Fundación
Charles Darwin
Foundation
GALAPAGOS

Alert on the current conservation status of the Galapagos natural assets:

institutional position of the Charles Darwin Foundation for the Galapagos Islands

Published © 2019
Charles Darwin Foundation for the Galapagos Islands - Charles Darwin Research Station
Puerto Ayora, Santa Cruz
Galapagos Islands, Ecuador

Photo cover: Flightless Cormorant /Daniel Unda

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Fundación
Charles Darwin
Foundation
GALAPAGOS

Table of Contents

Alert on the current conservation status of the Galapagos natural assets....................3

Institutional position of the Charles Darwin Foundation..3

The Marine Dimension..5

The challenges of the Galapagos artisanal fishing fleet and the conservation of its marine ecosystems..6

Ecology, evaluation, and fisheries management: steps towards sustainability.................11

Sea Mountains and other Depth Ecosystems in the Galapagos Marine Reserve................14

Study of the status of the populations of Galapagos penguin, flightless cormorant, and Galapagos albatross...16

Study of the status of the Galapagos flamingo and the lagoon bird population................19

The sharks of Galapagos...21

Reducing threats to sea turtles in Galapagos...24

Subtidal Long-term Ecological Monitoring...26

Marine invasive species in the GMR: prevention, detection, and management.................29

The Terrestrial Dimension..32

Pilot research for the reduction of bird mortality on the roads of Santa Cruz Island..........33

Searching for solutions to control the avian parasite *Philornis downsi* and to conserve Galapagos land birds...40

Galapagos Verde 2050: Ecological Restoration and Sustainable Agricultural Practices.....45

Galapagos Giant Tortoise Movement Ecology Program: The importance of health for the welfare of animals and their ecosystem...49

In conclusion...52

Authors...53

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Alert on the current conservation status of the Galapagos natural assets

Institutional position of the Charles Darwin Foundation

The Galapagos Islands have been—and continue to be—imagined as pristine spaces, free from human influence. However, current situations in the natural and social systems of the archipelago indicate that this image is not exactly the only one, nor is it the most dominant image on the islands. Among others, the major risks threatening the conservation of the Galapagos biological diversity and the viability of the human populations in the islands are: Disorderly urban planning; poor management of solid and liquid waste; high dependence on non-renewable energy sources; increase in the dependency of fossil-fuel for transportation; increase in the demand and reliance of products and goods coming from the mainland (which logically increases the possibility of introducing invasive marine and terrestrial species); substantial increase in the number of tourists per year; significant decrease in the original distribution of endemic plant species; endangered species seriously compromised; and the broader dispersion of terrestrial invasive species in broad areas.

Along this daunting scenario, management actions taken by the environmental authority, who tries to better address the challenges that the Galapagos Archipelago faces, on a day-to-day basis. However, their job gets compromised by the complexities associated to the governance of a protected area, with such levels of diversity and dynamics. In this light, it is necessary to think about an extended time scale to understand the situation that reduces the possibility of resolving these issues and what to do to face them.

Along the last decades, the model of sustainable development for Galapagos has been, and continue to be, the dominant image, inspired by a "business-as-usual" format, and promoted by the traditional political, economic and conservation discourses. Yet, little or nothing has been done to put on a discussion table the need to reflect, define, and negotiate what does "sustainable" and what does "development" mean, for the local actors within the islands.

To start with, there is no agreement on what is meant by "sustainable" and by "development." It is here, that the confusion and contradiction in the practices and policies that are implemented in Galapagos get originated. Only when we are honest regarding what model of development we want for Galapagos, only when we know what implications this model has, and only when we implement that format, as the essential requirement to live in such a special place, will we be able to talk about sustainability in the enchanted islands.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

This executive summary aims to raise a warning voice, triggered by the knowledge generated by our scientific work, in the last decade. This illustration is aligned to the emergency situation in Galapagos, given the numerous threats that affect the conservation of the natural systems and the viability of the social systems. In the same light, this document presents the scientific evidence provided by the scientific research projects conducted at the Charles Darwin Research Station (CDRS) has been developing in the last two years (AOP 2017-2018). This summary seeks to draw the attention of the state, the authorities, the community, the civil society, and the market, on the urgent aspects that require attention in Galapagos.

The position expressed by the Charles Darwin Foundation for the Galapagos Islands (CDF) is supported by scientific evidence and is expressed with caution, but with the necessary urgency. A compilation of the most relevant aspects of the research, produced by the FCD projects, have been summarized by the main researchers of each project. Their inputs correspond, to information published in scientific peer-reviewed articles and in other information formats (i.e., Technical Reports, Advance Reports, outreach material). Some of these references are available in digital and/or printed formats. The process of gathering the information used for the preparation of this document and the process of systematization of the information provided, have followed the process of iterative communication with researchers. It has been described in a narrative format for the general public.

The following sections illustrate highlights the most outstanding results of the research projects conducted by the Charles Darwin Research Station, within both, the marine and terrestrial dimensions.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

The Marine Dimension

Flightless Cormorant. Photo: Sam Rouley.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

The challenges of the Galapagos artisanal fishing fleet and the conservation of its marine ecosystems

The Galapagos Islands harbor one of the best-preserved marine environments on the planet, mainly as a direct consequence of these three factors: the historical absence of an indigenous population and the geographical isolation of the archipelago; a late colonization, strictly limited by the Galapagos Special Law; and the protection provided by the Galapagos Marine Reserve against industrial fishing activities, since 1998. Yet, the human interactions within these ecosystems currently play a significant role in their conservation status.

However, the successful achievements at governing this marine area is not homogenous for all the marine species and ecosystems, within the archipelago. As an illustration, while the GMR has been effective in protecting charismatic species such as mammals, turtles, seabirds, or even some species of sharks and pelagic fish,[1,2,3,4] the deficiencies at successfully governing the artisanal fisheries activities, allowed under license within this multi-purpose protected area, has resulted in overexploitation and even collapse of valuable fishing resources[5,6,7]. These governance pitfalls are illustrated by the degradation of coastal ecosystems through affectation of trophic cascades[8,9], or even by the bycatch incidence of protected and threatened species, with the consequent risk to become extinct, due to the use of non-selective fishing gear, such as surface longlines[10,11].

---

[1] Salinas de León, P. et al. Largest global shark biomass found in the northern Galápagos Islands of Darwin and Wolf. PeerJ 4, e1911 (2016).
[2] Seminoff, J. et al. Post-nesting migrations of Galápagos green turtles *Chelonia mydas* in relation to oceanographic conditions: integrating satellite telemetry with remotely sensed ocean data. Endanger. Species Res. 4, 57–72 (2008).
[3] Boerder, K., Bryndum-Buchholz, A. & Worm, B. Interactions of tuna fisheries with the Galápagos marine reserve. Mar. Ecol. Prog. Ser. 585, 1–15 (2017).
[4] Acuña-Marrero, D. et al. Residency and movement patterns of an apex predatory shark (*Galeocerdo cuvier*) at the Galapagos Marine Reserve. PloS One 12, e0183669 (2017).
[5] Hearn, A. The rocky path to sustainable fisheries management and conservation in the Galápagos Marine Reserve. Ocean Coast. Manag. 51, 567–574 (2008).
[6] Wolff, M., Schuhbauer, A. & Castrejón, M. A revised strategy for the monitoring and management of the Galapagos sea cucumber *Isostichopus fuscus* (Aspidochirotida- Stichopodida.pdf. Rev. Biol. Trop. 60, 539–551 (2012).
[7] Usseglio, P. et al. So long and Thanks for All the Fish: Overexploitation of the Regionally Endemic Galapagos Grouper *Mycteroperca olfax* (Jenyns, 1840). PLoS ONE 11 (10), (2016).
[8] Edgar, G. J. et al. El Niño, grazers and fisheries interact to greatly elevate extinction risk for Galapagos marine species: El Niño, Grazers and Fisheries Interact With Galapagos Marine Species. Glob. Change Biol. 16, 2876–2890 (2010).
[9] Schiller, L., Alava, J. J., Grove, J., Reck, G. & Pauly, D. The demise of Darwin's fishes: evidence of fishing down and illegal shark finning in the Galápagos Islands. Aquat. Conserv. Mar. Freshw. Ecosyst. n/a-n/a (2014). doi:10.1002/aqc.2458
[10] Murillo, J. C., Reyes, H., Zárate, P., Banks, S. & Danulat, E. Evaluación de la captura incidental durante el Plan Piloto de Pesca de Altura con Palangre en la Reserva Marina de Galápagos. (2004).
[11] Reyes, H. et al. Plan Piloto de Pesca de Altura con arte de pesca 'Empate Oceánico Modificado' en la Reserva Marina de Galápagos. 36 (Dirección del Parque Nacional Galápagos, 2014).

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

The coastal zoning of the GMR: …as a paper park?

Despite scientific evidence proves that the GMR has been key at improving the catch of the tuna-fish-large- scale fleet, carrying out fishing activities off the GMR, *via* the spill-over effect[19, 12], improvement in fishing catch, by the large scale fleet, in the preliminary coastal zoning established in 2000[13],[14] has not been documented. Within the current management strategy, only 1% of the 139,000 km^2, covered by the GMR, is closed to artisanal fishing activities[15]. However, illegal fishing conducted mostly by large scale fleets within these protected area, still occur and remain as one important reason behind the reduction of the spill-over effect[29, 30]. In addition, this management format has not included fishing-free-areas in Galapagos, which would be necessary for the maintenance of ecological processes, for the improvement of fisheries in adjacent areas[16], and for the improvement of ecosystem's resilience, against extreme climatic phenomena such as climate change or El Niña/La Niña cycles[17].

The GMR re-zoning approved in 2016, was aimed at expanding non-fishing areas to cover 30% of the total area of the GMR, a percentage recommended by international experts[18] as a desired scenario to enhance marine conservation. This aim was intended to accelerate the improvement of fishing activities, due to the spill-over effect, a phenomenon that has demonstrated to be successful in a multitude of marine reserves that are adequately protected[19, 20, 21, 22]. This new zoning proposal, included the marine sanctuary of Darwin and Wolf—the two most pristine islands of the archipelago—based on three features: the geographically isolation of the sanctuary, the recognition of their high biodiversity, and the abundance registered of sharks and other marine megafauna[23], which converts it in one of the best diving destinations in the world. Additionally, the new zoning process aimed to protect fewer but larger marine areas, under a more cost-effective scenario, by optimizing the patrol, monitoring and control actions[24].

---

[12] Bucaram, S. J. et al. Assessing fishing effects inside and outside an MPA: The impact of the Galapagos Marine Reserve on the Industrial pelagic tuna fisheries during the first decade of operation. Mar. Policy 87, 212–225 (2018).

[13] Buglass, S. et al. Evaluating the effectiveness of coastal no-take zones of the Galapagos Marine Reserve for the red spiny lobster, *Panulirus penicillatus*. Mar. Policy 88, 204–212 (2018).

[14] Usseglio, P. The Galapagos grouper fishery: mostly dead, stunned, or in need of management regulations.pdf. (2015).

[15] Moity, N. Evaluation of No-Take Zones in the Galapagos Marine Reserve, Zoning Plan 2000. Front. Mar. Sci. 5, (2018).

[16] Sala, E. & Giakoumi, S. No-take marine reserves are the most effective protected areas in the ocean. ICES J. Mar. Sci. (2017).

[17] Micheli, F. et al. Evidence That Marine Reserves Enhance Resilience to Climatic Impacts. PLoS ONE 7, e40832 (2012).

[18] O'Leary, B. C. et al. Effective Coverage Targets for Ocean Protection: Effective targets for ocean protection. Conserv. Lett. 9, 398–404 (2016).

[19] McClanahan, T. R. & Mangi, S. Spillover of exploitable fishes from a marine park and its effect on the adjacent fishery. Ecol. Appl. 10, 1792–1805 (2000).

[20] Russ, G. R., Alcala, A. C. & Maypa, A. P. Spillover from marine reserves: the case of *Naso vlamingii* at Apo Island, the Philippines. Mar. Ecol. Prog. Ser. 264, 15–20 (2003).

[21] Goñi, R. et al. Spillover from six western Mediterranean marine protected areas: evidence from artisanal fisheries. Mar. Ecol. Prog. Ser. 366, 159–174 (2008).

[22] Stobart, B. et al. Long-term and spillover effects of a marine protected area on an exploited fish community. Mar. Ecol. Prog. Ser. 384, 47–60 (2009).

[23] Salinas-De-León, P., Acuña-Marrero, D., Carrión-Tacuri, J. & Sala, E. Valor ecológico de los ecosistemas marinos de Darwin y Wolf, Reserva Marina de Galápagos. 15 (Fundación Charles Darwin/Dirección del Parque Nacional Galápagos, 2015).

[24] Balmford, A., Gravestock, P., Hockley, N., McClean, C. J. & Roberts, C. M. The worldwide costs of marine protected areas. Proc. Natl. Acad. Sci. U. S. A. 101, 9694–9697 (2004)

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

In the last years, despite the need for effective governance, represented by the need of full protection of the GMR to ensure its long-term conservation, hindrance in the governability of this area has been experienced. In fact, the unsuccessful implementation of the zoning system and marine sanctuary, declared in 2016, illustrates a historical step backwards in the conservation of the islands, and shows an unequivocal movement oriented towards the continuity of the overfishing of coastal resources.

Serious deficiencies encountered in fisheries governance within Galapagos

In the last five years, together with the repeal of implementing the 2016 zoning for the GMR, other key processes for fisheries governance, aimed at ensuring the sustainable usage of the insular resources of the GMR, have not presented much progress. All of this happened, despite the recommendations provided by the UNESCO reports, the specific requests from the artisanal fishing sector, and the advice provided by various international experts, on fisheries management and governance.

