Introduction

J.D. Mumford* & M.M. Quinlan

Centre for Environmental Policy, Imperial College London, Silwood Park, Buckhurst Road, Ascot, SL5 7PY United Kingdom

*Corresponding author: j.mumford@imperial.ac.uk

Both authors contributed to the content and conclusions of this article.

Keywords

Insects – Beneficial insects – Honeybees – Regulation – Shipping.

Why are we shipping insects?

Every year shipments of live insects, from billions at a time in some cases to a single insect or only a few in others, cross international borders under a variety of regulatory frameworks or following voluntary industry or sector guidance. Leading up to this special issue of the OIE *Scientific and Technical Review*, we have not had a clear idea of the number of shipments or the volume of trade in live insects or insect-based products. The largest volumes of live shipments are for pest control approaches such as inundative release of biological control agents (see Vila *et al.* [1]; Kumar *et al.* [2]; Sanchez *et al.* [3], this issue) and the sterile insect technique (described in Enkerlin and Pereira [4], this issue), or for introduction of efficient pollinators – each of which has decades of historic successes and broad societal acceptance. Perhaps the highest number of shipments is of *Drosophila melanogaster*, including 5,000 shipments a year from just one production facility, as reported by Cook and Parks ([5], this issue). The value of this species as a model organism for research and educational purposes has been proven over the course of 100 years of use.

Innovations that have evolved over the past 20 years include the use of pollinating bumblebees to serve as entomovectors. Insects as delivery mechanisms offer exciting options for crop protection but complicate

the regulation of cross-border transport (Temmermans and Smagghe [6], this issue). For health, innovations in the use of insects have led to area-wide control of mosquitoes, which are vectors of significant human or zoonotic diseases (e.g., Bellini [7], this issue). These innovations have already resulted in large-scale shipment of mosquito eggs infected with an intracellular *Wolbachia* bacteria for control of *Aedes* species (see Denton *et al.* [8], this issue) and small shipments of mosquito eggs for research purposes on methods to combat malaria vector species, some of which are genetically modified strains (Simoni [9], this issue).

When we talk of trade, we do not refer only to commercial endeavours: the intentional movement of insects is conducted for several reasons, many of which are not commercial. An impressive array of insects are being shipped for purposes that support several Sustainable Development Goals (SDGs) ([10]; also described at sustainabledevelopment.un.org), which are shown in Figure 1 and listed below.

- Zero hunger (SDG 2) – Live insects are widely used to support sustainable agricultural systems, which are less dependent on pesticides thanks to biocontrol agents. Insects also are increasingly being used directly for food and feed [11], although much of this is domestic trade or trade in insect-based products rather than living insects.

- Good health and well-being (SDG 3) – Live insects are used for research and implementation of genetic strategies against species that vector human and animal diseases or cause nuisance conditions, remarked on above (see also [12, 13]). Such research may include insecticide resistance testing, study of diseases, vector biology research, and emerging use of novel genetic control methods and *Wolbachia*-infected vector species [14, 15].

- Industry, innovation and infrastructure (SDG 9) – Research into many biological products has built on studies using insects in the laboratory [16]. Some insects and other arthropods are the basis for industrial applications, including pollination services, sericulture, production of

resins and other biomaterials, and pharmaceutical and direct health uses or serve as model organisms for population research (summarised in Cook and Parkes [5], this issue).

– Responsible consumption and production (SDG 12) – Live insects are used for researching and implementing pest control (e.g. as biological control agents for exotic weeds or for sterile insect release) as noted above; such uses significantly reduce the losses to food supply and reduce the agricultural chemicals used [17, 18].

– Life on land (SDG 15) – Research and release of insects for conservation biology and environmental protection are also crucial to help halt and reverse biodiversity loss (highlighted in Saul-Gershenz [19], this issue).

In addition to facilitating meaningful contributions to these SDGs, insects can provide enjoyment as pets and through hobby and educational collections, as described in this issue by Goka [20], and Saul-Gershenz [19].

This *Review* establishes the increasing demand for transport of live insects across borders, with input from some of those involved reported in Oliva *et al.* ([21], this issue).

What are our concerns around trade in insects?

There are several components of international trade in live insects and these present unique potential hazards. Different risks can occur at each stage (sources, transport and end uses) and should be managed. Some risks are related to the process of collecting or rearing insects; other risks relate to their intended use within the importing territory, or the possibility of an unintended or undeclared use. The risks to biodiversity and human or animal health that arise during the transport stage of the trade are relatively few, and become negligible when measures such as proper packaging are taken to prevent escape of insects [9, Wohlfarter *et al*. [22], this issue]. The greatest risk – due to its frequency of occurrence – is to the quality of the insects once delivered, in other words a risk to the utility of the shipment. These

components are distinct and relate to different scenarios and requirements, as shown in Figure 2.

