

Interim report for the Rufford Foundation on Marine Invasive Species in the Galapagos Marine Reserve

Goal: The project goal is to ensure long-term conservation of the ecosystems and species of the Galapagos Marine Reserve (GMR) through minimizing the negative impacts of invasive species on the marine biodiversity, ecosystem services, and health of the GMR

Objectives:

1. An in depth review of literature of all invasive species in the Galapagos Marine Reserve and elaborate a list of potential marine invasive species.
2. Conduct monitoring surveys in the 5 ports of the Galapagos Islands twice a year.
3. Conduct yearly monitoring surveys throughout the GMR.
4. Determine the occurrence and spatial distribution of marine invasive species already established in the GMR.
5. Elaborate marine invasive species distribution maps and sensitivity maps combined with traffic routes and the density of maritime traffic in the GMR.
6. Elaborate a risk categorization for incoming ships, combining their providence and recent shipping route with identified hotspots of transmission and propagation of invasive species in the Eastern Pacific and elsewhere.
7. Elaborate a rapid response protocol applicable in case of invasive species detection within GMR.

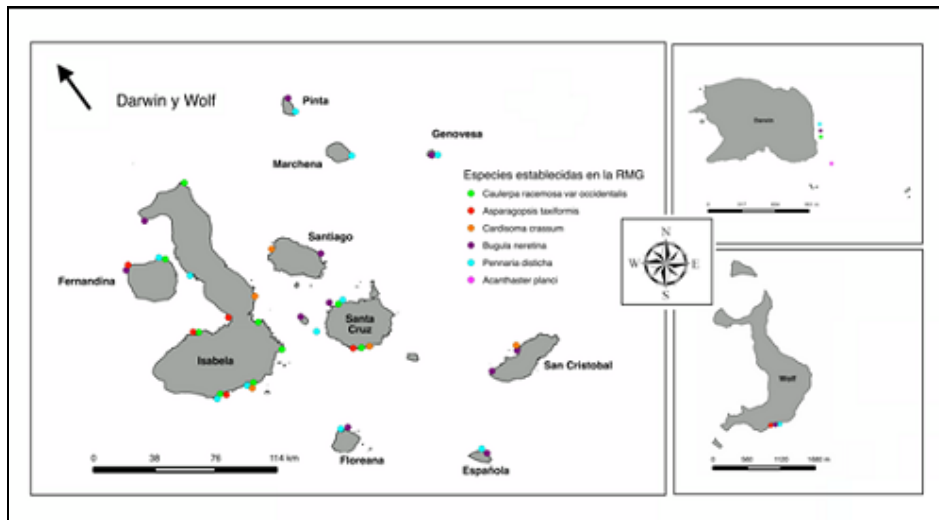
Results:

Monitoring of GMR sites

Monitoring surveys of different sites around the GMR where conducted, with a total of 115 sites monitored. After conducting monitoring and directed searches through these sites, 28 sites were found to have one or several of the established marine invasive species (described in Annex I, Table1). Using this information we were able to map out a preliminary distribution of which species is located in the GMR. (Map below)



Figure 1: Inti Keith conducting monitoring of marine invasive species



Map 1: Preliminary distribution of established marine species in the GMR.

Potential marine invasive species for the GMR

Data collected on marine invasive species worldwide highlighted eighteen high-risk species (species that could negatively impact the biodiversity of the GMR) with potential to arrive in the GMR through various vectors (Annex I, Table 2).

Monitoring of marine ports

Monitoring of the main ports in the Galapagos Islands is of great importance and is considered a high priority as these are the most likely areas where possible invaders can arrive, due to the marine traffic that arrives from abroad, as well as continental Ecuador. If non-native species were to arrive to one of the ports, it is possible that this species could be spread around the Archipelago through local marine traffic and current systems.

The first port monitored was Puerto Baquerizo Moreno on the island of San Cristobal. In this port, three docks and one navigation buoy were surveyed for marine invasive species (Figure 2). Fish, macro-invertebrates and sessile organisms were found on all the docks and no established invasive species or potential invasive species were found on these structures. The species found in all three docks were not out of the ordinary and were expected to be observed. However, on the outer navigation buoy that was surveyed, *Bugula neritina* was observed. This species is on the established invasive species list and is considered a cryptogenic species that was most likely introduced on a wooden hull many years ago, however this can't be proven. The risk of this species spreading is quite high as these navigation buoys are moved around before being inspected and cleaned.



