapagos racer, in a pattern that resembles the decline of the Floreana racer (*Pseudalsophis biserialis biserialis*) on Floreana Island (Steadman, 1986). The current distribution of the central Galapagos racer currently includes Baltra, Seymour Norte and Santa Fe islands (Arteaga et al., 2019) as well as offshore islets of Santa Cruz, however, access to these sites is only sporadic, and there are no recent accounts of the current status of the vertebrates on these islets, including the central Galapagos racer. Until recently the species was thought to occur on Santiago Island, but a recent study has recognised this as separate species (Zaher et al., 2018). Field observations indicate that the central Galapagos racer is a cluster of various taxa, rather than a single species (Ortiz-Catedral, pers. comm.). Zaher et al. (2018) failed to resolve the inter-population affinities of central Galapagos racers in their study. This suggests that as the taxonomic revision of the Galapagos terrestrial snakes continues it is likley that new taxa will be identified, and the extant distribution of the central Galapagos racer will be revealed as much reduced than currently understood (see also Chapter 4 and 5).

The current distribution of the central Galapagos racer throughout the Galapagos archipelago is still not fully understood. It has only been the recent research from Thomas (1997) and Zaher et al. (2018) that have begun to expose the true diversity of species, yet there are still several islands and islets that may contain unidentified populations or new species. Identifying these relic populations on offshore islands or islets can help conservation organisations plan for future restoration projects. For instance, these may involve pest management in the relic population habitat to ensure the population is stable, and later performing conservation translocations to a pest free site within their historical distribution. However, identifying a historically accurate source population for a translocation involves surveying all possible areas that contain relic populations to compare with the type specimen(s). Following discussions with the Galapagos National Park and Island Conservation, a key recommendation was to identify potential relic populations of central Galapagos racers on islands and islets near Santa Cruz and assess their current status and management needs, including predator control. To this end a team of six including myself, visited key locations to search for central Galapagos racers.

METHODS

In 2016-2017 a number of potential localities to survey central Galapagos racers near Santa Cruz island were discussed with Mr. Danny Rueda, Director of the Galapagos National Park and Dr. Karl Campbell from Island Conservation, and a subset was identified based on the following criteria: safe access to field personnel, historical records of the species, area greater than 1.2 ha, anecdotal records by park rangers and absence of feral cats (*Felis catus*) and absence of introduced rodents. The Directorate of the Galapagos National Park and Island Conservation regularly develop eradication and control programs for introduced vertebrates, one of the main threats to biodiversity in the Galapagos Islands (Carrion et al., 2008; Phillips et al., 2012), thus understanding the current status of central Galapagos racer on islands large enough to sustain vegetation could help future planning of priorities for control or eradication of feral cats and introduced rodents.

There are 22 islets and small islands in proximity to Santa Cruz ranging in distance to the coastline from a mere 30 m to 10 km (Snell et al., 1995). Of these, only 12 fit the criteria outlined above (Table 9). The original plan was to visit these islets in two parts, part I in 2019 and part II in 2020. However, part II has now been postponed indefinitely due to COVID-19 (see Chapter 1). In addition to these six islets, I visited an area known as the Canal de Itabaca in the northern part of mainland Santa Cruz (Table 1, Table 9) however no snakes were located in this area. The six islets visited during part I are listed in Table 9, however central Galapagos racers were only found on El Eden. Snakes were searched during the periods of greater activity of Galapagos terrestrial snakes, captured and measured as per standard protocols (see Chapter 1, General Field methods).

RESULTS

A team of five and I visited a total of six islets and two mainland sites (Table 1, Table 2). The combined area surveyed was 53 ha, searched for a total of 37.5 man-hours. Central Galapagos racers were only found on El Eden (Fig. 11), where eight individuals were captured. One individual was released before it could be measured (Table 4). In addition a small individual, possibly a juvenile < 30 cm long escaped (Ortiz-Catedral, pers. obs.).

Figure 21. Habitat on El Eden, Santa Cruz Island in the distance. Note the narrow gap between both islands.

Figure 22. Central Galapagos racer in its habitat on El Eden. Photo: L. Ortiz-Catedral

The scale series for snakes on El Eden falls within the range of scale counts for central Galapagos racers on Seymour Norte, Baltra and Santa Fe (Table 6).

On other localities, no evidence of live snakes, or shed was located. Similarly, no evidence of black rats was found on the localities visited, except El Eden. During searches of central Galapagos racers, the team reported four sightings of black rats (*Rattus rattus*), however their numbers could not be quantified.

Table 9. Localities identified for searches of central Galapagos racer, Santa Cruz Island.

Locality	Island	Type	Search area (ha)	Search effort (Man-hours)	Individuals caught	Individuals escaped
El Eden	El Eden	Islet	10	37.5	8	1
Las Ninfas	Santa Cruz	Mainland site	10	16	0	0
Canal de Itabaca	Santa Cruz	Mainland site	8	10	0	0
Zona de Anidacion	Venecia	Islet	8	15	0	0
Bowditch	Bowditch	Islet	2	8	0	0

Locality	Island	Type	Search area (ha)	Search effort (Man-hours)	Individuals caught	Individuals escaped
Plaza Norte	Plaza Norte	Islet	7	6	0	0
Plaza Sur	Plaza Sur	Islet	7	12.5	0	0
Guy Fawkes 4	Guy Fawkes 4	Islet	1	2	0	0

Locality	Island	Type	Search area (ha)	Search effort (Man-hours)	Individuals caught	Individuals escaped
Isla Caamaño	Isla Caamaño	Islet	4.5	Not visited	0	0
Roca Gordon Este	Roca Gordon Este	Islet	2.9	Not visited	0	0
Isla Daphne Chica	Isla Daphne Chica	Islet	7.9	Not visited	0	0
Isla Daphne Major	Isla Daphne Major	Islet	33	Not visited	0	0
Guy Fawkes Oeste	Guy Fawkes Oeste	Islet	3.4	Not visited	0	0

Table 10. Measurements of central Galapagos racers on El Eden (n=7).

ID	SVL (cm)	TL (cm)	Total L (cm)	Mass (g)	Sex
E4	52.20	14.10	66.30	44.00	M
E3	55.00	20.80	75.80	41.00	M
E2	49.30	19.00	68.30	32.00	F
E1	46.50	18.20	64.70	33.00	M
0007D2B694	51.00	27.00	78.00	58.00	F
0007D328EC	50.80	20.60	71.40	28.00	M
0007D2C3FF	52.00	19.20	71.20	41.00	M

Table 11. Scale series counts for central Galapagos racers.

First, second and third refer to temporal scale series.

Island	Ventral	Subcaudal	First	Second	Third
Seymour Norte (74)	195-234	47-122	18-19	17-19	15-19
Baltra (6)	211-232	47-94	18-19	18-19	16-18
Santa Fe (4)	211-226	89-94	18-19	19	16-18
El Eden (7)	198-230	47-104	18-19	18-19	15-19

DISCUSSION

The presence of the central Galapagos racers on El Eden, despite lack of reliable records since the 1980s, opens up the possibility of using this population as source of individuals for future reintroductions within their historical distribution. This is a significant finding as it represents a population within the historical distribution of the type specimen. Nevertheless, the discovery of black rats threatens this population. Daltry et al. (2001) described in detail the threats of black rats to small island populations of Antiguan racers (*Alsophis antiguae*), which include bites, and in some cases death. Eradications of black rats have allowed the Antiguan racer to recover, and within two years the population more than doubled in size (Varnham et al., 1998). The successful capture of eight central Galapagos racers on El Eden may not be representative of the island's carrying capacity as we have observed this racer in much larger numbers when searching a similar sized area on Seymour Norte. One very small individual was seen but escaped before capture (Ortiz-Catedral pers. comm.) which indicates local recruitment. The high possibility of black rats threatening the racer population on this island needs to be addressed. The racers captured and measured at El Eden did not have noticeable signs of rat bites, however a larger number of snakes needs to be examined.

The Galapagos National Park has completed several successful rat eradication projects, one such project was Pinzon which achieved complete eradication black rats (Rueda et al., 2019). Due to the small size of El Eden, total eradication of rats is feasible, but the high probability of reinvasion from Santa Cruz remains a challenge. El Eden will however require further attention due to its proximity to Santa Cruz. Tabak, Poncet, Passfield, and del Rio (2015) outlined the swimming ability of rats, showing 72% of islands within 500 m of a potential rat source had rats, which makes El Eden highly susceptible to reinvasion from Santa Cruz. There have been a total of nine reinvasions of black rats within pest free islands in New Zealand and in almost all cases swimming was the most likely source of invasion, with some rats capable of swimming up to 500 m offshore (Russell, Towns, & Clout, 2008). To prevent reinvasion of rats to El Eden there will need to be a regularly maintained rat control programme throughout the island and a buffer on the coast of Santa Cruz parallel to El Eden. I would recommend pulses of rat control to be performed initially for the eradication and baiting can continue on the coast of Santa Cruz. To prevent rat reinvasion there will be a monitoring programme using tracking tunnels and wax tags, this has been proven as an effective detection method as outlined in Russell, Towns, & Clout (2008). A similar programme was developed in Rey Francisco Island (12 ha) and resulted in complete eradication and following reinvasions were quickly identified and eliminated with monitoring followed by poison bait pulses (Orueta, Aranda, Gomez, Tapia, & Sanchez-Marmol, 2005).

Additional searches for central Galapagos racers in the islets identified in this study could reveal further populations of snakes and potentially more areas with black rats. In coming years this should be determined while at the same time maintaining surveillance on El Eden. Within seven months of concluding my field season in Galapagos, park rangers from the Directorate of the Galapagos National Park encountered two dead specimens of central Galapagos racer, on the road to Granillo Rojo and at Los Gemelos, within 12 km south of the are surveyed in Santa Cruz. These sightings indicate the existence of a remnant population of central Galapagos racer in mainland Santa Cruz island. Determining the approximate population size of these remnant populations on islets and mainland sites is a top management priority for the conservation of the central Galapagos racer.

A better understanding of the central Galapagos racer population size on El Eden and the level of predation are important to set a baseline to measure success of rat control and effects on snakes. Due to the small size of El Eden, it would be relatively easy to implement a mark-recapture study on these snakes, similar to the study by Christian (2017). To follow up these requirements I developed a project proposal for the Auckland Zoo grant which was successful (Appendix). However, the COVID-19 global pandemic has prevented the implementation of this project. Hopefully, future researchers and managers can use the information outlined here to measure the effects of black rats, control their numbers on El Eden and measure the response of the population of central Galapagos racers.

CHAPTER 5: SIGNIFICANT GAPS IN RESEARCH AND POTENTIAL FUTURE RESEARCH

Figure 23. “El Pirata” the research vessel used to conduct the field research described in this thesis. Photo: L. Ortiz-Catedral.

ABSTRACT

In contrast to other reptile groups in the Galapagos Islands, the Galapagos terrestrial snakes (*Pseudalsophis* spp.) have received little attention from the scientific community, with only a handful of field studies documenting aspects of their biology. In this thesis I present new information about the dietary spectrum, distribution and phenotypic variation of the central Galapagos racer. However, due to the challenges to travel to the Galapagos Islands resulting from the COVID-19 pandemic, a number of questions remained unanswered. Here I discuss four key gaps in knowledge and potential research projects that could be developed to address these in the coming years. Since my first visit to Galapagos in 2017, the local community of Puerto Ayora has reported numerous terrestrial snakes in their backyards and gardens. These reports are made directly to park rangers of the Galapagos National Park, but to date there is no standard format to register information. I argue that this could serve as the basis for a citizen science project, and provide a basic template that could be used to begin organising information. Most of the information available on Galapagos terrestrial snakes comes from observations or studies near the coast, I therefore recommend a study into the altitudinal distribution of species to better understand the range of habitats these vertebrates occupy. To date, only one registered observation and one anecdotal reference exist about the eggs of Galapagos terrestrial snakes. This represents a major gap in knowledge of these snakes and a study on their reproduction is urgently needed. There is still much to be learned about the dietary spectrum of Galapagos racers. Despite its limitations, faecal analysis can reveal important aspects of the prey consumed by these snakes. I discuss the need of a comparative study to better understand the seasonal variation in the diet of these reptiles.

Citizen science and conservation of Galapagos terrestrial snakes

The human population of the Galapagos Islands consists of approximately 25,000 people in the towns of Puerto Ayora (Santa Cruz Island), Puerto Villamil (Isabela Island), Puerto Baquerizo Moreno (San Cristobal), Puerto Velasco Ibarra (Floreana Island) and members of the Ecuador Army on the island of Baltra. Puerto Ayora is the most populated town with over 12,000 inhabitants. In these towns people are no stranger to endemic wildlife, for instance, Galapagos sea lions (*Zalophus wollebaeki*) frequently visit local fish markets in search of scraps, or occupy public seats and benches. Finches (*Geospiza* spp.) and mockingbirds (*Mimus* spp.) are regular visitors to gardens in Puerto Baquerizo Moreno, Puerto Villamil and Puerto Ayora. Field guides, responsible for guided tours on the islands are active naturalists and often share their local knowledge of the flora and fauna with visitors and visiting scientists. In 2015, Eli Christian (then a MSc student) and Luis Ortiz-Catedral (my thesis supervisor) started a field study on the Floreana racer (*Pseudalsophis biserialis*) as part of this project they conducted irregular interviews with locals, field guides and rangers to create a map of localities where Galapagos terrestrial snakes could be seen regularly. While park rangers and field guides shared information readily, there were only a handful of records from the general population. Since my first visit in the Galapagos Islands in December 2017, members of the local community have reported 21 Galapagos terrestrial snakes in private residences, streets and gardens (Table 12). Most of the records (61%) consisted of live snakes, which were released on the nearest patch of native vegetation, while the remaining were found dead, apparently run over by motor vehicles. Dead snakes were deposited at the Charles Darwin Foundation Vertebrate Collection (Figure XXX).

Table 12. Specimens of Galapagos terrestrial snakes reported by members of the community in townships of the Galapagos Islands. Status: Released = snake brought to Directorate of Galapagos National Park offices and subsequently released in the nearest patch of native habitat; CDF collection = specimen fixed in alcohol and deposited in the vertebrate collection of the Charles Darwin Foundation, in Pto. Ayora, Sta. Cruz.

Date	Common name	Scientific name	Locality /Island	Notes	Status
13/12/2017	Western Galapagos racer	*Pseudalsophis occidentalis*	Pto. Villamil/ Isabela	Found on road	CDF collection
12/05/2018	Painted racer	*Pseudalsophis steindachneri*	Pto. Ayora/Sta. Cruz	Found in garden	Released
23/06/2018	Painted racer	*Pseudalsophis steindachneri*	Pto. Ayora/Sta. Cruz	Found inside shop	Released
23/07/2018	Painted racer	*Pseudalsophis steindachneri*	Pto. Ayora/Sta. Cruz	Found on street	Released
27/07/2018	Painted racer	*Pseudalsophis steindachneri*	Pto. Ayora/Sta. Cruz	Found inside house	Released

16/08/2018	Painted racer	*Pseudalsophis steindachneri*	Pto. Ayora /Sta. Cruz	Found in garden	Released
25/08/2018	Western Galapagos racer	*Pseudalsophis occidentalis*	Pto. Villamil/ Isabela	Found on road	CDF collection
29/08/2018	Painted racer	*Pseudalsophis steindachneri*	Pto. Ayora/Sta. Cruz	Found inside house	Released
1/10/2018	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found on street	Released
5/02/2019	Eastern Galapagos racer	*Pseudalsophis biserialis*	Pto. Baquerizo/S. Cristobal	Found on street	CDF collection
17/02/2019	Eastern Galapagos racer	*Pseudalsophis biserialis*	Pto. Baquerizo/S. Cristobal	Found on street	CDF collection
25/06/2019	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found in bathroom	Released
28/06/2019	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found in garden	Released

30/06/2019	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found on street	Released
15/07/2019	Central Galapagos racer	*Pseudalsophis dorsalis*	Army base/Baltra	Found in patio	Released
7/08/2019	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found on street	Released
24/08/2019	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found on street	CDF Collection
5/09/2019	Western Galapagos racer	*Pseudalsophis occidentalis*	Pto. Villamil/ Isabela	Found on road	CDF collection
31/10/2019	Painted racer	*Pseudalsophis steindachneri*	Pto Ayora/Sta. Cruz	Found on wall	Released
11/01/2020	Central Galapagos racer	*Pseudalsophis dorsalis*	Los Gemelos/Sta. Cruz	Found in farm	CDF collection
13/02/2020	Central Galapagos racer	*Pseudalsophis dorsalis*	Los Gemelos/Sta. Cruz	Found in farm	CDF collection

Figure 24. Six different individuals of Painted racer (Pseudalsophis steindachneri) captured in private gardens of members of the community of Puerto Ayora. Photos: D. Rueda.

Altitudinal distribution of Galapagos terrestrial snakes

The majority of records of Galapagos terrestrial snakes to date are from localities and populations close to the coast. As more field studies and observations of these reptiles are conducted it becomes clear they are not restricted to coastal vegetation and associated habitats. In September 1835, Charles Darwin collected the first and only specimen of Galapagos terrestrial snake on Floreana Island without specifying a collection site. This specimen, now at the Natural History Museum, served as the basis for the description of the eastern Galapagos racer (*Pseudalsophis biserialis*). Although Darwin collected a single specimen, the Beagle's Captain, Robert Fitzroy states "there are a few small snakes, but those we caught were not venomous" (Fitzroy, 1839/1977), in Fitzroy correspondence the location where the snakes were sighted was not specified either, but it is possible that it was either Post Office Bay or Black Sand Beach, as their name implies, close to the coast. During his visit to the Archipelago, Beebe (1924) registered Central Galapagos racers (*Pseudalsophis dorsalis*) on El Eden islet (see Chapter 4). During the early 1980s Greene (1991, in litt.) conducted a field study on the snakes of Santiago Island, across different habitats and a range of altitudes in the area known as Las Campeonas, on the western side of the Island near the coast. However, this study was never published and details of the localities and numbers of individuals encountered are not available. In 1986, Steadman described subfossil bones of Floreana racers from a locality known as Pirate Caves, also near the coast (Steadman, 1986). Later, Altamirano (1996) conducted a study on Espanola racers (*Pseudalsophis hoodensis*) in Gardner Bay. In 2015-2017 Christian (2017) studied Floreana racers on Champion and Gardner Islets, once again on populations of snakes near the coast. Park rangers have reported snakes near volcano summits on Isabela. One of these volcanoes, Wolf (1707 masl) was visited in 2019 by a team of five experienced herpetologists but no snake or evidence of snakes were located after nearly 200 man-hours of searches in a 250 ha area (Ortiz-Catedral et al., unpublished). To date the only records of snakes at high altitudes in Galapagos consist of three individuals, one of which was ingesting an Isabela lava lizard (*Microlophus albermarlensis*) at 1400 masl (Ortiz-Catedral et al., 2019) (Fig. 25).

