GALAPAGOS REPORT 2013-2014

MARINE MANAGEMENT

MARINE INVASIVE SPECIES IN THE GALAPAGOS MARINE RESERVE: A CASE FOR ADDITIONAL RESEARCH, IMPROVED MANAGEMENT, AND POLICY REVIEW

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The **Galapagos National Park Directorate** has its headquarters in Puerto Ayora, Santa Cruz Island, Galapagos and is the Ecuadorian governmental institution responsible for the administration and management of the protected areas of Galapagos.

The **Governing Council of Galapagos** has its headquarters in Puerto Baquerizo Moreno, San Cristóbal Island, and is the Ecuadorian governmental institution responsible for planning and the administration of the province.

The **Charles Darwin Foundation**, an international non-profit organization registered in Belgium, operates the Charles Darwin Research Station in Puerto Ayora, Santa Cruz Island, Galapagos.

Galapagos Conservancy, based in Fairfax, Virginia USA, is the only US non-profit organization focused exclusively on the long-term protection of the Galapagos Archipelago.

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Marine invasive species in the Galapagos Marine Reserve: A case for additional research, improved management, and policy review

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Introduction

Biological invasions occur when species enter a new environment, become established, and impact native species populations, disturbing the balance of plant and animal communities (Emerton & Howard, 2008; Williamson & Fitter, 1996). The introduction of alien species has been identified worldwide as the second most important reason for biodiversity loss after habitat destruction; in oceanic islands, it is undisputedly the first (IUCN, 2011). Marine invasions are currently a widespread problem throughout the world's oceans with significant impacts to the environment, the economy, and health (Campbell & Hewitt, 2013).

The rate of biological invasions has increased during recent decades, mostly due to increasing global trade, transport, and tourism, which allow an accelerated spread of species by overcoming natural barriers, such as currents, land masses, and temperature gradients (Seebens *et al.*, 2013; Hilliard, 2004). Climate change and extreme climate events can alter vital aspects of the environment through significant changes in temperature and precipitation, which allow invasive species to establish and spread more easily than if the system were stable and more resistant to invasion. El Niño Southern Oscillation (ENSO) events can often have devastating effects on the flora and fauna of an area by facilitating transport and/or invasion of non-native species. Algae and corals can die off, creating niches that the opportunistic invasive species can occupy faster than the recovering native species. The connectivity of oceanic currents combined with the lack of control measures make it very easy for new invasions to occur.

The Charles Darwin Foundation (CDF), in close collaboration with the Galapagos National Park Directorate (GNPD), the Galapagos Biosecurity Agency (ABG – Spanish acronym), and the Ecuadorian Navy and their Oceanographic Center (INOCAR – Spanish acronym), began the Marine Invasive Species Project in 2012, with the support of the University of Dundee and the University of Southampton in the UK. The project aims to minimize the impact of invasive species on the biodiversity of the Galapagos Marine Reserve (GMR) by creating risk assessment tools for the prevention, early detection, and management of invasive marine species along with rapid response protocols.

Established marine invasive species in the GMR

All existing literature was reviewed and underwater surveys conducted by the marine invasive species team of the Charles Darwin Foundation (CDF, 2013) A preliminary list was produced indicating six invasive species that are now established in the GMR (Table 1).

Potential marine invasive species for the GMR

Data collected on marine invasive species worldwide highlighted 18 high risk species (species that could negatively impact the biodiversity of the GMR) with potential to arrive in the GMR through various vectors (Table 2).

Table 1. List of established invasive species in the Galapagos Marine Reserve.

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

Table 2. List of potential invasive species for the Galapagos Marine Reserve.

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

Examples of high potential invasive species that are already established in the GMR include grape algae (*Caulerpa racemosa*; Figure 1) and red sea plume (*Asparagopsis taxiformis*; Figure 2).