Among the stalled key governing processes are:

1) The ‘cleaning’ and ‘updating’ of the fishing records, within the GMR.
If done, this process would ensure the availability and access to an updated fishing database. This step would make it possible to be certain in who, from the artisanal fishing community, is (has been) actively fishing within a season, who among them, has active and valid fishing license, and who needs to renew it. In fact, currently there are more than 1200 fishing licenses; however, it is estimated that less than 500 fishers actually conduct artisanal fishing, as their main economic activity.

2) The reform of the fishing regulation.
This step, with clear and updated rules to exercise the fishing activity within a protected area and UNESCO World Heritage Site, could be established and implemented.

3) The updating of the fishing calendar which includes the implementation of management plans for overfished species based on technical information already available. This step would enhance the recovery of these resources well in advance, before it is too late and by doing so, avoiding what happened with the sea cucumber fishery;

4) The improvement of Galapagos fishery products’ trade, so that fishers can first, access to national and international markets that value regulated artisanal fishing and second, obtain a greater share of the value chain, which has traditionally been dominated by few intermediaries;

5) The implementation of value-added mechanisms, such as the sustainable fishing gears used to fish, the traceability certification, some fair trade strategies, all of which increase the value chain of marine products and which would contribute to increase the commercial value of the fish produce of Galapagos. These mechanisms help to improve the profitability for

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

fishers, without increasing fishing effort. By achieving this, the pressure over fishing resources would diminish and would contribute to the maintenance of sustainable fishing practices.

However, none of these ideas or initiatives have been significantly advanced by the local fishing authority, in the last decade neither have the management strategies been improved or updated according the current status of the marine natural systems. On the contrary, in the last years, the management initiatives for fisheries resources that have been put in place have only addressed day-by-day actions, in order to keep the current condition of the fishing stocks status or at least, trying to maintain the fishing activity in Galapagos. Additionally, concerning management practices, three experimental longline fishing projects were developed in order to get evidence of the incidence of bycatch events by this, —a non-selective fishing gear that has an enormous impact on megafauna species of the GMR[10, 11]. Another management action regarded the inclusion of 'recreational fishing', under a *de-facto* process approved in the GMR, which obscured the spirit of the 'Live Fishing' initiative, which was approved in 2005, as an alternative to longline fishing[25]. Finally, an umpteenth experimental longline pilot fishing program is currently underway, where species protected by local, national and international legislation are being caught, in order to demonstrate, again, that this fishing practice is not appropriate within Galapagos context.

Fear of making decisions due to social pressure?

Despite the availability of enough sound scientific evidence, portraying the overexploitation of some fisheries in the GMR (e.g., "*The sunset of Darwin's fish*"[26] or "*See you later and thanks for all the fish*"[27]), the increasing pressure over them, by one segment part of the artisanal fishing fleet in Galapagos remain. In fact, the lobby put in place by part of this sector, has demonstrated to be heard better than any technical criteria, and that the application of the precautionary principle, that should be the guiding light to govern this World Heritage Site, in favor of the fisheries sustainability. In fact, incidents happening in the past, when offices of the Galapagos National Park were put under siege or by the death threats to giant tortoises by fishers, still remain in the local collective and authorities' memory and still are elements of high relevance at taking decisions and policy making, on a daily basis[28,29].

Although the magnitude of complaints has gradually decreased during the last decades, some protests—included the blocking of key infrastructures such as highways, airports or gas stations– arose recently, against some of the most ambitious (and successful) management decisions adopted by the local authorities, the 2016 re-zoning system for the marine area.

[25] Schuhbauer, A. & Koch, V. Assessment of recreational fishery in the Galapagos Marine Reserve: Failures and opportunities. Fish. Res. 144, 103–110 (2013).

[26] Usseglio et al., 2016. So long and thanks for all the fish: Overexploitation of the regionally endemic Galapagos grouper *Mycteroperca olfax* (Jenyns, 1840). *PLoS ONE,* 11(10).

[27] Schiller et al., 2014. The demise of Darwin's fishes: Evidence of fishing down and illegal shark finning in the Galapagos Islands. *Aquat Conserv Mar Freshw Ecosyst*.

[28] Ferber, D. Galápagos station survives latest attack by fishers. Science 290, 2059–2061 (2000).

[29] Stone, R. fishers threatened galapagos.pdf. 267, (1997).

Again, socially and politically influenced events, prevent a management action to be implemented, despite the process behind the declaration, could still be contested. The new riots have, once again, resulted either in the lack of action or, in political concessions made to fishers. This undesired situation becomes of preoccupation when it comes to decision and policy making, which are expected to favor sustainability of the marine ecosystems within the GMR and therefore, promote fisheries sustainability.

Conclusion

The current diminished status of some economically important fish species' stocks, that are targeted by the small-scale fishing fleet in the GMR, represents the greatest threat to the conservation of the marine ecosystems and to the fishing resources themselves, in the short term. This problem becomes more worrisome if one takes into account the legal and illegal industrial fishing carried out by national and international longline fleets, in areas near the GMR and within the Exclusive Economic Zone of Galapagos[9, 30, 31, 32, 33,34]. In a highly variable climate-change driven scenario, it is predicted that the El Niño event will be more intense and more recurrent in the coming decades[35], therefore, areas fully protected against fishing activities, are among the few tools available to build resilience for the marine ecosystems and to diminish vulnerability of coastal human communities in Galapagos, by ensuring the spillover effect of the economically attractive fish species. In this sense, by ensuring the GMR success, it also ensures Galapagos sustainability, at large.

If the pressure one sector executes over governing bodies, and if their influence dominates the management decisions, that should, otherwise be supported by the best available science, the future of the GMR and its systems remains uncertain. In fact, the marine social-natural systems and the future of the environmental services that sustain the local population and the humanity, will be mortgaged for the financial (and electoral) benefit of few actors.

[30] Martínez-Ortiz, J., Aires-da-Silva, A. M., Lennert-Cody, C. E. & Maunder, M. N. The Ecuadorian Artisanal Fishery for Large Pelagics: Species Composition and Spatio-Temporal Dynamics. PLOS ONE 10, e0135136 (2015).

[31] Carr, L. A. et al. Illegal shark fishing in the Galápagos Marine Reserve. Mar. Policy 39, 317–321 (2013).

[32] Alava, J. J. et al. Massive Chinese Fleet Jeopardizes Threatened Shark Species around the Galápagos Marine Reserve and Waters off Ecuador: Implications for National and International Fisheries Policy. Int J Fish. Sci Res 1, 1001 (2017).

[33] Jacquet, J., Alava, J. J., Pramod, G., Henderson, S. & Zeller, D. In hot soup: sharks captured in Ecuador's waters. Environ. Sci. 5, 269–283 (2008).

[34] Alava, J. J. & Paladines, F. Illegal fishing on the Galápagos high seas. Science 357, 1362.1-1362 (2017).

[35] Wang, G. et al. Continued increase of extreme El Niño frequency long after 1.5 °C warming stabilization. Nat. Clim. Change 7, 568–572 (2017).

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Ecology, evaluation, and fisheries management: steps towards sustainability

Since the establishment of the Galapagos Marine Reserve (GMR) in 1998, only small-scale fishing activities are allowed within Galapagos, within specific fishing areas defined by the Zoning Plan of 2000[36, 37]. Since then, the GMR has been managed as a multipurpose protected area, which implies that, specific areas are granted to different activities in order to, reduce use conflicts, to protect marine biodiversity and to promote the sustainable use of resources[66]. According to the zoning process, conservation and tourism areas cover only 1% of the GMR, while the extraction of fishing resources is allowed in 99% of the reserve[38].

Through a spatial analysis-based process, conducted within this project, some conflicting uses between areas of the zoning system were identified. These areas highlighted complex interactions among users and issues that took relevance when evaluating the implementation effectiveness, of non-extraction areas, for the protection and recovery of key species. Additionally, the evaluation of the 'reserve effect' that GMR has had on the two species of lobster (*Panulirus penicillatus* and *P. gracillis*) and Galapagos prawns (*Scyllarides astori*), shows that no significant differences were detected between extraction and non-extraction zones after eleven years of protection[39], despite having specific management plans. On the other hand, demersal fishery does not have any specific regulation or management, showing clear signs of overfishing; in the case of the Galapagos cod (*Mycteroperca olfax*), no significant differences were detected between extraction and non-extraction zones[40].

To reduce the impact of fishing on demersal fish, one alternative has suggested to redirect fishing effort towards fast-growing large pelagic fish such as albacore (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*) on sites where Fish Aggregating Devices (FADs) have been set, or even without utilizing them. Results of this exercise shows that the sizes of the albacore species caught, varied spatially and temporally, for instance, 66% of the catches were young individuals (<100 cm). Additionally results show that the biomass aggregated in the FADs is high, and that it varies drastically between islands, with higher values in Isabela.

[36] Heylings, P., R. Bensted-Smith, and M. Altamirano. 2002. Zonificación e historia de la Reserva Marina de Galápagos, p. 10–22. In: Linea Base de la Biodiversidad de la Reserva Marina de Galápagos. E. Danulat and D. G. Edgar (eds.). Fundación Charles Darwin y Dirección Parque Nacional Galápagos, Puerto Ayora, Galápagos, Ecuador.

[37] Castrejón, M., O. Defeo, G. Reck, and A. Charles. 2014. Fishery science in Galapagos: from a resource-focused to a social-ecological systems approach, p. 159–186. In: The Galapagos Marine Reserve: Social and Ecological Interactions in the Galapagos Islands. J. Denkinger and L. Vinueza (eds.). Springer Science+Business Media, New York.

[38] Moity, N. 2018. Evaluation of No-Take Zones in the Galapagos Marine Reserve, Zoning Plan 2000. *Front. Mar. Sci.* 5:244. doi: 10.3389/fmars.2018.00244

[39] Buglass, S., H. Reyes, J. Ramírez-González, T.D. Eddy, P. Salinas-de-León and J.R. Marín Jarrín. 2018. Evaluating the effectiveness of coastal no-take zones of the Galapagos Marine Reserve for the red spiny lobster, *Panulirus penicillatus*. *Mar.Policy* 88, 204–212. doi: 10.1016/j.marpol.2017.11.028

[40] Salinas-de-León, P., J.R. Marín Jarrín, R. Bermúdez. 2016. Evaluación preliminar de las zonas de conservación y turismo (no pesca) en las poblaciones de bacalao *Mycteroperca olfax* en la Reserva Marina de Galápagos. RESUMEN EJECUTIVO PARA EL GRUPO DE APOYO TECNICO (GAT), Fundación Charles Darwin, Puerto Ayora, Galápagos, Ecuador.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

However, the still low price paid for tuna produce and the difficulties encountered at marketing the product, particularly in Isabela, substantially reduces the economic feasibility of this fishery, by using the FADs[41].

Due to the pressure of the fishing sector for the use of longline gear in the GMR, according to Cerutti-Pereyra et al., (submitted), 79% of the catch was albacore, 15% was escolars, and ~6% remaining was bycaught megafauna, including species protected by international agreements such as the hammerhead shark (*Sphyrna lewini*) and the giant manta ray (*Mobula birostris*).

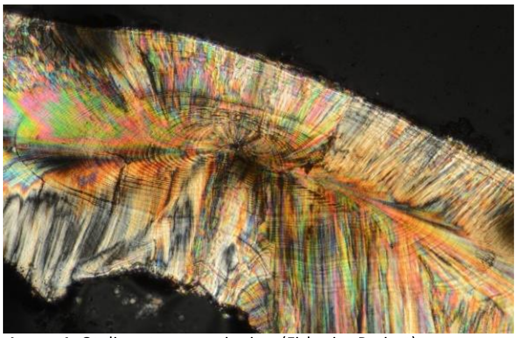

Image 1: Otolit – stereoscopic view (Fisheries Project) (S.Andrade/Archive CDF)

Decision makers require biological information of the most economically and ecologically important fish species in order to take decisions and make policy. In order to provide the authorities with this information, life history studies of key demersal fish species, such as the mottled scorpionfish (*Pontinus clemensi*), the Galapagos cod (endemic to the Eastern Tropical Pacific, ETP) (*Mycteroperca olfax*), and the camotillo (*Paralabrax albomaculatus*) (endemic to Galapagos) have been carried out by CDF staff. These species are characterized by having a slow growth and a late reproductive and maturity age. The mottled scorpionfish, for instance, takes between 12 to 14 years to reach sexual maturity, which occurs when it reaches 34-44 cm in length[42], whereas the camotillo gets mature and is ready to reproduce at 37 cm, which happens at the age of five years[43]. Moreover, wild populations of species like the Galapagos cod, which has been highly exploited since the 1940s with ca. 100% of the landings being represented by this specie, is facing stress. This situation obeys the traditional intensive usage of this fish for a religious-based gastronomic practice[44] which has caused that a decrease in the abundance and catch sizes of these species have been noted along the last decades. Additionally, this species is hermaphroditic. It is born as a female and reaches sexual maturity at age seven when has about 57cm. Afterwards, it reaches ~80cm, when it changes sex[45].

---

[41] Moina, E., R. Visaira, S. Andrade-Vera, H. Reyes and J.R. Marín Jarrín. 2018. Evaluación del uso de Dispositivos Agregadores de Peces para asegurar la sostenibilidad de las pesquerías en las Galápagos. Informe Técnico. Fundación Charles Darwin y Dirección Parque Nacional Galápagos, Puerto Ayora, Galápagos, Ecuador.

[42] Marín Jarrín J.R., S. Andrade-Vera, C. Reyes-Ojedis and P. Salinas-de-León. 2018. Life history of the mottled scorpionfish, *Pontinus clemensi*, in the Galapagos Marine Reserve. COPEIA 106, 3:515–523

[43] Salinas-de-Leon, P., A. Bertolotti, C. Chong-Montenegro, M. Gomes-Do-Rego, and R. Preziosi. 2017. Reproductive biology of the Endangered white-spotted sand bass *Paralabrax albomaculatus* endemic to the Galapagos Islands. Endangered Species Research 34:301–309.