Figure 25. A western Galapagos racer (Pseudalsophis occidentalis) at La Cumbre (1400 masl), Fernandina Island after ingesting an Isabela lava lizard (Microlophus albermarlensis). Photo: L.Ortiz-Catedral.

Reproduction of Galapagos terrestrial snakes

The biology of Galapagos racers is poorly understood, in particular with regards to their reproductive behaviour. Beebe (1924) described one snake (possibly *Pseudalsophis dorsalis*) on El Eden islet in April 1923, containing two eggs and "*almost ready for deposition"*. Greene and Reynolds (in litt.) mentions two individuals of *Pseudalsophis hoodensis* found on Española Island in 1964 having two eggs each, but no further information is provided. Biol. P. Buitron (pers. comm.), described two snake hatchlings found accidentally inside a terrarium at the Charles Darwin Foundation in the early 1990s "*during the garua season*" (June to December), possibly the dirt used contained the developing eggs. The hatchlings were released in the gardens of the Charles Darwin Foundation but their fate was not followed.

Field observations of copulatory behaviour of Galapagos terrestrial snakes is scattered and mostly consists of anecdotal references, notes on field reports or direct observations by park rangers or visiting scientists. Here I compile the available information for a range of species based on interviews with park rangers and notes on field reports to the Directorate of the Galapagos National Park. The terminology is based on the study by Gillingham and Carptenter (1977).

Floreana racer (*Pseudalsophis biserialis biserialis)*

Eight individuals (two females/six males) were observed during the tactile phase on Gardner-by-Floreana (1° 19' 52" S, 90° 17' 20" W) at 8:35 am on 7th January 2017. The air temperature was 25.87 °C (CDF weather station). Observers: M. Skirrow and E. Christian.

Two individuals were found copulating at 7:41 am

Gardner-by-Floreana (1° 19' 52" S, 90° 17' 20" W) on 27th January 2018. The air temperature was 24.86 C (CDF weather station), these were observed from a distance of 6 m, the copulation lasted 2 minutes but not recorded when it started, so most likely were found towards the end of the copulatory behaviour. Observers: L. Ortiz-Catedral and S. Ascencio.

Western Galapagos racer

Two individuals were found copulating near the shore at Cape Douglas in Fernandina (0° 22' 0" S, 91° 31' 20" W) on 6th July 2018 these were observed from a distance of approximately 9 m, the duration of the copulation lasted 8 minutes. The air temperature was 23.54 °C (CDF weather station). Observers: L. Ortiz-Catedral and J. Ramirez.

In addition to these, Beebe (1924) described two eggs extracted from a "striped" central Galapagos racer collected in Santa Cruz on April 1923 . No further notes are included. Young snakes, possibly a few months old have been noticed in the field, including a very small central Galapagos racer on El Eden (see Chapter 4).

Floreana racer (*Pseudalsophis biserialis biserialis*)

Champion (1° 14' 7" S, 90° 23' 8" W), a very small possibly 20 cm long snake was seen on 28th November 2016. The snake escaped through a narrow crevice. No information available on the air temperature. Observers: L. Ortiz-Catedral and J. Macias

From these observations it can be said that copulation happens in the austral summer and winter (all observations below the equatorial line). With egg laying possibly during the spring and autumn.

A field study looking into the development of testes and possibly egg-carrying females could be conducted on small islands such as Seymour Norte.

Seasonal variation in diet and dietary spectrum of Galapagos terrestrial snakes

The diversity of prey types and prey species consumed by Galapagos terrestrial snakes has been partially documented, starting with descriptions of food items recovered from museum specimens, to more recent field studies describing the range of species consumed. In the present study my colleagues and I provide an updated description of the prey consumed by these snakes (Chapter 2). Nevertheless, much remains to be studied in this regard. One possibility is to include state of the art methods to document diet such as micropore etc. The examination of faeces is still a useful approach but the main limitation is the amount of organic matter that cannot be ascribed to reference voucher specimens. Molecular methods can be useful to compare diets described on the basis of faecal remains and those derived from sequencing genomes of prey. Populations on small islets such as El Eden, Champion or Venecia could be used as study sites to conduct seasonal assessments of the diets of snakes.

This information will be useful to describe the ecological role of snakes in the ecosystems of the Galapagos Islands.

Alternative or complementary methods to faecal analysis could reveal the broader extent of diet of Galapagos terrestrial snakes. Stomach flushing, or forced regurgitation of prey has proven useful for analysing stomach contents of reptiles without the need for dissection, it has been effectively used on turtles, lizards, and crocodilians (Legler, 1977; Herczeg et al., 2007; Tucker et al., 1996). This method has been used in Semi-aquatic snake diet analysis however in this study the snakes (*Natrix natrix* and *N. tessellate*) were deposited into a herpetological collection shortly after (Reshetnikov et al., 2013). More research into this methods success on live snakes is needed as well as a thorough assessment of the animal ethics requirements for it. As mentioned with the forced regurgitation method, outlined in the general study methods section, this is a similarly intrusive method that requires recently ingested prey. Less than 20% of snakes captured had ingested prey recently. The small populations of snakes and prey on some islands means the loss of an individual by this method or its missed meal will affect the population health. In addition, flushing methods may be inappropriate for snakes with a single large prey item whereas a faecal sample can contain multiple prey items it has consumed over time. Regardless, the Galapagos terrestrial snakes represent good models to investigate predator-prey interactions on islands with different degrees of restoration.

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APPENDICES

Figure 26. Eastern Galapagos racer (*Pseudalsophis occidentalis*) in its natural habitat on Cape Douglas, Fernandina. Photo: L. Ortiz-Catedral.

APPENDIX I.

Research permit PC-74-17 by the Ministry of the Environment and Directorate of the Galapagos National Park, Ecuador.

Ministerio del Ambiente

Parque Nacional GALÁPAGOS Ecuador

PUNTO VERDE — ÁREAS PROTEGIDAS POR TI

DIRECCIÓN DEL PARQUE NACIONAL GALÁPAGOS
DIRECCIÓN DE GESTIÓN AMBIENTAL
PERMISO DE INVESTIGACIÓN CIENTÍFICA: **N° PC-74-17**

Versión: 01 Fecha: 09/01/17

Título del Proyecto: Diversidad taxonómica de las culebras terrestres en Galápagos.	
Nombre del Aplicante: Danny Rueda	**Contraparte Institucional/DPNG:** N.A.
Dirección actual completa: Dirección de Ecosistemas de la DPNG, Puerto Ayora. Correo electrónico: drueda@galapagos.gob.ec	
Otros participantes en el Proyecto: Luis Ortiz Catedral, Christian Sevilla (Guardaparque), Danielle Edwards, Graeme Reynolds.	
Clasificación del Proyecto: Herpetología.	**Requiere Contrato Marco de Acceso a Recursos Genéticos:** NO
Se requiere colectar muestras: NO	**Factura:** NO APLICA
Duración del Permiso de Investigación: Del 06 de septiembre del 2017 al 05 de septiembre 2018.	
Islas: Santiago, Bartolomé, Española, Santa Fé, Isabela, Fernandina, San Cristóbal, Santa Cruz, Pinzón, Baltra, Seymour y Rábida	Sitios: Bahía Sullivan, Espumilla, Playa frente al Pináculo de Bartolomé **(Santiago)**, Islote Gardner, Punta Cevallos **(Española)**, El Miedo, Centro de la isla **(Santa Fe)**, Islote Tortuga, Quinta Playa, Caleta Tagus, Volcán Wolf, Bahía Elizabeth, Bahía Cartago **(Isabela)**, Cabo Douglas, Cueva Norte, La Cumbre, Cabo Hammond **(Fernandina)**, Isla Lobos, Punta Pitt, Puerto Baquerizo Moreno **(San Cristóbal)**, El Garrapatero, El Mirador, Islote Venecia, Islote Edén, Punta Estrada **(Santa Cruz)**, **isla Pinzón, isla Baltra, isla Seymour Norte, isla Rábida**
Instituciones auspiciantes: Dirección del Parque Nacional Galápagos, Massey University, Universidad de California, Merced, Universidad de Carolina del Norte, Asheville, Mohamed bin Zayed Species Conservation Fund, Galapagos Conservation Trust.	

Condiciones de cumplimiento obligatorio:

1. Los investigadores deberán cumplir estrictamente con todas las regulaciones establecidas en el Manual de Procedimientos para Científicos Visitantes y Protocolos para viajes de Campo y Campamentos en las Islas Galápagos.

2. Únicamente el equipo de investigadores incluido en el presente permiso está autorizado para participar durante el desarrollo del proyecto, tanto en la fase de campo, análisis de muestras, tabulación de datos y desarrollo de publicaciones. En caso de requerir la participación de investigadores adicionales, los responsables del proyecto deberán solicitar la autorización correspondiente por escrito a esta Dirección, presentado las justificaciones necesarias.

3. Previo a la salida de campo, el investigador principal deberá presentar a la DPNG el AVISO DE VIAJE DE CAMPO correspondiente, con mínimo 72 horas de anticipación y de acuerdo al formato establecido; y coordinar permanentemente con el Responsable del Departamento de Investigación Aplicada de la DPNG en Santa Cruz, a fin de sistematizar todas las actividades que se ejecuten dentro del proyecto.

4. Para las salidas de campo del proyecto, los investigadores deberán contar con una copia legible del respectivo Permiso de Investigación y el Aviso de Viaje de Campo firmado por los técnicos de Investigación Aplicada de la DPNG.

5. Los sitios e islas autorizados serán exclusivamente: Bahía Sullivan, Espumilla, Playa frente al Pináculo de Bartolomé **(Santiago)**, Islote Gardner, Punta Cevallos **(Española)**, El Miedo, Centro de la isla **(Santa Fe)**, Islote Tortuga, Quinta Playa, Caleta Tagus, Volcán Wolf, Bahía Elizabeth, Bahía Cartago **(Isabela)**, Cabo Douglas, Cueva Norte, La Cumbre, Cabo Hammond **(Fernandina)**, Isla Lobos, Punta Pitt, Puerto Baquerizo Moreno **(San Cristóbal)**, El Garrapatero, El Mirador, Islote Venecia, Islote Edén, Punta Estrada **(Santa Cruz)**, **isla Pinzón, isla Baltra, isla Seymour Norte, isla Rábida**.)

6. Previo al inicio de las actividades, el responsable del proyecto deberá coordinar las actividades con el Dr. Diego Cisneros de la USFQ, con la finalidad de evitar la duplicación de esfuerzos, específicamente para este estudio en las islas de San Cristóbal y Española.

7. Durante el trabajo de campo en sitios con acceso de turistas, se deberá evitar el contacto con estos y no deberán manipular la fauna y flora, mientras haya visitantes en los sitios; de no ser posible, el investigador principal del proyecto deberá brindar una breve explicación de las actividades de investigación a los visitantes y posteriormente retomar el desarrollo de sus actividades.

8. Se autoriza la realización de censos, captura de especímenes, toma de medidas morfológicas, pesaje de culebras de Galápagos.

9. Se autoriza la colocación de un máximo de 200 micro-chips (TROVAN PIT TAG modelo ID-100B/1.4 9, 6x1.5 mm), con jeringa estéril en el flanco latero-dorsal de cada culebra capturada en la fase de campo.

10. **No se autoriza** la recolección de ningún tipo de muestras biológicas.

11. El desarrollo de actividades de investigación científica dentro de las Áreas Protegidas como el Parque Nacional y la Reserva Marina de Galápagos es un privilegio concedido por el Gobierno Ecuatoriano a través de la DPNG, por lo que los responsables del proyecto deberán citar el número de Permiso de Investigación Científica otorgada por la DPNG, e incluir los reconocimientos y/o agradecimientos en las publicaciones científicas, Tesis o informes técnicos científicos que se emita como producto generado en base al presente permiso de investigación.

12. El análisis de los datos y los avances de la investigación deberán estar disponibles permanentemente para la DPNG, existiendo el compromiso de estos de usarlos únicamente para acciones de manejo y no publicarlos sin el consentimiento de los investigadores principales del proyecto.

13. Una vez concluido el análisis de las muestras, estas, las bibliotecas de datos y/o cualquier material resultante deberán ser devueltos a la DPNG. Estas deben ser preservadas, curadas y depositadas correctamente en las colecciones de referencia en Galápagos, de lo contrario, se deberán sufragar los gastos que demanden la preparación del material para su ingreso a la colección correspondiente.

14. Previo a la renovación del permiso de investigación, el científico responsable del proyecto o su contraparte institucional de investigación deberán entregar a la DPNG y cumplir con lo siguiente:

    - Una copia digital (Tabla de Excel 97-2003) de todos los datos obtenidos durante la ejecución del proyecto.
    - Un INFORME TECNICO DE CAMPO por cada Aviso De Viaje De Campo presentado a la DPNG, para la ejecución del proyecto.
    - Dos conferencias para los guardaparques de la DPNG, guías naturalistas y otras personas interesadas sobre los avances del proyecto. Para establecer el cronograma se deberá coordinar con el Responsable de Investigación Aplicada de la DPNG.
    - Un INFORME DE AVANCES del proyecto con todos los detalles de la investigación y sus recomendaciones técnicas aplicables al manejo de las Áreas Protegidas.
    - Artículos y publicaciones resultantes de la siguiente manera: en el caso de publicaciones únicamente en formato digital, si son libros o tesis, 5 impresas y una digital, en el caso de la versión digital lo harán en dispositivos magnéticos adecuadamente identificados.

15. Los datos que se desprendan de esta investigación, no podrán ser utilizados para estudios posteriores sin la previa autorización del Ministerio del Ambiente a través de la Dirección del Parque Nacional Galápagos.

16. Del incumplimiento de las obligaciones dispuestas anteriormente se responsabiliza al Ing. Danny Rueda de la DPNG y al Dr. Luis Ortiz-Catedral como Responsable del proyecto. Por lo tanto el incumplimiento de cualquiera de estas condiciones así como el uso indebido de este documento, serán sancionados conforme a la Ley Forestal y de Conservación de Áreas Naturales y Vida Silvestre Codificada, Texto Unificado de la Legislación Ambiental Secundaria y dependiendo de la infracción podría conllevar a suspensión inmediata de la investigación.

Valoración Técnica: Galo Quezada	**Categoría:** FUNCIONARIO DPNG 2017

Considerando que el Título II, numeral 2.2, literal V del Estatuto Orgánico de Gestión por Procesos de la Dirección del Parque Nacional Galápagos publicado en la Edición Especial N° 349 del Registro Oficial publicado el martes 16 de octubre del 2012, establece entre las atribuciones y responsabilidades del Director de Gestión Ambiental "Administrar y organizar las actividades de investigación que se desarrollen en las áreas protegidas de Galápagos, en coordinación con el proceso de investigación", además que mediante Resolución N° 71 del 14 de Diciembre del 2012, el Director del Parque Nacional Galápagos delegó al Director de Gestión Ambiental, para que en su nombre y representación tramite y suscriba los actos relacionados con el desarrollo de proyectos de investigación científica en las áreas protegidas de Galápagos; en uso de la facultad delegada y de conformidad a lo señalado en el Título Cuarto, capítulo I del Estatuto Administrativo de la Dirección del Parque Nacional Galápagos, otorga el presente PERMISO DE INVESTIGACIÓN.

Reporte de avances: 15 de febrero 2018 **Reporte Final:** 15 de agosto 2018	**FIRMA DEL INVESTIGADOR PRINCIPAL**

Fecha de emisión: 06 de septiembre 2017	**Director de Gestión Ambiental** **DIRECCIÓN DEL PARQUE NACIONAL GALÁPAGOS**	**Sello PNG**

Parque Nacional GALAPAGOS Ecuador

APPENDIX II.

Research permit by the Ministry of Environment, Ecuador.

