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Conservation Letter

Robots as vectors for marine invasions: best practices for minimizing transmission of invasive species via observation-class ROVs.

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Abstract

Remotely operated vehicles (ROVs) present a potential risk for the transmission of invasive species. This is particularly the case for small, low-cost microROVs that can be easily transported among ecosystems and, if not properly cleaned and treated, may introduce novel species into new regions. Here we present a set of 5 best-practice guidelines to reduce the risk of marine invasive species introduction for microROV operators. These guidelines include: educating ROV users about the causes and potential harm of species invasion; visually inspecting ROVs prior to and at the conclusion of each dive; rinsing ROVs in sterile freshwater following each dive; washing ROVs in a mild bleach (or other sanitizing agent) solution before moving between discrete geographic regions or ecosystems; and minimizing transport between ecosystems. We also provide a checklist that microROV users can incorporate into their pre- and post-dive maintenance routine.

Resumen

Robots teledirigidos, particularmente de tamaño reducido y coste económico, representan un riesgo para la transmisión de especies invasoras. Los pilotos pueden mover estas herramientas sumamente portables entre ecosistemas, y si no están debidamente limpiados e desinfectados, pueden introducir especies invasoras en nuevos hábitats. Aquí presentamos un conjunto de 5 recomendaciones para reducir el riesgo de la transmisión de especies invasoras. Estas recomendaciones incluyen: La educación de los pilotos en materia de especies invasoras y su efecto negativo en un ecosistema; Inspección visual del robot anterior y posterior de cada inmersión; La limpieza del robot con agua dulce tras cada inmersión; La limpieza del robot en una solución de lejía u otro agente esterilizador, antes de moverlo entre ecosistemas; Minimizando su transporte entre ecosistemas. Con todos esto, proveemos a los pilotos de los robots teledirigidos una lista de chequeo que deben incorporar en sus programas de mantenimiento y operación.

Keywords: microROV, invasive species, robots, conservation, OpenROV

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Introduction

The introduction of invasive species into non-native ecosystems is among the most challenging issues facing marine management [1,2]. Once invasive species colonize a new habitat, they are notoriously difficult to extirpate [3,4]. Lacking natural predators, invasive species can be exceptionally good at outcompeting native flora fauna for resources, as has been seen among zebra mussels in the Great Lakes [5], lionfish in the western Atlantic [6], kelp in Patagonia [7], and green crabs in New England [8]. These invaders can have profound negative effects and may permanently alter their new ecosystems.

There are numerous potential vectors for species invasion, including ship ballast, exotic animal trade, and accidental or intentional import [9]. Recently, researchers identified a novel vector for introduction of non-native species: submersible assets like remote operated vehicles (ROVs) and human occupied vehicles (HOVs). In 2012, limpets from the East Pacific Rise were transported 635 kilometers south via the *DSV Alvin* [10]. In the western Pacific, an unidentified fungal infection was hypothesized to be the result of transmission via research submersibles [11]. Though no species invasion has, as yet, been directly attributed to work-class research submersibles, these are among the most heavily scrutinized underwater vehicles currently in operation and undergo thorough inspection and cleaning following each dive. With tens of thousands of submersible vehicles operating around the world for research, industry, exploration, and recreation, there is a tremendous potential for the introduction of invasive species via these high-tech vectors.

As the cost of submersible remotely operated vehicles (ROVs) decreases, they are becoming more accessible to a broad user base, including conservation, management, and scientific organizations (see [12] for a brief overview of the state of the art for low-cost ROVs for science and conservation). MicroROVs—the smallest size class of ROVs—are often light enough to be transported as carry-on luggage, facilitating easy transfer and deployment. These robots are ideal for many applications, particularly in small island developing states, where their portability, low-cost, and simple design are optimal for use in regions with limited financial and infrastructure resources.

Among the most capable microROVs is the OpenROV, an open-source ROV that can be built from a kit or purchased fully assembled. The OpenROV has seen significant growth in the last two years, with over 1,500 OpenROVs distributed to 35 countries (David Lang, personal communication). One particularly well-travelled OpenROV dove in Greenland, Cuba, California, and Papua New Guinea (Bergman, personal observation). While the OpenROV has incredible potential as a tool for underwater conservation, research, and education, it also, if not properly treated, has the potential to act as a global vector for the transport of invasive species.

In October/November of 2014, we conducted a program on marine ecology via remote observation in Kavieng, Papua New Guinea as part of the Nautilus Minerals' Marine Science Short Course, a capacity building and community engagement initiative of Nautilus Minerals. This program focused on bringing the skills and tools of microROV operation to students from Papua New Guinea and other western Pacific island nations (Fig. 1). During and following this three-week program, we developed a series of best practice guidelines for minimizing the transmission of invasive species via OpenROV and other microROV platforms (summarized in Table 1).

