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Editorial

Evolving Marine Biosecurity in the Galapagos Islands

Marnie L. Campbell[1]*, Inti Keith[2,3], Chad L. Hewitt[4], Terry P. Dawson[3] and Ken Collins[5]

[1]*Environmental Research Institute, University of Waikato, Hamilton, New Zealand*
[2]*Charles Darwin Foundation, Galapagos Islands, Ecuador*
[3]*School of the Environment, University of Dundee, Dundee, United Kingdom*
[4]*School of Science, University of Waikato, Hamilton, New Zealand*
[5]*Ocean and Earth Science, University of Southampton, United Kingdom*

E-mail: marnie.campbell@waikato.ac.nz (MLC), inti.keith@fcdarwin.org.ec (IK), chewitt@waikato.ac.nz (CLH), t.p.dawson@dundee.ac.uk (TD), kjc@noc.soton.ac.uk (KC)

**Corresponding author*

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Some of my co-authors and I have just returned from one of the paradises on earth and a natural history mecca – The Galapagos Islands, Ecuador. We participated in (MLC, CLH) or hosted (IK, TD, KC) the 1st Tropical Island Marine Bioinvasions Workshop convened at the Charles Darwin Research Station. From a terrestrial standpoint, the Ecuadorian government's biosecurity for the most part is intelligent (but see Gardener et al. 2010), well organised and seems to be effective, with a number of publications detailing introduced terrestrial plant (e.g., Buddenhagen 2006; Jager and Kowarik 2010) and animal (e.g., Cruz et al. 2005; Carrion et al. 2011) eradications and impacts (e.g., Schofield 1989; Itow 2003; Renteria et al. 2012; Kueffer et al. 2010), invasion risks (e.g., Gottdenker et al. 2005), and ecosystem restoration, management and conservation (e.g., Gibbs et al. 1999; Causton et al. 2006). Yet, as with so many other systems, marine biosecurity lags behind (a quick review of the literature shows no marine introduction publications) and is consequently less well managed, but not for a lack of effort.

The current workshop was designed to build upon two previous workshops that considered marine bioinvasions in the Galapagos Archipelago: The first workshop occurred in 1987 and was jointly convened by the Instituto Oceanografico de la Armada (INOCAR) and the Woods Hole Oceanographic Institution in 1987 to examine the roles of science in the management of coastal resources (Gaines and Andrade 1988). In 1988, Dr Jim Carlton drew attention to the ability to pro-actively consider introduced marine species in the management plan for the Galapagos Islands (Carlton 1988), noting that no other marine park plan, at that point in time, had considered marine invasions in their plans (biosecurity was yet to be a recognised phrase). This was in effect a "call to arms" opportunity.

The second workshop, funded by Global Environment Facility (GEF) and convened by the Charles Darwin Foundation, occurred 20 years later and explicitly focussed on marine biosecurity risks associated with vectors (transport mechanisms) as part of a wider programme examining biosecurity protection of the islands. This second workshop aims included capacity building and training on marine biosecurity risk assessment with a vector management focus, facilitated by Professor Chad Hewitt, Dr Carmen Primo and Professor Marine Campbell (Campbell and Hewitt 2007). The outcomes and recommendations of the second workshop were:

- **Information Needs:** These are associated with knowledge of the receiving or donor region, the source regions, transport mechanisms (i.e., vectors), and the transport pathways:
  - **Establish a baseline of known marine introduced species currently in the Galapagos Islands.** This will allow for management actions to be taken into the future. Baseline studies

provide the ability to manage prevention and reliably make response decisions when new organisms are found. If a species is already established and widespread, but unrecognized until it is brought to the attention of authorities, significant time delays and expenditure of funds are likely before arriving at a management decision. A number of survey and surveillance techniques exist for introduced marine species and are summarized in Campbell et al. (2007).

- **Encourage dive and tourism operators to participate in surveillance for non-native species.** Develop outreach and education materials to circulate to operators, highlighting risks and behaviours that can cause harm. Engagement with the community to provide opportunistic surveillance has been successful in marine biosecurity (e.g., Delaney et al. 2008) and reef monitoring programs (e.g., Beeden et al. 2014) that provide early warning for pests such as the Crown of Thorns starfish.
- **Baseline evaluations of Ecuador mainland source sea ports and container terminals (San Lorenzo, Esmeraldas, Bahia De Caraquez, Manta, La Libertad, Guayaquil, and Puerto Bolivar).** Source region information was difficult to obtain in 2007, however via interviews it became evident that many vessels that arrive into the Galapagos are from mainland Ecuador. Therefore, the knowledge of which species have been introduced into these ports and terminals is needed to develop robust risk assessment that examines the threat of introduced species arrival posed to the Galapagos Islands.
- **Collection and assessment of vessel arrival information.** In 2007, the current level of information concerning vessel arrivals into the Galapagos Islands and their origin was insufficient to undertake a complete risk analysis across all vessel transport types that restricted the ability to determine the highest risk components. Information needs include the vessel origin, maintenance history, last port of call (preferably going back to at least the last five ports of call; Hewitt et al. 2011a,b), number of days in port, size of vessels (length, width, draft), and last dry dock period.