SECRETARIA GENERAL

Ministerio del Ambiente

FECHA REG 13 ABR 2017

REGISTRO 6072

FOLIO 361

Ministerio del Ambiente

CONTRATO MARCO DE ACCESO A LOS RECURSOS GENÉTICOS DEL PROGRAMA DE INVESTIGACIÓN CIENTÍFICA DENOMINADO: "*RESTAURACIÓN ECOLÓGICA DE LA ISLA FLOREANA*" CELEBRADO ENTRE EL ESTADO ECUATORIANO, A TRAVÉS DEL MINISTERIO DEL AMBIENTE; E, ISLAND CONSERVATION

MAE – DNB – CM – 2016 – 0060

COMPARECIENTES:

A la suscripción del presente Contrato Marco de Acceso a los Recursos Genéticos comparecen, por una parte el Ministerio del Ambiente, a través de la Subsecretaría de Patrimonio Natural, legalmente representado por el Biólogo Francisco José Prieto Albuja, en su calidad de Subsecretario de Patrimonio Natural, delegado de la máxima autoridad conforme se desprende del Acuerdo Ministerial Nro. 024 de 09 de marzo de 2016, publicado en el Registro Oficial Nro. 725 de 04 de abril de 2016, a quien en adelante se le denominará **"MAE"**; y, por otra parte, Island Conservation, debidamente representada, por el Señor Diego Ramiro García Montoya, en su calidad de Apoderado General, conforme se desprende de la Protocolización Nro. 2015-17-01-06-P02354 de 05 de junio de 2015, certificado el 01 de febrero de 2017, ante la Doctora Tamara Garcés Almeida, Notaria Sexta del cantón Quito, que se agrega como documento habilitante y a quien en adelante se le denominará **"IC"**;

Las partes convienen en celebrar, el presente Contrato Marco de Acceso a los Recursos Genéticos respecto de la solicitud del programa de investigación científica denominado "*Restauración ecológica de la isla Floreana*", contenido y estipulado en las siguientes cláusulas:

PRIMERA. ANTECEDENTES.-

1. La Constitución de la República del Ecuador, en los artículos 3, numeral 7 y 83, numerales 6 y 13 establece como deberes y responsabilidades del Estado y de sus habitantes el resguardo del patrimonio cultural y natural del país, así como también el respeto a los derechos de la naturaleza, la preservación de un ambiente sano y utilización de los recursos naturales de modo racional, sustentable y sostenible;

2. La Constitución de la República del Ecuador, en los artículos 14, 74, 275, 276, 387, 388 reconoce el derecho de la población a vivir en un ambiente sano y ecológicamente equilibrado, que garantice la sostenibilidad y el buen vivir, sumak kawsay. Declara de interés público la preservación del ambiente, la conservación de los ecosistemas, la biodiversidad y la integridad del patrimonio genético del país, la prevención del daño ambiental y la recuperación de los espacios naturales degradados. Además, establece como un requerimiento para el buen vivir, que las personas, comunidades, pueblos y nacionalidades gocen efectivamente de sus derechos, y ejerzan responsabilidades en el marco de la interculturalidad, del respeto a sus diversidades, y de la convivencia armónica con la naturaleza;

3. La Constitución de la República del Ecuador, en los artículos 313 y 400 establecen que el Estado ejercerá la soberanía sobre la biodiversidad y el patrimonio genético, considerados sectores estratégicos, sobre los cuales el Estado se reserva el derecho de administrar, regular, controlar y gestionar de acuerdo a los principios de sostenibilidad ambiental, precaución, prevención y eficiencia;

4. La Constitución de la República del Ecuador, en el artículo 322 reconoce la propiedad intelectual de acuerdo con las condiciones que señale la ley, así como prohíbe toda forma de apropiación en el ámbito de las ciencias, tecnologías, saberes ancestrales y sobre los recursos genéticos que contienen la diversidad biológica y la agro-biodiversidad;

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5. La Constitución de la República del Ecuador, en los artículos 385, 386, 387 y 388, establece como una responsabilidad del Estado el desarrollo de la ciencia, tecnología, innovación y saberes ancestrales en el marco del respeto al ambiente, la naturaleza, la vida, las culturas y la soberanía;

6. La Constitución de la República del Ecuador, en el artículo 395, numerales 1, 2 y 4 reconoce y establece que el Estado enmarca una "política para la conservación de la biodiversidad", asumiendo responsabilidad obligatoria pero compartida con todos los integrantes de la sociedad que incluye el aspecto precautelatorio a favor de la naturaleza;

7. La Constitución de la República del Ecuador, en el artículo 397, numeral 4 señala que el Estado asegurará la intangibilidad de las áreas naturales protegidas, de tal forma que se garantice la conservación de la biodiversidad y el mantenimiento de las funciones ecológicas de los ecosistemas;

8. La Constitución de la República del Ecuador, en el artículo 404 establece que: *"El patrimonio natural del Ecuador único e invaluable comprende, entre otras, las formaciones físicas, biológicas y geológicas cuyo valor desde el punto de vista ambiental, científico, cultural o paisajístico exige su protección, conservación, recuperación y promoción. [...].";*

9. La Constitución de la República del Ecuador, en el artículo 408 establece que son propiedad inalienable, inembargable, irrenunciable e imprescriptible del Estado ecuatoriano la biodiversidad y su patrimonio genético;

10. La Constitución de la República del Ecuador, en el artículo 417 determina que: *"Los tratados internacionales ratificados por el Ecuador se sujetarán a lo establecido en la Constitución. [...]";*

11. El Convenio sobre la Diversidad Biológica, publicado en el Registro Oficial Nro. 647 de 06 de marzo de 1995, reconoce el derecho soberano que ejercen los Estados sobre su biodiversidad, estableciendo como objetivos primordiales la conservación de la diversidad biológica, la utilización sostenible de sus componentes y la participación justa y equitativa en los beneficios que se deriven de la utilización de los recursos genéticos;

12. La Decisión de la Comunidad Andina Nro. 391, publicado en el Registro Oficial Suplemento Nro. 05 de 16 de agosto de 1996, promulgó el: *"Régimen Común sobre Acceso a los Recursos Genéticos."*, en los artículos 5 y 6 determinan que los recursos genéticos y sus productos derivados son inalienables, imprescriptibles e inembargables, por lo tanto, son por soberanía, bienes y patrimonio de los países de origen que los contienen y en consecuencia determinan las condiciones de su acceso de acuerdo con los principios y disposiciones contenidos en el Convenio sobre la Diversidad Biológica y la mencionada Decisión de conformidad con lo establecido en sus respectivas legislaciones internas;

13. La Decisión de la Comunidad Andina Nro. 391, en el artículo 36 establece que el Ministerio del Ambiente podrá celebrar contratos marco de acceso con instituciones o investigadores reconocidos, que amparen la ejecución de varios proyectos de conformidad con la legislación nacional;

14. La Decisión de la Comunidad Andina Nro. 391, en el artículo 41 señala que los *contratos accesorios son aquellos que se suscriban, a los efectos del desarrollo de actividades relacionadas con el acceso al recurso genético o sus productos derivados, entre el solicitante y* el propietario, poseedor, administrador, centro de conservación *ex situ* o institución nacional de apoyo, mismo que no se considerará autorización al acceso al recurso genético o su producto derivado y su contenido se sujeta a lo dispuesto en el Contrato Marco;

15. La Decisión de la Comunidad Andina Nro. 391, en el artículo 50, literales i), j), k), m) y p) facultan al Ministerio del Ambiente como Autoridad Ambiental Nacional competente a delegar, revisar, supervisar y coordinar el cumplimiento de las condiciones de los contratos y de lo dispuesto en la referida Decisión Andina;

16. La Ley de Gestión Ambiental, publicada en el Registro Oficial Suplemento Nro. 418 de 10 de septiembre de 2004, en el artículo 8 señala que el Ministerio del Ambiente: *"[...] actuará como instancia rectora, coordinadora y*

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reguladora del Sistema Nacional Descentralizado de Gestión Ambiental, [...]";

17. La Ley Forestal y de Conservación de Áreas Naturales y Vida Silvestre, publicada en el Registro Oficial Suplemento Nro. 418 de 10 de septiembre de 2004, en el artículo 5, literales c), d) y f) dispone que el Ministerio del Ambiente, dentro de sus objetivos y funciones es administrar, conservar y fomentar los recursos naturales renovables existentes, así como también promover y coordinar la investigación científica dentro del campo de su competencia con el fin de fomentar y ejecutando políticas relativas a la conservación, fomento, protección, investigación, manejo, industrialización y comercialización del recurso forestal, así como de las áreas naturales y de vida silvestre;

18. El Decreto Ejecutivo No. 195-A de 04 de octubre de 1996, publicado en el suplemento del Registro Oficial No. 40 de 04 de octubre de 1996 se crea el Ministerio del Medio Ambiente, el mismo que fue reformado mediante Decreto Ejecutivo No. 259 publicado en el Registro Oficial No. 51 de fecha 5 de abril de 2000, se reforma el nombre de la institución por Ministerio del Ambiente;

19. El Decreto Ejecutivo Nro. 905 publicado en el Registro Oficial Suplemento Nro. 553 de 11 de octubre de 2011, expidió: "*El Reglamento Nacional al Régimen Común sobre Acceso a los Recursos Genéticos en aplicación a la Decisión 391 de la Comunidad Andina.*", en el artículo 2, numeral 4 sobre las exclusiones del ámbito de aplicación, precisa que se suscribirá Contratos Marco de Acceso con aquellas instituciones o investigadores reconocidos en el país para realizar investigación científica y que cuyo uso de material genético y/o biológico sea para sistemática, taxonomía, conservación, evolución, biología de poblaciones, biogeografía y filogeografía;

20. El Decreto Ejecutivo Nro. 905, en el artículo 8, numeral 5) dispone como atribución de la Autoridad Ambiental Nacional establecer los requisitos específicos para la suscripción de los contratos marco en concordancia con el artículo 41 del mismo cuerpo jurídico que señala los requisitos para acceder a un Contrato Marco;

21. El Acuerdo Ministerial Nro. 025 de 15 de marzo de 2012, en el artículo 7 numeral 7.1.) literales a), b), f) y l), establece que la Subsecretaría de Patrimonio Natural tiene como misión dirigir y promover la gestión ambiental para la conservación y uso sustentable del patrimonio natural del Ecuador; entre sus atribuciones y responsabilidades deberá direccionar, dirigir, vigilar y proponer las políticas y estrategias de gestión de preservación y mantenimiento de la biodiversidad mediante la conservación y el uso sustentable del patrimonio natural del Estado en cumplimiento de la normativa nacional e internacional;

22. El Acuerdo Ministerial Nro. 034 de 04 de febrero de 2015, publicado en el Registro Oficial Nro. 449 de 02 de marzo de 2015, establece la: *"Norma que Regula el Procedimiento para la Suscripción de Contratos Marco de Acceso a Recursos Genéticos."*, en el artículo 3 determina que las personas naturales o jurídicas acreditadas para realizar investigación científica son quienes deberán presentar una solicitud para la suscripción de un Contrato Marco de Acceso a los Recursos Genéticos;

23. El Acuerdo Ministerial Nro. 034, en el artículo 18 determina que: *"Los informes deben contener toda la información relacionada con la ejecución y cumplimiento de las obligaciones del Contrato Marco de Acceso a los Recursos Genéticos, misma que deberá ser entregada en un ejemplar impreso y magnético en el formato establecido para el efecto por la Dirección Nacional de Biodiversidad."*;

24. El Acuerdo Ministerial Nro. 024 de 09 de marzo de 2016, el Ministerio del Ambiente reformó el artículo 13 del Acuerdo Ministerial Nro. 034 de 04 de febrero de 2015, publicado en el Registro Oficial Nro. 449 de 02 de marzo de 2015; y, a su vez delegó al Subsecretario de Patrimonio Natural la suscripción de los Contratos Marco de Acceso a los Recursos Genéticos;

25. La Resolución Nro. 007/SETECI/2014 de 14 de febrero de 2014, la Secretaría Técnica de Cooperación Internacional, autorizó la suscripción de Convenio Básico de Funcionamiento con la ONG extrajera "Island Conservation", la misma que cuenta con el Registro Único de Contribuyentes Nro. 1792504198001, en donde

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consta como actividad económica principal la investigación y desarrollo de las ciencias naturales;

26. Mediante oficio s/n de 20 de septiembre de 2016, el Director de Programa de Island Conservation, Doctor Karl Campbell, solicitó al Director Nacional de Biodiversidad se: *"analice y se apruebe la información que se detallará en el presente oficio para proceder con la firma del Contrato Marco de Acceso a Recursos Genéticos para el Proyecto de Restauración Ecológica de la isla Floreana"*, amparados en la ley de la materia, por lo cual remitió adjunto los formularios correspondientes;

27. Mediante oficio Nro. MAE-DNB-2016-0660 de 27 de septiembre de 2016, el Director Nacional de Biodiversidad solicitó al Director de Programa de Island Conservation, Doctor Karl Campbell, remitir la acreditación como investigador;

28. Mediante oficio No. IC-03.10.2016-ct-02 de 03 de octubre de 2016; el Director de Programa de Island Conservation, Doctor Karl Campbell, remitió al Director Nacional de Biodiversidad, la solicitud de acreditación para personas naturales como investigadores en el país de la Doctora Paula Andrea Castaño Jiménez, con pasaporte Nro. CC 29361592;

29. Mediante Evaluación Técnica de Solicitudes Nro. 01 de 07 de noviembre de 2016, la Unidad de Acceso a Recursos Genéticos aceptó la solicitud por ser favorable con el *"99,88 / 100% (APROBACIÓN);*

30. A fecha 01 de febrero de 2017, la Especialista Legal y Administrativa de Island Conservation, Abogada Carolina Torres Trueba remitió a la Dirección Nacional de Biodiversidad la copia certificada de la protocolización Nro. 2015-17-01-06-P02354;

31. Mediante memorando Nro. MAE-DNB-2017-0466-M de 15 de marzo de 2017, el Director Nacional de Biodiversidad solicitó a la Coordinación General Jurídica proceda con: *"[...] el análisis y viabilidad de la propuesta de Contrato Marco de Acceso a los Recursos Genéticos."*; y,

32. Mediante memorando Nro. MAE-CGJ-2017-0452-M de 22 de marzo de 2017, la Coordinación General Jurídica remite el Contrato Marco de Acceso a Recursos Genéticos con varias observaciones y recomienda que: *"[...] una vez que sean subsanadas se continúen con los trámites respectivos para su suscripción"*;

CLÁUSULA SEGUNDA: LEGISLACIÓN APLICABLE.-

2.1 La legislación aplicable a este contrato es la Constitución de la República del Ecuador, tratados internacionales de los cuales el Ecuador sea parte, leyes, reglamentos, decretos, regulaciones, así como cualquier otra norma emitida o que se emita de conformidad con la legislación ecuatoriana, a la que en adelante, nos referiremos como la "Ley Aplicable".

2.2 Los derechos y obligaciones de las partes según este contrato, se ejecutarán de acuerdo con la Ley Aplicable.

CLÁUSULA TERCERA: JUSTIFICACIÓN.-

3.1 Es de importancia primordial para el Estado ecuatoriano la suscripción del presente Contrato Marco de Acceso respecto de los recursos biológicos y/o genéticos señalados en el programa "*Restauración ecológica de la isla Floreana*", pues dicho instrumento busca la trazabilidad de los recursos de la biodiversidad, el uso sostenible, el acceso y el manejo del recurso biológico y genético materia del presente contrato; su manipulación, su investigación y resultados de la misma, su conservación en las fases de investigación y mínimos referenciales para la fase de desarrollo.

3.1.1 Asimismo, el presente contrato coadyuvará a sentar las bases para el reconocimiento y valoración de los recursos biológicos y/o genéticos, con el fin de promover el desarrollo y la consolidación de las capacidades

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científicas, tecnológicas y técnicas a nivel local.

CLÁUSULA CUARTA: INTERPRETACIÓN, DEFINICIONES DE TÉRMINOS E IDIOMA.-

4.1 Interpretación.- Los términos del presente contrato deberán interpretarse en un sentido literal, en el contexto del mismo y cuyo objeto revele claramente la intención de las partes.

4.1.1 En todo caso su interpretación sigue las siguientes normas:

4.1.1.1 Cuando los términos se encuentran definidos en las leyes ecuatorianas, se estará a tal definición;

4.1.1.2 Si no están definidos en las leyes ecuatorianas se sujetará a lo dispuesto en el presente contrato en su sentido literal y obvio, de conformidad con el objeto contractual y la intención de las partes;

4.1.1.3 En su falta o insuficiencia se aplicarán las normas contenidas en el Título XIII del Libro IV del Código Civil, "DE LA INTERPRETACIÓN DE LOS CONTRATOS";

4.1.1.4 De existir contradicciones entre el contrato y los documentos del mismo, prevalecerán las normas del contrato; y,

4.1.1.5 De existir contradicciones entre los documentos del Contrato, será el **"MAE"** el que determine la prevalencia de un texto, de conformidad con el objeto contractual.

4.2 Definiciones.- Los términos y/o expresiones utilizados en el presente contrato deberán ser entendidos de acuerdo con las definiciones contenidas en el Convenio sobre la Diversidad Biológica, publicado en el Registro Oficial Nro. 647 de 06 de marzo de 1995, en la Ley de Gestión Ambiental y en la Ley Forestal y de Conservación de Áreas Naturales y Vida Silvestre, publicada en el Registro Oficial Suplemento Nro. 418 de 10 de septiembre de 2004, en la Decisión del Acuerdo de Cartagena 391 de la Comunidad Andina, publicado en el Registro Oficial Suplemento Nro. 05 de 16 de agosto de 1996, en el Decreto Ejecutivo Nro. 905 publicado en el Registro Oficial Suplemento Nro. 553 de 11 de octubre de 2011 y en las demás leyes, normas y regulaciones aplicables y conexas al presente instrumento.

4.2.1 Los términos y/o expresiones no definidos en estas leyes, normas y regulaciones, tendrán el significado que se deriva de su sentido técnico de acuerdo con el uso general de tal término o expresión comúnmente utilizado para la celebración y ejecución de este contrato debiendo entenderse de acuerdo con su significado natural y obvio; y,

4.2.2 Los términos o expresiones que denoten singular también incluyen el plural y viceversa, siempre y cuando el contexto así lo requiera.

4.3 Idioma.- Este contrato es redactado y suscrito por las partes en idioma castellano. Será considerada para todos sus efectos como la única válida.

4.3.1 Las comunicaciones entre las partes, así como, la información requerida por la legislación aplicable serán redactadas en idioma castellano, excepto aquellos que por su índole deban ser presentados en otro idioma, en cuyo caso, de considerarse indispensable por el Estado ecuatoriano, deberán ser acompañados con una traducción al castellano preparada de conformidad con la ley.

CLÁUSULA QUINTA: DOCUMENTOS HABILITANTES.-

5.1 Forman parte integral del presente contrato, los siguientes documentos:

5.1.1 (ANEXO 1) Acuerdo Ministerial Nro. 024 de 09 de marzo de 2016, publicado en el Registro Oficial Nro.

725 de 04 de abril de 2016, mediante el cual el Ministro del Ambiente delegó al Subsecretario de Patrimonio Natural la suscripción de Contratos Marco de Acceso a los Recursos Genéticos;

5.1.2 (ANEXO 2) Copia de la Protocolización Nro. 2015-17-01-06-P02354 de 05 de junio de 2015, del Poder General otorgado por Island Conservation a favor de Diego Ramiro García Montoya;

5.1.3 (ANEXO 3) Solicitud del Contrato Marco de Acceso a los Recursos Genéticos; y,

5.1.4 (ANEXO 4) Informe de Evaluación Técnica de Solicitudes No. 01 de 07 de noviembre de 2016, en el cual se aprueba la solicitud con una calificación de 99,88 / 100 %.

