Executive Summary

Importance of the project for Galapagos

The Galapagos Marine Reserve is extremely susceptible to invasive marine species. This project aims to continue work to minimize the negative impacts of invasive species on the marine biodiversity, ecosystem services and health of the GMR, thus helping to maintain ecological diversity in marine ecosystems.

Project objectives

1. Show the connectivity that exists through marine traffic and set up long term monitoring program for local decision makers
2. Identify sensitive areas to climate change, ENSO events and marine traffic
3. Work with local authorities to insure regulations for ballast water
4. Work on proposals to secure additional funding

Proposed methodology

Marine settlement plates will be installed at mainland ports, the 5 main docks of the populated islands, and a number of sites in the GMR that are highly susceptible to ENSO events, have high percentage of daily traffic and are shown by marine currents dispersal monitoring to be at risk, and also if possible, on the hulls of the cargo boats. Protected bay areas will be monitored for invasive algae and stakes will also be placed in different locations to measure the growth of *Caulerpa racemosa*; cameras will be placed in different locations to record predation of this species by different species of fish. We will work with local stakeholders to insure that there are regulations in place for the present and future regarding ballast water, and we will_create a risk assessment analysis of boat transport from Panama, Manta, Salinas and Guayaquil in Ecuador.

Target audience

Galapagos National Park Directorate (GNPD), Galapagos Biosecurity Agency (ABG), Transport Ministry and INOCAR (Oceanographic institute)

Plan for dissemination of results

Map of marine traffic and the hotspots of possible transmission shared with GNPD, ABG, Transport Ministry and INOCAR. Risk assessment reports shared with GNPD, ABG, Transport Ministry and INOCAR. Technical reports submitted to government agencies. Participatory workshops with government agencies; Outreach materials distributed to the local community, Guides, GNPD, ABG, Transport Ministry and INOCAR and MPA management authorities. Educational campaign with Ministry of Education, school children and teachers. Training Courses and workshops provided for GNPD, ABG, Transport Ministry, INOCAR and National Park Guides. Scientific publications shared with the local community, Guides, GNPD, ABG, Transport Ministry and INOCAR and MPA management authorities, and international audiences via the internet.

1. Background and Justification:

Marine biological invasions occur worldwide due to global trade, transport and tourism. Every year invasions increase through the effective violation of natural barriers, such as currents, land masses and temperature ranges that in the past restricted them to certain areas. (Seebens, 2013; Hilliard, 2004). These invasions are causing noticeable impacts on the environment, the economy and health all around the world. The possible invasion by marine species of the Galapagos Marine Reserve (GMR), given the connectivity that exists with the Eastern Tropical Pacific (ETP), the increase in marine traffic, and possible climate changes, is a reality that cannot be ignored.

The Galapagos Marine Ecosystem is unique due to the different currents that influence the islands and the connectivity to the Eastern Tropical Pacific (ETP). This oceanic framework is considered largely responsible for the colonization of the islands that led to the evolution and the presence of the diverse species that exist there today. Oceanic currents heavily influence trans-oceanic dispersal, and enable species to be dispersed between widely separated areas, especially species capable of long distance larval transport (Hickman, 2009).

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, 2002; Hulme, 2009) and it is estimated that 10,000 species are transported around the world in ballast water every day, due to increasingly larger and faster cargo ships (De Poorter 2009; Hutchings, et al. 2002; Bax et al. 2003). The increase in marine traffic in and through the GMR and ETP and to mainland Ecuador increases the threat of marine invasive species entering and spreading within the GMR.

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 El Niño Southern Oscillation (ENSO) events, greater intensity and frequency of extreme weather events, including sea surface temperature, thermal shocks and increased precipitation/runoff, will affect vital aspects of the marine environment and enable invasive species to become established and expand more easily than in a stable system capable of resisting an invasion. ENSO events can often have devastating effects on the flora and fauna killing or displacing species from their natural habitats, increasing the likelihood of transport, introduction or invasion by non-native species.

In 2012, the Charles Darwin Foundation (CDF) in collaboration with the University of Southampton, England, was successful in securing two years of full project funding plus a third year's partial funding for work with marine invasive species, from the UK Government fund The Darwin Initiative. The Principal Investigator of the project Inti Keith also secured funding from the Rufford Foundation (UK). In addition CDF successfully secured counterpart funding from Galapagos Conservancy for the 3rd year of the project. Successes to date include:

- List and background information of currently established marine invasive species in the GMR
- List and background information of marine invasive species presenting a high potential risk of arrival to and invasion of the GMR