[44] Usseglio, P., A. M. Friedlander, H. Koike, J. Zimmerhackel, A. Schuhbauer, T. Eddy, and P. Salinas-de-Leon. 2016. So long and thanks for all the fish: overexploitation of the regionally endemic Galapagos Grouper *Mycteroperca olfax* (Jenyns, 1840). PLoS ONE 11:e0165167.

[45] Usseglio, P., A. M. Friedlander, E. E. DeMartini, A. Schuhbauer, E. Schemmel, and P. Salinas de Leon. 2015. Improved estimates of age, growth and reproduction for the regionally endemic Galapagos sailfin grouper *Mycteroperca olfax* (Jenyns, 1840). PeerJ 3:e1270.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

This condition suggests that most of the individuals caught in the past were males. Finally, the most up-to-date analyses of landings suggest that 81% of the catch had not reproduced.

The knowledge about distribution of these and other species throughout their lives and their role in the trophic chain, are fundamental aspects for their conservation and governance. In that regard, some findings of this project shows that mangrove is a key ecosystem for the economically and non-economically important fish species, since it is the areas where these species are recruited. The mangrove ecosystems in Galapagos covers 35% of the coastline and it is estimated that during the last ten years they have experienced an increase of ~24% of their extension[46]. Additional to importance of mangroves as fish species breeding areas, the socio-ecological importance of mangroves relies on the environmental service they offer. For instance, it is estimated that 47% of the tourism sites in Galapagos are based in mangrove areas, generating more than $ 62 million dollars to the local economy. Furthermore, the mangrove extension in Galapagos (approximately 3700 hectares) was valued at $27,852, due to the CO_2 storage capacity of more than 778,000 tons. This constitutes a significant measure of adaptation and mitigation to climate change within the Galapagos context. However, the mangrove-dependent fishery is worth more than $ 900,000 per year, in net benefits for small-scale fishers, of which cod represents 69% of the value[47].

Image 2 (Photo: Nicolás Moity/ Archive CDF)

The mangroves in Galapagos are of extreme importance for the local fauna. As an illustration, other commercial fish species (e.g., snapper, mullet, and small pelagic fish such as sardines, anchovies, and herring) are used as bait or foraging fish and as food supply for larger predators (e.g., blue footed boobies, Galapagos penguins[48], and sea lions[49]) who use the mangrove zones, bordering sandy beaches, as their feeding and breeding grounds along their life cycle[50].

[46] Moity, N., B. Delgado, G. Banda-Cruz and P. Salinas-de-León (en revisión). Distribution and dynamics of mangrove forests in the Galapagos islands. PLOS ONE.

[47] Tanner, M.K., N. Moity, M.T. Costa, J.R. Marin Jarrina, O. Aburto-Oropeza, P. Salinas-de-León (2019) Mangroves in the Galapagos: Ecosystem services and their valuation. Ecological Economics, 160: 12–24.

[48] Anchundia, D., K. Huyvaert, and D. Anderson. 2014. Chronic lack of breeding by Galápagos Blue-footed Boobies and associated population decline. Avian Conservation and Ecology, 9(1): 6

[49] Páez-Rosas, D. and Aurioles-Gamboa, D. 2013. Spatial variation in the foraging behaviour of the Galapagos sea lions (*Zalophus wollebaeki*) assessed using scat collections and stable isotope analysis. Journal of the Marine Biological Association of the United Kingdom, 94(06), pp.1099-1107.

[50] Brito, C., S. Andrade-Vera, M. Schuiteman and J.R. Marín Jarrín. (en escritura). Distribución espacio-temporal de larvas de peces pelágicos nativos de Galápagos: *Anchoa sp.* y *Opisthonema sp.* Informe Técnico. Fundación Charles Darwin, Puerto Ayora, Galápagos, Ecuador.

Sea Mountains and other Depth Ecosystems in the Galapagos Marine Reserve

Due to the active volcanic history of the Galapagos archipelago, hundreds of seamounts rise between 100 and 1000 m from the seabed. These topographic structures are known to divert ocean currents and encourage physical, chemical, and biological interactions between the seafloor and upper waters. Therefore, seamounts often foster rich biodiversity and productive habitats such as cold-water reefs, and support numerous fisheries. However, given the technological challenges of deep-water study, very little is known about the life and physical environments of these deep ocean marine landscapes within the Galapagos Marine Reserve and the Tropical Eastern Pacific region.

Image 5: Sandy benthos at 336 m depth. Invertebrates present include offiuras (Ophiacanthidae) and epibenthic bivalves (pectinidae), an anemone (actiniaria), and a hedgehog (*Centrocidaris doederleini*) next to it (Photo: Archive CDF)

To close this great knowledge gap, in 2015, researchers of the Charles Darwin Foundation in collaboration with the Galapagos National Park Directorate developed a research project of Submarine Mountains (i.e., Seamounts) in the Galapagos Marine Reserve (GMR), with the main objective of characterizing the biodiversity and describing the ecology of these and other deep-sea ecosystems, such as lava flows.

This was possible thanks to the collaboration with Ocean Exploration Trust, Woods Hole Oceanographic Institute, and Pristine Seas National Geographic, which between 2015-2016 brought three oceanographic research vessels to explore deep-water habitats in the GMR. Using remotely operated vehicles (ROVs) and manned submersibles, we explored numerous seamounts and lava flows in depths between 100-3500 m. To raise the first baseline on biodiversity of these ecosystems, video transects were carried out and more than 300 benthic fauna specimens were collected. The vessels also carried out multi-band bathymetry surveys covering an area of 7065 km^2 to support the creation of high-resolution maps of the archipelago seabed.

These data allowed the following actions: to identify specimens of benthic depth species, based on morphological analysis by expert taxonomists; to develop an inventory of depth species based on the organisms documented in the transect videos; and to develop a semi-quantitative study of the ecology of the benthic communities of seamounts based on an analysis of the video transects. By using our preliminary results, we have already identified 93 species (Phyla: Annelida, Arthropoda, Cnidaria, Echinodermata, Mollusca and Porifera), of which 37 are possibly new species for science. Additionally, a pilot study was recently

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

initiated, using a low-cost commercial ROVs, to explore and describe the habitats of island seamounts, locally known as "*bajos*". These habitats ("bajos") are key fishing grounds for local artisanal fishers, and they harbor mesophotic reefs and possibly kelp forests, which are also a barely known ecosystem in the Tropical Eastern Pacific region. The mapping of this first baseline will also be conducted by video transects.

These studies will provide the first biological inventories of the different seamounts and other depth ecosystems for Galapagos, which are still unknown today. Publicizing the biodiversity and distribution of the deep-sea fauna that these unknown ecosystems foster is essential to guide the decision-making processes for the management of marine resources within the GMR. It is essential, for example, to establish zoning that protects key biodiversity sites, or to design adequate zoning in case that submarine telecommunications cables are installed. In addition, this information is critical as it not only increases the evidence of the archipelago as a reservoir of biodiversity and endemism, but also highlights the role seamounts play as a refuge for fishing species of high commercial value that currently exhibit overexploitation characteristics.

Image 6: Benthos of volcanic rock at 1227 m depth. Present invertebrates include zoanthids of yellow polyps (*Bullagummizoanthus sp*.), Epibiotic ophiurids (Euryalidae), and white corals (Stylasteridae). (Photo: Archive CDF)

In the context of the future impacts of climate change in the marine systems, where high-impact sea level and temperature rise scenarios are increasingly accurate, seamounts could tentatively play a critical role in preserving species that are adversely affected by these anthropogenic impacts. Being deeper and with colder waters, seamounts could play a critical role as refuge for species that are already threatened. It is of utmost importance to expand and continue research regarding seamounts and, in particular, their role in management policies of the GMR—whether they are zoning policies, fisheries policies, or adaptability to climate change context policies.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Study of the status of the populations of Galapagos penguin, flightless cormorant, and Galapagos albatross

The Galapagos penguin, the flightless cormorant, and the Galapagos albatross are marine bird species, endemic to Ecuador. All three species appear on the IUCN Red List of Endangered Species. The penguin is listed as Endangered (EN), the cormorant is listed as Vulnerable (VU), and the albatross is listed as Critically Endangered (CR). Except for the albatross, the other two species are listed as mentioned because due to two main aspects: the limited geographic distribution range, and the low population number they show. In addition, due to the presence of the El Niño phenomenon, these marine bird populations show a steady decrease which substantially affects their reproductive rate. Additionally, introduced species such as cats and rats feed on chicks and eggs of penguins and cormorants, which make ever less likely their survivorship.

Image 7: Sea Birds Project. Photo: Sam Rowley

In the case of albatrosses, the anthropogenic interaction is mainly represented by fishing bycatch incidence (either large- or small-scale) in Ecuadorian mainland waters. In the penguins' case, this mostly occurs with small-scale fisheries. More instances of anthropogenic impacts include collision events with rapidly moving "pangas" (i.e., small vessels), human disturbance in nests, and fuel-spill-related pollution. Other threats are pathogen-agents and other contaminants that heavily affect marine bird populations. Finally, we could also mention the tsunamis and volcanic eruptions, as natural events that occurred during the last decade, whose impact is still unknown for the marine bird conservation.

The central question of the project is: how is the population status trend of the Galapagos penguin, the flightless cormorant, and the Galapagos albatross in the face of threats such as climate change, introduced species, human interaction, the impact of pathogens, and non-infectious diseases?

- 37 monitoring sessions were carried out from 2010 to 2018 in conjunction with the GNPD. In addition, there was collaboration with the University of Missouri, Colorado State University, Universidad Central del Ecuador, Universidad San Francisco de Quito, Universidad del Azuay, Agence Nationale de Securite Sanitaire de France, Remote Imaging, and the National Geographic Society.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

- A first study was carried out to detect heavy metals in penguins and other seabirds, where the presence of lead and cadmium in Galapagos penguins is found and the question arises of how these pollutants reach the islands[51].

- A publication on penguins' bycatch in the world was made, showing that fishing with drift nets (planted) that enter the Galapagos Marine Reserve is the main problem of incidental fishing affecting the Galapagos penguin[52] .

- Two scientific articles on "endoparasites in the three marine birds" were published, being the first publications on this topic to explain which species of parasites live in these birds[53,54]

- A publication on the presence of a species of *Plasmodium* (i.e, bird malaria causign blood parasite) in penguins was made. The biggest result found is that this parasite did not turn out to be virulent, unlike the one that caused the extinction of several bird species in Hawaii[55].

- Two publications on the longevity records of albatrosses and cormorants were made. Real data that help to understand the ecology of the species[56, 57].

- Advice was provided to the Ecuadorian Ministry of Environment and the GNPD. They were informed on the monitoring and results of albatrosses. The information was used in the ACAP (Agreement for the Conservation of Albatrosses and Petrels) meetings, where the Government of Ecuador is a member and a part. GJU is a member of the ACAP research working group.

---

[51] **Jiménez-Uzcátegui, G.**, Vinueza, R.L., Urbina, A.S., Egas, D.A., Garcia, C., Cotin, J. & C. Sevilla. **2017**. Lead and cadmium levels in Galapagos penguin, *Spheniscus mendiculus*, Flightless Cormorant *Phalacrocorax harrisi* and Waved Albatross *Phoebastria irrorata*. *Marine Ornithology* 45: 159-163.
[52] Crawford, R., Ellenberg, U., Frere, E., Hagen, C., Baird, K., Brewin, P., Crofts, S., Glass, J., Mattern, T., Pompert, J., Ross, K., Kemper, J., Ludynia, K., Sherley, R., Steinfurth, A., Suazo, C., Yorio, P., Tamini, L., Mangel, J., Bugoni, L., **Jiménez-Uzcátegui, G.**, Simeone, A., Luna-Jorquera, G., Gandini, P., Woehler, E., Pütz, K., Dann, P., Chiaradia, A. & C. Small. **2017**. Tangled and drowned: A global review of penguin bycatch in fisheries. Endangered Species Research. 34: 373-396.
[53] Carrera-Játiva, P., Rodríguez-Hidalgo, R., Sevilla, C., & **G. Jiménez-Uzcátegui**. **2014**. Gastrointestinal parasites in the Galápagos Penguin *Spheniscus mendiculus* and the Flightless Cormorant *Phalacrocorax harrisi* in the Galápagos Islands. *Marine Ornithology* 42: 77-80.
[54] **Jiménez-Uzcátegui, G.,** Sarzosa, S.M., Encalada, E., Rodríguez-Hidalgo, R., Celi-Erazo, M., Sevilla, C. & K.P. Huyvaert. **2015**. Gastrointestinal Parasites in the Waved Albatross (*Phoebastria irrorata*) of Galápagos. *Journal of Wildlife Diseases* 51 (3): 784-786.
[55] Levin, I.I, Zwiers, P., Deem, S., Geest, E., Higashiguchi, J.M., Iezhova, T.A., Jiménez-Uzcátegui, G., Kim, G., Morton, J., Perlut, N., Renfrew, R., Sari, E.H.R., Valkiunas, G. & P.A. Parker. 2013. Multiple lineages of avian malaria parasites (Plasmodium) in the Galápagos Islands and evidence for arrival via migratory birds. Conservation Biology 27 (6): 1366-1377.
[56] **Jiménez-Uzcátegui, G.,** Harris, M.P., Sevilla, C. & K.P. Huyvaert. **2016**. Longevity records for the waved Albatross Phoebastria irrorata. *Marine Ornithology*: 40: 133-134.
[57] **Jiménez-Uzcátegui, G**., Valle, C.A. & F.H. Vargas. **2012**. Longevity records of Flightless Cormorant *Phalacrocorax harrisi*. *Marine Ornithology* 40: 127-128.