CLÁUSULA SEXTA: OBJETO, OBJETIVOS, PROYECTOS Y EQUIPO TÉCNICO.-

6.1 Objeto.- El presente contrato que se suscribe entre el **"MAE"** y **"IC"**, tiene por objeto autorizar la investigación científica mediante el uso, acceso y manejo del recurso biológico y genético acordado por este instrumento legal, excluyendo toda apropiación, uso y aplicación del recurso biológico y genético, sus derivados, análogos y sintetizados, que no tenga fines académicos y/o de investigación científica y que se utilizarán exclusivamente para cumplir con el objetivo de esta investigación científica y sin ninguna extensión a otros usos o estudios que tengan fines académicos y/o de investigación científica que puedan derivarse.

6.1.1 El presente contrato no otorga autorización para acceder, usar y/o experimentar cualquier conocimiento tradicional, ancestral, expresión cultural tradicional o componente intangible asociado a los recursos genéticos; y,

6.1.2 Para el cumplimiento del objeto contractual **"IC"** se obliga y está sujeta única y exclusivamente a contribuir a la restauración de la función de los ecosistemas naturales, la recuperación de especies nativas, como del bienestar de la población humana de la isla Floreana por medio de la erradicación conjunta de gatos y roedores invasores introducidos.

6.2 Objetivos.- Los objetivos planteados en esta investigación son:

6.2.1 Proporcionar asistencia técnica a la Dirección del Parque Nacional Galápagos (DPNG) con la erradicación de roedores (ratas y ratones) y gatos ferales en la isla Floreana (17,125 ha) y la mitigación de los impactos negativos sobre poblaciones de especies no-meta nativas y endémicas, que presentan un riesgo inaceptable como consecuencia de los efectos secundarios del uso de rodenticidas anticoagulantes;

6.2.2 Permitir la recuperación de especies de invertebrados, vertebrados y vegetación endémica y nativa como de los ecosistemas de la isla Floreana, con lo cual se reduce la probabilidad de ocurrencia de extinciones;

6.2.3 Crear capacidades en el personal de la DPNG y Agencia de Bioseguridad para Galápagos (ABG) en las técnicas utilizadas para la erradicación de roedores invasores y gatos ferales, así como la mitigación de los posibles impactos negativos resultantes de esta;

6.2.4 Determinar el flujo genético entre otras poblaciones de *Asio flammeus galapagoensis* (de islas como Isabela, Santa Fe) y la población de Floreana;

6.2.5 Determinar el nivel de diversidad genética en las poblaciones de *Pseudalsophis biseralis* en los islotes Champion y Gardner-por-Floreana;

6.2.6 Establecer afinidades filogeográficas de *Pseudalsophis biseralis* de los islotes aledaños a la isla Floreana y muestras contemporáneas de poblaciones de serpientes en otras islas del archipiélago con respecto a muestras de especímenes de museo provenientes de Floreana, con el fin de determinar las posibles fuentes de individuos para su reintroducción a Floreana;

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6.2.7 Análisis genético de muestras de roedores (*Rattus rattus* y *Mus musculus*) y gatos (*Felis silvestris catus*) obtenidas durante los procesos de captura y erradicación (pre y post), para en caso de detección de estos post-erradicación determinar si es una re-invasión o la erradicación no fue exitosa;

6.2.8 Análisis genético de muestras de gavilanes de Galápagos en las islas Pinzón y Rábida con el fin de determinar si nuevos individuos observados en cada isla presentan genética de esa población o por consiguiente migraron de otras poblaciones aledañas;

6.2.9 Monitoreo por medio de observación de varias especies terrestres (caracoles, aves, incluyendo a los petreles de galápagos, y reptiles) para determinar su estado de conservación actual pre-erradicación, y posteriormente su estado post-erradicación;

6.2.10 Monitoreo de los niveles de brodifacoum en la cadena trófica de las islas de Rábida y Pinzón post-erradicación por medio del análisis toxicológico de hígados de lagartijas de lava; y,

6.2.11 Implementación de un plan de manejo para la población de gavilanes de Galápagos de la isla Pinzón con el objetivo de que se restablezcan y reproduzcan en la isla.

6.3 Proyectos.- Los proyectos autorizados para el cumplimiento de esta cláusula serán aquellos que sean puestos en conocimiento del **"MAE"** de conformidad con lo estipulado en el numeral 9.2.13 de la Cláusula Novena de este contrato, así como también el que se detalle a continuación:

PROYECTO	RESPONSABLE TÉCNICO
Determinar el flujo genético entre otras poblaciones de *Asio flammeus galapagoensis* (de islas como Isabela, Santa Fe) y la población de Floreana.	Paula Andrea Castaño Jiménez
Determinar el nivel de diversidad genética en las poblaciones de *Pseudalsophis biseralis* en los islotes Champion y Gardner-por-Floreana y establecimiento de las afinidades filogeograficas de la especie de estos islotes con poblaciones de otras islas en el archipiélago.	
Análisis genético de muestras de roedores invasores y gatos ferales obtenidas durante los procesos de captura y erradicación (pre y post-erradicación).	
Monitoreo y análisis genético gavilanes de Galápagos de la isla Pinzón y Rábida.	
Monitoreo de varias especies terrestres (caracoles, aves terrestres, petreles de Galapagos, reptiles) para determinar su estado actual pre-erradicación.	
Monitoreo de los niveles de brodifacoum en la cadena trófica de las islas Rábida y Pinzón post-erradicación.	

6.4 Equipo Técnico.- El presente contrato autoriza y responsabiliza solidariamente con **"IC"**, para la ejecución de la colecta, manipulación y acceso a los recursos biológicos y/o genéticos al equipo técnico que se detalla a continuación:

NOMBRE	C.C., C.I. PASAPORTES	TELÉFONO / CORREO ELECTRÓNICO	AFILIACIÓN	GRADO ACADÉMICO	FUNCIÓN EN LA INVESTIGACIÓN
Paula Andrea Castaño Jiménez	CC29361592	052526189/ 0959820398 paula.castano@islandconservation.org/ paula.a.castano@gmail.com	IC	Cuarto Nivel	Responsable Técnico y Especialista en Especies Nativas
Karl Jay Campbell	1723938385	052526189/ 0984660893 karl.campbell@islandconservation.org/ carolina.torres@islanconservation.org	IC	Cuarto Nivel	Director del Programa y Proyectos
Victor Alejandro Carrión González	2000025219	593-5-25320370987000182 victor.carrion@islandconservation.org/ v.carriong@hotmail.com	IC	Tercer Nivel	Especialista en Restauración de Islas
Nicholas David Holmes	QI271310	0986110034 nick.holmes@islandconservation.org	IC	Cuarto Nivel	Director de Ciencias - investigador

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Chad Christopher Hanson	473108833	0986110034 chad.hanson@islandconservation.org	**IC**	Tercer Nivel	Director de planificación en conservación – coordinador implementación erradicación.
Julia Beth Ponder	486230405	0986110034 Ponde003@umn.edu	**University of Minnesota**	Cuarto Nivel	Científico colaborador
Jeffery Allan Johnson	498142853	0986110034 jajohnson@unt.edu	**University of North Texas**	Cuarto Nivel	Científico colaborador
Christine Parent	WG480039	052526189 ceparent@uidaho.edu	**University of Idaho**	Cuarto Nivel	Científico colaborador
Danielle Lisa Edwards	N8233818	0986110034 dedwards5@ucmerced.edu	**University of California**	Cuarto Nivel	Científico colaborador
Luis Ortiz Catedral	G15268240	0986110034 l.ortiz-catedral@massey.ac.nz	**Massey University**	Cuarto Nivel	Científico colaborador
Patricia Gail Parker	490648943	0986110034 pparker@umsl.edu	**University of Missouri**	Cuarto Nivel	Científico colaborador
Thomas Jeffrey Hall	048360896	052526189/ 0986110034 tommy.hall@islandconservation.com	**IC**	Tercer Nivel	Administrador de Proyecto

6.4.1 Para el cumplimiento del numeral 9.2.12, en cuanto a la incorporación o sustitución de algún miembro del equipo técnico, se deberá remitir dicha información mediante los parámetros establecidos en el: "*FORMULARIO HOJA DE VIDA GRUPO TÉCNICO DE TRABAJO*".

CLÁUSULA SÉPTIMA: PLAZO Y VIGENCIA.-

7.1 El presente contrato tendrá una duración de tres (3) años contados a partir de la fecha de suscripción del presente instrumento, en conformidad con el artículo 14 del Acuerdo Ministerial Nro. 034 de 04 de febrero de 2015, publicado en el Registro Oficial Nro. 449 de 02 de marzo de 2015, emitido por el **"MAE"**.

7.2 Al vencimiento del plazo se evaluará el cumplimiento del objeto del presente contrato.

7.3 Si **"IC"** requiere una ampliación en el plazo del mismo podrá hacerlo siempre que se cumpla con las obligaciones establecidas en la Cláusula Novena numeral 9.2 y se justifique debidamente la solicitud de ampliación, con por lo menos treinta (30) días antes de la terminación del plazo contractual.

7.4 Este contrato podrá ser modificado por las partes en cualquier momento, mediante la suscripción del correspondiente contrato modificatorio, ampliatorio y/o complementario siempre y cuando no varíe el objeto del mismo.

7.5 Cualquier modificación o alteración a las estipulaciones de este contrato, que no conste expresamente en el referido contrato modificatorio, ampliatorio y/o complementario no podrá ser alegada por ninguna de las partes.

CLÁUSULA OCTAVA: NO EXCLUSIVIDAD.-

8.1 El **"MAE"** en representación del Estado ecuatoriano como propietario del recurso biológico y/o genético podrá celebrar o ejecutar acuerdos y convenios que autoricen el acceso al recurso biológico y/o genético materia del presente contrato con entidades públicas o privadas, sean nacionales o extranjeras, sin perjuicio de lo estipulado en el presente contrato.

CLÁUSULA NOVENA: DECLARACIONES DE "IC" Y OBLIGACIONES DE LAS PARTES.-

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9.1 Declaraciones de "IC".-

9.1.1 Autorización: "IC" declara y garantiza que está debidamente autorizada y capaz para celebrar este Contrato Marco de Acceso a los Recursos Genéticos;

9.1.2 Conocimiento de la legislación ecuatoriana e internacional: "IC" declara expresamente que a la fecha de vigencia de este contrato tiene pleno conocimiento de la legislación ecuatoriana e internacional aplicable en cuanto al acceso a los recursos genéticos;

9.1.3 Calificación y conformidad con requerimientos y prácticas: "IC" declara y garantiza que, por sí misma, posee toda la experiencia adecuada y necesaria para ejecutar sus obligaciones según este contrato, así también garantiza y se obliga a mantenerse permanentemente calificada y en capacidad de ejecutar el objeto contractual, de acuerdo con los términos y condiciones de este contrato, por tal razón se compromete a ejecutar todas las actividades y prestar todo lo requerido por el **"MAE"** para garantizar la conservación de las especies que son objeto de investigación científica constante en este contrato;

9.1.4 Conocimiento de este contrato: "IC" declara y garantiza que conoce la base en la cual se generó este contrato, requisitos y procedimientos, que ha examinado a cabalidad este instrumento legal, y que conoce bien sus términos y disposiciones y que por tanto, renuncia a reclamos alegando desconocimiento o falta de comprensión de los mismos;

9.1.5 Declaración de solvencia: "IC" declara y garantiza que está financieramente solvente, en capacidad de ejecutar según su plazo de vencimiento y que posee suficiente capital de trabajo para cumplir las obligaciones previstas en este contrato;

9.1.6 Declaración sobre capacidades técnicas profesionales y acreditación: "IC" declara y asegura que todas las personas que llevarán a cabo la investigación científica contemplada por este contrato cuentan con todas las capacidades técnicas profesionales y acreditaciones requeridas por la Ley Aplicable para la consecución de sus respectivas actividades; y,

9.1.7 Cumplimiento de ley: "IC" expresamente declara que la celebración y ejecución de este contrato no resultará en una violación o incumplimiento a las disposiciones ambientales contenidas en cualquier ley, reglamento o sentencia a la que estuviesen sujetas, incluyendo la Ley Aplicable.

9.2 Obligaciones de "IC".-

9.2.1 Cumplir con la normativa ecuatoriana e internacional vigente, con especial énfasis en la legislación ambiental;

9.2.2 Planificar y asumir todos los costos, gastos y tiempo para la realización de este programa de investigación científica, así como solicitar los permisos, autorizaciones, licencias y demás requerimientos que se encuentren definidos sobre la base de la solicitud propuesta o de algún pedido que pueda cubrir el objeto de este contrato y sea aprobado por el **"MAE"**;

9.2.3 Entregar al **"MAE"** los datos generados a través de esta investigación científica en una base de datos según el formato emitido por la Dirección Nacional de Biodiversidad;

9.2.4 Entregar al **"MAE"** el o los certificados originales del depósito o recibo de las muestras biológicas y/o genéticas emitidas por las colecciones científicas ecuatorianas como internacionales depositarias del material;

9.2.5 Depositar los holotipos y muestras únicas de material biológico y/o genético en uno o varios centros de tenencia y manejo de vida silvestre;

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9.2.6 Notificar al **"MAE"** en caso de encontrarse nuevas especies, adjuntando la ubicación, descripción y la respectiva publicación;

9.2.7 Entregar en formato digital al **"MAE"** el o los informes en conformidad con el artículo 18 del Acuerdo Ministerial Nro. 034 de 04 de febrero de 2015, publicado en el Registro Oficial Nro. 449 de 02 de marzo de 2015, emitido por el **"MAE"**;

9.2.8 Citar en las publicaciones científicas, tesis, informes técnico-científicos el número de contrato otorgado por el **"MAE"** con el que se lleva a cabo la investigación científica;

9.2.9 Enviar e informar al **"MAE"** las publicaciones científicas arbitradas e indexadas que se deriven del objeto de esta investigación;

9.2.10 Responder administrativa, penal y civilmente por el uso indebido y no autorizado de los recursos genéticos y/o sus productos derivados, así como también por los daños causados a la naturaleza, restaurar y/o remediar los impactos negativos o daños ambientales a consecuencia del desarrollo de la investigación;

9.2.11 Asegurar que sus investigadores, funcionarios, personal, estudiantes, y demás personas a su cargo o bajo su responsabilidad, conozcan y cumplan con los términos del presente contrato, las leyes, normas y regulaciones, especialmente las de carácter ambiental a que se hace referencia en esta cláusula;

9.2.12 Notificar al **"MAE"** la incorporación, sustitución o salida de algún miembro del equipo técnico autorizado, con su respectiva justificación;

9.2.13 Notificar a la Dirección Nacional de Biodiversidad mediante los formatos establecidos por el **"MAE"** la incorporación, inicio, ejecución y terminación de cada proyecto de esté programa de investigación científica, siempre que guarde estricta relación con la línea de investigación y la Cláusula Sexta de este contrato;

9.2.14 Brindar capacitación técnica al personal del **"MAE"** acorde a los requerimientos de información en cuanto al objeto del contrato mientras el plazo esté vigente;

9.2.15 Apoyar en los programas de capacitación desarrollados por el **"MAE"** que tengan relación con el objeto de este contrato;

9.2.16 Para el ingreso a las áreas naturales protegidas autorizadas, los investigadores deberán informar de su ingreso para las actividades correspondientes, al jefe del área protegida autorizada;

9.2.17 Contar con la carta de aceptación, contrato accesorio o contrato del proveedor de los recursos biológicos y/o genéticos si las colecciones fueran dentro de predios privados o en centros *ex situ* de recursos biológicos y/o genéticos;

9.2.18 Celebrar con terceros, contratos, convenios y acuerdos que sean necesarios para el desarrollo de la investigación amparada por este contrato, previa revisión del **"MAE"**; y,

9.2.19 Los demás previstos en la Ley Aplicable y en este contrato.

9.3 Obligaciones del "MAE".-

9.3.1 Verificar que el objeto del presente contrato se cumpla de acuerdo a los requerimientos técnicos y formatos establecidos por la Dirección Nacional de Biodiversidad del **"MAE"**;

9.3.2 Realizar desde el Estado las acciones necesarias a fin de que el acceso al recurso solicitado en este contrato se cumpla de conformidad con lo establecido en la Constitución de la República del Ecuador y leyes

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conexas;

9.3.3 Realizar la inscripción en el Libro Único del Registro Público de Solicitantes y en el sistema informático que lo soporte;

9.3.4 Efectuar sin previo aviso, visitas sorpresa e inspecciones aleatorias en campo o en los laboratorios con el fin de dar seguimiento y control a las actividades ejecutadas y el número de especímenes o muestras colectadas;

9.3.5 Tomar acciones administrativas, penales o civiles cuando del presente acceso al recurso solicitado no cumpla con los fines por el que fue autorizado o de la derivación del mismo produzca daños o impactos al ambiente y al recurso genético;

9.3.6 Informar a las Direcciones Provinciales del **"MAE"** el contenido del presente contrato; y,

9.3.7 Las demás previstas en la Ley Aplicable y en este contrato.

CLÁUSULA DÉCIMA: DE LA RECOLECTA.-

10.1 La recolecta no podrá afectar sitios de anidación, comederos, saladeros, sitios de reproducción específicamente en épocas reproductivas, áreas de importancia biológica y áreas Importantes para la Conservación de las Aves (AICAS).

10.2 Se autoriza la recolección, manipulación y acceso a los recursos genéticos como a continuación se detalla:

ESPECIES MANIPULADAS	CANTIDAD Y TIPO DE MUESTRA	PROVINCIAS	LOCALIDAD
Asio flammeus galapagoensis	150 muestras sangre	Galápagos	Isla Baltra Isla Bartolomé Isla Española Isla Fernandina Isla Floreana Isla Genovesa Isla Isabela Isla Marchena Isla Pinta Isla Pinzón Isla Rábida Isla San Cristóbal Isla Santa Cruz Isla Santa Fe Isla Santiago Isla Seymour Norte Islote Champion Islote Gardner -Por - Floreana
Buteo galapagoensis	100 muestras sangre		
Rattus rattus	100 muestras tejido		
Mus musculus	100 muestras tejido		
Felis silvestris catus	100 muestras tejido o sangre		
Pseudalsophis biseralis	230 muestras tejidos		
Pseudalsophis hoodensis	20 muestras tejidos		
Pseudalsophis slevini	40 muestras tejidos		
Pseudalsophis steindachneri	60 muestras tejidos		
ESPECIES SACRIFICADAS	**CANTIDAD Y TIPO DE MUESTRA**		
Microlophus duncanensis	100 muestras tejidos (individuos completos)		
Microlophus albemarlensis	100 muestras tejidos (individuos completos)		

10.3 Este contrato es emitido bajo los términos expresados en la propuesta de investigación científica, por lo

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cual, para el fiel cumplimiento de esta Cláusula los proyectos serán ejecutados mediante los parámetros establecidos en el: "*FORMULARIO DE PROYECTO ENMARCADO DENTRO DEL PROGRAMA DE INVESTIGACIÓN CIENTÍFICA*", que determina la información de cada proyecto: (información general, área geográfica que cubre la recolección de las especies o especímenes, especímenes a recolectar, metodología (fase de campo), metodología (fase de laboratorio), equipo científico- técnico).