- **Vessel management**: It is widely recognized that vessels are responsible for the majority of marine species introductions. Either hard or soft regulatory frameworks can be put into place to require or encourage best practice for ballast water management and biofouling reduction. To aid with this we suggest the following vessel focused recommendations:

- **All vessels carrying ballast water into the Galapagos should either undertake ballast water exchange at sea in compliance with the IMO Guidelines, or not discharge while in the Galapagos Islands.** Ecuador should consider adoption of the International Convention for the Management and Control of Ships Ballast Water and Sediments.
- **Vessels should be encouraged or required to undertake proper vessel hull maintenance.** Outreach and education programs with permitting for vessels wishing to enter the Galapagos Islands including information about how to undertake best practice hull maintenance.
- **Undertake periodic inspection of hulls from the surface to determine level of fouling.** This simple technique may aid in identifying high risk vessels and allow for correction of behaviours. Vessels should be met on entry and hulls inspected in-water and from the surface.

- **GIS risk mapping (risk management):** We recommend the use of geospatial tools to help understand what ecological, economic, social and cultural values are found in the Galapagos Islands, how these values change over time, and how to contain a non-native species incursion (if one occurs) is crucial. This would require:
- **Developing a GIS of high marine values of the Galapagos Islands to enable rapid assessment of impacts.**
- **Identify stakeholder groups to undertake consequence (impact) analyses.**
- **Determine current distribution of introduced marine species in the Galapagos Islands.**

From 1997 till 2007, vessels from nine IUCN source provinces (Australia and New Zealand, Baltic, Caribbean, Mediterranean, Northeast Atlantic, Northwest Atlantic, Northeast Pacific, Southeast Pacific, and the South Pacific) entered the Galapagos Marine Park waters (Campbell and Hewitt 2007). Typically, these vessels bought tourists to destinations where they joined smaller tourist class vessels (16–100 passengers) that would island-hop, taking in the marvellous wildlife scenes, hiking to volcanic ridges, snorkelling and diving. Vessel types that travelled to and within the islands included: international tourist vessels; international cruise liners; local tourist vessels, scientific expeditions; cargo vessels, naval vessels and; illegal fishing vessels (Campbell and Hewitt 2007). During this time, few tourists stayed on islands, with most visiting the ports of Santa Cruz (Puerto Ayora) and San Cristobal on the way to their local tourist live-aboard cruise vessels.

In 2015 at the recent workshop, we have witnessed a changing marine biosecurity focus in the Galapagos Islands. Evident changes that have biosecurity implications are:

- **Altered pathways and exposure to threats:**
  - No longer do international cruise vessels come into the Galapagos waters, with international tourists flying in and then joining cruises or staying on island; island based tourism is expanding (de Groot 1983; Baine et al. 2007), with many inter-island day trips now available for island staying tourists;
- **Increased site access**:
  - The number of tourist sites available has increased from 35 land sites only in 1983 (de Groot 1983) to include 169 marine sites in 2014 (Dirección del Parque Nacional Galápagos 2014), with a consequence that the connectivity between islands has increased dramatically;
- **Pre-border and border inspections**:
  - Vessels entering the islands are subject to hull inspections to help manage the transfer of introduced species from mainland Guayaquil to the Galapagos Islands;
  - Vessels that fail hull inspections must leave the Galapagos Marine Reserve (GMR) waters and be cleaned before re-entry into the Galapagos;
  - Annual marine traffic analysis occurs to examine the cargo boats and oil tankers that commute between the islands, and mainland Ecuador, as well as tourist, fishing, patrol, and private boats that can arrive from mainland Ecuador and international ports.
- **Post-border species surveys and surveillance:**
  - Annual introduced marine species monitoring occurs at the 5-main ports in the GMR;
  - Directed searches for marine invasive species at key sites around the GMR; and
  - Deployment of settlement plates in the port of Santa Cruz in 2015, using the Smithsonian Environmental Research Center (SERC) methodology. This will enable comparisons with other international locations that also use settlement plates. Settlement plate deployment will be extended to the other four ports in the GMR, and later to key visitor sites around the GMR and ports in mainland Ecuador.

Future expansion of biosecurity work is also planned, including:

- Examining the potential climate change or possible implications of ENSO events within a marine invasion context;
- The use predictive models to determine what species may arrive in the GMR and to determine natural connectivity in the Eastern Tropical Pacific via oceanic modelling;
- Preparing for a range of response plans for potential marine invasive species should they arrive in the Galapagos;
- Strengthening multi- institutional relationships between the Charles Darwin Foundation and local Government institutions (such as the Dirección del Parque Nacional Galápagos [GNPD] and Agencia de Regulation y Control de la Bioseguridad y Cuarentena para Galapagos http://bioseguridadgalapagos.gob.ec [ABG]) to create protocols for hull inspections and movement of dive/snorkel equipment within the GMR; and
- The creation of a (marine focus) rapid response team that involves the local institutions.

Hence, we see that many recommendations from 2007 have been put in place and as a consequence the marine biosecurity focus and actions have evolved. But has it evolved enough? Increasing tourist pressure and interconnectivity between Galapagos Islands has led to this workshop where one of the goals was to develop a marine biosecurity management plan that would help ready the Galapagos Island environmental managers for the prospect of an invasion. Plans for governance, communication, rapid response decision tools, risk analyses, tropical marine island (northern hemisphere) bioinvasion trends and action plans for pest species such as *Carijoa riisei* (already present on the mainland coasts and at marine protected areas nearby) were discussed and initiated.

It's now with further expectation that we watch the research and publication space in anticipation of the outcomes of this workshop and to see the further changes to the evolving management of introduced species in the Galapagos Islands. While we wait, we can contemplate how Ecuador is a good role model for a comprehensive biosecurity system that extends across terrestrial, freshwater and marine ecosystems, and actively engages with many agencies. As such, the Galapagos Islands biosecurity system provides an opportunity for us all to continue learning and to improve how introduced species are managed for our future generations.

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