Fig. 1. OpenROV as implemented during the Nautilus Minerals Marine Science Short Course in Kavieng, PNG. Clockwise from top left: Students assemble OpenROV version 2.6 during the MSSC; Forward view of OpenROV version 2.6 in Kavieng Lagoon; Students deploy OpenROV version 2.6 from a small boat in Kavieng Lagoon; Rearward view of OpenROV version 2.6 examining seagrass habitat. Photos by A. Freitag and D. Fretz

1. Education and awareness.

End users should be educated about the potential for invasive species transport in order to make sound decisions regarding the deployment and decontamination of their ROVs. General information is available from sources such as the United State Department of Agriculture, which maintains a comprehensive database of all known invasive species, both within the U.S. and globally [13], although this resource is skewed towards terrestrial and freshwater invasions by plants, vertebrates, and large invertebrates and contains few, if any, records of microscopic, microbial, and viral invasions. There is currently no central, global database of marine invasive species. To increase literacy among microROV operators, we encourage ROV manufacturers to include briefings on broad principles regarding invasive species and best practices to mitigate potential vector transmission with new ROV shipments.

Users should therefore also consult key available scientific literature, such as Allendorf and Lundquist [2], Lowry et al. [14], and Lovell and Stone [15], which provide a broad, overview of the causes, effects, and economic impacts of species invasions, and the textbook *Invasive Species: What Everyone Needs to Know* [16] to gain a broader appreciation for the processes that enable an introduced species to become invasive. We recognize that detailed local knowledge of invasive species may often be lacking, but where information is available, it should be incorporated into expedition planning.

2. Visual inspection of each robot prior to and immediately following deployment.

Prior to any deployment, ROVs should be inspected to determine whether any visibly observable biological material is present on the vehicle. Users should pay extra attention to the o-ring seals, where tiny grains can become lodged, around the thrusters where sea grass and other filamentous organic matter can become entangled, and inside motor bells where material is hard to detect. After each dive, users should perform the same visual inspection, returning any organic matter to its place of origin to prevent secondary uptake (secondary uptake occurs when material that has been removed from the ROV is subsequently attached to other objects, such as clothing, shoes, or equipment). Users should also inspect their shoes, clothing, and any gear to confirm that no organic material will be transmitted between sites.

3. Freshwater soak prior to beginning an expedition and freshwater rinse at the conclusion of each dive.

A freshwater rinse can be an effective treatment for preventing marine invasive uptake. In sensitive marine environments, such as Hawaii's Papahānaumokuākea Marine National Monument, divers are required to soak their SCUBA gear in freshwater for 24 hours prior to entering the monument [17]. ROV operators should adhere to this standard practice by soaking MicroROVs in freshwater for 24 hours prior to transport between different geographic regions.

Good microROV maintenance already includes rinsing ROVs in clean, fresh water following each dive. This will help remove salt and minimize corrosion of critical components. A freshwater rinse can also help remove any organic matter and dislodge potential invasive vectors. Fresh water is also lethal to many marine species, including microscopic organisms that cannot be detected during visual inspection. As transportation of rinse-water can serve as a potential source of secondary uptake, water for freshwater rinses should be acquired and prepared as close to the dive site as possible (if freshwater is not available nearby, ROV users may need to carry in additional water for rinsing) and disposed of at the same location.

4. Bleach soak before transporting robots between sites or preparing for long term storage.

Following a successful series of dives at a discrete site, and after examining submersible elements and providing a sterile rinse, microROVs should be thoroughly washed using a weak bleach solution or other readily available sanitizing agent. Based on the guidelines for SCUBA divers in the Papahānaumokuākea Marine National Monument [17] which have been shown to be both effective in minimizing invasive species transport and non-destructive to sensitive equipment, ROV operators should soak their microROVs in a dilute bleach solution (7.75 mL household bleach per liter of water) for no more than 15 minutes to avoid damage to o-rings from long-term bleach exposure. This will kill many microbial and viral vectors that could be transported between sites. This step is particularly important when microROVs will be deployed in different biomes or in different geographic regions (*e.g.,* transitioning from a coastal lagoon to an alpine lake).

5. Minimize transport between ecosystems.

No mitigation strategy can be completely effective, and even a small number of potentially invasive individuals can be catastrophic (the Atlantic lionfish invasion has been traced to the introduction of a relatively small founder population: [18]). The most effective method of avoiding species introduction, therefore, is to limit the geographic and ecologic range of each robot. The low cost and high availability of the OpenROV and other microROVs are conducive to minimizing risk by dedicating individual robots to discrete ecosystems. By dedicating robots to specific ecosystems (or even specific bodies of water), responsible users can eliminate the possibility of invasive transport. Barring that, users can minimize the amount of transport between ecosystems by planning their expeditions such that all dives in a specific site are completed contiguously, with the fewest possible transitions between geographically or biologically distinct regions.

In cases where robots must be carried internationally, users should declare their ROVs at customs checkpoints and provide an opportunity for host nations to implement their own disinfectant procedures. Low-cost microROVs such as the OpenROV provide an incredible opportunity for ocean research and exploration. They can be powerful tools for conservation, education, and outreach, but they also carry with them the potential to cause environmental harm through the transport of non-native and potentially invasive species. By following this set of guidelines, microROV users can reduce the risk of species introduction. We encourage all microROV users to incorporate these guidelines into their preparation, pre-, and post-dive maintenance.