10.4 **"IC"**, en virtud de este contrato, no tiene derecho a manipular y/o colectar recursos biológicos y/o genéticos distintos a los que son autorizados en esta Cláusula, aunque esos recursos hubieren sido descubiertos por ella; excepto en los casos en que celebrare un contrato modificatorio, previsto en la Cláusula Séptima numerales 7.4 y 7.5 de este contrato y de acuerdo con la Ley Aplicable.

10.5 No se autoriza el sacrificio de ningún individuo y la colección de especímenes categorizados en Peligro Crítico con excepción de los autorizados en el numeral 10.2 de esta Cláusula.

10.6 Para la movilización de las muestras recolectadas en este contrato, **"IC"** deberá contar con la respectiva guía de movilización emitida por las Direcciones Provinciales del Ambiente del **"MAE"**.

10.7 Si durante el análisis y desarrollo de este programa de investigación científica llegare a ser necesario colectar muestras adicionales, **"IC"** solicitará autorización al **"MAE"** mediante un informe técnico, en el cual se justifique el incremento de la recolecta, en tal razón, el **"MAE"** analizará técnicamente si es procedente conceder dicha solicitud.

10.8 Si **"IC"** necesita transferir material biológico y genético con fines de investigación científica, deberá estar acorde al objetivo de este contrato y será indispensable que se genere mediante un Acuerdo de Transferencia de Material (ATM), mismo que será un instrumento legal remitido para revisión del **"MAE"** y regulará la transferencia, el uso del material de investigación y el retorno o disposición final de las muestras; las muestras únicas serán exportadas con propósitos de investigación científica por un plazo no mayor a doce (12) meses.

10.9 Este contrato no ampara el permiso de exportación de muestras, por lo que deberán ser requeridos al **"MAE"** previa revisión del ATM.

CLÁUSULA DÉCIMA PRIMERA: RESPONSABILIDAD POR DAÑO.-

11.1 **"IC"** tomará las precauciones necesarias, para prevenir, controlar, mitigar, rehabilitar, restaurar, remediar y compensar los efectos negativos que las actividades investigativas puedan tener sobre el medio ambiente y el recurso genético, sin perjuicio de su responsabilidad frente a terceros de conformidad con la Constitución de la República del Ecuador, leyes, normas y regulaciones aplicables al presente instrumento.

CLÁUSULA DÉCIMA SEGUNDA: TERMINACIÓN.-

12.1 **Terminación.-** Además de las causales previstas en la Ley Aplicable y en este contrato, el mismo terminará en los siguientes casos:

12.1.1 Por el cumplimiento del objeto del contrato;

12.1.2 Por cumplimiento del plazo;

12.1.3 Por terminación unilateral y anticipada, a causa del incumplimiento de alguna de las obligaciones o condiciones previstas en este instrumento, comunicada por escrito a la parte incumplida sin que la misma lo solucione en un plazo máximo de quince (15) días;

12.1.4 Por mutuo acuerdo entre las partes, bien sea que se origine en razones técnicas o de conveniencia

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institucional, para lo cual deberán suscribir el acta correspondiente;

12.1.5 Procederá de igual manera la terminación por mutuo acuerdo, en caso de suscitarse casos de fuerza mayor o caso fortuito, que impidan el cumplimiento del presente contrato, conforme a lo dispuesto en el Art. 30 del Código Civil ecuatoriano, debiendo los hechos ser debidamente justificados por parte de la entidad que lo alegare dentro de los treinta (30) días de ocurrido el hecho, siempre y cuando las circunstancias hubieren hecho imposible la ejecución de este contrato; y,

12.1.6 El **"MAE"** podrá dar por terminado unilateralmente el contrato, sin perjuicio de las acciones penales, civiles o administrativas, en cualquiera de los siguientes casos:

12.1.6.1 Por explotación y/o acceso al recurso biológico y/o genético no autorizado;

12.1.6.2 Por lo estipulado en el numeral 12.1.3 de esta Cláusula;

12.1.6.3 Por presentación de información falsa o por haber alterado la misma;

12.1.6.4 Por declaratoria de daño ambiental por parte del Ministerio del Ambiente; y,

12.1.6.5 Por daño al recurso biológico y/o genético del Estado.

CLÁUSULA DÉCIMA TERCERA: SOLUCIÓN DE DIVERGENCIAS O CONTROVERSIAS.-

13.1 Negociaciones Directas.- En conflictos que por su naturaleza puedan ser transigibles y que tengan relación con la aplicación, interpretación, ejecución, incumplimiento, resolución de actos técnicos y operativos, así como por la terminación anticipada o cualquier otra circunstancia relacionada con las operaciones realizadas durante la vigencia del contrato, las partes buscarán negociar un arreglo directo entre ellas.

13.2 Mediación.- Si se suscitaren divergencias o controversias que las partes no llegaren a un acuerdo mediante negociación directa, podrán utilizar la mediación para la solución de sus controversias, para lo cual, las partes estipulan acudir al Centro de Mediación de la Procuraduría General del Estado.

13.2.1 Si se llegara a firmar un acta de acuerdo total, o parcial la misma tendrá efecto de sentencia ejecutoriada y cosa juzgada, su ejecución será del mismo modo que la sentencia de última instancia, conforme lo dispuesto en el artículo 47 de la Ley de Arbitraje y Mediación.

13.3 Contencioso Administrativo.- En el caso de no existir acuerdo, las partes suscribirán la respectiva acta de imposibilidad de acuerdo, y la controversia se ventilará ante el Tribunal de lo Contencioso Administrativo del domicilio principal del **"MAE"**.

13.4 En consecuencia, **"IC"** renuncia a utilizar la vía diplomática para todo reclamo relacionado con este contrato.

CLÁUSULA DÉCIMA CUARTA: COMUNICACIONES, NOTIFICACIONES Y RESPONSABLES DEL SEGUIMIENTO Y EJECUCIÓN.-

14.1 Todas las comunicaciones y notificaciones que las partes deban cursarse entre sí, con relación a este contrato, serán por escrito en castellano y deberán ser enviadas mediante entrega personal, correo especial (courier), por fax y/o por correo electrónico.

14.2 Las partes señalan como direcciones para efectos de las comunicaciones indicadas en esta cláusula las siguientes:

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Ministerio del Ambiente:		Island Conservation:	
		Nombre:	Diego Ramiro García Montoya
Cargo:	Director/a Nacional de Biodiversidad	Cargo:	Apoderado General
Dirección:	Calle Madrid 11-59 y Andalucía, Quito- Ecuador	Dirección:	Av. Charles Darwin, Galápagos-Ecuador
Teléfono:	(593) 3987600 ext.1422	Teléfono:	(+593) 986110034
Correo Electrónico:	uarg.dnb@ambiente.gob.ec	Correo Electrónico:	karl.campbell@islandconservation.org carolina.torres@ islandconservation.org
Con copia a:	lenin.nunez@ambiente.gob.ec	Con copia a:	paula.castano@islandconservation.org
Responsable:	Director/a Nacional de Biodiversidad	Responsable:	Paula Andrea Castaño Jiménez

14.3 Para todos los efectos de este contrato se entenderá que una comunicación fue recibida por la otra parte, cuando sea recibida por entrega personal, correo especial (courier), por fax y/o por correo electrónico o cuando exista una constancia escrita de recepción de la parte notificada.

14.4 En caso de cambio en la información antes detallada, la parte deberá notificar a la otra de manera previa al cambio o en el plazo no mayor de cinco (05) días posteriores a dicho cambio, bastará con la notificación y su debida confirmación de recepción, en este sentido, para que este acápite se entienda modificado en cuanto a la información de contacto. Si la parte cuya información ha cambiado, no notifica de dicho cambio a la contraparte, se entenderán recibidas todas las notificaciones que se hubieren realizado a las direcciones y números aquí establecidos.

14.5 Para el seguimiento y ejecución de las actividades y obligaciones que se deriven del presente contrato, se establece a los responsables, quienes se encargarán de la administración, coordinación y seguimiento técnico de la ejecución del referido instrumento.

14.5.1 Los responsables del seguimiento y ejecución serán el órgano de planificación, seguimiento y evaluación de las acciones derivadas de este contrato, que entenderá y resolverá todas las cuestiones relacionadas con él y con los planes de trabajo u hojas de ruta específicos.

14.5.2 Las partes de común acuerdo manifiestan que en caso de requerir el cambio de los responsables del seguimiento y ejecución de este contrato, bastará cursar la respectiva notificación, sin que sea necesario realizar modificaciones al texto contractual.

CLÁUSULA DÉCIMA QUINTA: DERECHOS DE PROPIEDAD INTELECTUAL.-

15.1 Los derechos sobre los recursos biológicos y/o genéticos materia de la investigación contemplada en el objeto de este contrato son por soberanía del Estado ecuatoriano.

15.2 **Derecho de autor.-** El derecho de autor que incluye los derechos morales de todo tipo de obra resultante de la investigación objeto de este contrato, se sujetará exclusivamente a la legislación ecuatoriana en materia de propiedad intelectual vigente en su parte pertinente, incluyendo las Decisiones de la Comunidad Andina y sus reglamentos.

15.3 **Publicaciones.-** En toda publicación y/o presentación pública de la investigación, las actividades y/o los resultados que se obtengan con base en los productos derivados, cuyo acceso se otorga en el presente contrato, comprometen a la **"IC"** hacer referencia a:

15.3.1 El presente contrato suscrito y el número asignado por el **"MAE"**;

15.3.2 Los recursos biológicos sobre los cuales se investigó; y,

15.3.3 Registrar las publicaciones indexadas que se generen sobre este contrato en el módulo correspondiente del Sistema de Información de Biodiversidad (SIB) contenido en el Sistema Único de Información Ambiental

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(SUIA) del **"MAE"**.

15.4 Derechos de Propiedad Industrial y de Obtenciones Vegetales.- De conformidad con el objeto de este contrato y con los fines investigativos del acceso al recurso genético, **"IC"** se compromete a no presentar solicitud alguna de protección de cualquier modalidad de propiedad industrial y/o de obtenciones vegetales, en el país o fuera de él, incluyendo pero sin limitarse a: patentes de invención, patentes de modelo de utilidad y derechos de obtentor, sobre el recurso genético materia de este contrato, ni productos análogos, derivados o sintetizados a partir de él, en ninguna jurisdicción a nivel mundial. Esta obligación sobrevivirá a la terminación de este contrato de forma indefinida, a menos que las partes de común acuerdo decidan lo contrario.

15.4.1 Los derechos de propiedad industrial y sobre obtenciones vegetales se sujetarán a la legislación ecuatoriana en materia de propiedad intelectual vigente en su parte pertinente, incluyendo las Decisiones de la Comunidad Andina y sus reglamentos.

15.5 Si **"IC"** tuviese interés en iniciar actividades de bioprospección con fines de aplicación industrial o aprovechamiento comercial derivadas de este programa de investigación científica, tendrá que solicitar previamente al **"MAE"** la suscripción de uno o varios Contratos de Acceso a Recursos Genéticos. La solicitud así presentada será objeto de análisis en el marco de la normativa vigente.

CLÁUSULA DÉCIMA SEXTA: RESTRICCIÓN Y CONFIDENCIALIDAD.-

16.1 **"IC"** no podrá destinar los recursos genéticos accedidos por efecto de suscripción del presente contrato a otros fines distintos a los establecidos en el mismo y en base a la solicitud presentada, tampoco podrá ceder ni transferir a terceros los derechos adquiridos por el presente contrato.

16.2 **"IC"** se obliga a mantener la más estricta confidencialidad de la investigación, y está obligada a no revelar ni exponer directa o indirectamente información que perjudique al **"MAE"**, por lo que su confidencialidad persiste incluso una vez finalizada la relación contractual, por un plazo de cinco (05) años contados a partir de la terminación del presente instrumento.

16.3 Toda la información técnica, comercial o de cualquier otra índole, sea escrita, tangible u oral provista por o en nombre de cualquiera de las partes a la otra, será considerada confidencial y utilizada solo para los fines expresados en este contrato, excepto en la medida que dicha información revistiera estado público y que ello no fuera consecuencia de un incumplimiento de este contrato.

CLÁUSULA DÉCIMA SÉPTIMA: RENUNCIA A DERECHOS O ACCIONES.-

17.1 El no ejercicio o el ejercicio parcial de los derechos o acciones de cualquiera de las partes, bajo los términos del presente contrato, no constituirá, bajo ningún concepto una renuncia a dichos derechos o acciones.

CLÁUSULA DÉCIMA OCTAVA: CAMBIOS EN EL CONTROL.-

18.1 Los derechos y obligaciones de las partes, bajo el presente contrato, no serán afectados por una fusión, consolidación, absorción u otra adquisición o cambios en el control, así como tampoco se verán afectados por el cambio de autoridades o competencias en el Estado ecuatoriano.

CLÁUSULA DÉCIMA NOVENA: SUPERVIVENCIA.-

19.1 No obstante la terminación del presente contrato por alguna de las partes o por cualquier razón, incluyendo la terminación unilateral respecto a que este contrato o a una parte de este ya no sea aplicable, las cláusulas Décima Sexta, Décimo Séptima y Décimo Octava sobrevivirán por el periodo necesario a dicha terminación, y producirán efecto con respecto a cualquier tema que sea objeto del presente contrato o que pudiera surgir, en relación o en conexión con el presente contrato.

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CLÁUSULA VIGÉSIMA: DIVISIBILIDAD.-

20.1 Si algún tribunal o jurisdicción competente considera nula, ilegal, inválida o inejecutable alguna de las disposiciones, partes de este contrato o su aplicación, se separará a dichas disposiciones, partes de este contrato o su aplicación en su totalidad del resto de las disposiciones contractuales.

20.2 Este contrato se interpretará y hará valer como si dicha disposición o parte ilegal, inválida o inejecutable jamás hubiere formado parte del mismo.

20.3 Las demás disposiciones de este contrato continuarán en pleno vigor y efecto, y no se verán afectadas por la disposición o parte nula, ilegal, inválida o inejecutable o por su separación de este contrato.

20.4 Asimismo, en lugar de dicha disposición o parte nula, ilegal, inválida o inejecutable, las partes negociarán de buena fe el reemplazo de la misma, con términos tan similares a ella como sea posible, y que tengan carácter legal, válido y ejecutable.

CLÁUSULA VIGÉSIMA PRIMERA: ACEPTACIÓN.-

21.1 Las partes declaran la aceptación de cada una de las cláusulas contenidas en este Contrato Marco de Acceso por ser acorde a sus intereses y no contravenir ninguna norma del ordenamiento jurídico vigente.

21.2 Para constancia y conformidad con lo antes expuesto y convenido, firman en unidad de acto en tres (3) ejemplares de igual contenido y valor legal.

En la ciudad de Quito, Distrito Metropolitano, a los 07 ABR 2017

Biólogo. **Francisco José Prieto Albuja** Subsecretario de Patrimonio Natural Ministerio del Ambiente	Señor **Diego Ramiro García Montoya** Apoderado General Island Conservation

	ÁREA	RESPONSABLE	SUMILLA
Aprobado	DNB	Santiago Silva	
Revisado	DNB	Wilson Rojas	
Revisado	DNB	Ricardo Andrade	
Revisado	CGJ	Jaime Piedra	
Revisado	CGJ	Lucy Estupiñan	
Elaborado	DNB	Lenin Núñez	

SECRETARIA GENERAL
Ministerio del Ambiente
FECHA REG 13 ABR 2017
REGISTRO 6072
FOLIO 361

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APPENDIX III.

Research proposal presented to the Auckland Zoo, Small Grants programme to conduct research on El Eden population of the Central Galapagos racer (Pseudalsophis dorsalis).

Auckland ZOO | Conservation Fund

Auckland Zoo Conservation Fund
Small Grants Application Form

- This form must be completed in English.

Section 1 – Contact Details

1.1	Date	**09/10/19**
1.2	Principal applicant and title	**Harrison Sollis**
1.3	Name of institution or organisation	**Galapagos National Park**
1.4	Contact telephone number	**02108682984**
1.5	Contact address	**13A Bevyn Street, Castor Bay, Auckland**
1.6	Email address	**harry-solace@hotmail.com**
1.7	Website address	http://www.islandsforever.com/harrison-sollis.html
1.8	Project partners or other participants	**Directorate of the Galapagos National Park**
1.9	Individual applicants please include (as separate attachments) your résumé/ CV and two professional reference letters, with contact details for your referees, with your application.	

Referees:

Dr Luis Ortiz-Catedral, School of Natural and Computational Sciences, Massey University, New Zealand.

Biol. Danny Rueda, Directorate of the Galapagos National Park, Galapagos Islands, Ecuador.