Figure 2: Google map of Puerto Baquerizo Moreno bay illustrating i) dock -1, ii) dock-2 and iii) dock-3 and iv) navigation buoy that were surveyed

Monitoring protected bays

During the survey trips, part of the monitoring takes place in the protected bay, on the coastal area near mangroves. *Caulerpa racemosa* was found in several bay areas, especially on the island of Isabela. (Figure 3).



Figure 3: *Caulerpa racemosa* found in bays on the island of Isabela.

Marine traffic

The history of the maritime traffic in the GMR is extensive, which makes it more difficult to know with certainty if some species existed naturally or if they were introduced by humans in the past. Since their accidental discovery in 1535 and through the 17th and 18th centuries, Galapagos became a haven for pirates. Then in the 19th century, whalers were attracted by the richness of the sea surrounding the islands. The first introductions of domestic animals and invertebrates occurred during these centuries. Various marine species could also have been introduced to the islands at this time. A possible example is *Bugula neritina*, a brown bryozoan that has a worldwide distribution, which is thought to have been transported on wooden hulls (Eldredge & Smith, 2001) and could have arrived in the Galapagos through this mechanism in centuries past. Industrial-fishing boats arrived during the 1940s and 1950s (Cruz *et al.*, 2007), and in 1942 during the Second World War, the United States of America constructed a naval base on Baltra Island, which increased the number of vessels in the area.

Today the marine traffic that navigates regularly in the GMR waters includes the following categories: tourism, transport, cargo, fishing, private, scientific, patrol boats and oil tankers (Figure 4). The movement of these vessels increases the threat of marine invasive species entering and spreading within the GMR. In the Galapagos Islands, tourism is the main economic base (Piu & Muñoz, 2008); 61% of tourists visit onboard boats. There are several different itineraries and routes that are managed by the GNPD and the Ministry of Transport. The number of inter-island vessels that operate fluctuates according to demand. During the first semester of 2007, approximately 1,900 journeys were made between the populated islands (Cruz *et al.*, 2007). A study conducted between February and November 2012, a period of only ten months, indicated 8,685 departures and arrivals of inter-island vessels recorded on Santa Cruz Island by the Ecuadorian Navy (Parra *et al.*, 2013), showing a marked increase in traffic between the populated islands. Fishing, private, scientific and patrol boats are harder to enumerate, as they do not have fixed itineraries or routes.

The number and frequency of cargo ships and other vessels sailing between mainland Ecuador and the Galapagos Islands have also increased in recent years, as has the number of private yachts arriving from different parts of the world. Between 2002 and 2006 four cargo ships transported goods to the islands approximately 68 times each every year. In 2006, an additional boat began operating bringing the total to five cargo ships (Cruz *et al.*, 2007). During 2011, due to new regulations, only four cargo ships travelled to and from the islands with a total number of trips of 224 (Bigue *et al.*, 2013).

