Streamlining cross-border shipping of live invertebrates

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Summary

The logistics of shipping live invertebrates should be straightforward, requiring mainly good packaging to ensure survival and confinement, and timely delivery. The first points pertain to the shipper, whose interest is to maintain the highest quality of the product shipped and to ensure there will be no escapees, while the latter relies on the ability of the shipping agent to organize the fastest reliable route of transport and carriers to fulfil their function effectively.

This article explores this underserviced sector. While similar logistics capacity exists for other goods that require fast delivery (such as vaccines and fresh food), stakeholders who require timely, live invertebrate shipping often have difficulties in finding transport stakeholders able or willing to handle such services. We stress that fast delivery is key to ensure survival and quality of invertebrates and bring examples from the biocontrol field, showing the current complexity and inconsistency of logistics. For some countries and stakeholders, this

issue can be a significant barrier to the growth of a sustainable biocontrol sector.

We also explore misconceptions (about packaging, liability, and paperwork) and unclear rules (generic veterinary certificates which are rarely relevant for most invertebrates) that may cause express courier companies to refuse carrying live invertebrates. These issues often result in packages not being handled as a priority during transport connections or customs clearance, and significant subsequent delivery delays.

This article proposes improvements that could streamline this kind of transport with changes that should fit within existing shipping processes. This article is furthermore intended as a call to transport and inspection stakeholders to use the existing guidance and other resources to support this underdeveloped sector more effectively.

Keywords

Biocontrol – Brokers – Express carriers – Live invertebrate – Logistics – Shipment.

Live invertebrate shipping: an underserviced market sector

Invertebrates are shipped across the world for various uses from research activities to commercial use in agriculture, environmental protection, and/or for human- and animal health purposes. Shipping activities can be of sporadic nature, consisting of single specimen to large consignments of millions of invertebrates shipped weekly (Table I). Failure to secure these shipments can have enormous impacts on field control activities that correspond with pest outbreaks, for example, or in the long term on the continued reliance on conventional pesticide, as opposed to the promoting the expansion of biocontrol-based crop protection. Non-commercial shipments are often less attractive for carriers; however, the impact of refusal and inefficient delivery, can result in the loss of invaluable samples for research activities.

INSERT TABLE I HERE

The industry faces major challenges which impair continued proliferation of biocontrol and research activities. This mainly relates to timorous transport stakeholders, inefficient routes and handling that result in delayed delivery, associated damage or loss of the insects, prohibitive costs, and ambiguous rules.

With over 1,000 biological control products supplied all over Europe, approximately 140 awaiting registration and a further 120 in development (1), the biocontrol industry is working hard to meet the targets of the EU Green Deal and filling the anticipated gap in invertebrate pest control resulting from the intended 50% pesticide-use reduction by 2030. According to Lamichhane *et al.* (2) availability of biological solutions to growers remains a significant constraint for greater substitution of conventional pesticides.

With growers (end users) of all sizes distributed across Europe (and globally), efficient transport is crucial for the timely delivery of live Invertebrate Biological Control Agent (IBCA), or 'macrobial' products. For this, large biological control industry players rely on well-developed distribution channels and partners. New and particularly small(er) suppliers and start-up businesses, or R&D teams who require small or infrequent shipments, often do not have sufficient economies of scale compared to their larger counterparts. Shippers making infrequent shipments often lack skills and knowhow on packaging, documentation, and other requirements, while a lack of understanding by express carriers at local offices, on the safety of such consignments, often leads to precautionary refusal of services.

The International Standards for Phytosanitary Measures (ISPM) no. 3 (3) guidelines have been developed to ensure seamless and safe export, shipment, import and release of IBCAs and are widely recognised by national plant protection organisations (NPPOs). Additionally, the European and Mediterranean region follow the European and Mediterranean Plant Protection Organization (EPPO) 6/3 (4) guidelines**.** However, a disconnect remains between these guidelines and express carriers' understanding of safety and their subsequent willingness to transport IBCAs. Misconceptions on whether and how

invertebrates should follow complex live animal transport regulations are often key deterrents for express carriers.