Section 2 – General Project Details

2.1	Project title	Rat control for the conservation of *Pseudalsophis dorsalis dorsalis* on Eden Islet, Galapagos Islands.
2.2	Project location and country	Eden Island, Galapagos Islands, **Ecuador**
2.3	Focal species and/or habitat	*Pseudalsophis dorsalis dorsalis*
2.4	Focal species IUCN (and /or National) threat status	Least Concern (**Status needs revision**), possibly Endangered.
2.5	Project start date	01/04/2020
2.6	Project completion date	22/04/2020
2.7	Project Summary (200 words or less)	

The Central Galapagos Racer (*Pseudalsophis dorsalis*) represents a complex of at least four separate species of terrestrial snakes distributed on the Central islands of the Galapagos archipelago including: Santa Cruz, Eden, Baltra, Seymour Norte, and Santa Fe. Although the species is classified as "Least Concern" based on the assumed distribution based on specimens collected from 1903-1960's, a search efforts of 3206 man-hours from June 2016 to July 2019 has revealed a single population for the nominal species "*Pseudalsophis dorsalis dorsalis*" on Eden Islet (26 ha) on the Northwest shore of Santa Cruz Island. While taxonomic revisions and molecular studies are underway to document the diversity of Galapagos snakes, it is imperative to ensure the conservation of this population of the nominal species. Formerly widespread on the island of Santa ruz, there have been no sightings of the nominal subspecies since the 1970's possibly owing to population declines caused by introduced predators like feral cats, black rats, feral pigs and dogs. Earier this year, during an expedition to Eden Islet as part of my MSc studies my team and I encountered a small population of *Pseudalsophis dorsalis dorsalis*. The islet is only 300 meters off the coast from Santa Cruz, and has fortunately remained uninvaded by feral cats. Searches on the nearest shore of Santa Cruz failed to locate snakes but encounter significant cat scats. Nevertheless we located live black rats (*Rattus rattus*), known to predate small snakes and their eggs. We encounter a total of 9 snakes including a recently hatched one on Eden Islet. Using comparative data from similar-sized rat-free and cat-free islets for other Galapagos terrestrial snakes, we suspect that the snake population on Eden islet is roughly 50% smaller. We also encounter at least four instances of rat bites on adult snakes, similar to those observed on other islets in Galapagos. In this project, we propose pulses of rat control via hand broadcast of Broadifacoum to reduce rat depredation pressure on Eden Islet terrestrial snakes.

Section 3 – General Grant Details

3.1	Amount of money requested from Auckland Zoo (in New Zealand dollars)	$5000
3.2	Total project budget (in New Zealand dollars)	$20,000
3.3	Other ***confirmed*** financial sources of project support	$9000 from the Galapagos Conservation Trust $1000 from Massey University
3.4	Other ***potential*** sources of financial project support	$5,000 from the Rufford Small Grants Program or Mohamed bin Zayed Species Conservation Fund (applications in progress).
3.5	Details of any ***in-kind*** project support	$8000 for field equipment from the School of Natural and Computational Sciences, Massey University.

		$9000 logistical support from the Directorate of the Galapagos National Park.
3.6	Previous awards from Auckland Zoo (give details)	N.A.

Section 4 – Project Aims and Objectives

Conservation Issue or Problem	Project Aim or Objective
Depredation by invasive black rats	Two pulses of hand broadcast application of Brodifacoum bait (50 ppm, 10 kg per ha), 6 months apart, to reduce the population of Black rats.
Response of target species to rat control	Monitor the population before and after the pest control application. Monitor population of another non-target indicator species (lava lizards) and black rats before and after application.

Section 5 – Project Activities and Anticipated Achievements

Project Aim/Objective (from Section 4)	Project Activity or Method	Anticipated Result/Achievement
Apply 260 kg of Brodifacoum (commercial name Klerat© in Ecuador) pellets on Eden Islet in April 2020 and October 2020).	I will gather a team with the support of the Galapagos National Park in order to manually disperse bait. This will be followed by using tracking tunnels to detect rat presence/absence.	Reduction in rat numbers on Eden as estimated by chew card indices.
Monitor the population before and after the pest control application.	We will perform surveys to determine the population size by performing mark–recapture and teach the rangers how to apply this method so they may determine any changes to the population size.	A decrease in snake mortality and an increasing snake population.
Estimate baseline and before and after rat density as indicated by chew indices on cards.	Installation of 150 chew cards two weeks before each bait application. Followed by 150 chew cards four weeks after each bait application.	Reduction to 5% or less rat chew index (this is considered "low to nil" rat density for similar sized islets in Galapagos).

Section 6 - Expertise, Experience and Knowledge

Project Activity or Method (from Section 5)	Relevant Expertise, Experience and Knowledge
Brodifacoum hand broadcast. Installation of 300 chew cards for before (150) and after (150) comparison of each bait application.	I have experience in pest control through my hands on work as a field member in Wildlands and Te Ngahere performing pest control. I have also monitored mice populations in Tawharanui using tracking tunnels prior to the release of Duvaucel's geckos. NOTE: application of bait in Galapagos will only be conducted by qualified staff from the Directorate of the Galapagos National Park.

mark-recapture population estimate of terrestrial snakes.	I have experience successfully capturing and analysing snakes on 9 different snake populations on separate islands across the Galapagos, including Eden islet. I have performed mark-recapture of snakes on 3 of those populations with successful recaptures. I have also monitored native geckos in several parks in Auckland at the volunteer and student level.

Section 7 – Project Evaluation

Anticipated Result/Achievement (from Section 5)	Measure of Success – give indicators
Detection of black rats 5% or lower after three weeks application of Brodifacoum.	Success will be defined by a drop to 5% detection rate (or lower) on Wax Chewing cards for black rats.
No change or increase in relative abundance of lava lizards one year following application of Brodifacoum.	No change relative to baseline or increase in Lava lizard density estimated by variable area circular plots.
No change or increase in population size of terrestrial snakes one year following application of Brodifacoum.	No change or increase in terrestrial snake population size relative to baseline based on Mark-recapture figures.

Section 8 – Other Information

7.2	Details of permissions and/or permits and/or licenses required to carry out project

Do you have permission to work at the site/s?

No

Permit application in progress.

7.3	Details of any animal capture, collection, handling, manipulation, sampling etc. required

Will you be capturing / handling / taking samples from any animals?

Yes	Yes
No	

If yes, please give details here:

To monitor the response of terrestrial snakes, I will conduct a mark-recapture survey two weeks before the application of bait, Mark-recapture for terrestrial snakes has been successfully used to estimate population sizes on small islets in Galapagos since 2016 by my supervisor. Snakes will be hand collected carefully to avoid damage and minimise stress to the animal, their locations will be marked on a GPS. Snakes captured will be placed in a cloth bag and kept in a cool place until they can be analysed. Analysis begins with scale counts which is performed on the following areas: temporal head scales, post-oculars, infra-labials, supra-labials, horizontal behind head, horizontal mid body, horizontal before vent, ventral, and sub-caudal. Furthermore, we will collect standard measurements of snout-vent-length (SVL), vent length, head length, head width, and weight. We will insert Passive Integrated Transponder (PIT) tags 2cm above the vent on the side of the body aiming down. The PIT tag will be located between layers of skin and only inserted in snakes longer than 30cm to avoid any damage to organs or impede movement. Faecal samples will be attempted on all snakes and stored in ethanol for the material to be later identified. During this period we will photograph the dorsal and ventral sides of snakes alongside a colour chart to effectively identify the colouration of individuals on the colour spectrum. Obtaining these results should take no more than 25-30 minutes and snakes will be released where they were. Lava lizards will be surveyed by counting individuals visually on circular plots of variable diameter (depending on vegetation features) on 10 min intervals. Each lava lizard observed will be assigned to size class (adult, juvenile) and sex id based on colouration (for adults only).

Do you have the necessary permits to capture / handle / take samples?		
Yes	Yes	If yes, give permit number if applicable: Galapagos park permit: PC08-19
No		
N/A		

7.4	Details of any potential human health or safety risks or issues and how they will be addressed

Broadifacoum ($C_{31}H_{23}BrO_3$) is a rodenticide commonly used for rat and other mammalian control in Tropical archipelagos and atolls around the world including the Galapagos Islands. Hand application or broadcast requires training and protective gear as the compound can be absorbed via the skin and respiratory system. The application of Brodifacoum will be conducted only by qualified staff from the Directorate of the Galapagos National Park.

All other field activities will be conducted within approved fieldwork protocols by the School of Natural and Computational Sciences, Massey University.

7.5	Details of any ethical considerations for the animals involved in your project

All the activities described here will be conducted within the legal guidelines for the capture and handling of native wildlife, according the Ecuadorian Ministry of Environment via the Directorate of the Galapagos National Park. The application of Brodifacoum falls under the standard operations of the Directorate of the Galapagos National Park.

Section 9 – Details of Project Budget

Description of Budget Item in Priority Order	**Proposed Auckland Zoo contribution** (please indicate In New Zealand dollars)	**Proposed contribution from other source** (please indicate in New Zealand dollars)	**Total Cost of Item(s)** (please indicate in New Zealand dollars)
Brodifacoum 25 ppm (commercial name in Ecuador is Klerat® pellets (1kg buckets, $15 each).	$3000	$4800	$7800
150 x PIT Tags ($3.5 each)		$500	$500
Per diem for field team	$350	$350	$700
600 x Chew cards (aniseed flavour) (ca. $30 per 100 chew cards)		$200	$200
Boat transfer for field operations		$4800	$4800
2 x Return flights	$1650	$4350	$6000
Sub-total: Auckland Zoo contribution	**$5,000**		
Sub-total: Contribution from other sources		**$15,000**	
Percentage	AZ% 25	Other % 75	
TOTAL PROJECT BUDGET			$20,000

Section 10 – The Final Appeal

Describe, in 200 words or less, why this proposed project is particularly special and why it should be specifically funded by Auckland Zoo.
This project represents an opportunity for a medium-investment/high conservation returns for the Auckland Zoo Conservation Fund. Galapagos Terrestrial Snakes are gaining popularity locally in Galapagos and internationally following the description of three new species in 2019. However, to date, only limited conservation work has been done on these reptiles. In 2015-2016 the Auckland Zoo also supported the first conservation project for Terrestrial snakes on Floreana Island, therefore this project represents a continuation of the Auckland Zoo work in the Galapagos Islands. Finally, the nominal species of the central Galapagos racer is in dire need of conservation action on Eden Islet, as this might serve as a source population to reintroduce the species to several islets and to the coast of Santa Cruz, following the eradication of invasive cats and rodents.

APPENDIX IV.

Confirmation of successful application to the Auckland Zoo Small Grants Programme.

Auckland ZOO
Conservation Fund

3 December 2019

Harrison Sollis
13A Bevyn Street
Castor Bay
Auckland

Dear Harrison,
Thank you for your funding application to The Auckland Zoo Conservation Fund Small Grant Programme.

We are delighted to inform you that your application titled "Rat control for the conservation of *Pseudalsophis dorsalis dorsalis* on Eden Islet, Galapagos Islands" was successful for a partial grant of NZ$3,000.

Terms and Conditions

Provision of this funding is dependent upon you agreeing to and meeting the following obligations to Auckland Zoo:

1. The funding provided is for the express purpose of, and may only be applied to, the project specified within your application as approved above.

2. The project must be referred to as an initiative being carried out or undertaken in association with 'Auckland Zoo Conservation Fund'.

3. The support of the Auckland Zoo Conservation Fund must be acknowledged in all appropriate publications, such as annual reports, website pages, brochures or any other publication where a list of sponsors, donors and/or supporters could be reasonably expected to appear.

4. Auckland Zoo may, in consultation with you, organise media and/or other official events related to the project. Auckland Zoo may also, in consultation, issue media releases related to the project from time to time.

5. You must seek permission from Auckland Zoo for any variation on the intended use of this grant.

6. Funds not spent at the completion date of the project as indicated in the application must be returned within 30 days of that date.

7. You must provide a report on the project, completed on our 'Support Feedback Form', within one month of the completion of the project to the Auckland Zoo Conservation Fund Administrator. You have indicated a completion date of 22 April 2020.

8. On acceptance of this offer we also require:
    - Three to five high-resolution photographs (with permission to publish), that illustrate the target species and/or the project, suitable for publication.
    - A short (200 to 300 word) overview or explanation of your project suitable for publishing on our website and various reports. You should be able to adapt this from 'Section 2.7 - Project Summary' in your application, but keep in mind this is designed to tell the public about your project.
    - If possible, a short video presentation (between 3 - 5 minutes is ideal) on the project for use on our website and social media channels (this is not a requirement).

On acceptance of this offer we require the following information sent to Melody Mobsby (melody@aucklandfoundation.org.nz). Not all bullet points may be applicable to you but generally, the more information you provide, the more efficient the process of payment is likely to be.

- Name, postal and email address of grant recipient.
- Pre-printed deposit slip or certified bank statement (i.e. certified means signed and stamped by bank official) or if appropriate, letter on company letterhead stating the bank account you want the payment to go into and signed by the director or finance person with their name and position stated
- For US accounts we require a SORT code
- For European accounts we require an IBAN number

- ➢ If the recipient's country of residence is different to the country where the funds are being sent, please explain why this is.
- ➢ If the payment is to an individual and not an organisation, please explain how you are involved in the transaction.
- ➢ Please provide the full names of all ultimate beneficial owners of your organisation. The ultimate beneficial owners must be natural persons (individuals) and cannot be legal persons. Directors, CEOs, presidents or chairpersons are not necessarily the beneficial owners.
- ➢ Please state who the final recipient of the funds, if not the organisation, that we are making the payment to.

Acceptance of Funding
Please confirm acceptance of the above terms and conditions by signing and dating this letter in the space indicated below and return (hard or scanned copy is fine) to Michelle Whybrow, Conservation Fund Administrator michelle.whybrow@aucklandzoo.co.nz or Auckland Zoo, Private Bag 78700, Grey Lynn, Auckland 1245, New Zealand.

Thank you again for your application and we wish you all the best with your project!

Yours sincerely

Michelle Whybrow
Conservation Fund Administrator

Harrison Sollis agrees to the Auckland Zoo terms and conditions of funding as outlined in this letter.

Applicant Signature

6/12/19
Date

APPENDIX V.

Attempted predation of Eastern Galapagos racer (*Pseudalsophis occidentalis*) on a smaller conspecific, Cape Douglas, Fernandina Island, June 2015. Photos: R. Wollocombe.

APPENDIX VI.

Catalogue of images of central Galapagos racer (*Pseudalsophis dorsalis*) from Seymour Norte.

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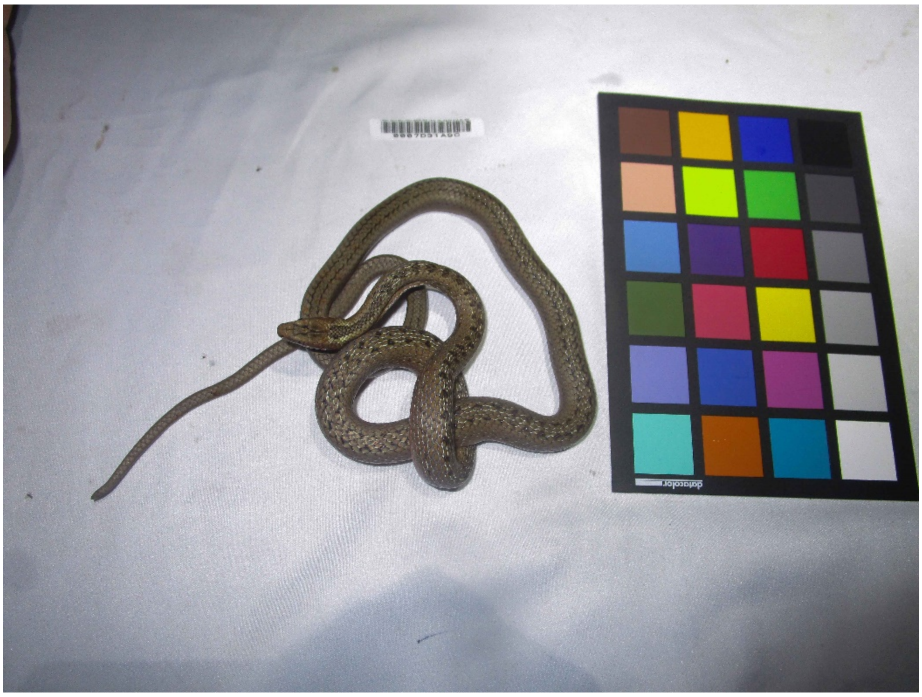
0007923BA5

0007D2B7FD



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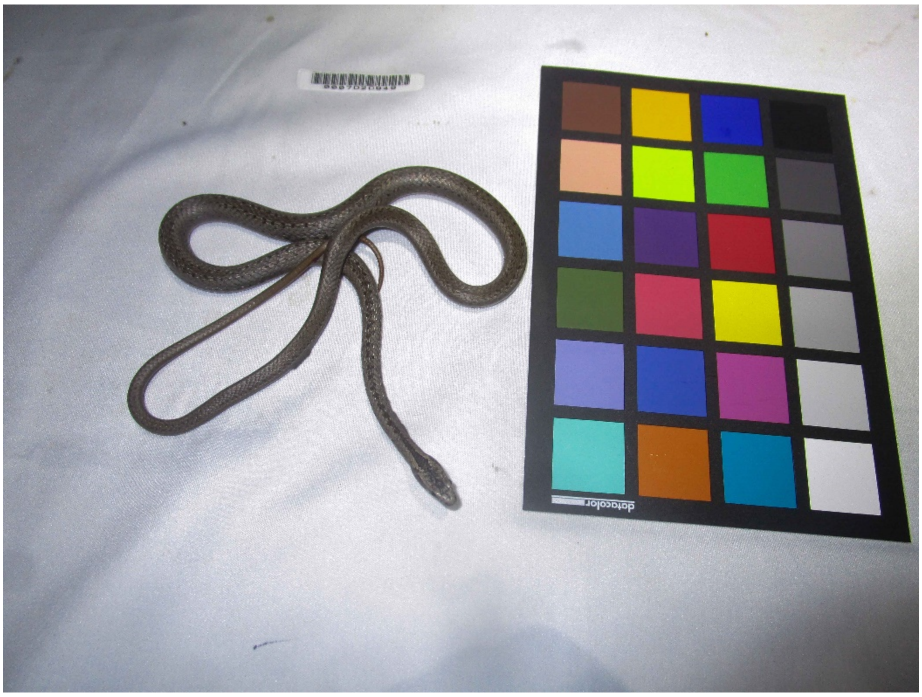