Photo 1. Grape algae (*Caulerpa racemosa*), Fernandina. Photo: © Noemi d'Ozouville

Photo 2. Red sea plume (*Asparagopsis taxiformis*), Cabo Douglas, Fernandina. Photo: © Inti Keith

Several species with a high potential to be introduced to the islands, such as the snowflake coral (*Carijoa riseii*; Figure 3), have already been reported in continental Ecuador and in the island of Malpelo, Colombia (Sanchez *et al.*, 2011).

Photo 3. Snowflake coral (*Carijoa riisei*). Photo: ©Fernando Rivera.

Marine traffic

Marine organisms have spread from their native regions through human transport and have managed to establish populations in different parts of the world (Cohen & Carlton, 1998). It is thought that marine traffic is the main cause of species translocation worldwide (Kolar & Lodge, 2001; Hulme, 2009), and it is estimated that 10,000 species are transported around the world in ballast water every day, due to the increasingly larger and faster cargo ships (De Poorter, 2009; Hutchings *et al.*, 2002; Bax *et al.*, 2003). The large amount of traffic that already exists combined with the rapid expansion of this industry increases the danger of species being transported and invasions occurring.

The study conducted by Seebens *et al.,* (2013) identifies the major shipping routes and number of journeys worldwide during 2007 (Figure 1).

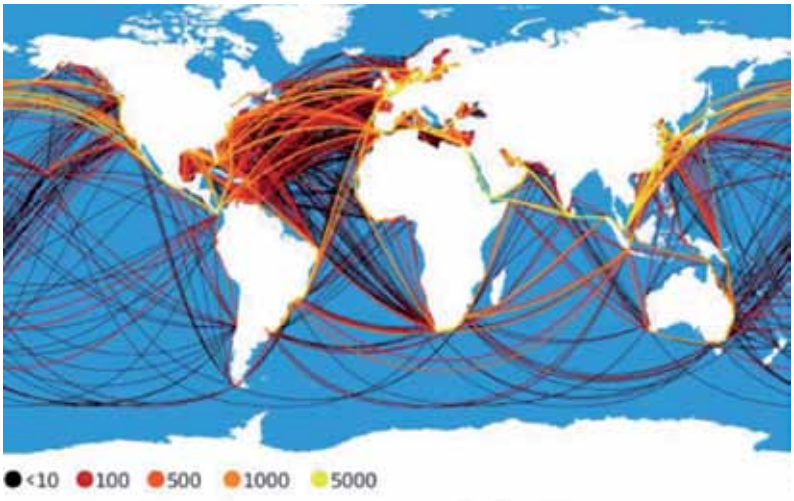

Figure 1. Worldwide shipping traffic in 2007 (Seebens *et al.*, 2013).

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 where introduced by humans in the past. Since their accidental discovery in 1535 and through the 17th and 18th centuries, the Galapagos Islands 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 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 5). 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 1900 journeys were made between populated islands (Cruz *et al.*, 2007). A study conducted between February and November 2012, a period of only ten months, indicated 8685 departures and arrivals of inter-island vessels recorded on Santa Cruz Island by the Ecuadorian Navy (Parra *et al.*, 2013), showing a marked increase. 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 has 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 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 of 224 trips (Bigue *et al.*, 2013).