The COVID-19 pandemic has exacerbated problems already arising from biocontrol programs and research activities' dependence on efficient logistics. This paper aims to bring the attention of logistics stakeholders to the crucial part they can play in contributing to sustainable production of quality food and protection of the environment by reducing pesticide externalities. A new partnership between shipping companies and live insect trade clients of all sizes and capacities addressing common goals could significantly contribute to meeting the European Union (EU) 2030 targets of pesticide-use reduction and United Nations (UN) Sustainable Development Goals.

For the purpose of this article, we refer to invertebrates as including arthropods, such as insects and arachnids (including biocontrol agents such as mites and nematodes) but excluding crustaceans. Additionally, the table presented Table IV, at the end of the article, provides a glossary of commonly used logistics terms for ease of understanding.

Transport constraints: time sensitivity

For the shipper, the most important requirement is on-time service. Invertebrates are shipped at crucial species-specific life stages. Therefore, reactivity and flexibility at collection is highly valuable, and priority handling all along the transit chain is crucial.

Rules for live invertebrate transport between countries are often unpredictable and inconsistent. Larger IBCA suppliers, governmental and/or international organizations are generally familiar with the variations and able to comply with shipping procedures. Yet even these larger organisations are not immune to sudden policy changes. For smaller suppliers, the variation in requirements represents a significant stumbling block and makes it difficult for start-ups to build reliable business models based on shipping of invertebrates. Additionally, this uncertainty and unreliability is highly detrimental for R&D, as unique samples can be lost when delays are incurred.

Transport through aircraft operators, via freight brokers or freight forwarders, is relatively straightforward thanks to the IATA (International Air Transports Association) Live Animals Regulation (LAR) guidelines (5); the guidelines include a paragraph and specific items on live invertebrates. The "known consignor" system (defined in Table IV) also supports relatively seamless transport, when available. A weak point in ensuring fast delivery remains port of entry inspections, where documentation requirements and customs procedures may differ among countries, and even between different ports of entry in a single country. This can be a source of significant delay, having detrimental effects on the survival of invertebrates, stressing the need to label live invertebrate packaging in ways that highlight priority handling requirements. Unfortunate cases of insects shipped as pupae (stage before adult emergence) have been reported by R&D institutions in 2021, when delayed handling at transit airports or agency and/or port of entry snowballed and resulted in a delivery outside of the survival window for the insects. Figure 1 shows the impact of the aforementioned extended transport duration on fruit flies; malformation at emergence and death due to suffocation (insufficient air supply).

INSERT FIGURE 1 HERE

Lack of available airfreight due to unforeseen situations, such as flight restrictions during the COVID-19 pandemic and/or unavailability of more direct routes only serviced by low-cost aircraft operators (prohibited from taking live cargo), highlights the need for alternatives, such as express carriers or integrators (DHL, FedEx, UPS, etc.) in filling the gap. These stakeholders have end-to-end multimodal supply chain capacities and existing logistics routes that could be exploited for more efficient transport of live invertebrates (Table II).

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The case of Biocontrol deployment: highly vulnerable to inconsistency of logistics

Regular weekly transcontinental shipments of invertebrates have been efficient and successful for several large-scale operational Sterile Insect

Technology (SIT) programmes (6), a category of IBCA requiring massive and frequent releases of sterilized live insects. A prime example is summarized in Wohlfarter (7). During the 2010/2011 release season, Entomon Technologies (Pty) Ltd, a semi-commercial *Cydia pomonella* (codling moth) SIT programme in the Western Cape Province, South Africa, experienced rearing difficulties. As the release-season was well underway, a supply interruption threatened the continued biocontrol programme for local apple and pear growers. Utilizing the effective structures of the government agency National Plant Protection Organisation of South Africa (NPPOSA), a division of the National Department of Agriculture, Land Reform and Rural Development (DALRRD), an emergency import permit was granted within a week and sterile moths were delivered from the Okanagan Kootenay Sterile Insects Release (OKSIR) programme in Osoyoos, BC, Canada (Box 1). The permit furthermore indicated a local priority shipping status, similar to that of medical supplies, allowing speedy customs processing and facilitating rapid road transport from the port of entry to the Entomon Technologies distribution facilities.