- For each monitoring, control of introduced species, cats and rats was carried out in the nesting areas. As a result, it was observed that the population of seabirds has increased and there are new nests with chicks, as was the case in Punta Moreno (Puerto Pajas), Marielas, and El Muñeco. In addition, it was shown that cats and rats were affected by the control performed.

Image 8: Sea Birds Project. Photo: Sam Rowley

- Two undergraduate theses have been made, and another thesis is in in the making. 32 people from the CDF and 24 people from the GNPD have been involved working as assistants and volunteers. In addition, several lectures have been given at congresses, symposia, training for guides and the general public. The project has had a high impact, which is why it has been part of written and audiovisual documentaries.

Study of the status of the Galapagos flamingo and the lagoon bird population

The Galapagos flamingo is a subspecies of lagoon bird endemic to Ecuador. It is listed on the Red List of Endangered Species of Ecuador as Endangered (EN), since its geographic range is limited, and its population number is small. In addition, the El Niño phenomenon affects its reproductive rate due to two important factors: the affectation of its nesting areas and the change of its habitat, as a result of modifying the structure of the lagoons where it lives[58]. Introduced species (pigs, cats and rats) feed on their chicks and eggs, while horses and cattle affect their nesting areas. Additionally, there are other anthropogenic impacts that disturb flamingo nests. Finally, flamingos are affected by pathogens and pollutants that easily attack flamingo populations, and by natural threats (such as tsunamis and volcanic eruptions that occurred in the last decade) that are believed to have affected the species, although their real impact is unknown.

Image 9: Galapagos Flamingo Project. Photo: Sam Rowley

Due to the imminent decrease in the number of individuals of the local populations of flamingos in Galapagos[59], in 2018, the CDF took charge of developing this initiative, under a bi-institutional collaboration with the GNPD. Part of this activity is supported by the control and eradication of introduced species, which is known to be affecting the reproductive success of this species. This also includes the analysis of the presence of heavy metals or other contaminants in these individuals. Unfortunately, these joint efforts depend on the funds

[58] Vargas, F.H, Barlow, S., Hart, T., **Jiménez-Uzcátegui, G.,** Chávez, J., Naranjo, S. & D.W. Macdonald. 2008. Effects of climate on the abundant and distribution of flamingos in the Galápagos Islands. Journal of Zoology 276: 252-265. IF: 1.669

[59] **Jiménez-Uzcátegui, G.,** & S. Naranjo. 2010. Population index of Flamingo *Phoenicopterus ruber* (Aves: Phoenicopteridae) in Galápagos 2009. Brenesia 73-74: 154-156.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

available for their execution, which in most cases are insufficient to cover the costs associated with this research.

Therefore, it is of interest for this research to document the current state of this population in order to determine the threats and their effects, and to suggest possible management actions.

Here is the central question of the project: What is the population status of Galapagos flamingos in the face of threats such as climate change, introduced species, human interaction, impact of pathogens and non-infectious diseases?

- Monitoring was carried out in 2018 in conjunction with the GNPD.
- The samples are being analyzed in the laboratories of Universidad San Francisco de Quito (USFQ).

Image 10: Laboratory. Galapagos Flamingo Project. Photo: CDF Archive

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

The sharks of Galapagos

Background information

Chondrichthyans (i.e., sharks and rays) represent one of the most threatened groups of terrestrial vertebrates on the planet, with estimates of a reduction of 90% in their original abundance and an annual catch of 100 million individuals per year[60],[61],[62]. Few places on the planet still foster healthy populations of sharks, and the Galapagos Marine Reserve (GMR) constitutes one of those last refuges.

Current status

Our research[63] has revealed that the Darwin and Wolf Islands in the north of the archipelago harbor the largest biomass of sharks on the planet, with an average of 17.5 tons per hectare. However, evidence found in longline pilot projects, shows that sharks bycatch within fishing activities in the GMR represent a serious threat, together with the overfishing by domestic and foreign fleets, outside the GMR. In 2016, the declaration of the Marine Sanctuary in Darwin and Wolf, constituted an relevant step in the conservation efforts for these unique marine ecosystems and species, in the long run. Its implantation is still pending, though.

Image 11: Sharks in the Galapagos Marine Reserve
Photo: Thomas Peschak / National Geographic.

In 2018, we presented the first baseline study to assess the abundance and diversity of sharks along the GMR. For that purpose, the use of remote cameras with bait (BRUVs)[64] was an important part of the methodology. This inventory has helped to understand the GMR effectiveness, in the long run, as a management instrument helping to conserve the shark populations. Additionally, this research has been developed to evaluate the impact of the El Niño/La Niña cycles and the climate change effects, in some shark populations, activities that currently are being developed together with the estimation of the effects of the new marine sanctuary (when implemented) in some shark populations.

---

[60] Myers RA, Worm B (2003) Rapid worldwide depletion of predatory fish communities. Nature 423:280–283.
[61] Worm B, Davis B, Kettemer L, Ward-Paige CA, Chapman D, Heithaus MR, Kessel ST, Gruber SH (2013) Global catches, exploitation rates, and rebuilding options for sharks. Mar Policy 40:194–204
[62] Dulvy NK, Fowler SL, Musick JA, Cavanagh RD, Kyne PM, Harrison LR, Carlson JK, Davidson LN, Fordham SV, Francis MP, others (2014) Extinction risk and conservation of the world's sharks and rays. Elife 3:e00590
[63] Salinas de León P, Acuña-Marrero D, Rastoin E, Friedlander AM, Donovan MK, Sala E (2016) Largest global shark biomass found in the northern Galápagos Islands of Darwin and Wolf. PeerJ 4:e1911
[64] Acuña-Marrero D, Smith A, Salinas-de-León P, Harvey E, Pawley M, Anderson M (2018) Spatial patterns of distribution and relative abundance of coastal shark species in the Galapagos Marine Reserve. Mar Ecol Prog Ser 593:73–95

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Large marine reserves such as the Galapagos protected area could greatly contribute in protecting highly mobile species such as tiger sharks. In 2017, a study was published[65] showing that the usage of satellite and acoustic transmitters in tiger sharks, could demonstrate their high site fidelity to the GMR, where they probably enjoy a recurring food source such as green sea turtles. Current studies are intended to understand the diet of tiger sharks and their long-term residence in the GMR.

Image 12: Sharks Project. Photo: Daniela Vilema/CDF.

However, marine reserves are only one among other management actions, under a more comprehensive governance approach. Some other examples such as biological corridors or temporal closures, are key for the protection of other highly migratory shark species such as hammerhead sharks. This species breed in the oceanic islands of the Tropical Eastern Pacific, but the great majority of its offspring are born in mangrove zones located on the coasts that stretch from Ecuador to Costa Rica[66]. Current studies are focused understanding the reproductive migration patterns of pregnant female hammerhead shark and on identifying breeding areas for this species, along the Ecuadorian continental coast.

Image 13: Sharks Project. Photo: Daniela Vilema/CDF.

The use of non-selective fishing gear such as the longline method, which has a high rate of shark and other species threatened with extinction bycatch and mortality, should be completely prohibited in the GMR. CDF staff, in collaboration with technicians from the

---

[65] Acuña-Marrero D, Smith AN, Hammerschlag N, Hearn A, Anderson MJ, Calich H, Pawley MD, Fischer C, Salinas-de-León P (2017) Residency and movement patterns of an apex predatory shark (*Galeocerdo cuvier*) at the Galapagos Marine Reserve. PloS One 12:e0183669

[66] Salinas-de-León P, Hoyos-Padilla EM, Pochet F (2017) First observation on the mating behaviour of the endangered scalloped hammerhead shark *Sphyrna lewini* in the Eastern Tropical Pacific. Environ Biol Fishes 100:1603–1608.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Galapagos National Park Directorate, collaborated to provide comments and recommendations on the results encountered of a pilot project of the longline effects within the GMR, during 2012-2013. The CDF position states that the study showed varied inconsistencies and that the longline cannot be used within a protected area, where enough evidence exist that proves that it causes the bycatch of hundreds of endangered marine species, within the protected area.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Reducing threats to sea turtles in Galapagos

The Galapagos Islands are a key site for several migratory species of the Tropical Eastern Pacific and are also significantly important for the conservation of the green turtle (*Chelonia mydas*), since the second most important nesting colony in the region is located here. In addition, they provide numerous feeding sites for the species, throughout the archipelago[67], [68]. Internationally, the impact of boats has been recognized as a threat to a wide variety of marine fauna, including cetaceans, sharks, manta rays, and especially sea turtles [69], [70], [71], [72], [73]. Galapagos have already registered cases of turtles affected by this threat in both nesting and feeding sites[56, 74].

For this reason, and taking into account early actions, the Charles Darwin Foundation (CDF), in partnership with Queen's University Belfast (QUB), has developed research to support the efforts of the Galapagos National Park Directorate (GNPD) to reduce the number of turtles affected by collision with vessels, and thus ensure a high level of protection for the species in the archipelago.

Image 14: Sea Turtles Project. Photo: Archive CDF

During 2018, the CDF and QUB, along with the support of the GNPD, initiated a study on the behavior of green turtles in the water, during the breeding season, to identify the activities they perform between one nesting and the next. The objectives were to evaluate which behaviors make sea turtles more vulnerable to boat collision and to identify areas of greater probability of interaction. Some behaviors taken into account were resting, swimming, or mating on the surface. In the same way, the study seeks to understand the reaction mechanisms of turtles when boats approach. These data will be key to design conservation strategies that avoid a negative impact of maritime transit, on the species within the Galapagos Marine Reserve.

---

[67] National Marine Fisheries Service & US Fish and Wildlife Service. 1998. Recovery Plan for US Pacific Populations of the East Pacific Green Turtle (*Chelonia mydas*). National Marine Fisheries Service, Silver Spring, MD.

[68] Seminoff, J. 2004. 2004 Global Status Assessment: green turtle (*Chelonia mydas*). Marine Turtle Specialist Group review, 71 pp

[69] Chalopuka M, Work TM, Balazs GH, Murakawa SK and R Morris 2008. Cause-specific temporal and Spatial trends in green sea turtle strandings in the Hawaiian Archipelago (1982–2003). Mar Biol, 154: 887–898.

[70] Hazel, J., Gyuris, E., 2006. Vessel-related mortality of sea turtles in Queensland, Australia. Wildl. Res. 33, 149–154.

[71] Hazel, J., Lawler, I.R., Marsh, H., Robson, S., 2007. Vessel speed increases collision risk for the green turtle *Chelonia mydas*. Endang. Species Res. 3, 105–113.

[72] Zárate, P. 2009. Amenazas para las tortugas marinas que habitan el archipiélago de Galápagos. Presentado al Parque Nacional Galápagos. Ecuador, 50 pp.

[73] Denkinger, J., M. Parra, J.p., C., Carrasco, E., Espinosa, F., Rubianes, and V., Koch. 2013. "Are Boat Strikes a Threat to Sea Turtles in the Galapagos Marine Reserve ?". Ocean & Coastal Management. 80:29-35.

[74] Parra D.M., Andrés M., Jiménez J. Banks S. Muñoz JP. 2013. Evaluación de la incidencia de impacto de embarcaciones y distribución de la tortuga verde (*Chelonia mydas*) en Galápagos. Documento Técnico. Fundación Charles Darwin. Puerto Ayora, Galápagos, Ecuador

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Image 15: Satellite tracking. Sea Turtles Project. Photo: Archive CDF

At the same time, we have been working with the authorities and the local community to take into consideration the socio-economic implications, to evaluate any proposed management measures, and to get users to become involved in project activities in order to generate a comprehensive plan that supports the conservation efforts of the GNPD, without diminishing the aspirations for economic growth of the local community.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Subtidal Long-term Ecological Monitoring

The rocky subtidal habitats of the Galapagos Marine Reserve (GMR) are full of emblematic fauna such as sharks, manta rays, seaturtles, corals, etc. The Ecological Monitoring Program was developed to provide to the Galapagos National Park Directorate (GNPD) with a complete description of this community and to provide information on the dynamics and magnitude of the fluctuations of this biota through space and time, as it incorporates natural and anthropogenic effects such as climate change[75]. The long-term monitoring of the marine ecosystem gives us the opportunity to observe and react to new changes in ecosystems such as changes in ecological phases, depletion of fish populations, invasion of non-native species, decrease of species with tourism interest, and possible, the threats posed by El Niño events and by climate change. This monitoring also provides us with a valuable tool to implement management measures[76].

The Ecological Monitoring program was created with the purpose of obtaining ecological quantitative information on rocky subtidal communities of sessile organisms, mobile macroinvertebrates, and fish. The objective of this monitoring was to obtain an ecological evaluation of the status, composition and abundance of these communities in order to establish a baseline and verify the existence of biogeographic regions and their representation in the zoning.

Over the past decade, the Charles Darwin Foundation (CDF) has achieved important results that have fueled a variety of initiatives and helped to raise awareness, to advise on changes in coastal zoning, and to help justify policies for emerging problems such as climate vulnerability, overfishing, and the risk of marine invasions. Long-term monitoring has allowed us to see the recovery of lobsters since the creation of Darwin and Wolf's marine sanctuary, but we will surely see the decline of this species and others of commercial interest if the zoning plan is not implemented neither respected and if vulnerable zones remain opened.