Quinlan et al. ([23], this issue) explain how gaps remain in the oversight and regulation of insect shipments despite the existing international frameworks, national regulations and some best practice materials. At the same time, oversight should not hinder progress; private carriers need better guidance to avoid disproportionate costs and barriers to those working in more innovative or research-phase applications of insects [22]. Risk-based decision making is at the heart of standards and guidance from those international bodies working on biological threats and issues. The variety of species being shipped, and the different purposes and conditions of these shipments, make harmonisation of such an approach challenging [24]. The current challenges to mankind make it more important than ever to include those affected by the potential uses of insects in discussions and consultation (Collins and Michaelakis [25], this issue).

Are there universal criteria for managing risks from international trade in live insects?

In this *Review*, those recording various scenarios involving trade in insects join their perspectives to lay out possible overarching criteria that could lead to a rationalised framework for risk-based decision making. A summary of discussions among the authors provides a unique view of a possible pathway towards more harmonised approaches in the future (Mumford *et al*. [26], this issue).

This coordinated response will require further work and agreement from a number of different public and private entities. Opportunities for coordination are considered in the final article in this issue (Quinlan *et al*. [27], this issue), with ideas around the potential role for the World Organisation for Animal Health covered in Torres *et al.* [28].

Acknowledgements

We would like to acknowledge Target Malaria and the EUCLID project for covering some of the costs of a 2018 meeting that led to this collaboration with the OIE. Target Malaria receives core funding from the Bill & Melinda Gates Foundation and from the Open Philanthropy Project Fund. EUCLID received funding from the European Union Horizon 2020 research and innovation programme under grant agreement No 633999.

References

1. Vila E., Wäckers F. & Klapwijk J. (2022). – Shipping augmentative biocontrol agents. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
2. Kumar P.S., Sreedevi K., Gupta A., Amala U. & Verghese A. (2022). – Shipment of insects and related arthropods into and out of India for research or commercial purposes. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
3. Sanchez M., Ferror E. & Cortese P. (2022). – [Procedimiento de evaluación de riesgo para la importación, cuarentena y liberación de ACB de plagas en Argentina]. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
4. Enkerlin W.R. & Pereira R. (2022). – The sterile insect technique: International framework to facilitate transboundary shipments of sterile insects. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
5. Cook K.R. & Parks A.L. (2022). – The international exchange of *Drosophila melanogaster* strains. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
6. Temmermans J. & Smagghe G. (2022). – Different bees as vectors for entomovectoring with enhanced pollination and crop protection control: current practices, use-cases and critical view on transport. *In* Safety, regulatory, and environmental issues related to international

trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…

7. Bellini R. (2022). – Safety, regulatory and environmental issues with SIT-based mosquito vector control in European countries. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
8. Denton J.A., Joubert D.A., Goundar A. & Gilles J.R.L. (2022). – International shipment of *Wolbachia*-infected mosquito eggs: towards scale up of World Mosquito Program Operations. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
9. Simoni A. (2022). – Movement of genetically modified insects for research purposes. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
10. United Nations (UN) (2015). – Transforming our world: the 2030 Agenda for Sustainable Development. Resolution 70/1 adopted by the General Assembly, 25 September 2015, UN, New York.
11. Van Huis A., Van Itterbeeck J., Klunder H., Mertens E., Halloran A., Muir G. & Vantomme P. (2013). – Edible insects: future prospects for food and feed security (No. 171). Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: www.fao.org/3/i3253e/i3253e.pdf (accessed on 30 September 2021).
12. James S., Collins F.H. […] & Toure Y.T. (2018). – Pathway to deployment of gene drive mosquitoes as a potential biocontrol tool for elimination of malaria in sub-Saharan Africa: recommendations of a scientific working group. *Am. J. Trop. Med. Hyg.*, **98** (Suppl. 6), S1–S49. doi:10.4269/ajtmh.18-0083.
13. Alphey L. (2014). – Genetic control of mosquitoes. *Annu. Rev. Entomol*, **59**, 205–224. doi:10.1146/annurev-ento-011613-162002.
14. Ritchie S.A., van den Hurk A.F., Smout M.J., Staunton K.M. & Hoffmann A.A. (2018). – Mission accomplished? We need a guide to the 'post release' world of Wolbachia for Aedes-borne disease control. *Trends Parasitol.*, **34** (3), 217–226. doi:10.1016/j.pt.2017.11.011.
15. Kohl A., Pondeville E. […] & Vernick K.D. (2016). – Advancing vector biology research: a community survey for future directions, research applications and infrastructure requirements. *Pathog Glob Health*, **110** (4 & 5), 164–172. doi:10.1080/20477724.2016.1211475.
16. Bellen H.J., Tong C. & Tsuda H. (2010). – Neuroscience: a history lesson for the future. *Nat. Rev. Neurosci.*, **11** (7), 514–522. doi:10.1038/nrn2839.100.