Table 1. Checklist for microROV users traveling between regions where there is a risk of transporting potential invasive species.

During expedition preparation	Before each dive	After each dive	Prior to travel between discrete sites
Familiarize yourself with the most recent scientific literature on current species invasions and potential risks in the geographic regions that you are traveling to and from. Thoroughly clean and sanitize microROVs and any associated equipment prior to departure. Soak microROV in freshwater for 24 hours prior to departure	Visually inspect all microROV components and associated gear for organic material and other potential vectors for species invasion. Dispose of any material in such a way as to prevent secondary uptake.	Rinse microROV in sterile, fresh water to remove any collected organic material. Dispose of any material in such a way as to prevent secondary uptake. Visually inspect all microROV components and associated gear for organic material and other potential vectors for species invasion. Dispose of any material in such a way to prevent secondary uptake.	Soak microROV in dilute bleach solution

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References

[1] Molnar, J.L., Gamboa, R.L., Revenga, C., Spalding, M.D. (2008) Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment* 6:485–492.

[2] Allendorf, F.W. and Lundquist, L.L. (2003) Introduction: Population Biology, Evolution, and Control of Invasive Species. *Conservation Biology* 17:24–30.

[3] Strayer, D.L., Eviner, V.T., Jeschke, J.M., Pace, M.L. (2006) Understanding the long-term effects of species invasions. *Trends in Ecology and Evolution* 21:645–651.

[4] Panetta, F.D. (2006) Evaluation of weed eradication programs: containment and extirpation. *Diversity and Distributions* 13:33—41.

[5] Ricciardi, A. (2003) Predicting the impacts of an introduced species from its invasion history: an empirical approach applied to zebra mussel invasions. *Freshwater Biology* 48:972–981.

[6] Albins, M.A. and Hixon, M.A. (2011) Worst case scenario: potential long-term effects of invasive predatory lionfish (*Pterois volitans*) on Atlantic and Caribbean coral-reef communities*. Environmental Biology of Fishes* 96:1151–1157.

[7] Casas, G., Scrosati, R., Luz Piriz, M. (2004). The Invasive Kelp *Undaria Pinnatifida* (Phaeophyceae, Laminariales) Reduces Native Seaweed Diversity in Nuevo Gulf (Patagonia, Argentina). *Biological Invasions*, 6(4), 411–416.

[8] Grosholz, E.D. and Ruiz, G.M. (1996) Predicting the impact of introduced marine species: Lessons from the multiple invasions of the European green crab *Carcinus maenas*. *Biological Conservation* 78:59–66.

[9] Bax, N., Williamson, A., Aguero, M., Gonzalez, E., Geeves, W. (2003) Marine invasive alien species: a threat to global biodiversity. *Marine Policy* 27:313–323.

[10] Voight, J.R., Lee, R.W., Reft, A.J., Bates, A.E. (2012) Scientific Gear as a Vector for Non-Native Species at Deep-Sea Hydrothermal Vents. *Conservation Biology* 26:938–942.

[11] Van Dover, C.L., Ward, M.E., Scott, J.L., Underdown, J., Anderson, B., Gustafson, C., Whalen, M., Carnegie, R.B. (2007) A fungal epizootic in mussels at a deep-sea hydrothermal vent. *Marine Ecology* 28:54–62.

[12] Selbe, S. (2014) Exploration to Conservation Through Underwater Robotics*. National Geographic Voices* [Online]. Available: http://voices.nationalgeographic.com/2014/12/10/exploration-to-conservation-through-underwater-robotics/ [Accessed: 12-Feb-2015].

[13] USDA (2014) Invasive Species Resource Library [Online] Available: http://www.invasivespeciesinfo.gov/resources/main.shtml. [Accessed: 09-Mar-2015]

[14] Lowry, E., Rollinson, E.J., Laybourn, A.J., Scott, T.E., Aiello-Lammens, M.E., Gray, S.M., Mickley, J., Gurevitch, J. (2012) Biological invasions: a field synopsis, systematic review, and database of the literature. *Ecology and Evolution* 3:182–196.

[15] Lovell, S.J. and Stone, S.F. (2005) The Economic Impacts of Aquatic Invasive Species: A Review of the Literature [Online] Available: http://yosemite.epa.gov/EE/epa/eed.nsf/ffb05b5f4a2cf40985256d2d00740681/0ad7644c390503e385256f8900633987/$FILE/2005-02.pdf [Accessed: 12-Feb-2015].

[16] Simberloff, D. (2013) Invasive Species: What Everyone Needs to Know, (1st edn) *Oxford University Press*. New York, NY.

[17] NOAA (2006) Northwest Hawaiian Islands Marine National Monument: A Citizen's Guide [Online] Available: http://www.papahanaumokuakea.gov/pdf/Citizens_Guide_Web.pdf [Accessed: 09-Mar-2015].

[18] Hamner, R.M., Freshwater, D.W., Whitfield, P.E. (2007) Mitochondrial cytochrome b analysis reveals two invasive lionfish species with strong founder effects in the western Atlantic. *Journal of Fish Biology* 71:214–222.