The long-term ecological monitoring also allowed to report the documented extinction of habitat-forming species, such as the brown intertidal *Bifurcia galapagensis* algae, the solitary corals, *Azurina eupalama* and the starfish *Heliaster solaris* that occurred during strong periods of El Niño[75]. These conditions, with that same intensity, have not been repeated, but when compared to the circumstances of the 80s and 90s, the scope of today has changed with more maritime traffic, much larger external dependence for food safety, and the threat of marine invasive species. It is necessary to take into account the changes that have happened over the past 20 years and look for ways to encourage the needs of the marine protected area (MPA)

---

[75] Banks, S., Acuña, D., Brandt, M., Calderón, R., Delgado, J., Edgar, G., Garske-García, L., Keith, I., Kuhn, A., Pépolas, R., Ruiz, D., Suárez, J., Tirado-Sánchez, N., Vera, M., Vinueza, L. y Wakefield E. (2016). Manual de monitoreo submareal. Conservación Internacional Ecuador y Fundación Charles Darwin. Quito, Ecuador.
[76] Glynn, P. W, Feingold, J. S, Baker, A, Banks, S, Iliana B. Baums, I. B, Cole, J, Colgan, M. W, Fong, P, Glynn, P. J, Keith, I, Manzello, D, Riegl, B, Ruttenberg, B. I, Smith, T. B, Vera-Zambrano, M. (2018). State of corals and coral reefs of the Galapagos Islands (Ecuador): Past, present and future. Marine Pollution Bulletin, 133, 717-733

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

to protect marine biodiversity. We cannot allow new extinctions or losses of important communities for the biodiversity of this MPA to happen.

The Subtidal Ecological Monitoring project has contributed to several processes of understanding, awareness and management of the GMR. Below, a list of several projects that have used the methodology of ecological monitoring to answer several questions from the 1970s to now[63], [77].

- Pioneering studies, which were key in the GMR declaration made to UNESCO.
- Observations on the ENSO events of 1982/83 and 1997/98
- First subtidal censuses for inputs to the zoning process and GMR declaration
- Development of the inventory and collections of the GMR marine species (datazone)
- GMR Biodiversity Baseline
- Evaluation of impacts caused by the spill of cargo vessel M/N Jessica
- Characterization of little-used sites as alternatives for the use of recreational diving
- Work performed by the Participatory Management Board Zoning Commission; coastal physical cartography and signage.
- Trophic modeling studies with coastal use scenarios
- Annual monitoring of 64+ diagnostic sites according to the agreement of the GMR Participatory Management Board
- Pilot monitoring of soft bottoms (Zero-Anchors Project)
- Oceanographic seasonal characterization; use of GMR oceanographic satellite information
- Comparative study between 6 Marine Protected Areas of the Eastern Tropical Pacific
- Habitat-makers and particularly-sensitive species added to the IUCN Red List
- Study of vulnerability to climate change

[77] Danulat E & GJ Edgar (eds.) 2002. Reserva Marina de Galápagos. Línea Base de la Biodiversidad. Fundación Charles Darwin/Servicio Parque Nacional Galápagos, Santa Cruz, Galápagos, Ecuador. 484 pp.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

- Modeling ocean circulation in the region and in Galapagos
- Baseline and detection of Marine Invasive Species
- Characterization of GMR deep habitats and rediscovery of *Eisenia galapagensis*
- Upwelling System, open waters
- The new Galapagos Protected Areas Zoning System of 2016 completely changes the concept of zoning and takes into account four zones: intangible, conservation, transition and sustainable-use zones.

In a multi-use reserve like the GMR, long-term marine monitoring has worked for decades as a valuable tool to assess how communities naturally develop. Likewise, management measures are effective to mitigate any undesirable negative impact between years. It is important to highlight that this tool allows us to see new developments that include changes in diversity, failure or recovery of fishing populations and emblematic species for tourism, bioinvasions, and potential threats to the future of the GMR due to climate change[64].

Imagen 16: Monitoring of pelagic species on Darwin Island. © Photo: Macarena Parra /CDF

Imagen 17: Subtidal Ecological Monitoring. 50 m transect and quadrant of sessile organisms. © Photo: Sofía Green/CDF

Marine invasive species in the GMR: prevention, detection, and management

This document provides an analysis and assessment of the current status of non-native marine species in the Galapagos Marine Reserve (GMR). Although they are less visible than the specimens in the terrestrial environment, the marine invasive species represent a threat to the ecosystem that needs to be evaluated urgently. The marine ecosystems of Galapagos harbor unique biological communities due to the confluence of currents and their connectivity with the Tropical Eastern Pacific (TEP). Besides, the marine ecosystems have a high incidence of endemic species. Galapagos was declared a World Heritage Site by UNESCO and was recognized for its high biodiversity and extraordinary oceanographic features that provide a variety of habitats in a unique environment. The investment made by Ecuador in the protection and sustainable development of Galapagos has been significant. However, due to the exponential growth of tourism, maritime traffic, and urban development, the sustainability of the archipelago and its ecosystems are at risk. The possible invasion of marine species into the (GMR) due to climate changes, connectivity, and the increased maritime traffic constitutes today an unknown risk for local biodiversity and a management challenge for the Ecuadorian authorities.

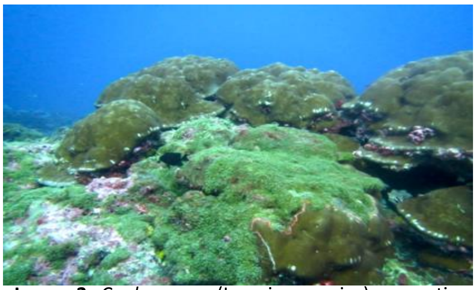

Image 3: *Caulerpa sp.* (Invasive species) competing with coral on Darwin Island. © 2018 Photo: Inti Keith/CDF

The introduction of invasive species has been identified as the second most important cause of the loss of biodiversity worldwide (International Union for Conservation of Nature, IUCN), and on oceanic islands it is recognized as the first cause, due to the damage that these species cause to biological productivity, habitat structure and species composition.

In recent years, the interest for the presence and research on invasive species in tropical marine ecosystems, including rocky coasts, coral reefs, and mangroves, has increased due to the environmental and economic impacts that these species have caused worldwide[78]. The number of marine invasions and their impact are accelerating around the world. Most regions lack the rigorous data needed to understand the status and trends of invasions, their change over time, and the effectiveness of management strategies to prevent further invasions and their associated impacts.

The risk posed by non-native marine species in the GMR and in the region should not be underestimated. By the same token, the amount of crucial research and funds needed to

[78] Glynn, P. W, Feingold, J. S, Baker, A, Banks, S, Iliana B. Baums, I. B, Cole, J, Colgan, M. W, Fong, P, Glynn, P. J, Keith, I, Manzello, D, Riegl, B, Ruttenberg, B. I, Smith, T. B, Vera-Zambrano, M. (2018). State of corals and coral reefs of the Galapagos Islands (Ecuador): Past, present and future. Marine Pollution Bulletin, 133, 717-733

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

mitigate this risk should be given proper consideration. The CDF has led the Marine Invasive Species Project since 2012, in collaboration with the Galapagos National Park Directorate (GNPD), the Galapagos Biosecurity and Quarantine Regulation and Control Agency (ABG), the Ecuadorian Navy, and the Ecuadorian Navy Oceanographic Institute (INOCAR). Since the beginning of this project several successful experiences have been achieved such as the following: the first baseline of non-native marine species in the GMR, the distribution of non-native species established in the GMR, genetic analyses, dispersion models, profiles of risk assessment, standardized monitoring protocols, training workshops, and information dissemination programs[79].

During the international workshop on marine bioinvasions in tropical island ecosystems organized by the CDF in Santa Cruz, Galapagos in February 2015, people worked on the first Action Plan and stressed the urgent need for prevention, monitoring and, when necessary, remediation to minimize any negative impacts that invasive species may cause on marine biodiversity, ecosystem services and the resilience of the GMR[80]. In 2018, a memorandum of understanding was signed with the Smithsonian Environment Research Center (SERC) to create the CDF-SERC Marine Invasive Species Program and to expand research throughout the Pacific. The program research analyzes the invasion of species, the loss of habitat, climate change, fishing, water quality, and marine litter.

The CDF-SERC Marine Invasive Species Program reported in a recent paper that the number of marine invasive species on the Galapagos Islands is ten times as much as the number believed to be present. A minimum of 52 marine bioinvasions are now documented in the archipelago, compared to 5 previously recognized invasions. At the same time, the critical drivers of today's biological invasions are ready to increase the number of invasive species in the warmer waters of the Tropical Pacific Ocean, including the Galapagos Islands.

Image 4: *Ascidia sydneiensis* (invasive species) growing on a settlement plate in Puerto Ayora © 2016 Photo: Inti Keith.

These drivers include the rapid growth of the global maritime trade network, the expansion of the 2015 Panama Canal (which could lead, for example, to the invasion of lionfish from the Pacific), climate change that alters the susceptibility to regional invasion, and the generalized

[79] McCann, L., Keith, I., Carlton, J. T., Ruiz, G. M., Dawson, T. P. & Collins K. J. (2015). First record of the non-native bryozoan Amathia (=Zoobotryon) verticillata (delle Chiaje, 1822) (Ctenostomata) in the Galapagos Islands. BioInvasion Records, 4(4), 255-260.

[80] Keith, I. & Toral, V. (2015). Action plan to minimize risks of marine invasive species introduction into the Galapagos Marine Reserve. Technical Report No. 1 2015. Charles Darwin Foundation, Santa Cruz, Galapagos, Ecuador. ISSN 1390-6526.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

and logarithmically increasing amount of marine plastic waste that acts as a vector that imports non-native species.

The challenges that must be addressed as a priority include getting more knowledge about high risk vectors such as biofouling on ship hulls, ballast water, and marine debris. It is very important to research on the scenarios leading to potential future invasions due to climate change, changes in cargo ship routes, and maritime traffic increase (commercial or recreational)[81]. Additionally, the management strategies required to face these scenarios must be studied. Addressing this knowledge gap is an urgent and integral need for the sustainability of the GMR's ecosystems. The CDF is committed to continuing its work in the monitoring, prevention, early detection of and rapid response strategies for marine invasive species. Finally, the CDF is also devoted to sharing its experience and success in order to protect the marine biodiversity of the region.

[81] Campbell, M. L., Keith, I., Hewitt, C. L., Dawson, T. P., & Collins, K. (2015). Evolving Marine Biosecurity in the Galapagos Islands. *Management of Biological Invasions,* 6(3), 227-230.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

The Terrestrial Dimension

Scalesia pedunculata. Photo: Heinke Jäger/CDF.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Pilot research for the reduction of bird mortality on the roads of Santa Cruz Island

Roads are indispensable for socio-economic development. However, they have negative effects such as habitat fragmentation, population decline, pollution, run-over accidents, etc. But it should be taken into account that roads provide resources to birds such as food, water and rest. The highway in Santa Cruz extends from south to north (Puerto Ayora-Itabaca Canal) and came into operation in 1974. The number of motorcars on the island increased from 28 in the eighties to more than 1100 today.

Studies on the impact of motor vehicles on avifauna were made in 1980, 2001, 2003 and 2004-2006[82].

Table 1. Individuals per species affected by car collision (1980-2206).

Common name	Scientific name	1980	2000	2001	2003	2004	2005	2006
Yellow Garbler	*Dendroica petechia aureola*	x	x	x	x	x	x	x
Dark-billed cuckoo	*Coccyzus melacoryphus*		x	x	x	x	x	x
Mockingbird	*Mimus parvulus*	x		x	x	x	x	x
Paint-billed crake	*Neocrex erythrops*			x	x	x	x	x
Smooth-billed ani	*Crotophaga ani*		x	x	x	x	x	x
Cattle egret	*Bubulcus Ibis*		x	x				x
Yellow-crowned night-heron	*Nyctanassa violacea pauper*		x	x	x		x	
Barn owl	*Tyto alba punctatissima*		x		x	x	x	
Short-eared owl	*Asio flammeus galapagoensis*		x	x	x			x
Vermilion flycatcher	*Pyrocephalus rubinus*			x				
Galapagos dove	*Zenaida galapagoensis*		x	x			x	x
Galapagos flycatcher	*Mylarchus magnirostrls*	x	x	x	x	x	x	x
Woodpecker finch	*Camarhynchus pallida*			x			x	x
Green warbler-finch	*Certhidea olivacea*			x				
Small tree finch	*Camarhynchus parvulus*		x	x	x	x	x	x
Cactus finch	*Geospiza scandens*			x	x			
Large ground finch	*Geospiza magnirostrosis*	x	x	x	x	x		x
Medium ground finch	*Geospiza fortis*	x	x	x	x	x	x	x
Small ground finch	*Geospiza fullginosa*	x	x	x	x	x	x	x
Vegetarian finch	*Platyspiza crassirostris*	x	x		x			
Unidentified finch *					x	x	x	x
Total of affected individuals		**7**	**14**	**18**	**15**	**11**	**13**	**14**

[82] **Jiménez-Uzcátegui, G.**, & F. Betancourt. 2008. Avifauna vs automotores. En: Informe Galápagos 2007-2008. FCD, PNG & INGALA. Puerto Ayora, Ecuador. pp 111–114.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

* The Unidentified Finch is not considered a species. ** Introduced species
Source: Carvajal, 1980; Márquez, 2000; Llerena *et al.,* 2001; Betancourt *et al.* 2004; Jimenez-Uzcategui & Betancourt, 2005, 2006, 2007.

After twelve years, this study is being replicated according to the methodology of 2006 to know the impact of motor vehicles on avifauna, especially when the dynamics of road use have changed, and to issue pertinent recommendations and their possible implementation by the management unit. This is a bi-institutional Project between CDF and GNPD.
The central question of the project is: What is the impact of motor vehicles on the avifauna on the Puerto Ayora - Itabaca route?

Current Status

- Eight monitoring sessions have been conducted in 2018 on a monthly basis in conjunction with the GNPD, with the following results:

Table 2. Results of the Monitoring Project of Bird Mortality by Car Collision (2018)

	Travel dates (Cleaning / Monitoring)	Cleaning day (# of affected individuals)	Monitoring day (# of affected individuals)	Number of vehicles Monitoring day (from 3:00 p.m. until 5:30 p.m.)
January	January 15 and 19, 2018	32	19	207
February	February 21 and 22 2018	20	11	197
March	March 19 and 20 2018	14	24	179
April	April 23 and 24 2018	59	41	168
May	May 16 and 17 2018	110	95	168
June	June 21 and 22 2018	119	63	285
July	-----	-----	-----	-----
August	August 15 and 16 2018	10	17	143
September	September 25 and 26 2018	29	8	145
October	October 17 and 18 2018	9	11	163
Total number of individuals affected by car-collision events and total number of cars circulating between Puerto Ayora-Itabaca-Puerto Ayora, during the monitoring period		**402**	**289**	**1655**

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Fundación
Charles Darwin
Foundation
GALAPAGOS

Image 18: Dead birds on the road/Photo: CDF Archive.