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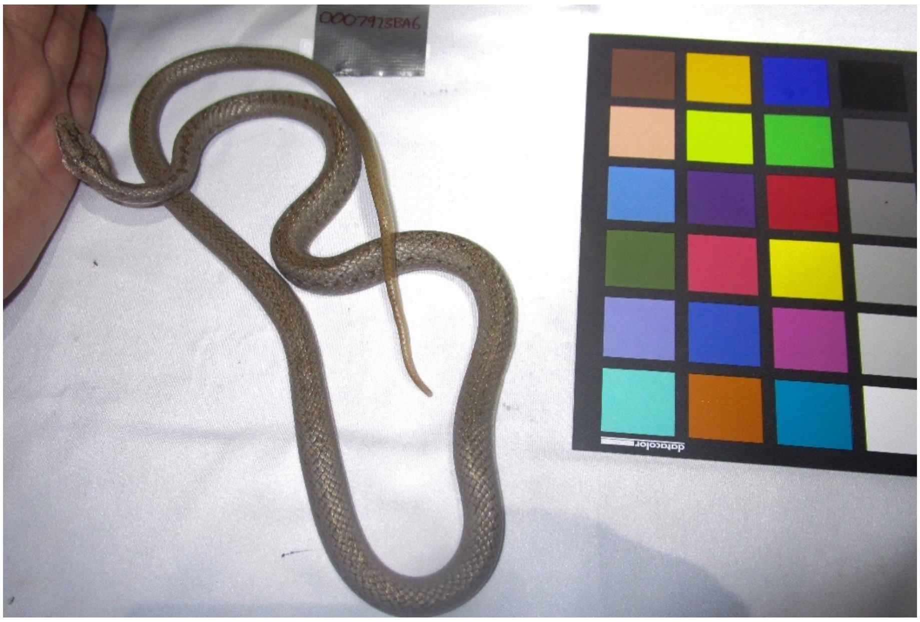

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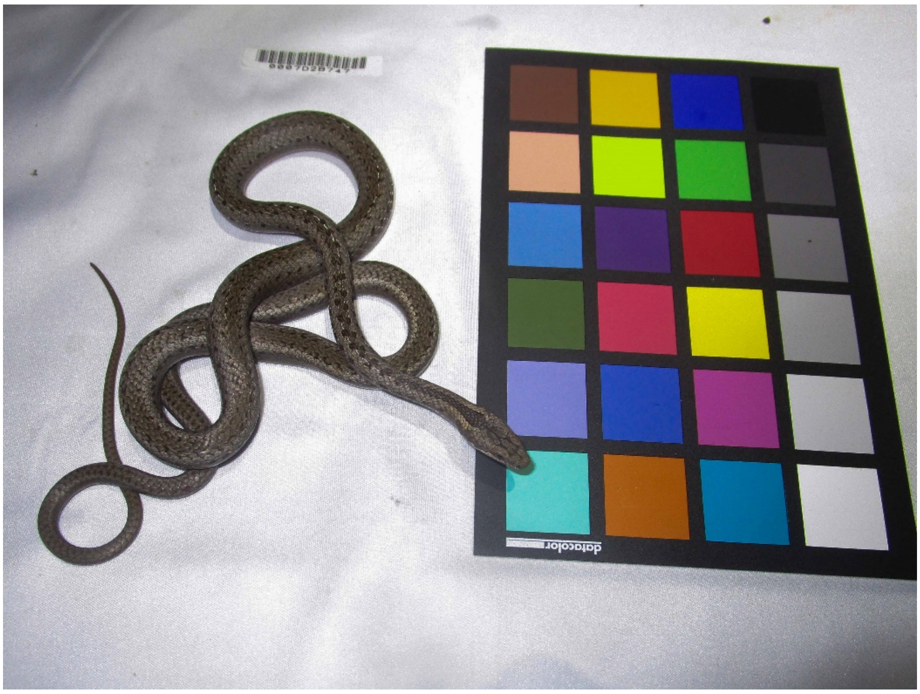

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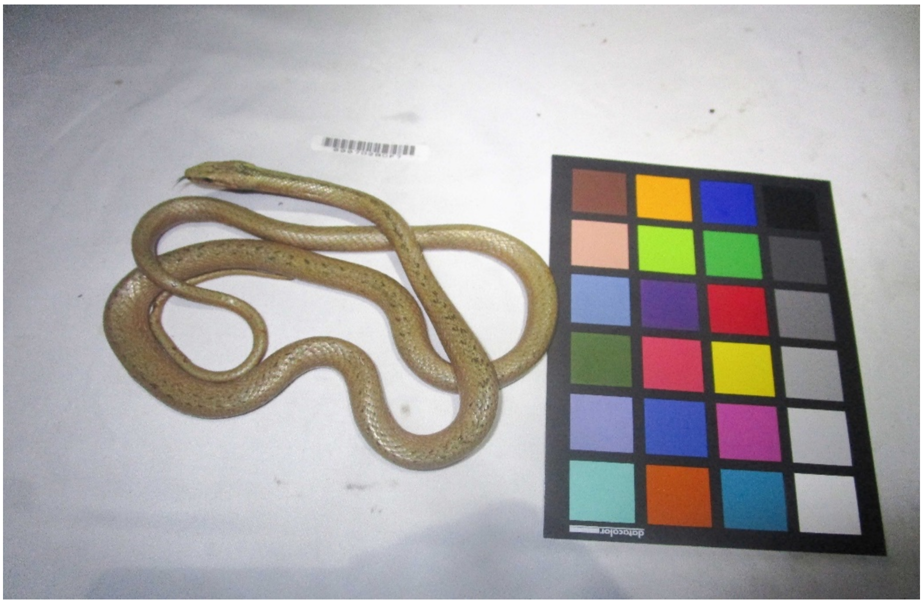

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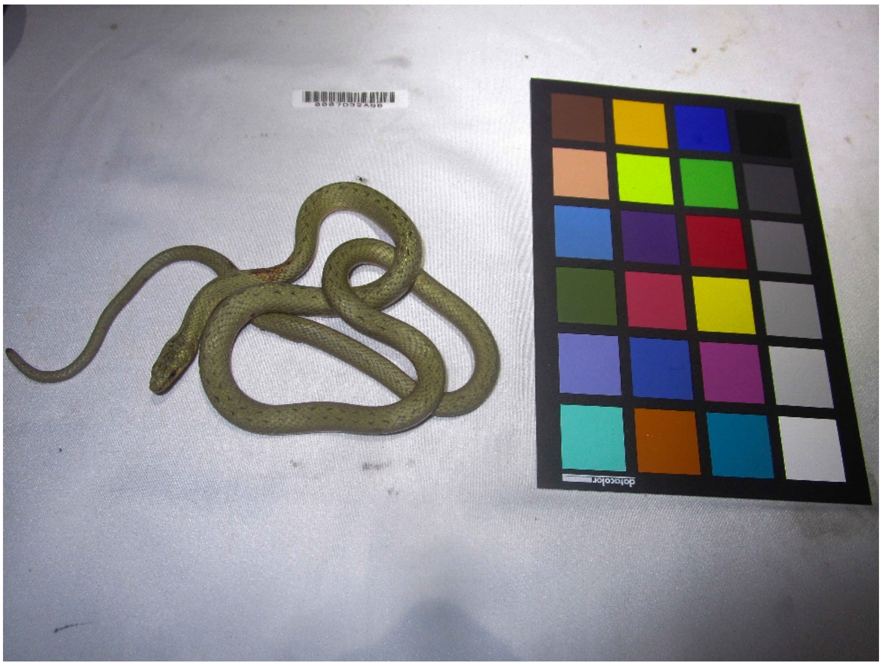

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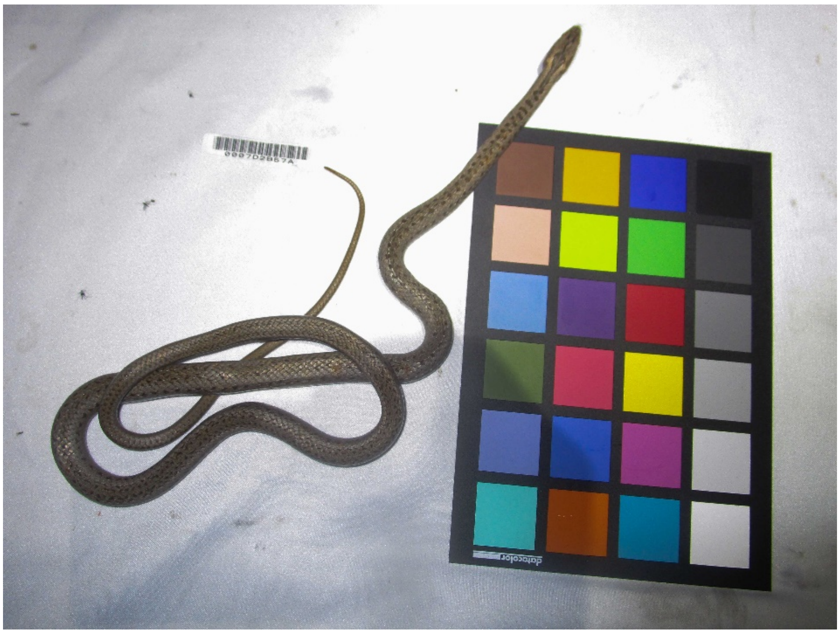

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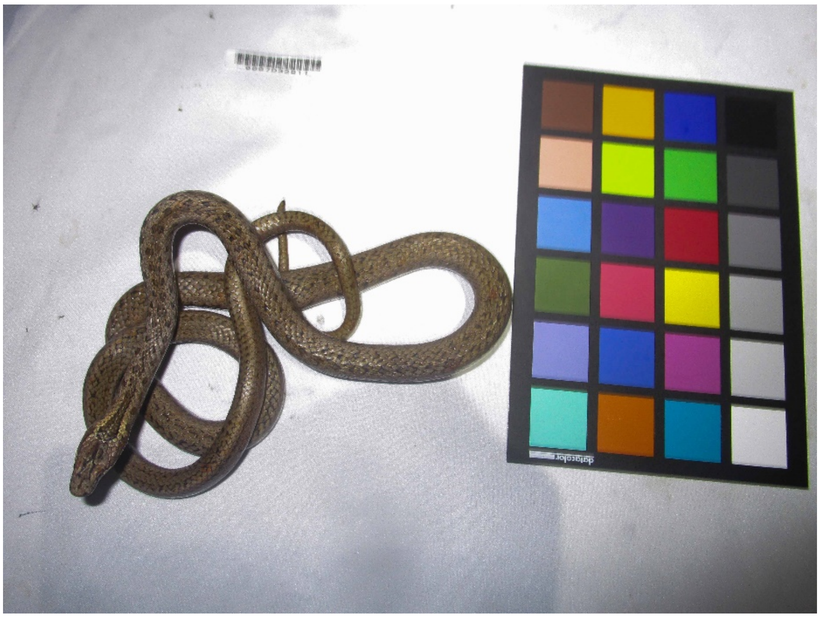

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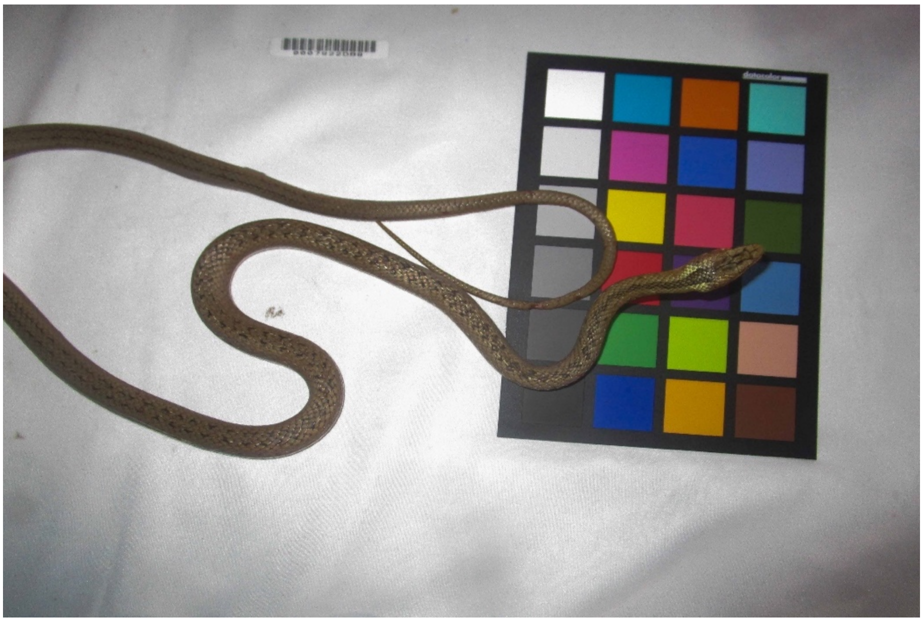

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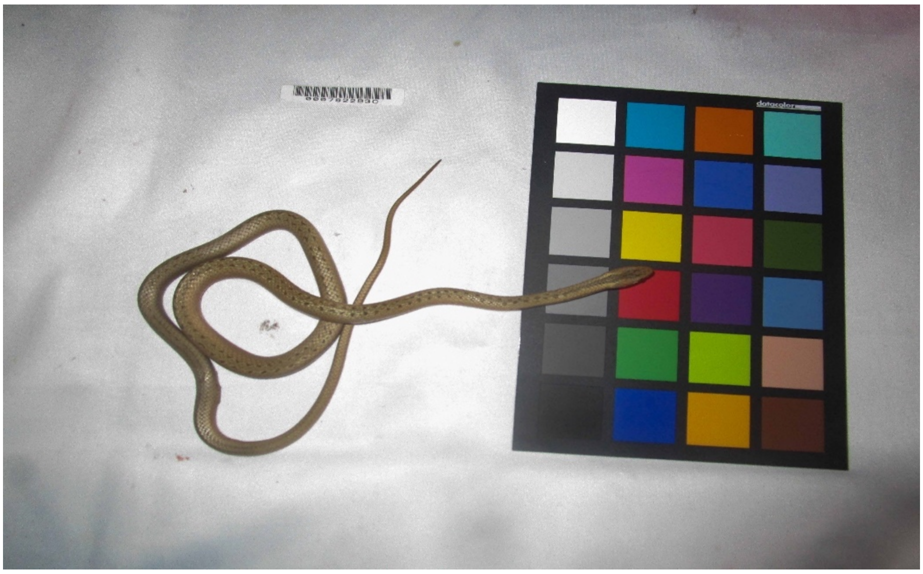

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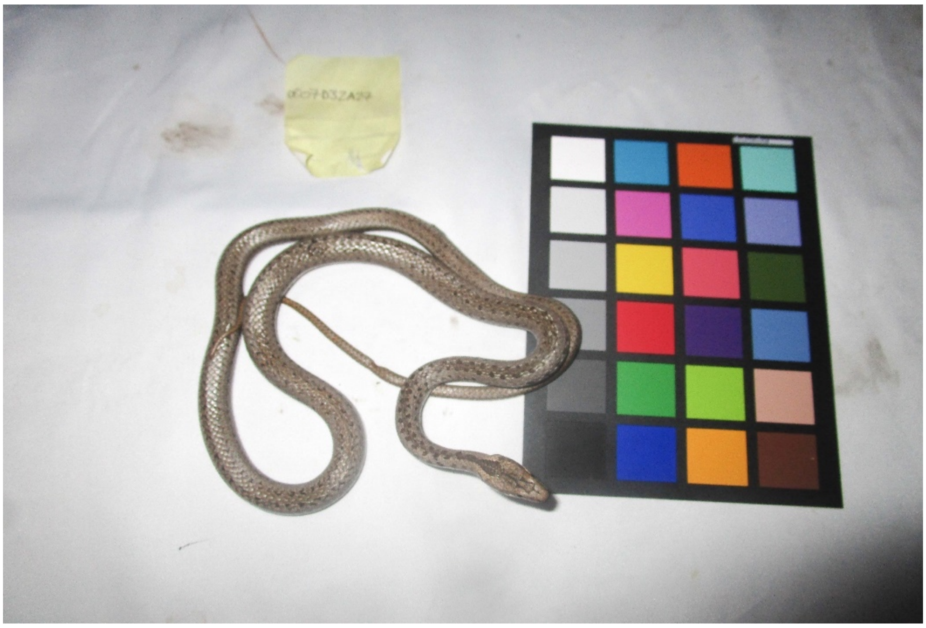

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0007D2BECA

SN45

SN77

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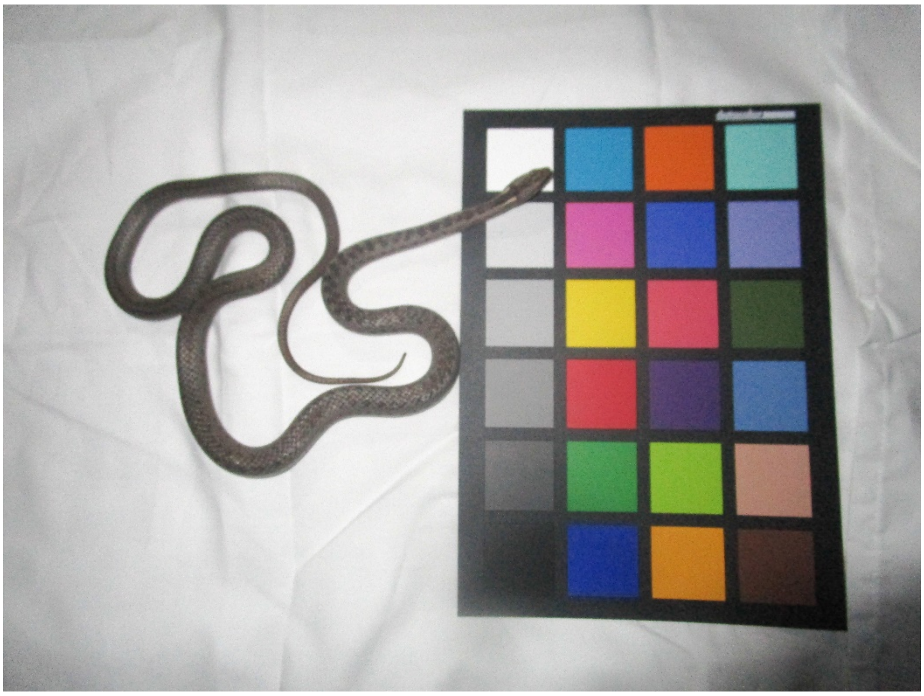
APPENDIX VII.