INSERT BOX 1 HERE

To date, very few operational SIT programmes exist in Europe, while emerging and promising projects have been impaired or stopped due to their reliance on commercial flights which were unavailable during the Covid pandemic. As examples: the longstanding successful operational *Ceratitis capitata* (Mediterranean fruit fly) SIT protection programme importing sterile medflies to the Neretva Valley in Croatia, had to revert back to conventional control (Popović pers. comm.). This dependency on logistics availability is a major impediment for customers. An experimental codling moth SIT pilot project in southern France is making slow progress as shipping from OKSIR, Canada (Box 1), was not possible due to lack of appropriate flights and connections during the Covid period. Yet even prior to the pandemic, trial import attempts had low success rates due to handling delays at the port of entry, which extended transport time and climatic conditions beyond the viable lifespan of the invertebrate stages shipped. These attempts had to involve multiple freight forwarders, each only able to provide the

appropriate logistics within either Canada or France. No single provider could be found to handle a complete door-to-door service. This added intermediary costs, reduced efficiency of tracking and reactivity, complicated documentation, and voided liability. Subsequently, resources urgently had to be diverted to develop local production capacity to circumvent import constraints. Such logistic limitations hamper rapid proof of concept and early adoption of biocontrol, at least in the short to mid-term (Box 1).

These challenges are also experienced by large commercial producers and international organizations on shipping routes between EU Member States, as well as from mainland Europe to outlying territories such as the French islands of Corsica (Mediterranean Sea) and Reunion (Indian Ocean). Several European SIT pilot projects have suffered from late delivery, often because of non-priority handling that extended the transit times to the end destination. Shipping attempts using packages designated only as unspecified 'cargo' had random chances of timely delivery or suffered from poor handling. In some instances, brokers or freight forwarders proposed solutions that would allow timely delivery, but related costs were prohibitive for long-term operations.

Express carriers or integrators (that access multiple modes of transport and have capacities to transport high-value-added or time-sensitive cargo) and low-cost airlines (that traditionally have not carried live cargo, but are increasingly opening new routes) present a potential efficient and flexible alternative to conventional air carrier operators or brokers. However, to date, some international express carriers maintain inconsistent rules that differ between countries, allowing live invertebrate transport on some routes, but classifying it as prohibited merchandise on others.

Such uncertainties in shipping insects and acarians makes the development of innovative programs and the expansion of biocontrol rather precarious. Reliable delivery depends on the category of IBCAs to be considered as 'essential' goods, as delayed delivery can have significant impact on commercial services such as crop protection or

control of vector transmitted diseases, as well as research activities (Table I).

A crucial role of express carriers or integrators

Concerns

A primary issue raised by express carriers has been shipper insurance requirements, i.e. on timely delivery and arrival quality (survival). Although no shipper/receiver expects 100% fault-free services, it is expected that the fastest routing and processing should be provided to ensure timeous delivery (similarly to other perishable products). Shipping routes that involve transit through airports may, however, suffer from delays that are beyond the responsibility of the carrier and would lead either to increased financial charges or viability loss of the shipment. Increased awareness by all stakeholders is crucial to ensure a streamlined service (Table II).

Secondly, low frequency shipments are not attractive for most carriers. However, taken collectively, the diversity of users (research centres/industrial applications) that are currently underserved should make this sector commercially attractive (Table I; Oliva *et al*. [9]; Enkerlin & Pereira [6], this issue).

Concerns on the shipping conditions and packaging are also often raised by express carriers. Some prohibit invertebrate transportation based on their perceived risks of escape and cross-contamination of vehicles, containers, and other products in warehouses, and/or risks of invertebrate-escape into the wild. These concerns seem to originate from a misconception regarding the packaging preparation by the shipper, or confusion over destruction or disposal procedures for undeliverable items. Prevention of escape is generally adequately handled by the shipper, to whom the security (confinement) and quality of the consignment is of primary importance (Table III).

INSERT TABLE III HERE

The IATA LAR guideline describes shipping and packaging processes that enable adequate confinement. Although these guidelines specify

the handling of invertebrates by carriers during transport by air, they appear not to be translated to road, rail, or water transportation. Transport guidelines such as the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN), International Maritime Dangerous Goods Code (IMDG), Regulation concerning the International Carriage of Dangerous Goods by Rail (RID) do not cover guidelines for non-hazardous biological products.