Two talks were given on the subject in a congress and a local school.

- Unidad Educativa Tomas de Berlanga, a school involved in the subject, was given instruction on the study.

It is vitally important to reinforce the public policy implemented several years ago by enforcing speed regulations on the Puerto Ayora - Itabaca Canal highway. Respect for avian wildlife on the part of drivers has been lost and there is no evidence that the authorities sanction offenders to enforce regulations previously implemented. The populations of land birds are in serious decline due to several factors, including the irresponsibility of those behind the wheel.

Image 19: Dead birds on the road/CDF Archive.

Invasive terrestrial species and restoration of threatened ecosystems

There are currently 1,469 introduced terrestrial species that have been established in Galapagos[83]. Many of these are not problematic, such as agricultural and ornamental plants. However, some have become invasive and negatively affect the flora and fauna of Galapagos. The best-known examples are the blackberry plant (*Rubus niveus*)[84,85], the quinine tree (*Cinchona pubescens*)[86,87,88,89], and the tropical fire ant (*Solenopsis geminata*)[90], among others.

Along with the Galapagos National Park Directorate (GNPD), we are studying the impacts of these species, and we are working to improve the control actions currently carried out to reduce their abundance. In addition, we are working on reducing the impacts caused by control actions on threatened ecosystems.

Our work on invasive terrestrial species and restoration of threatened ecosystems is divided into four projects:

1. Control of the blackberry plant (*Rubus niveus*) and restoration of the Scalesia forest in Los Gemelos
2. Impacts and control of the quinine (*Cinchona pubescens*)
3. Mapping of invasive plants
4. Distribution and impacts of the introduced frog (*Scinax quinquefasciatus*)

A habitat that has declined drastically is the *Scalesia* forest in Santa Cruz, dominated by the daisy tree *Scalesia pedunculata*[91]. Due to agricultural activities and invasive plant and animal

---

[83] Toral-Granda MV, Causton CE, Jäger H, Trueman M, Izurieta JC, Araujo E, et al. (2017) Alien species pathways to the Galapagos Islands, Ecuador. PLoS ONE 12(9): e0184379

[84] Rentería JL & CE Buddenhagen. 2006. Invasive plants in the *Scalesia pedunculata* forest at Los Gemelos, Santa Cruz, Galapagos. Noticias de Galápagos - Galapagos Research 64:31-35.

[85] Rentería JL, MR Gardener, FD Panetta, R Atkinson & MJ Crawley. 2012. Possible impacts of the invasive plant *Rubus niveus* on the native vegetation of the Scalesia forest in the Galapagos Islands. PLoS One 7(10). Doi:10.1371/journal.pone.0048106.

[86] Jäger H, Tye A, Kowarik I (2007) Tree invasion in naturally treeless environments: impacts of quinine (*Cinchona pubescens*) trees on native vegetation in Galapagos. Biol Conserv 140:297–307

[87] Jäger H, Kowarik I (2010) Resilience of native plant community following manual control of invasive *Cinchona pubescens* in Galapagos. Restor Ecol 18:103–112

[88] Jäger H, Alencastro MJ, Kaupenjohann M, Kowarik I (2013) Ecosystem changes in Galapagos highlands by the invasive tree *Cinchona pubescens*. Plant Soil 371:629–640

[89] Jäger H (2015) Biology and impacts of Pacific Island invasive species. 11. *Cinchona pubescens* (red quinine tree) (Rubiaceae). Pac Sci 69(2):133–153

[90] Causton CE, Peck SB, Sinclair BJ, Roque-Albelo L, Hodgson CJ, Landry B. Alien insects: Threats and implications for conservation of Galápagos Islands. Conservation Biology and Biodiversity. 2006; 99: 121-143

[91] Mauchamp A & R Atkinson. 2011. Rapid, recent and irreversible habitat loss: Scalesia forest on the Galapagos Islands. Galapagos Report 2011-2012. GNPS, GCREG, CDF and GC. Puerto Ayora, Galapagos, Ecuador.

species, it is estimated that the forest currently covers less than 1% of its original distribution (imagen #20). Only 100 hectares remain, and this is where restoration efforts are focused by the GNPD.

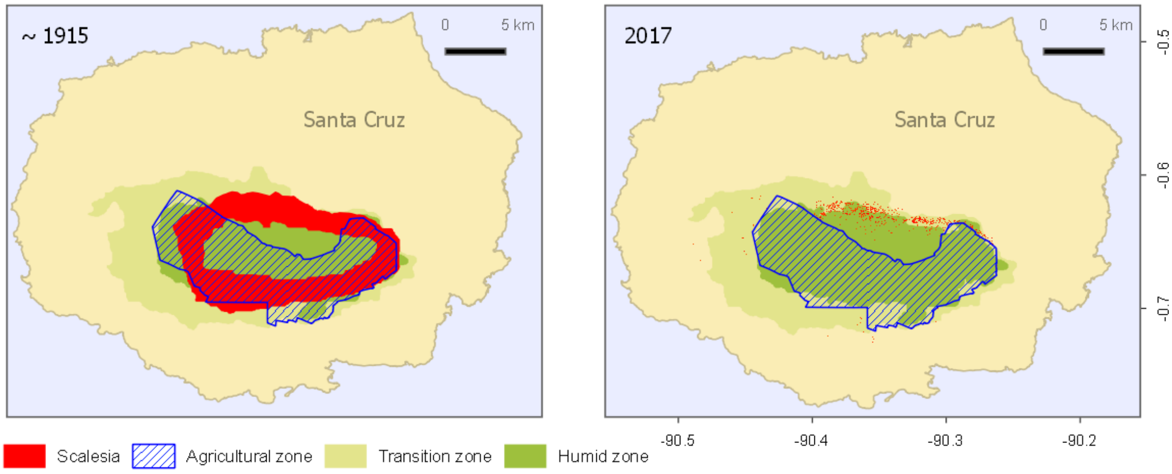

Image 20: Extension of the Scalesia forest in Santa Cruz in 1915 (left, in red) and in 2017 (right, in red)

Results of our monitoring shows that in only 2 years, 27% of the trees died[92]. Probably, it is a natural process because the forest usually goes through a cycle of death and recovery[93], but due to the shade caused by the presence of the blackberry in the forest, the *Scalesia* seeds can no longer germinate[84]. Our studies show that in 4 years there has been no natural regeneration of *Scalesia* in Los Gemelos. At the same time, there was a spectacular recovery in areas where the GNPD carried out control of blackberry plants. These results show the need for an immediate (well planned and careful) control of the blackberry plant to prevent the Scalesia forest from disappearing forever.

The control of the blackberry is a challenge because this plant produces many seeds, so it reproduces quickly. The control with herbicides can have a negative impact on the flora and fauna[94], and it can affect the soil. It is essential to look for more environmentally friendly control alternatives. Therefore, the CDF, in collaboration with the Center for Agricultural Bioscience International in the United Kingdom and with the GNPD, is working on the search for an agent of biological control of the blackberry. The first two stages of the project have been completed, but more funds are needed to complete the remaining four stages. Meanwhile, the blackberry is dispersing rapidly, impacting the flora and fauna of Galapagos.

---

[92] Jäger H, S Buchholz, A Cimadom, S Tebbich, J Rodriguez, D Barrera, A Walentowitz, M Breuer, A Carrion, C Sevilla and C Causton. 2017. Restoration of the blackberry-invaded Scalesia forest: Impacts on the vegetation, invertebrates, and birds. Pp. 142-148. *In:* Galapagos Report 2015-2016. GNPD, GCREG, CDF and GC. Puerto Ayora, Galapagos, Ecuador.
[93] Hamann, O. 1979. Dynamics of a stand of Scalesia pedunculata Hooker fil., Santa Cruz Island, Galapagos. Botanical Journal of the Linnean Society 78: 67-84.
[94] Filek, N., Cimadom, A., Schulze, C. H., Jäger, H. & Tebbich, S. The impact of invasive plant management on the foraging ecology of the Warbler Finch (*Certhidea olivacea*) and the Small Tree Finch (*Camarhynchus parvulus*). Journal of Ornithology

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Fundación
Charles Darwin
Foundation
GALAPAGOS

In order to plan management actions to control plant species in humid areas of the Galapagos Islands, we need to know their distribution and abundance. For this, the CDF uses very high-resolution satellite images and drone images to map the distribution of dominant plant species, with emphasis on invasive species. So far, we have produced large-scale maps of these species in Santa Cruz and Floreana, but maps for other inhabited islands and Santiago island are not available yet.

Image 21: Invasive species mapping project on Santa Cruz Island. Photo: Marcelo Loyola/CDF.

Above all, it is important to know the distribution of blackberry plants in Santiago because they have dispersed explosively after the eradication of goats on this island, and the impacts of this invasion are not known. Distribution maps of the most invasive plants will help the GNPD and other decision makers to better plan the control measures. At the same time, those maps are indispensable for conservation actions for endangered flora and fauna species. For example, maps of the distribution of *Scalesia pedunculata* can also be used to identify the surrounding vegetation of the Vermilion flycatcher, an endangered species in Santa Cruz.

Invasive plant and animal species not only disturb the biodiversity balance of the protected areas in Galapagos, but they also affect food production in inhabited islands. Currently, there is little systematized information on plants and animals introduced into the agricultural areas of the Galapagos Islands. To ensure good management of introduced species, it is vital to know their distribution and the impacts they generate. In addition, it is necessary to research on the consequences of using agrochemicals (herbicides and insecticides) for their control.

In collaboration with the Ministry of Agriculture and Livestock (MAG), we have carried out a study in the agricultural area of Santa Cruz that has provided valuable information seeking to fill this knowledge gap. The results showed that the invasive plants called blackberry, common guava, and yellow cestrum (*Cestrum auriculatum*), together with the tropical fire ant (*Solenopsis geminata*) are the most problematic invasive species on farms. We obtained information about the agrochemicals used to control these species and the concentrations and frequency of application. The next steps will be to help standardize and enrich farmers' knowledge to manage invasive species.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Fundación
Charles Darwin
Foundation
GALAPAGOS

Additionally, we are studying the distribution of the invasive tree frog (*Scinax quinquefasciatus*) on Isabela and Santa Cruz, since there is little information available about its current distribution and mode of dispersal. In this way, we are evaluating the potential for invasion of the species throughout the archipelago. The research combines field evaluations, controlled experiments and laboratory dietary analyses. The results will be used to formulate proactive management actions that can be recommended to the Galapagos National Park Directorate.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Searching for solutions to control the avian parasite *Philornis downsi* and to conserve Galapagos land birds

The status of some of the populations of land birds, particularly on inhabited islands, is critical and there is a need to slow down their decline and avoid additional extinctions as has already occurred on some islands. Species at risk that require special protection include: the Galapagos dove, the large tree finch, the Galapagos Vermilion flycatcher, the mangrove finch, the woodpecker finch, and the medium tree finch.

The status of land birds on the islands of Santa Cruz, San Cristobal, Isabela, and Floreana is of greater concern due to the high population numbers of the parasitic fly, *Philornis downsi*, found in these islands, and due to other types of pressure such as the reduction of habitat, and the predation by cats and rats, among others.

There is an urgent need to obtain substantial funding to continue with the research that leads to find short-term and long-term solutions to reduce the impact of *Philornis downsi*. The search for complementary measures (such as replanting trees and shrubs for shelter, food, and nesting; predator trapping; and creation of reserves) is essential to reverse the decline of bird populations.

We recommend the following as the highest priority measures:

- Galapagos Vermilion flycatcher: Search for mechanisms to prevent its imminent extinction on Santa Cruz Island, where it is estimated that the number of Vermilion flycatchers with territories is 40;

- Galapagos dove, large tree finch, and woodpecker finch: Identify areas with important populations and identify conservation measures;

- Mangrove finch: Implement new techniques to eliminate rodents from a protection area greater than the current area, and evaluate additional techniques to protect chicks from *Philornis downsi*;

- Medium Tree Finch: Restore Cerro Pajas in Floreana, which is currently invaded by an introduced climbing plant and expand the rodent control area.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Table 3. Presence, declines, and extinctions of land-bird populations on the Galapagos Islands (inhabited islands, in gray). Species with IUCN categories in red: VU – Vulnerable, EN – Endangered, CR – Critically endangered, EX* – Extinct (but with sightings until 2008). The other species have the LR category – Lower risk.

● Stable bird populations; ○ populations in decline (data from the CDF and GNPD Landbird Conservation Program); ● (red) species reported in the past but not found in recent monitoring (2016-2018); X confirmed absence – considered extinct on this island. (X) confirmed absence – previous presence on the island: uncertain.