- Multi-institutional coordination of actions including monitoring of port facilities in Galapagos and the mainland
- Directed searches of marine invasive species using SCUBA in different sites of the GMR.
- Identification of marine traffic to and from Galapagos and associated risks
- Initial stages of oceanographic modeling of the currents in the GMR to understand dispersion risks
- Capacity building of local students and government institutional staff
- Presentation of work at the 8th International Conference on Marine Bioinvasions 2013
- Outreach material such as informative posters and identification factsheets for the public and institutions
- A presentation of the project and the risks associated with marine invasive species to the GMR presented to 500 Galapagos National Park guides in order to raise awareness and knowledge of this new threat to the GMR
- Didactic and informative material published on GNPD and ABG web pages.
- Keith, I., Dawson, T., Collins, K., Banks, S. (2014). A case for additional research, improved management and analysis of current and new policy for Marine Invasive Species in the GMR. Galapagos Report.
- Risk assessment profiles for the potential invasive species
- Working with local institutions on risk assessments and control measures for incoming marine traffic
- National and international boat inspections and training of local institution staff members
- Presentation of work at the International Marine Conservation Congress 2014.

Upcoming activities and results:

- Economic impact assessment of marine invasive species already present in the GMR and the threat of the identified potential marine invasive species that could arrive
- Campaign for private yachts entering the GMR to prevent introductions of marine non-native species
- Outreach programs with schools and the local community
- Manuscript: Marine Bioinvasions of the Galapagos: The Introduced and Cryptogenic Marine and Estuarine Animals and Plants of the Galapagos Archipelago – A preliminary assessment. Carton, J.T & Keith, I.
- Manuscript: Marine Bioinvasions, Connectivity and the Galapagos Marine Reserve. Keith, I., Dawson, T., Collins, K.
- Manuscript: The Invasive Algae *Caulerpa racemosa* var. *cylindracea* in the Galapagos Marine Reserve. Tompkins, P., Keith, I.
- International Workshop on Marine Bioinvasions of Tropical Island Ecosystems. February 2015.

2. Project 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. The topic of Marine Invasive Species is recognized within the Galapagos Conservancy Conservation Challenges as one aspect of the overarching Invasive Species Challenge. This project looks to continue the important work done for the prevention of marine invasive species in the GMR and to look in more depth at the possible vectors that can transport these species, such as climate change and ENSO events, marine traffic and connectivity within the ETP.

3. Methods

Marine settlement plates

Many marine invasive species are considered to be "hitchhikers" because they attach to the bottom of hulls and get transported around the world. They are considered to be fouling organisms. When the infected boats are in port and the reproductive adults of the attached species spawn and produce larvae, these settle on and around the docks and pilings of ports. This is why ports are very susceptible to being colonized by non-native species from around the world and why they are a great place to look for marine invasive species. The GMR has five main ports that are being visited more each year by yachts coming from different national and international ports and there are 70 terrestrial and 75 marine visitor sites in the Galapagos National Park that are visited on a daily basis by tour operators leaving from these five ports.

Settlement plates will be installed at mainland ports and at the 5 main docks of the populated islands as well as at a number of sensitive sites that are highly susceptible to ENSO events, have high percentage of daily traffic and are shown by marine currents dispersal monitoring to be at risk. 10 PVC plates will be placed using SCUBA on each dock and left for a period of 3 months, at the end of this period they will be collected and analyzed in the laboratory and repeated. A comparison of hot/cold season recruitment will be conducted.

In addition if possible, we would like to install some PVC plates on the hulls of the cargo boats for a period of 3 months to observe the difference of being exposed to rough conditions and to the natural barrier that is the river Guayas.

Protected bay areas

Through the research that has been carried out so far on marine invasive species in the GMR, a significant number of protected bay areas have been identified as sensitive areas for invasion, specifically by the green algae *Caulerpa racemosa var. Occidentalis.* This alga competes for space and can alter fundamental ecological processes such as sedimentation and nutrient cycles.

Monitoring of these bays consists of using a PVC quadrant of 0.5 x 0.5m ($0.25m^2$). Each quadrant has a grid of 5 x 5cm constructed with polypropylene twine with 81 intersection points. The quadrant is placed every 5m along a 50m transect and every time the algae falls in the intersections it is counted to determine the abundance.

Stakes will also be placed in different locations to measure the growth of *Caulerpa racemosa* and cameras will be placed in different locations to record predation of this species by different species of fish.

Management of Ballast water

Work with the Galapagos National Park Directorate (GNPD), the Ecuadorian Biosecurity Agency (ABG) and the team in charge of the new re-zoning of the GMR to insure that there are regulations in place for the present and future regarding ballast water.

Risk Assessments

Work with the Ministry of Transport and WildAid to create a risk assessment analysis from Panama, Manta, Salinas and Guayaquil in Ecuador.