17. Sheppard A.W., Hill R., DeClerck-Floate R.A., McClay A., Olckers T., Jr P.C.Q. & Zimmermann H.G. (2003). – A global review of risk-benefit-cost analysis for the introduction of classical biological control agents against weeds: a crisis in the making? *Biocontrol News Inf.*, **24** (4), 91N–108N.
18. Smith D., Hinz H., Mulema J., Weyl P. & Ryan M.J. (2018). – Biological control and the Nagoya Protocol on access and benefit sharing – a case of effective due diligence. *Biocontrol Sci. Technol.*, **28** (10), 914–926. doi:10.1080/09583157.2018.1460317.
19. Saul-Gershenz L. (2022). – Insect Zoo and butterfly houses for public education: importation, shipping, safety, regulatory, and environmental issues related to breeding and international trade of non-native insects. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
20. Goka K. (2022). – Conservation biology issues for the commercial insect trade in Japan: bumblebees for agriculture and companion animal insects as examples. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
21. Oliva C.F., Chand R., Prudhomme J., Messori S., Torres G., Mumford, J.D., Deme I. & Quinlan M.M. (2022). – International live insect trade: a survey of stakeholders. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
22. Wohlfarter M., Oliva C.F. & Nelson, C. (2022). – Streamlining cross-border shipping of live invertebrates. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
23. Quinlan M.M. *et al.* (2022). – Gaps in regulatory environment at global level. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
24. Kumschick S., Devenish A., Kenis M., Rabitsch W., Richardson D.M. & Wilson J.R.U. (2016). – Intentionally introduced terrestrial invertebrates: patterns, risks, and options for management. *Biol. Invasions*, **18** (4), 1077–1088. doi:10.1007/s10530-016-1086-5.
25. Collins C.M. & Michaelakis A. (2022). – Managing stakeholder concerns associated with releases of imported stock in insect control programmes. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
26. Mumford J. *et al.* (2022). – Common risk framework for live insect shipping. *In* Safety, regulatory, and environmental issues related to

international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…

27. Quinlan M.M. & Mumford, J. (2022). – Opportunities and challenges. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…
28. Torres G., Diaz F., Okamura Y., Messori S. & Hutchison J. (2022). – World Organisation for Animal Health international standards for bee health: the potential for their extension to the safe trade of insects. *In* Safety, regulatory, and environmental issues related to international trade of insects (J. Mumford & M.M. Quinlan, eds). *Rev Sci Tech. Off. Int. Epiz.*, **41** (1), XXX–YYY. doi:…

Fig. 1 Sustainable Development Goals supported by international movement of insects

Source: sustainabledevelopment.un.org

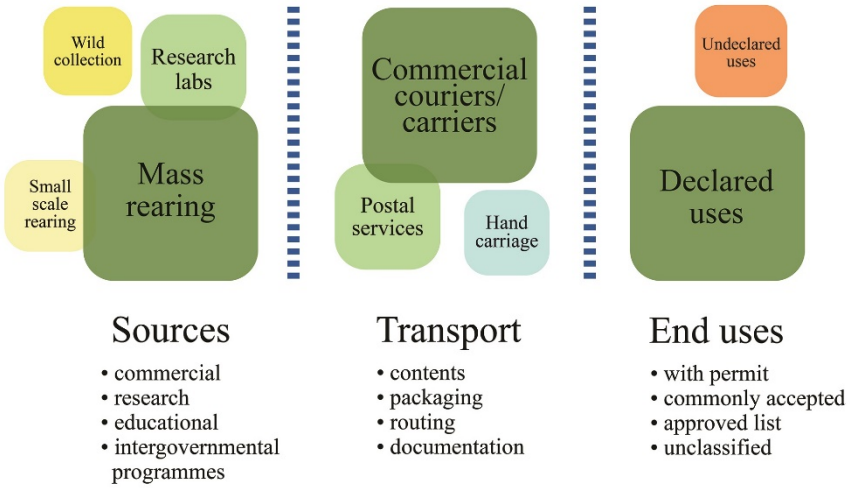

Fig. 2
Components of trade in insects, with some characteristics of each stage