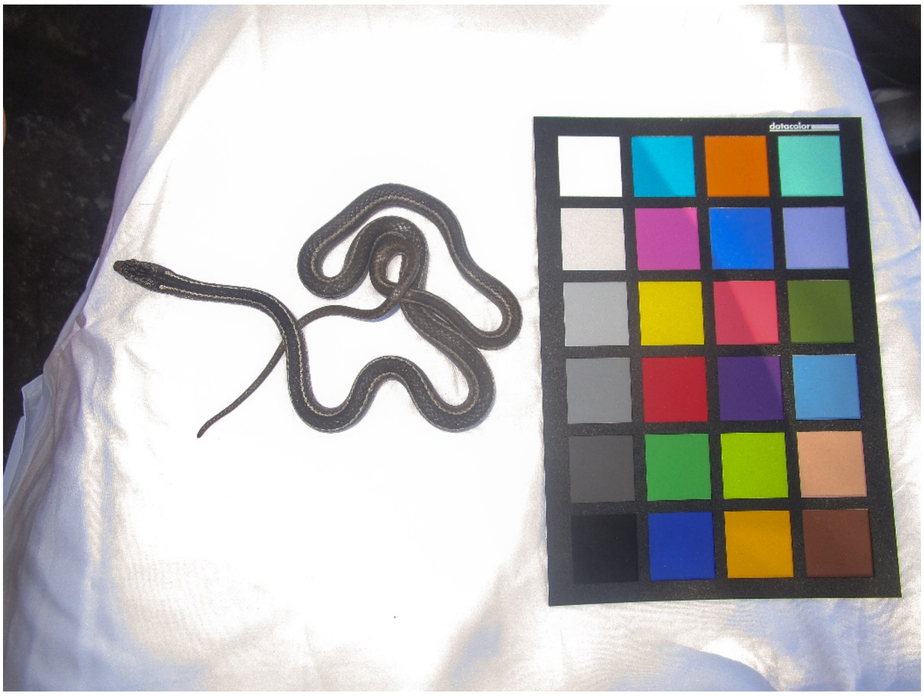
Catalogue of images of central Galapagos racer (*Pseudalsophis dorsalis*) from Santa Fe.

Santa Fe catalogue

SF20



SF21



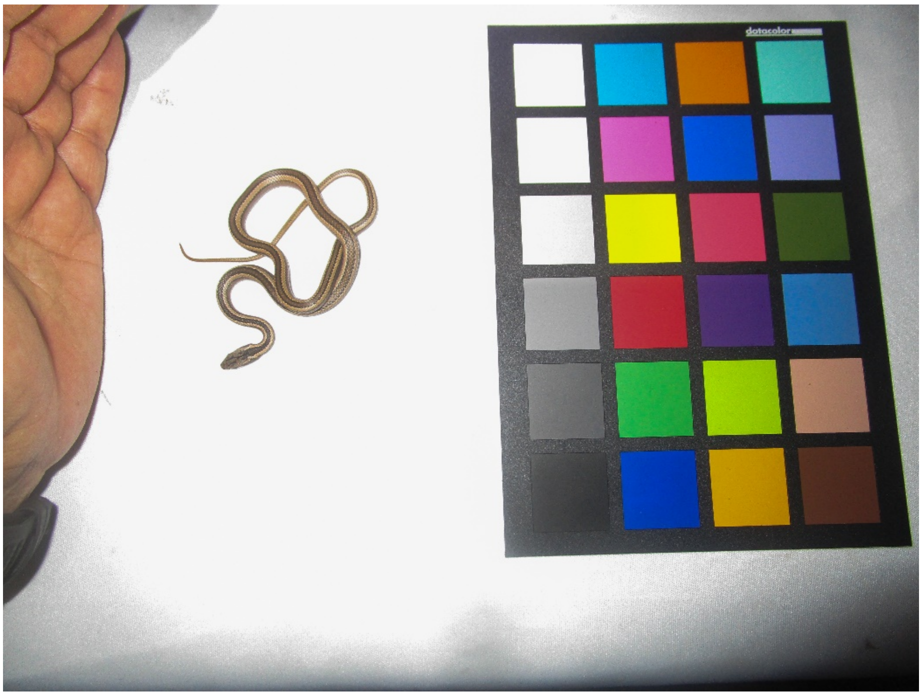
SF22

SF23

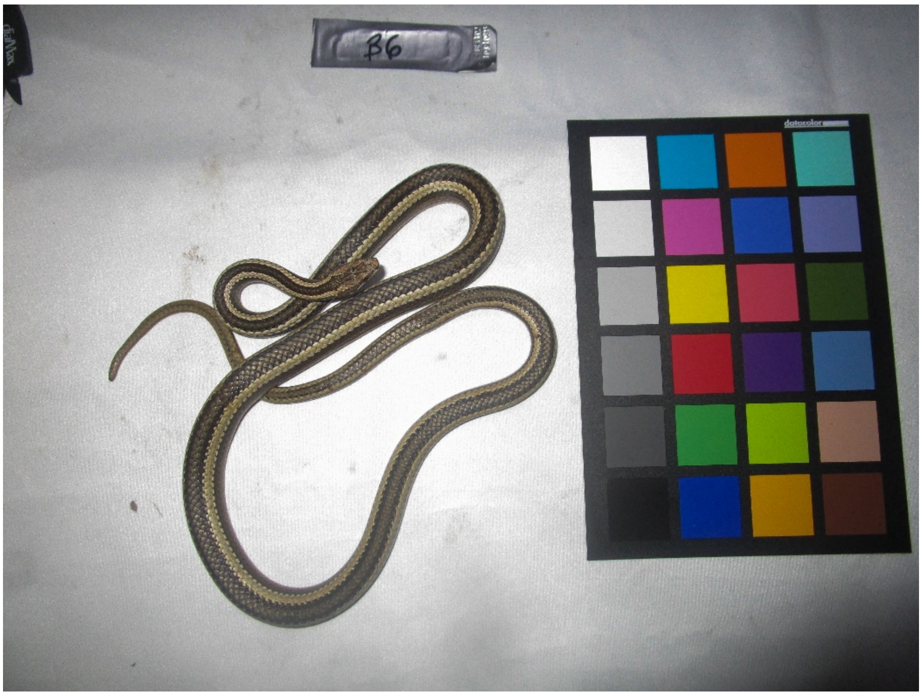
APPENDIX VIII.

Catalogue of images of central Galapagos racer (*Pseudalsophis dorsalis*) from Baltra.

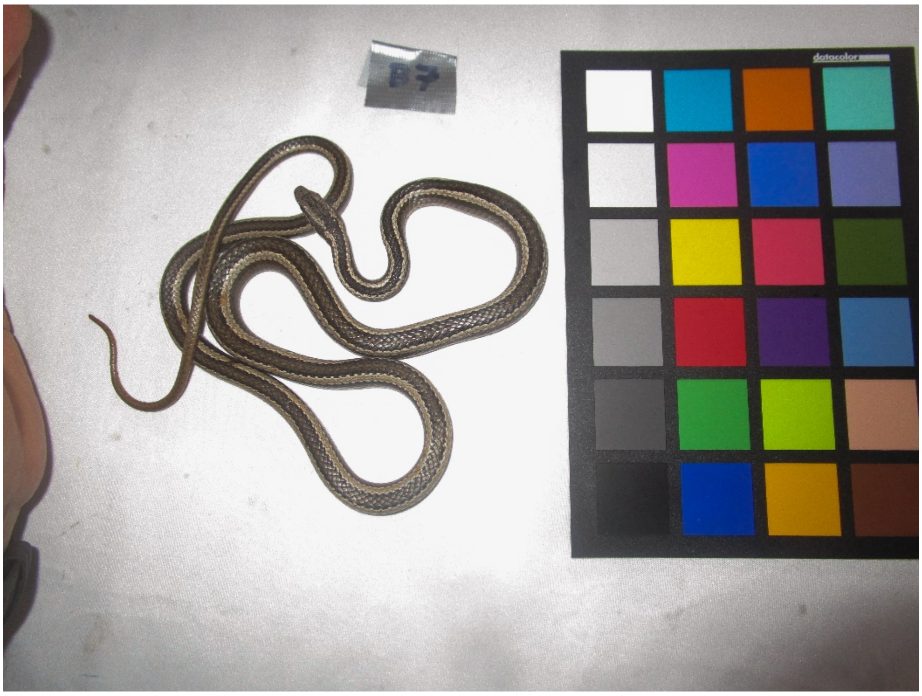
B2



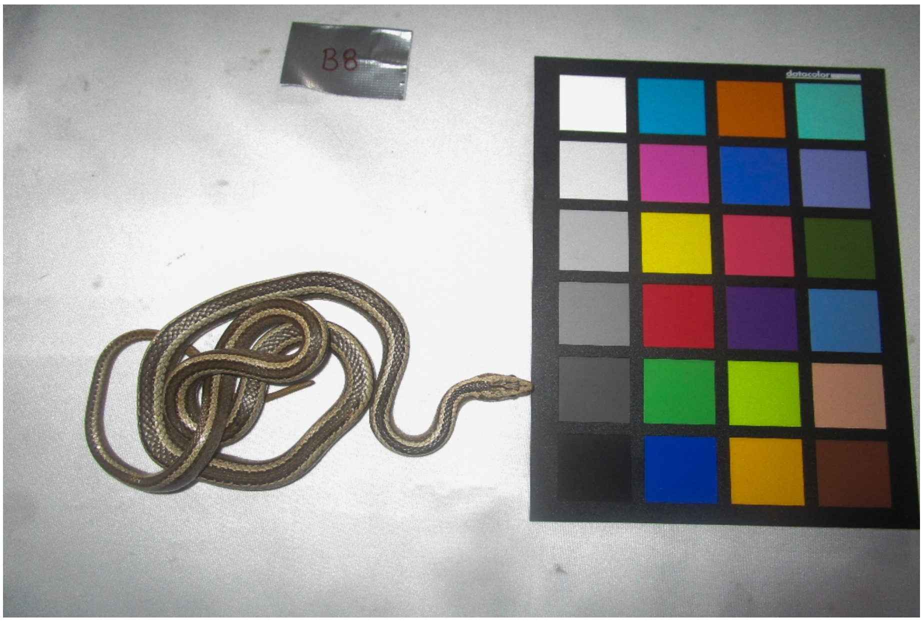
B5



B6



B7

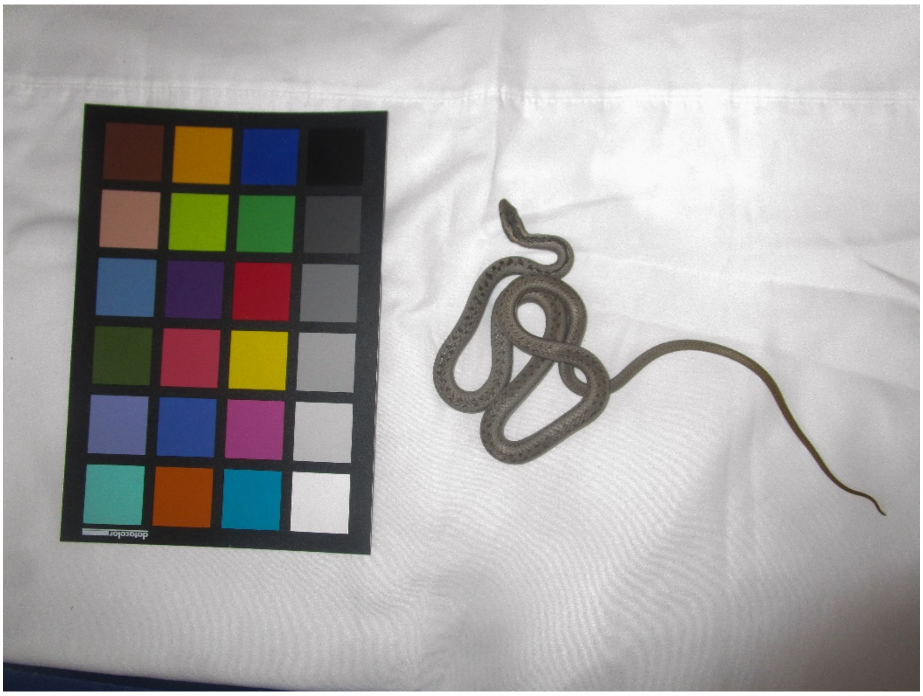


B8

APPENDIX IX.

Catalogue of images of central Galapagos racer (*Pseudalsophis dorsalis*) from El Eden.

E1

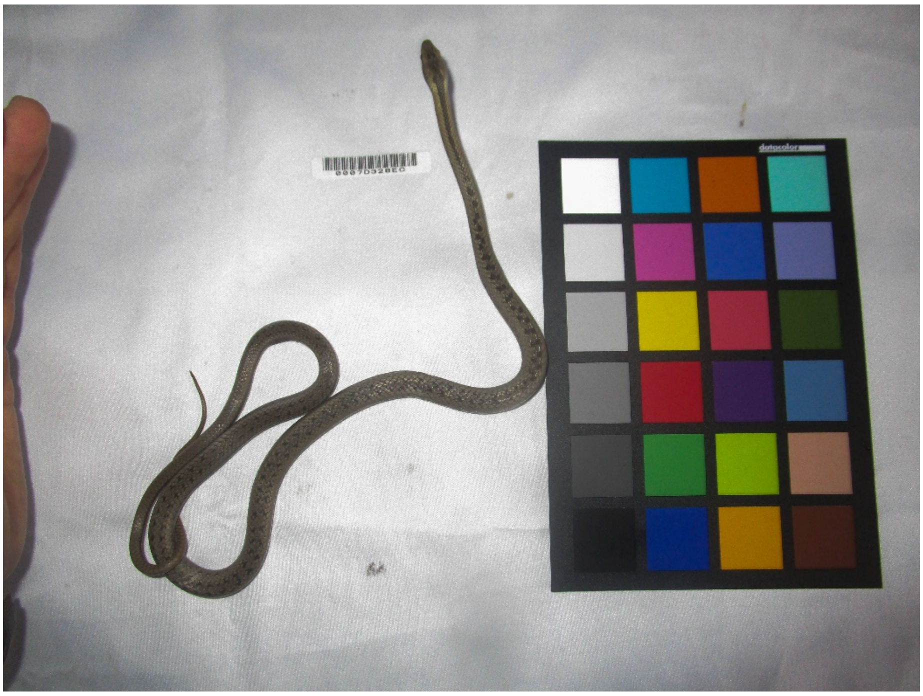


E2

E3

E4

E5



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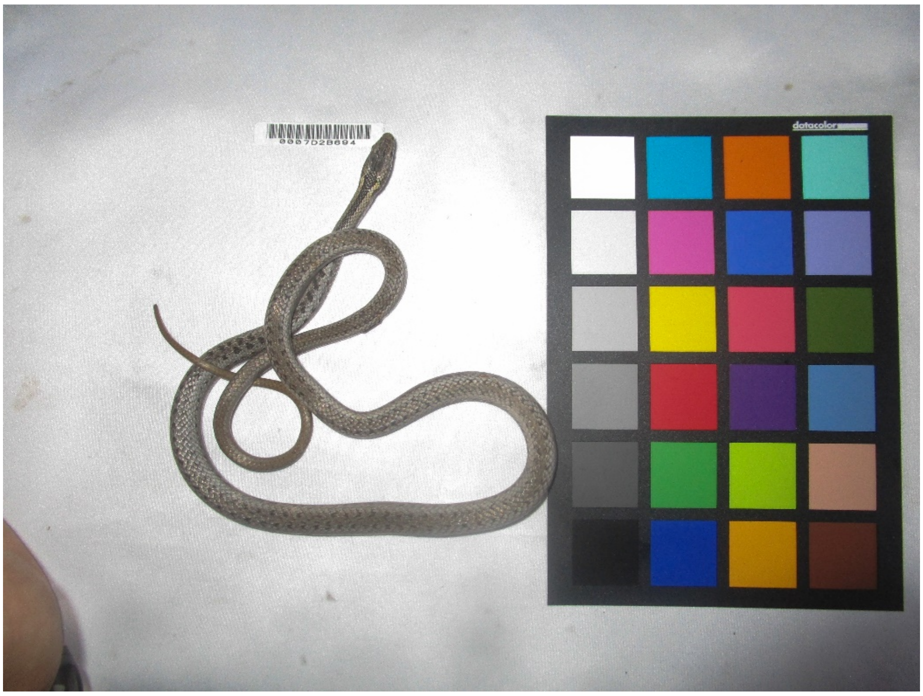

0007D2B694

APPENDIX X

Catalogue of images of central Galapagos racer (*Pseudalsophis dorsalis*) from Seymour Norte, photographed in the wild.

0007D2B7FD

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0007923BA6

0007D2B747

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0007D2BCF7

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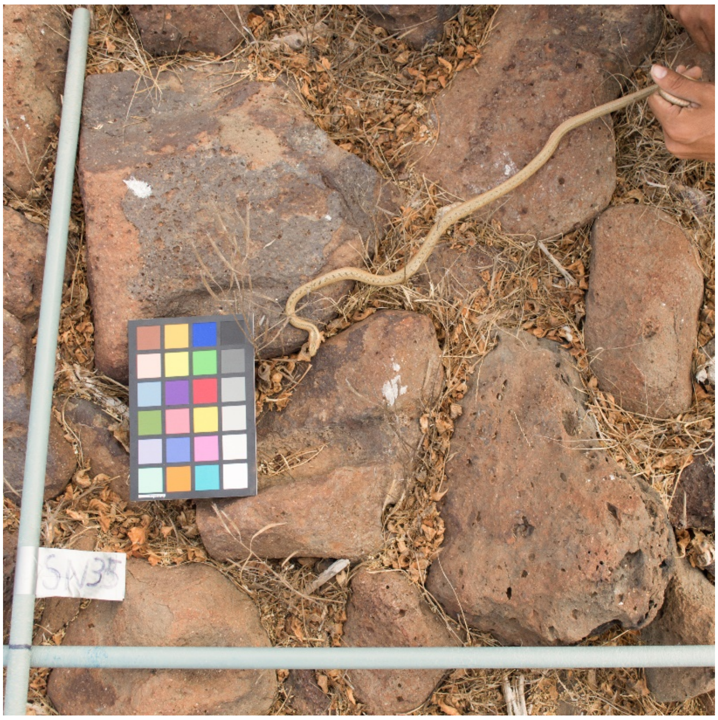

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0007922B3C

0007922D6D

0007922E7E

0007922EC6

0007923CF1

0007922B97

c.f. 0007923C9A (?)

0007922B9D

0007923C85

0007922D0E

0007922B1C

0007922C14

0007923E35

0007923BE4

0007923B46

0007922D49

0007922E02

0007D2BECA

SN45

SN77

0007922E0A

0007922D7C