Towards Guidelines for Mechatronic Ecosystem Monitoring and Management

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Abstract

Mechatronic devices installed as Ecosystem Management and Monitoring Units, EMUs, are an emerging trend with the potential to improve our understanding of natural and agricultural ecosystems. They may improve biodiversity and provide socio-economic benefits, but if poorly implemented such technology can undermine conservation efforts, damage habitat and drive people into poverty. This article proposes draft guidelines that help to ensure EMUs embedded within ecosystems generate more global benefit than harm, preserve the aesthetic and cultural value of their environment, and kill organisms only as a last resort.

Introduction

Potentially controversial mechatronic technology is being embedded in ecosystems to build understanding, to fill ecological niches and to perform ecosystem services. For brevity we refer to all such devices as *EMU*s – *Ecosystem Monitoring/Management Units*. Robot-like EMUs have been surveyed previously (Grémillet et al. 2012, Wynsberghe and Donhauser 2017, Frank Bonnet et al. 2019); a lighter but more inclusive overview is presented shortly. The extent to which unintended and undesirable EMU ecosystem interference has already occurred is arguably minimal. But as we increasingly intervene in our planet's natural environments, we ought to anticipate and systematically avoid problems generated by EMU deployment. The purpose of this article is therefore to begin constructing and discussing guidelines for ecosystem-embedded technology that mitigates threats to the globe's diverse lifeforms caused by anthropogenic pressures, to avert the emerging extinction crisis (Ceballos et al. 2020), for monitoring, or for socio-economic reasons.

Robo-bees. In response to population declines and colony losses among bees and other insect pollinators of horticultural crops, several engineering labs are designing robotic micro unmanned aerial vehicles, *robo-bees*, as substitute flower visitors (Gleadow et al. 2019).

Starfish destroyers. Australia's Great Barrier Reef is a reserve of aquatic biodiversity and a major tourist drawcard suffering under the impacts of climate change, human activity and outbreaks of Crown-of-Thorns Starfish (COTS) that destroy coral. To counter this, submarine robots, *COTSbots*, equipped with lethal syringes have been operated to reduce starfish numbers (Dayoub et al. 2015, Zeldovich 2018).

Salmon sorters. To sort escaped farm salmon from wild fish and prevent interbreeding, a system called *QuadEye* is being set in the Etne River in Norway (Guerrero and Moore 2020). Fish swimming upstream must pass the 4-camera trap where they are photographed and documented. The images are used to train an AI classifier to distinguish between farm escapees for re-capture and wild fish to be set free. Transponder-tagged fish are also detected and appropriately directed.

Intelligent scarecrows. To scare away large flocks of geese and rooks before they damage crop fields, researchers in Denmark are trialing an intelligent scarecrow, *Animan* (Wildlife-Communication-Technologies 2020). The device acoustically monitors its environment to detect the presence of birds. It classifies bird behavior and, in response to this, adapts its own sonic techniques for frightening them away. In this way the device circumvents the usual habituation of birds to a scarecrow's presence.

Animal tags/collars, video/acoustic monitors. GPS tags, aerial drones, rovers, fixed camera traps and microphones widely monitor terrestrial and aquatic ecosystems and the creatures that inhabit them (Blumstein et al. 2011, Cheshire and Uberti 2016, Bonnin et al. 2018, Tabak et al. 2018).

The infeasibility of robo-bees as an approach to satisfy global pollination needs has been raised, but in this case the inadequate critical consideration of ethical and ecological issues by the project engineers and their media teams is particularly alarming (Gleadow et al. 2019). Arguably, this falls beyond their expertise, but it should still be their concern. Why must ecologists and conservationists be left to counter the impact of such misguided "help"? Fortunately, many EMUs, including the non-bee devices above, are co-developed with ecologists – their potential for harm is not always so frightening. But how should we assess this potential for new devices, or existing devices installed under new conditions? There is an urgent need for guidelines for mechatronic interventions in ecosystems to minimise harm. Regulation can ensure units are not developed or installed unless they are likely to have benefits that outweigh their costs.