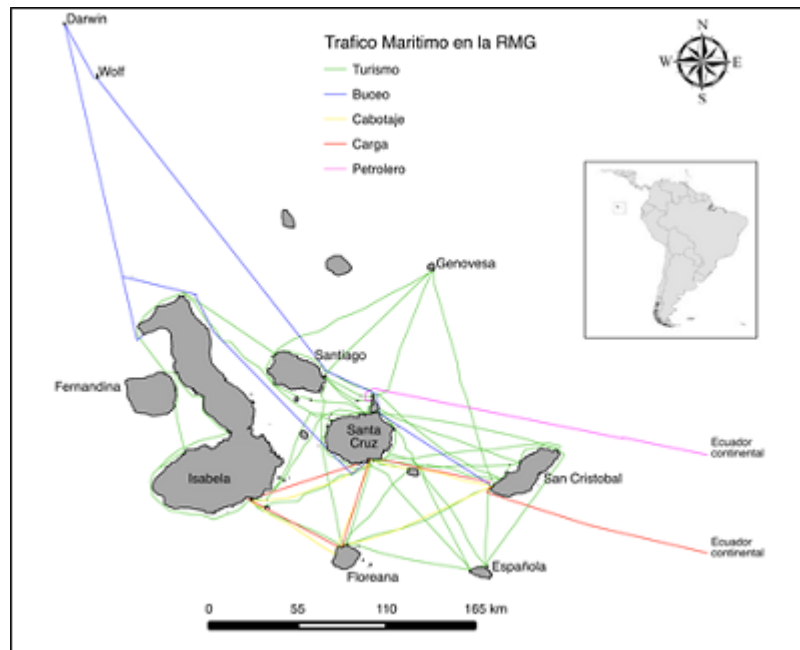


Figure 4: map of marine traffic in the GMR

Risk assessments for incoming ships

The risk of a potential spread of marine invasive species in Galapagos is very real, because of the high percentage of vessels that circulate in the GMR, the diversity of habitats, the oceanographic patterns, and the connectivity that exists through currents and extreme weather events such as El Niño and/or Nina. A risk is defined as the possibility of damage or change that occurs due to natural events or man-made events. The risks associated with the introduction of marine invasive species is measured by taking into account vectors of introduction, the probability that a species can successfully establish and the potential damage that this introduction could cause.

The value of a healthy marine environment has been widely accepted and understood for some time. What has changed is the increased awareness ecosystem services have on people's livelihoods. Non-native invasive species threaten our marine ecosystems and ecosystem services.

Table 1: Example of risk assessment

	ALTO	MEDIO	BAJO
1. Are there visible organisms on the docks bellow the watermark?			
2. Are there organisms visible on the boys bellow the watermark?			
3. Where organisms detected during the dive?			

Table 1 indicates an example of a risk assessment questionnaire used to inspect docks and incoming boats. Depending on the level of organisms that the area in question has they will be allowed or immediately ordered to be cleaned. It is important to have a biosecurity plan to minimize the introduction or spread of invasive non-native species to ports. This results in eradication protocols not being necessary which is a positive thing as these can be very expensive. A Biosecurity plan also serves as a tool to raise awareness at the local, national and regional level and shows visitors how the GMR is responding to a serious environmental threat, such as non-native invasive species.

Recommendations:

I am working with the Charles Darwin Foundation and strong collaboration with local authorities we are working to minimize the negative impacts that marine invasive species can have on marine biodiversity, ecosystem services, and the health of the RMG. Recommendations based on this analysis include:

- Implement monitoring and early detection systems for marine invasive for the main ports of the populated islands along with rapid response protocols.
- Create a multi-institutional dive team to carry out inspections of marine invasive species in sensitive areas and in the main ports.
- Create a multi-institutional coordination committee to establish a network of professionals to address the problem of marine invasive species in the GMR and in continental Ecuador.
- Study the regulations that are in place in the Eastern Tropical Pacific (ETP) and establish the necessary documentation for the inspection of vessels in Galapagos.
- Conduct studies on the distribution, abundance, and interactions of introduced marine species and their dispersal potential using oceanic modelling.
- Disseminate information of the potential threats and impacts of marine invasive species and preventive measures that can be put in place along with rapid response protocols.
- Work within the scope of the Convention on Biological Diversity as the focal point of the Environment Ministry.

ANNEX I

Table 1: Preliminary list of established invasive species in the GMR.

Scientific name	Common name
<i>Cardisoma crassum</i>	Blue crab
<i>Bugula neritina</i>	Brown bryozoan
<i>Pennaria disticha</i>	Christmas tree hydroid
<i>Caulerpa racemosa</i>	Grape algae
<i>Asparagopsis taxiformis</i>	Red sea plume
<i>Acanthaster planci</i>	Crown of thorns

Table 2: Preliminary list of potential invasive species for the GMR

Scientific name	Common name	Scientific name	Common name
<i>Asteria amurensis</i>	Northern Pacific Seastar	<i>Hypneamusciformis</i>	Hook weed
<i>Chthamalus proteus</i>	Caribbean barnacle	<i>Acanthophora spicifera</i>	Spiny seaweed
<i>Mytilopsis sallei</i>	Black-striped mussel	<i>Chama macerophylla</i>	Leafy jewelbox
<i>Undaria pinnatifida</i>	Japanese Kelp “Wakame”	<i>Diadumene lineata</i>	Orange-striped green anemone
<i>Carijoa riisei</i>	Snowflake coral	<i>Didemnum candidum</i>	White didemnid
<i>Caulerpa racemosa</i> <i>var. cylindracea</i>	Grape algae	<i>Haliclona caerulea</i>	Blue Caribbean sponge
<i>Codium fragile</i>	Sponge weed	<i>Carcinus maenas</i>	European green crab
<i>Asparagopsis armata</i>	Harpoon weed	<i>Lutjanus kasmira</i>	Blue stripped snapper
<i>Gracilaria salicornia</i>	Red alga	<i>Pterois volitans</i>	Lionfish

References

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