Species	Baltra	Española	Fernandina	Floreana	Genovesa	Isabela	Marchena	Pinta	Pinzon	Rábida	San Cristobal	Santa Cruz	Santa Fe	Santiago	Darwin & Wolf
Small ground finch	●	●	●	●		●	●	●	●	●	●	●	●	●	
Medium ground finch	●		●	○		●	●	●	●	●	●	●	●	●	
Large ground finch	●		●	X	●	●	●	●	●	●	X	●	●	●	Wolf
Sharp-beaked ground finch			●	X		(X)		●			X	X		●	
Genovesa ground finch VU					●										
Vampire Ground-Finch VU															●
Cactus finch	●			○		●	●	●	●	●	○	●	●	●	
Española cactus finch VU		●													
Genovesa cactus finch VU					●										
Small tree finch	●		●	●		●		● (red)	●	● (red)	●	○	● (red)	●	
Medium tree finch VU				○											
Large tree finch VU			●	(X)		○	●	●	X	● (red)		○	● (red)	○	
Woodpecker finch VU			●			●		●	● (red)	● (red)	●	○	● (red)	●	
Mangrove finch CR			○ y visits. Does not nest		○										
Vegetarian finch	●		●	X		●	●	●	● (red)	● (red)	●	●		●	

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Table 4 cont. Presence, declines, and extinctions of land-bird populations on the Galapagos Islands (inhabited islands, in gray). Species with IUCN categories in red: VU – Vulnerable, EN – Endangered, CR – Critically endangered, EX* – Extinct (but with sightings until 2008). The other species have the LR category – Lower risk.

● Stable bird populations; ○ populations in decline (data from the CDF and GNPD Landbird Conservation Program); ● (red) species reported in the past but not found in recent monitoring (2016-2018); X confirmed absence – considered extinct on this island. (X) confirmed absence – previous presence on the island: uncertain.

Species	Baltra	Española	Fernandina	Floreana	Genovesa	Isabela	Marchena	Pinta	Pinzón	Rábida	San Cristóbal	Santa Cruz	Santa Fe	Santiago	Darwin & Wolf
Green warbler-finch VU			●			●			●	●		○		●	
Gray warbler-finch		●		X	●		●	●			●		●		●
Galapagos Mockingbird	●		●		●	●	●	●		●		●	●	●	●
Española Mockingbird VU		●													
Floreana Mockingbird EN				●											
San Cristobal Mockingbird EN											●				
Galapagos flycatcher	●	●	●	●		●	●	●	●	●	●	●	●	●	
Little Vermilion flycatcher VU			●	X		●	●	●	●	●		○	● (red)	○	
San Cristobal Vermilion flycatcher EX*											● (red)				
Yellow Garbler	●	●	●	●	●	●	●	●	●	●	○	●	●	●	●
Galapagos martin EN	●	●	●	●		●			●	●	●	●	●	●	
Galapagos dove	●	●	●	○	●	○	●	●	●	●	○	○	●	●	●
Dark-billed cuckoo	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Smooth-billed ani	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Galapagos Rail VU			●	X		○		●	●		X	○		●	
Paint-billed crake				●		●									
Gallinule		●	●	●		●									
Barn owl	●	●	●	X	●	●	●	●	●	●	●	●	●	●	
Short-eared owl	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Galapagos hawk VU		●	●	X		●	●	●	●	●	X	X	●	●	

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Statement of Experts - Attendants to the *Philornis* Workshop (2018) Approved by the Galapagos National Park Directorate.

We, the participants of the international workshops "Search for Solutions for the Control of the Avian Parasite *Philornis downsi* and for the Conservation of Galapagos Land Birds" held on January 30, 2017 and February 15, 2018, in Puerto Ayora, Santa Cruz Island, after having evaluated the data presented, have concluded the following:

1. The status of some of the populations of land birds, particularly on inhabited islands, is critical and there is a need to slow down their decline and avoid additional extinctions as has already occurred on some islands. Species at risk that require special protection include: the Galapagos dove, the large tree finch, the Galapagos Vermilion flycatcher, the mangrove finch, the woodpecker finch, and the medium tree finch.

2. The status of land birds on the islands of Santa Cruz, San Cristobal, Isabela, and Floreana is of greater concern due to the high population numbers of the parasitic fly, *Philornis downsi*, found in these islands, and due to other types of pressure such as the reduction of habitat, and the predation by cats and rats, among others.

3. There is an urgent need to obtain substantial funding to continue with the research that leads to find short-term and long-term solutions to reduce the impact of *Philornis downsi*.

4. The search for complementary measures (such as replanting trees and shrubs for shelter, food, and nesting; predator trapping; and creation of reserves), are essential to reverse the decline of bird populations.

5. We recommend the following as the highest priority measures:

   - Galapagos Vermilion flycatcher: Search for mechanisms to prevent its imminent extinction on Santa Cruz Island, where it is estimated that the number of Vermilion flycatchers with territories is 40;
   - Galapagos dove, large tree finch, and woodpecker finch: Identify areas with important populations and identify conservation measures;
   - Mangrove finch: Implement new techniques to eliminate rodents from a protection area that is greater than the current one, and evaluate additional techniques to protect chicks from *Philornis downsi*;
   - Medium Tree Finch: Restore Cerro Pajas on Floreana—currently invaded by an introduced climbing plant—and expand the rodent control area.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Signed by the participants in the workshops	
Name / Last Name	**Institution**
Walter Bustos	Galapagos National Park Directorate, Ecuador
Wilson Cabrera	Galapagos National Park Directorate, Ecuador
Jorge Carrión	Galapagos National Park Directorate, Ecuador
Rafael Chango	Galapagos National Park Directorate, Ecuador
Diana Gil Villacis	Galapagos National Park Directorate, Ecuador
Danny Rueda	Galapagos National Park Directorate, Ecuador
Christian Sevilla	Galapagos National Park Directorate, Ecuador
Paolo Piedrahita	Escuela Superior Politécnica del Litoral (ESPOL), Ecuador
Sonia Kleindorfer	Flinders University, Australia
David Anchundia	Charles Darwin Foundation, Ecuador
Andrea Cahuana	Charles Darwin Foundation, Ecuador
Charlotte Causton	Charles Darwin Foundation, Ecuador
Francesca Cunninghame	Charles Darwin Foundation, Ecuador
Birgit Fessl	Charles Darwin Foundation, Ecuador
Arturo Izurieta	Charles Darwin Foundation, Ecuador
Heinke Jäger	Charles Darwin Foundation, Ecuador
Gustavo Jiménez	Charles Darwin Foundation, Ecuador
Paola Lahuatte	Charles Darwin Foundation, Ecuador
Ainoa Nieto	Charles Darwin Foundation, Ecuador
Courtney Pike	Charles Darwin Foundation, Ecuador
Erika Ramírez	Charles Darwin Foundation, Ecuador
Jacqueline Rodríguez	Charles Darwin Foundation, Ecuador
Lorena Rojas	Charles Darwin Foundation, Ecuador
Paola Carrión	Galapagos Science Center, Ecuador
Boaz Yuval Hebrew	University of Jerusalem, Israel
Tui De Roy	Independent
Michael Dvorak	Independent
Erwin Nemeth	Independent
Enzo Reyes	Massey University of New Zealand
Sebastian Cruz	Max Planck Institute for Ornithology, Germany
Sandra Hervías Parejo	Mediterranean Institute for Advanced Studies, IMEDEA (CSIC-UIB), Spain
Alejandro Mieles	State University of New York, College of Environmental Science and Forestry, USA
Carolina Proaño	Tierra Mar, Ecuador
Sarah Knutie	University of Connecticut, USA
Johanna Harvey	University of Connecticut, USA
Rebecca Boulton	University of Minnesota, USA
George Heimpel	University of Minnesota, USA
Dale Clayton	University of Utah, USA
Sabrina McNew	University of Utah, USA
Arno Cimadom	University of Vienna, Austria
Christian Schulze	University of Vienna, Austria
Sabine Tebbich	University of Vienna, Austria

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Galapagos Verde 2050: Ecological Restoration and Sustainable Agricultural Practices

"Galapagos Verde 2050" is a multi-institutional and interdisciplinary project that actively contributes to the conservation of Galapagos natural assets and human well-being by using three water-saving technologies as tools to implement a successful model of both ecological restoration and sustainable agricultural practices (Jaramillo et al. 2013b, c). In the field of ecological restoration, we work on two main lines: the line of restoration of degraded ecosystems and recovery of threatened species, and the line of agricultural practices, where we develop experiments that seek to develop a method that allows to produce all year round, thus promoting local self-sufficiency[95], [96], [97], [98], [99], [100], [101], [102], [103], [104], [105], [106], [107] .

Up to September of this year we have 78 study sites distributed on 6 islands (Menendez and Jaramillo 2015). The component of ecological restoration so far includes 34 study sites, distributed on the following islands: Española, Floreana, North of Isabela, South Plaza, Baltra, and Santa Cruz. The objective of this component has two aspects: to restore ecosystems to recover and/or maintain their capacity to generate benefits (services) for the local population,

---

[95] Jaramillo P (2015) Water-saving technology: the key to sustainable agriculture and horticulture in Galapagos to BESS Forest Club (April 2015).

[96] Higgs ES (1997) What is good ecological restauration ? Conservation Biology 11:338-348

[97] Jaramillo P, Guézou A, Mauchamp A, Tye A (2017a) CDF Checklist of Galapagos Flowering Plants - FCD Lista de especies de Plantas con flores de Galápagos. Charles Darwin Foundation Galapagos Species Checklist - Lista de Especies de Galápagos de la Fundación Charles Darwin.

[98] Simbaña W, Tye A (2009) Reproductive biology and responses to threats and protection measures of the total population of a Critically Endangered Galápagos plant, Linum cratericola (Linaceae). Botanical Journal of the Linnean Society 161:89-102

[99] Andrus N, Tye A, Nesom G, Bogler D, Lewis C, Noyes R, Jaramillo P, Ortega JF (2009) Phylogenetics of Darwiniothamnus (Asteraceae: Astereae) – molecular evidence for multiple origins in the endemic flora of the Galápagos Islands. Journal of Biogeography 36:15. doi:10.1111/j.1365-2699.2008.02064.x

[100] Tye A (2007) La flora endémica de Galápagos: aumentan las especies amenazadas. In: FCD, PNG, INGALA (eds) Informe Galápagos 2006-2007. Puerto Ayora, Galápagos, Ecuador, pp 101-107

[101] Atkinson R, Jaramillo P, Simbaña W, Guézou A, Coronel V (2007) Avances en la conservación de las especies de plantas amenazadas de Galápagos. In: Informe Galápagos 2007-2008. Puerto Ayora, Galápagos, pp 105-110

[102] Tye A, Jaramillo P (1999) Plantas Amenazadas en Varias Islas del Archipiélago. Informe Técnico de Viaje a la Isla San Cristóbal. Estación Científica Charles Darwin, Galápagos-Ecuador.

[103] MAGAP (2014) "Plan de Bioagricultura para Galápagos: Una oportunidad para el buen vivir insular" (En preparación). Galápagos

[104] Guzmán JC, Poma JE (2015) Bioagricultura: Una oportunidad para el buen vivir insular. In: Cayot L, Cruz D (eds) Informe Galápagos 2013-2014. DPNG, CGREG, FCD y GC. Puerto Ayora, Galápagos, Ecuador. pp 25-29

[105] Vélez N (2017) Efecto de retenedores de agua en la producción de lechuga (Lactuca sativa L.) variedad Crespa Salad en la Granja Experimental Yuyucocha provincia de Imbabura. Universidad Técnica del Norte, Ibarra-Ecuador

[106] COCOON (2015) Benefits of the COCOON Technology. http://www.landlifecompany.com/.

[107] Hoff P (2014) Groasis Technology: Manual de Instrucciones de plantación.1-27

and to recover populations of endemic plant species that are in danger of extinction[108], [109], [110]. Among the most important achievements in this component, the following are included:

- In **Floreana**'s Granillo Mine, we have been able to establish a forest with similar characteristics to the original in 100% of the intervened surface.
- In **Baltra,** we have managed to establish more than 4,000 plants in three hectares and we have established an ecological corridor in the Seymour Ecological Airport. In addition, by using 12 native and endemic species of the island, we have developed an experimental model to restore normal ecological processes in arid island ecosystems[111], [112], [113], [114].
- In **Plaza Sur**, we have increased the cactus population (*Opuntia echios* var. *Echios*) by 200%, a species whose population had decreased by 85% in the last century and constitutes the main food of terrestrial iguanas[100], [115].
- In **Española**, we have been developing experiments to reproduce cactus (*Opuntia megasperma* var. *Orientalis*) and we have obtained several seedlings from seeds coming from the feces of giant tortoises[116], [117], [118].
- In **Santa Cruz**, we have increased the population of the Scalesia of Puerto Ayora (Scalesia affinis) by 35%[119], [120], [121], [122].