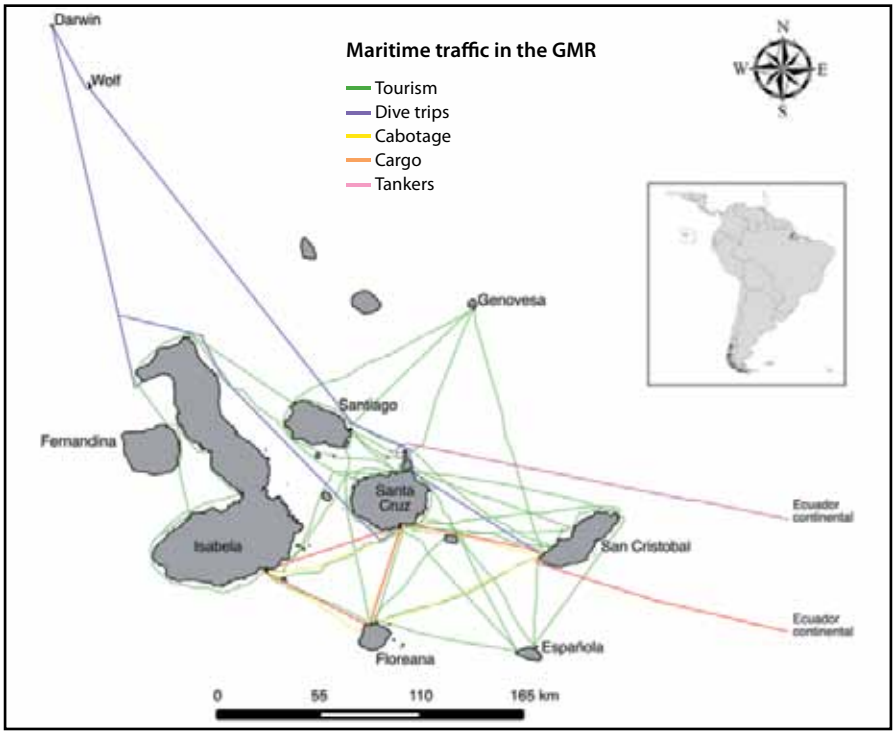

Figure 5. Main marine traffic routes in the GMR in 2014.

Reducing marine invasion risk

The possible invasion of marine species to the GMR, given the connectivity that exists within the Eastern Tropical Pacific (ETP), the increase in marine traffic, and climate change, is a reality that should not be ignored. Invasive species and climate change are two of the most prevalent issues biodiversity is facing (Rahel & Olden, 2008). When a habitat changes, for example through climate change, invasive species can often become established and spread more easily than in a stable system; native species often struggle to adapt to new conditions, while many invasive species are excellent in adapting quickly (Emerton & Howard, 2008). In extreme cases, climate-driven invasions could completely transform ecosystems to where non-native species dominate ecosystem processes, species richness, or both, leading to reduced diversity of native species (Mack *et al.*, 2000; Walther *et al.*, 2009).

Studies show that marine ecosystems in the Galapagos are not well adapted to extreme thermal impacts (Edgar *et al.*, 2010). Whether one talks about climate change or ENSO events it is clear that changes in sea surface temperature can affect the ecosystems in the GMR. Understanding the human influences that affect the GMR is a high priority in order to protect the biodiversity of the Archipelago. Oceanic currents heavily influence trans-oceanic dispersal, often moving species between widely separated areas, especially species capable of long-distance larval transport (Hickman, 2009). The historical geographic isolation of the Galapagos Islands once limited immigration of new species, allowing the established species to evolve with few strong

competitors and predators. Due to the oceanographic connectivity that the Archipelago has with the rest of the Eastern Tropical Pacific (ETP), it is important to improve our understanding of the various human factors that influence the GMR. The potential loss of biodiversity and risks to ecosystem processes are mainly due to factors such as climate, fisheries, maritime traffic, pollution, and extreme natural events (Banks, 2002). The ever-increasing marine traffic in the GMR and the ETP is putting the Galapagos Islands under more and more pressure as they become more geographically accessible and the potential for marine biological invasion intensifies.

The growth of tourism and immigration associated with the islands in the last 20 years has led to a dramatic increase in the number of exotic species introduced (CDF & WWF, 2002). The majority are terrestrial species but some marine species have been introduced; an example is the blue crab (*Cardisoma crassum*), which was introduced to the islands when live crabs escaped from a hotel in Puerto Ayora where they were being cooked for the captain of a tourist boat (Hickman, 2000). The number of private vessels arriving in the Galapagos from different parts of the world has increased in recent years. As more yachts arrive to the Islands, the higher the risk of a marine species invasion. An efficient policy to support conservation and social sustainability must act on the connections between Galapagos, continental Ecuador, and the rest of the world, to reduce the flows that enter and leave the Archipelago (Grenier, 2010).

Recommendations

The Charles Darwin Foundation, in strong collaboration with local authorities, is 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 invasives 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 Ministry of the Environment.

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