

## Letter

Cryptic Female  
Choice: A General  
Phenomenon. A  
Reply to EberhardRenée C. Firman,<sup>1,\*</sup>  
Clelia Gasparini,<sup>1</sup>  
Mollie K. Manier,<sup>2</sup> and  
Tommaso Pizzari<sup>3</sup>

A major goal of our review [1] was to critically assess the scope of and empirical evidence for cryptic female choice (CFC) as an agent of evolutionary change in phylogenetically diverse sexually reproducing organisms, as did Eberhard in his influential monograph [2]. This breadth precludes a detailed discussion of individual taxa, for which we refer to more specialised publications [1]. We stand by our general conclusion that while CFC has the potential to be a general phenomenon and a powerful evolutionary force, evidence for this has often been indirect and correlational. We therefore wholeheartedly embrace Eberhard's [3] recent call to demonstrate CFC experimentally and welcome his suggestion to harness the wondrous diversity and numerous advantages offered by arthropods for the study of CFC [4]. By the same token, we are wary of inferring CFC and its fitness consequences (e.g., male coercion versus female control) based on phylogenetic patterns or behavioural observations alone, although this information may be highly relevant. Studying CFC and its consequences requires a clear demonstration of a female-driven postmating bias in sperm use, fertilisation, or paternity outcome and a causal link between such bias and male phenotype or genotype [2]. This demonstration has proved challenging, although recent developments promise exciting progress ahead. We have no doubt that arthropods will continue to play a prominent role in the rapidly expanding field of CFC.

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## Letter

Invasion Science in  
the Developing  
World: A Response  
to Ricciardi *et al.*Rafael D. Zenni,<sup>1,\*</sup>  
Sílvia R. Ziller,<sup>2</sup>  
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and Martin A. Nuñez<sup>5</sup>

In the publication 'Invasion Science: A Horizon Scan of Emerging Challenges and Opportunities' [1], Ricciardi *et al.* 'identified emerging scientific, technological, and sociopolitical issues likely to affect how biological invasions are studied and managed over the next two decades'. We agree with many of the points raised by the horizon scan. However, the authors stated that 'most developing countries have limited capacity to respond to invasions and can act as hubs to spread species into developed regions'. We found this assertion worrisome because the authors make an opinionated statement that may not reflect

reality and can have negative implications in attributing the spread of invasive species uniquely to developing countries. We therefore want to present some perspectives of developing countries on invasion science to shed light on the authors' statement [1] and clarify potential misconceptions.

The assertion that most developing countries have limited capacity to respond to invasions is a poor generalization with two misconceptions. First, it ignores world-leading efforts of developing nations in dealing with invasions. For instance, South Africa maintains the Working for Water (WfW) program, which has cleared more than one million hectares of invasive alien plants since 1995 and provided jobs and training to approximately 20 000 people. WfW has no parallel in the developed or developing world. Mexico, Jamaica, Guyana, Cuba, Brazil, Colombia, Uruguay, Argentina, and Chile have developed or are in the process of elaborating national strategies for invasive non-native species in alignment with the Convention on Biological Diversity. Many developed countries do not have such strategies [2]. Besides, Brazil is used by Ricciardi *et al.* [1] as an example where genomic technologies are tested for use for the management of invasions, highlighting research in the forefront of invasion management. There are national IAS databases in Argentina, Brazil, Uruguay, Chile, Colombia, Costa Rica, Venezuela, and Jamaica. These efforts to improve governance on invasive species are perhaps often ignored due to language issues: publications in Portuguese or Spanish do not often catch the attention of the English-speaking world. Second, the capacity to respond to invasions, although variable among countries, is generally low at the global level. Exceptions are countries where invasions have been devastating (e.g., Australia, New Zealand, South Africa). Also, for many developing countries invasions are a more recent issue because species

**Box 1. We Present Some Perspectives for Invasion Science from Countries in the Developing World in an Attempt to Broaden and Balance (Not Replace or Devalue) the Issues and Opportunities Proposed by Ricciardi *et al.* [1]**

- Improve governance on invasive species in all countries where these problems are still underestimated or not a priority in biodiversity conservation, including information sharing, public policies, and legal frameworks focused on prevention, early detection, and control.
- Increase and improve capacity (i.e., human resources) to work on biological invasions.
- Understand pathways and vectors of species introductions to improve the capacity to bar new entries and adopt risk assessment to screen species requested for entry.
- Understand the ecological impacts of biological invasions in highly biodiverse ecosystems and develop appropriate management strategies.
- Understand the economic and social impacts of biological invasions in poor, traditional, and rural communities and develop appropriate management strategies.
- Work collaboratively with international groups from both developing and developed countries to increase the rate and speed of innovation and information sharing while avoiding duplicate efforts.

introductions are also more recent [3]. Even in Europe not all countries deal with invasions equally. Capacity and awareness are very relative and mainly dependent on governance and funding, although not necessarily related to economic development. South Africa has a fantastic program combining good governance with solutions for environmental problems.

We find the second assertion, that developing countries can act as hubs to spread species into developed regions, more troublesome. It is well known that the level of invasion is closely related to trade rather than economic status. International organizations such as the Food and Agriculture Organization (FAO), development banks, and aid initiatives are often responsible for introducing species in countries, developed or not, where they eventually become invasive. The movement of species worldwide cannot be characterized by economic status [4]. Invasive Australian acacias and North American and European pines were introduced from developed to developing countries throughout the Southern Hemisphere [5,6]. Invasive zebra mussels, and golden mussels and forage grasses were moved from developing countries to both developed and developing countries. Indeed, several of Ricciardi *et al.*'s [1] examples indicate developed countries as potential hubs for developing countries. It is clear

that invasive species originate from all regions and may spread to any region when adequate vectors and pathways exist.

The horizon scan [1] was conducted by researchers from eight countries: Canada, the UK, the USA, New Zealand, Germany, the Czech Republic, South Africa, Sweden, and Singapore – all but one developed. It was coherent of the authors to acknowledge that their assessment was based on a limited pool of views and that ‘participants from developing countries might have proposed alternative issues’. That is certainly true (Box 1): not only because developing and developed countries are economically different, but also because each country and region has unique environmental, economic, and sociopolitical realities that demand unique approaches [7]. Consequently, the issues raised most certainly differ on a country basis and it is unlikely that any deeper analysis would propose making distinctions between countries based solely on current economic development [8].

For invasion science, it seems to us far more appropriate to understand and manage invasive species based on global trade, continentality, biodiversity, and ecosystems. Invasive species are a global problem that requires concerted efforts to find solutions that suit many countries at a

time [9]. It will be best for countries and experts to engage in discussions about the opportunities and challenges associated with invasions with the inclusion of scientists, managers, and society as a whole [9,10]. The program of work of the Convention on Biological Diversity (Article 8 h), the Global Invasive Species Information Partnership (GIASIP), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) are examples of inclusive efforts in this direction.

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