---

[108] Jaramillo P, Ortiz G, Masaquiza F, Rueda D, Tapia W, Gibbs J Galápagos Verde 2050 – Technology Innovation in Support of Ecological Restoration. In: Science, Conservation, and History in the 180 Years Since Darwin, 2015.
[109] Jaramillo P, Tapia W, Gibbs J (2017b) Action Plan for the Ecological Restoration of Baltra and Plaza Sur Islands, vol 2. Fundación Charles Darwin, Puerto Ayora.
[110] Jaramillo P, Tapia W, GIbbs J (2017c) Action Plan for the Ecological Restoration of Baltra and Plaza Sur Islands. 2:1-29.
[111] Gibbs J (2013) Restoring Isla Baltra's Terrestrial Ecosystems: A Prospectus.1-19
[112] Jaramillo P, Jiménez E, Cueva P, Ortiz J Baltra: un reto para la restauración ecológica de ecosistemas áridos. In: Jornadas Ecuatorianas de Biología, Universidad de Santa Elena, 2013a.
[113] Sulloway FJ, Noonan KM (2015) Opuntia Cactus Loss in the Galapagos Islands, 1957-2014 (Pérdida de cactus Opuntia en las Islas Galápagos, 1957-2014). Puerto Ayora
[114] Jaramillo P, Tapia W, Gibbs J (2017b) Action Plan for the Ecological Restoration of Baltra and Plaza Sur Islands, vol 2. Fundación Charles Darwin, Puerto Ayora
[115] Sulloway FJ, Olila KJ, Sherman D, Queva S, Torres A (2014) Documentando cambios ecológicos en las islas Galàpagos a través de tiempo desde de Darwin en Plaza Sur, Plaza Norte, Cerro Colorado (Santa Cruz), Santa Fe.:1-7
[116] Coronel V Germinación de semillas de Opuntia megasperma de la Isla Española. In: III Congreso Ecuatoriano de Botánica, Quito-Ecuador, 2000. p 35
[117] Coronel V (2002) Distribución y Re-establecimiento de *Opuntia megasperma* var. *orientalis* Howell. CACTACEAE) en Punta Cevallos, Isla Española–Galápagos. Universidad del Azuay, 78 pp.
[118] Gibbs JP, Marquez C, Sterling EJ (2008) The role of endangered species reintroduction in ecosystem restoration: tortoise–cactus interactions on Española Island, Galápagos. Restoration Ecology 16 (1):88-93. doi:doi.org/10.1111/j.1526-100X.2007.00265.x
119 Jaramillo P (2005) Scalesia affinis, "la Scalesia de Puerto Ayora" casi extinta en Santa Cruz, propuesta para su conservación. Fundacion Charles Darwin, Puerto Ayora, Galápagos
120 Vinueza Granda CP (2006) Germinación exsitu de semillas de Scalesia affinis Hook f. (Asteraceae), especie en peligro crítico de extinción en la isla Santa Cruz, Galápagos, mediante la utilización de fitoestimulantes biol y AG3. In: Informes de miniproyectos realizados por Voluntarios del Dpto de Botánica. Fundación Charles Darwin, Puerto Ayora, Galapagos, pp 170-192
121 Jaramillo P (2007) Amenazas para la Sobrevivencia de las Últimas Plantas de Scalesia affinis. El Colono. Parte II,
122 Atkinson R, Jaramillo P, Tapia W (2010) Establishing a new population of Scalesia affinis, a threatened endemic shrub, on Santa Cruz Island, Galapagos, Ecuador. In: Conservation Evidence, vol 6. pp 42-47

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

- In the **North of Isabela**, we have increased the population of Galvezia (*Galvezia leucantha* var. *Leucantha*) by 80%[123].

Image 22: Galapagos Verde 2050 Ecological Restoration Project. Photos: CDF Archive.

In the component of Sustainable Agricultural Practices, we are developing experiments on six farms: 3 in Santa Cruz and 3 in Floreana. The study sites include both open-field crops and greenhouse crops, and their objectives are to evaluate the effectiveness of the use of water-saving technologies, both in short-cycle crops and in perennial crops; and to analyze the cost/benefit of using Groasis Technology (GT) in agriculture [124], [125], [126], [127], [128].

The crops evaluated included broccoli, tomato, pepper, watermelon and melon, because these crops have high economic importance for producers, especially those of tomato and pepper. Due to their high demand, they are considered permanent-production vegetables. Preliminary results show that short-cycle crops give a profitability of 1.12 dollars per dollar invested, when projected in a production period of 5 years.

In addition to scientific and technical work, we have established a direct link with the local community, and the information has been transmitted through tools such as the book "Siémbrame en tu Jardín (Plant me in your Garden)", workshops, conferences, and open houses.

123 Guzmán B, Heleno R, Nogales M, Simbaña W, Traveset A, Vargas P (2016) Evolutionary history of the endangered shrub snapdragon (Galvezia leucantha) of the Galapagos Islands. Diversity and Distributions:1-14
124 Hoff P (2013) Waterboxx instrucciones de plantación. . Tecnoloía Groasis,
125 Hoff P (2014) Groasis Technology: Manual de Instrucciones de plantación.1-27
126 Rodríguez-Martínez AG (2017) Evaluación de un Hidrogel y Ácido Salicílico Durante el Crecimiento, Desarrollo y Rendimiento de un Cultivo de Frijol (Phaseolus vulgaris L.) bajo Invernadero., Universidad Autónoma Agraria Antonio Narro, México
127 Jaramillo P, Tapia W, Romero ML, Gibbs J (2017d) Galápagos Verde 2050: Restauración ecológica de ecosistemas degradados y agricultura sostenible utilizando tecnologías ahorradoras de agua. Fundación Charles Darwin, Puerto Ayora, Isla Santa Cruz.
128 Vélez N (2017) Efecto de retenedores de agua en la producción de lechuga (Lactuca sativa L.) variedad Crespa Salad en la Granja Experimental Yuyucocha provincia de Imbabura. Universidad Técnica del Norte, Ibarra-Ecuador

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

The preliminary results of the GV2050 project show that through cooperative work between strategic partners and the involvement of union and individual actors, the proposed goals can be achieved.

Image 23: Galapagos Verde 2050 Ecological Restoration Project. Photo: CDF Archive.

The magnitude of this project makes visits to each island infrequent. Despite that, in each visit to the study sites in the populated islands, the presence of invasive species is evident. Some of these invasive species are *Lantana camara*, *Rubus niveus*, *Psidium guajava*, *Ricinus communis*, and *Leucaena leucocephala*. Therefore, in addition to the normal project work, we have to eliminate the invasive species in each study site, as part of the ecological restoration component. Likewise, in the case of the component of sustainable agricultural practices, the involvement of the local community (specifically, farmers) is vital not only to maintain their productive properties but also to be free of invasive species. However, the farmers' efforts are ineffective because near their properties, they possess farms that are abandoned and invaded, which turns these places into seed dispersers.

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Galapagos Giant Tortoise Movement Ecology Program: The importance of health for the welfare of animals and their ecosystem

The program led by Dr. Stephen Blake and Dr. Sharon L. Deem has been working in Galapagos for 9 years to understand the migration of giant tortoises and the ecological, social, and health factors that can affect the conservation of these emblematic species.

Throughout these years, numerous researchers and donors have contributed to this program, which has generated information of great relevance for the management of these species. Some of the most important results include the establishment of tortoise migration patterns and routes in Santa Cruz island, Española island, and the Alcedo volcanoes on Isabela Island, testing for the first time how the migration of these reptiles is directly associated with the quality and availability of food. The ecological role of turtles as dispersers of seeds and engineers of the ecosystem, and the influence of their reproductive cycle on migration have also been studied.

In recent years, work has been emphasized in nesting areas to understand two factors: first, the main threats that affect egg hatching (and there are many!), such as climate change or introduced species, and second, the survival rate of baby tortoises in the wild. In 2017, we were able to determine the sex of newborn turtles for the first time by using a simple procedure called laparoscopy.

Image 24: Freddy Cabrera and Ainoa Nieto collaborating with the Directorate of the Galapagos National Park in the protection and conservation of newborn tortoises. Photo: Joshua Vela/ CDF.

This information is very relevant since, as we know, the temperature of incubation is what determines the sex of our baby tortoises. Did you know that a one-degree increase in the climate of Galapagos could seriously affect the proportion of males and females born in the wild each year?

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

Another very important factor to consider is health, which affects in a decisive way the conservation and survival of the species. Since 2017, we have studied which diseases tortoises present, and how human impacts can affect not only the health of tortoises but also other animal species (wild and domestic) or impact the health of the entire ecosystem. Our first preliminary results indicate that Galapagos tortoises are dispersing antibiotic-resistant bacteria. Medicine abuse in human health and farm animals are factors that are causing a worldwide dramatic increase in antibiotic-resistant bacteria. It is necessary to study in depth the health of unique species such as tortoises and take urgent measures to regulate the purchase and use of medicines. The work with local institutions is decisive to develop education and awareness campaigns that help to avoid future impacts for human and animal health.

In the social sphere, it is necessary to take immediate actions in conjunction with institutions such as ABG (Agency for Regulation and Control of Biosecurity and Quarantine for Galapagos) and MAG (Ecuadorian Ministry of Agriculture and Livestock) to identify and understand potential conflicts caused by the close coexistence between wild tortoises and humans. The ultimate goal is to find solutions and alternatives on which the local community agrees. This will allow to maintain a balance and coexistence between local farmers and ranchers, without losing sight of the well-being of the Galapagos wildlife and the integrity of the ecosystems, decisive and critical factors for the archipelago conservation.

Image 25: Anne Guezou leading an educational activity with local students.
Photo: Surya Castillo/ CDF.

The conservation of unique species such as turtles requires urgent actions and the joint work of local institutions and researchers. We need to find solutions that ensure the health of animals, humans, and the environment, which in turn will allow future generations to continue to enjoy these enchanted islands[129].

[129]Abrahms, B., Seidel, D. P., Dougherty, E., Hazen, E. L., Bograd, S. J., Wilson, A. M., Getz, W. M. (2017). Suite of simple metrics reveals common movement syndromes across vertebrate taxa. *Movement Ecology*, *5*(1), 1–11.

Fundación Charles Darwin Foundation GALAPAGOS

Bastille-Rousseau, G., Gibbs, J. P., Yackulic, C. B., Frair, J. L., Cabrera, F., Rousseau, L. P., Blake, S. (2017). Animal movement in the absence of predation: environmental drivers of movement strategies in a partial migration system. *Oikos*, *126*(7), 1004–1019.
Bastille-Rousseau, G., Potts, J. R., Yackulic, C. B., Frair, J. L., Ellington, E. H., & Blake, S. (2016). Flexible characterization of animal movement pattern using net squared displacement and a latent state model. *Movement Ecology*, *4*(1), 15.
Bastille-Rousseau, G., Yackulic, C. B., Frair, J. L., Cabrera, F., & Blake, S. (2016). Allometric and temporal scaling of movement characteristics in Galapagos tortoises. *Journal of Animal Ecology*, *85*(5), 1171–1181.
Benitez-Capistros, F., Camperio, G., Hugé, J., Dahdouh-Guebas, F., & Koedam, N. (2018). Emergent conservation conflicts in the Galapagos Islands: Human-giant tortoise interactions in the rural area of Santa Cruz Island. *PLOS ONE*, *13*(9), e0202268.
Blake, S., Guézou, A., Deem, S. L., Yackulic, C. B., & Cabrera, F. (2015). The Dominance of Introduced Plant Species in the Diets of Migratory Galapagos Tortoises Increases with Elevation on a Human-Occupied Island. *Biotropica*, *47*(2), 246–258.
Blake, S., Wikelski, M., Cabrera, F., Guezou, A., Silva, M., Sadeghayobi, E., Jaramillo, P. (2012). Seed dispersal by Galapagos tortoises. *Journal of Biogeography*, *39*(11), 1961–1972.
Blake, S., Wikelski, M., Deem, S., Gibbs, J., Parker, M., Flowers, S., Cabrera, F. (2015). The Ecology and Conservation of Migration in Galapagos Giant Tortoises. *Final Report. Charles Darwin Foundation*, (January).
Blake, S., Yackulic, C. B., Cabrera, F., Tapia, W., Gibbs, J. P., Kümmeth, F., & Wikelski, M. (2013). Vegetation dynamics drive segregation by body size in Galapagos tortoises migrating across altitudinal gradients. *Journal of Animal Ecology*, *82*(2), 310–321.
Blake, S., Yackulic, C. B., Wikelski, M., Tapia, W., & Gibbs, J. P. (n.d.). Informe Galapagos 2013-2014. Biodiversidad y Restauración de Ecosistemas: la Migración de las Tortugas Gigantes de Galápagos Requiere de Esfuerzos de Conservación a Escala de Paisaje.
Ellis-Soto, D., Blake, S., Soultan, A., Guézou, A., Cabrera, F., & Lötters, S. (2017). Plant species dispersed by Galapagos tortoises surf the wave of habitat suitability under anthropogenic climate change. *PLoS ONE*, *12*(7), 1–16.
P. G. Parker, S. L. Deem. (2010). Wildlife health monitoring and disease management, 39–63.
Sheldon, J. D., Stacy, N. I., Blake, S. C. V. P., Cabrera, F., & Deem, S. L. (2016). Comparison of Total Leukocyte Quantification Methods in Free-Living Galapagos Tortoises (*Chelonoidis spp*). *Journal of Zoo and Wildlife Medicine*, *47*(1), 196–205.

In conclusion

The coincidences and disconnections between the normative instruments and the results obtained from the research are highlighted here. The decisions seek to resolve the most relevant conflicts and emergencies, but there are structural issues and principle-related issues that have not been resolved: the constant-growth model is a format that Galapagos cannot bear anymore. It is our belief that the implementation of a complementary and comprehensive policy, along with a rethinking of the development model that should exist in Galapagos, could help to increase the governability of the protected areas, which will immediately result in a greater probability of achieving the sustainability of Galapagos and the viability needed for the communities that inhabit the archipelago.

Arturo Izurieta Valery, PhD
Executive Director
Charles Darwin Foundation for the Galapagos Islands

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador

CDF Staff who has contributed to the preparation of this document

- Solange Andrade. solange.andrade@fcdarwin.org.ec
- María José Barragán P. mariajose.barragán@fcdarwin.org.ec
- Salome Buglass. salome.buglass@fcdarwin.org.ec
- Charlotte Causton. charlotte.causton@fcdarwin.org.ec
- Francesca Cunninghame. Francesca.cunninghame@fcdarwin.org.ec
- Birgit Fessl. birgit.fessl@fcdarwin.org.ec
- Heinke Jäger. Heinke.jaeger@fcdarwin.org.ec
- Patricia Jaramillo. patricia.jaramillo@fcdarwin.org.ec
- Gustavo Jiménez-Uzcátegui. gustavo.jimenez@fcdarwin.org.ec
- Inti Keith. inti.keith@fcdarwin.org.ec
- Stephen Blake, Sharon Deem, Ainoa Nieto, Anne Gezou. ainoa.nieto@fcdarwin.org.ec
- Macarena Parra. macarena.parra@fcdarwin.org.ec
- Pelayo Salinas de León. pelayo.salinas@fcdarwin.org.ec

Puerto Ayora, Santa Cruz, Galápagos, Ecuador + 593 (5) 2526 146 / www.darwinfoundation.org / PO Box 17-1-3891 Quito - Ecuador