Guidelines to minimise harm

The life-cycle of any manufactured device has environmental consequences that are often poorly handled (Perkins et al. 2014). Likewise, the human-social implications of new technology are often unanticipated – social media for instance is having surprising impacts on democracy (Jha and Kodila-Tedika 2020). Such possibilities ought to be deeply considered *before* new technology is introduced! Designers must achieve clarity of purpose *before* they finalise and install EMUs. Likewise, if the aim of an EMU is to improve our ability to sustain ecosystems, restore biodiversity, or to improve socio-economic outputs from healthy ecosystem function, it is imperative that designers and users make *substantial* efforts to weigh costs and benefits beyond their own narrow focus. The first and foremost guidelines for any technology, including EMUs, must therefore be to:

1. *Provide greater global benefit than damage.*
2. *Minimise intervention spatially, temporally & systemically.*

The intent to embed EMUs within ecosystems adds complexity to assessing their potential consequences akin to unravelling the human-social implications of technology. The issues are of two essential kinds, those generated by the mere presence of foreign materials and those actively generated by a device's interventions. All guidelines for dealing with these must be subordinate to guidelines 1 and 2.

The introduction of foreign materials in terrestrial or aquatic ecosystems can be managed in the same way as standard litter. If damaged or unretrieved prior to breakdown, EMU materials may pollute physically with electronic circuit boards and components, wire and cord fragments, structural (micro-) plastics, resins, metals and carbon fibre. The ways in which these elements might cause harm are as diverse as biotic-biotic and biotic-abiotic interactions. For instance, components might be ingested if mistaken for prey (a rubber-band for a worm, a flapping robo-bee for an insect) or caught among plant material consumed by herbivores. Moving parts can trap or injure, and hot lamps can incinerate tiny creatures on contact. Battery chemicals, solvents and petroleum oils may leech into soil and water making it uninhabitable and unpotable. These issues are handled by guidelines:

3. *Cause no unintended harm to organisms or habitats.*
4. *Retrieve devices prior to decomposition.*

Side-effects from active EMU intervention in ecosystem dynamics are subtle and hard to anticipate. To see why, we can use past experience in removing, introducing and changing the behavior of biological species. For instance: cane toads introduced to consume native Australian cane beetles (a failure by any measure); bumblebees to pollinate clover in New Zealand; honeybees to provide honey for Australian colonialists; and crops now growing far from their native ranges (Ewel et al. 1999). We have hunted Dodos and Thylacines to extinction (Kyne and Adams 2017). We change wild animal behavior by inadvertently providing alternative food sources, fencing them in/out, clearing land and fragmenting forests with roads and urban development, illuminating the night and dispersing chemicals. Our long experience with the harmful consequences of our activity *should* warn us to tread carefully (Carson 1962). The International Union for the Conservation of Nature (IUCN) publishes numerous guidelines that specifically deal with a host of issues to this point (IUCN 2020). One such document addresses the creation of biological proxies of extinct species via cloning or genome engineering for conservation benefit and is particularly pertinent to the issues discussed here (IUCN-SSC 2016). The document details 38 guiding principles and a set of legal and other considerations, many of which are important details to consider prior to the introduction of EMUs. A commonsense overarching guideline addresses these issues:

5. *Conduct thorough risk assessments for impacts on biotic, abiotic and socio-economic interactions.*

These would include investigations of any alteration to the environment that might interfere with the sensory systems of organisms. But also consider the possibility that a device diverts/attracts, inhibits/promotes or alters any physical, chemical, biological, ecological, cultural or socio-economic process. The tendency for such changes to cascade, accumulate, amplify or decay over time must be explicitly addressed. There is no doubt that the possible range of interactions may be vast, and the job of unravelling them time-consuming, difficult and expensive. It is likely that the sheer complexity of an EMU's potential ramifications might overwhelm a researcher. This isn't an excuse though to skimp on rigorous risk assessments, nor is it a reason to throw up our arms in despair. Instead, we ought to take seriously our responsibilities for ecosystem custodianship, and we must avoid stalling.

Finally, here are two more EMU guidelines worthy of discussion, and upon which entire theses have been written:

6. *Preserve the aesthetic and cultural value of ecosystems.*
7. *Intentionally harm organisms only as a last resort.*

Conclusion

These seven guidelines will be tricky to enforce and expensive and troublesome to abide by. They will often conflict with one another, and there will be disagreements among stakeholders as to which should have priority in specific situations. However, their importance to ensure sustainability of EMUs far outweighs these difficulties. There is a concerning lack of such guidelines in regulatory frameworks at present. It is hoped they promote much-needed cross-disciplinary debate to ensure wide consultation and research prior to embedding mechatronic interventions in ecosystems. As hard as it will be to achieve, we would like for an outcome of this discussion to be intergovernmental regulation. Too much is at stake to leave adherence to good will and the myopic agendas of individual researchers or nations.

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