4. Integrating Objectives, Project Components, Expected Results, and Impacts (use matrix):

Project Components (activities)	**Expected Results**	**Expected Impacts**
Objective 1: Show the connectivity that exists through marine traffic and set up long term monitoring program for local decision makers		
Activity 1: Risk analysis of each port looking at the origin and type of traffic that arrives. Working with the Ministry of Transport and WildAid.	• Technical reports to government agencies (GNPD, ABG • Online dataset	**Short-term**: Knowledge of where possible invasions could come from. **Long-term:** Improved management policy for alert response of marine invasive species at local and national level
Activity 2: Install settlement plates in 5 main ports and in selected areas around the GMR and on cargo boats traveling from the mainland	• Training of PNG and ABG staff • Scientific publication • Contribution to CDRS marine collections	**Short-term**: Identification of species arriving to the GMR. **Long-term:** GNPD establishes long term monitoring program and/or can continue to enforce management and control measures
Objective 2: Identify sensitive areas to climate change, ENSO events and marine traffic		
Activity 1: Monitor specific sites where transmission of marine invasive species could take place	• Technical reports to government agencies (GNPD, ABG • Sensitivity maps • Protocols	**Short-term:** Identify hotspots for future monitoring that can be used for different analysis of threats to the GMR. **Long-term:** GNPD establishes long term monitoring program and/or can continue to enforce management and control measures
Activity 2: Build capacity within institutions for diving, species identification and monitoring techniques	• Training of GNPD and ABG staff • Scientific publication	**Short-term:** improvement of communication and sharing of knowledge and understanding with local

Project Components (activities)	Expected Results	Expected Impacts
		authorities **Long-term:** Improve knowledge for the local stakeholders to be able to apply management decisions
Activity 3: Run an awareness campaign with schools and local community	• Increased local knowledge and understanding of the risks of invasive marine species to the GMR • Posters and visual aids • Education presentations to school children • Outdoor activity for community	**Short-term:** Dissemination and increased awareness of the possible impacts marine invasive species can have on the GMR **Long-term:** Show commitment to the community and the authorities of a long term prevention and rapid response program that is necessary for good management of a marine reserve
Objective 3: Work with local authorities to insure regulations for ballast water		
Activity 1: Have meetings and/or workshop with GNPD and ABG and the group in charge of re-zoning of the GMR Activity 2: Work with WildAid in continental Ecuador to ensure regulations for boats leaving from ports in the mainland comply with regulations for the GMR	• Insure no ballast water can be exchanged in the GMR or close to the GMR • Technical report	**Short-term:** Integration with new GMR re-zoning **Long-term:** Implementation of an important regulation for the conservation of biodiversity in the GMR
Objective 4: Work on proposals to secure additional funding		
Activity 1: Apply to Darwin Initiative for Post Project funding to continue this important project Activity 2: Look for more possible organizations that would like to fund this project	• Positive outcome in securing additional funds	**Short-term** and **Long-term**: By winning more proposals we will be able to establish continuity of work with GNPD and ABG through monitoring practices and appropriate management skills

5. **Deliverables and Application:** The marine invasive species project requires a joint effort and coordination of activities among personnel of the GNPD, ABG, Ministry of Transport, INOCAR and CDF, showing how well-planned inter-institutional collaboration can lead to positive results replicable to other projects in the Galapagos. This project is creating the basis for implementing a management and control strategy of marine invasive species in Galapagos, serving as a replicable model to be used for other MPAs in mainland Ecuador and

the region. The planned workshops with National Park guides and local authorities will promote the idea of prevention, early detection and rapid response in order to protect the biodiversity of the GMR. The proposed idea of doing research and combining it with citizen science specifically with school children will increase the knowledge of this developing issue and improve relations between the scientific community and the teaching community, which is key for the government of Ecuador and CDF.

Deliverables / Products / Measurable Outcomes	**Target Authority and/or Application**
Map of marine traffic and the hotspots of possible transmission from international ports	GNPD, ABG, Transport Ministry and INOCAR
Risk assessment reports	GNPD, ABG, Transport Ministry and INOCAR
Technical reports to government agencies	GNPD, ABG
Technical participatory workshops with government agencies	GNPD, ABG, Transport Ministry and INOCAR
Outreach materials	Community, Guides, GNPD, ABG, Transport Ministry and INOCAR and MPA management authorities
Educational campaign	Ministry of Education, school children and teachers
Training Courses and workshops	GNPD, ABG, Transport Ministry, INOCAR and National Park Guides
Scientific publications	Community, Guides, GNPD, ABG, Transport Ministry and INOCAR and MPA management authorities, international awareness