Some express carriers are reluctant to guarantee transport when they cannot control the ambient temperature conditions (in particular during summer periods). However, tailored packaging by the shipper enabling and maintaining conditions of low light, low temperature, suitable O_2:CO_2 balance, etc., can help preserve the climatic conditions required, should delays be experienced. Similarly, this is achieved for shipping fresh or sensitive commodities, and it essentially remains the shipper's responsibility when preparing the parcel (Table III). 'Known consignor' agreements are also an effective procedure where the shipper is trusted as an experienced safe exporter, therefore, allowing faster processing of the packages by airlines and customs in the countries covered by the agreement. Such arrangements, however, only work when shipping through cargo, and still do not guarantee rapid processing for delivery, as it mainly circumvents inspection at the exporting country airport(s), but not during international transit steps or at the final port of entry.

Logistics of commodities with similar requirements

Express carriers or integrators already have efficient logistic solutions in place for several kinds of fragile goods, such as vaccines and other perishables. Table III draws a comparison between the requirements for vaccine shipment and that of invertebrates. We show that the capabilities and capacities already exist for the former and, therefore, argue that there is no reason why it cannot be employed for invertebrates. Consultation with these stakeholders could provide solutions to the issues encountered by live invertebrate shippers (Table II).

What's in it for carriers?

Express carriers are strictly governed by various internationally accepted guidelines on hazardous or dangerous goods transport. IBCAs are not classified under these categories, however, the IATA LAR (5) provides a brief explanatory note on what IBCAs are and how they can be handled safely.

Large commercial IBCA manufacturers and distributors have traditionally relied on in-house logistics operations for short to medium haul shipments. With globalisation of the business and an increasing demand for smaller volumes sent to an expanding number of unique locations, existing transport solutions have limited capacity or efficiency. Additionally, smaller start-up businesses with limited shipping frequency contribute to a growing need for transport flexibility. 'Business as usual' risks missing this growing business opportunity.

The ability of express carrier to differentiate their service is becoming increasingly important to maintain competitiveness and customer loyalty. Much focus is placed on CO_2 emissions and biodiversity protection, yet transport of IBCAs (for agriculture or animal/human health protection, or conservation objectives) has a direct positive effect on the environment, as it enables the replacement of conventional pesticides in pest management programs. The logistics sector should be surveyed to learn if there is interest in a method for evidence-based claims by a business for supporting such green initiatives.

Current limitations of live invertebrate import documentation

There are a various guidelines (official and voluntary; international, regional, national) regarding general or sometimes sector-specific procedures supporting safe and efficient (timely) trade in live invertebrates. Shipping agents should have confidence that the shipper and receiver have adequately dealt with these requirements. These guidelines are, however, rarely known by shippers and transport stakeholders.

The ISPM 3 (3) aims to ensure safe global movement (export, shipment, import and release) of biocontrol agents and other beneficials. NPPOs are advised to adopt these guidelines and accordingly communicate with and train local stakeholders. ISPM 3 lists the type of documentation that might be required for trade in biocontrol and beneficial insects but does not provide model templates, unlike for official phytosanitary certificates. Use of phytosanitary certificates is restricted. ISPM 12 (11) states that 'They should not include statements that requirements have been met and should not include references to animal or human health matters.', thereby limiting their application to some of the issues identified for insect trade. Other documentation can be linked or noted on a phytosanitary certificate, however. The scope of ISPM 3 is considered further by Quinlan *et al*. [12], this issue.

The EPPO guidelines PM 6/1 (13), PM 6/2 14), PM 6/3 (4) and PM 6/4 (15) align with the international standard and are largely adopted by the NPPOs in the 52 member countries of these Regional Plant Protection Organizations (RPPO) including from Europe, Eastern Europe, Middle East, Central Asia, and Northern Africa.

Additionally, the International Atomic Energy Agency (IAEA) has extensively published on shipping guidelines to ensure safe transport of insects for SIT (16). Cross references to ISPM 3, or even its inclusion as an addendum into IATA LAR guidance, might clarify the relationship among the different sources. Regarding aircraft transport, IBCAs are briefly described in Section 10.4.5 of IATA LAR, particularly pointing out that IBCAs are "thoroughly researched" and that "...there is no evidence of them causing problems for humans, animals and the environment…" (5). These statements are intended to provide carriers with assurance/clarity on their safety. IATA LAR furthermore provides a 'Container Requirement Section', requirements 61-63, 65, 6768 (5) with detailed suggestions on the criteria containers should meet for the safe transport of IBCAs, including pollinators.

Sanitary (OIE Terrestrial Animal Health Code) and Phytosanitary certification (ISPM12)

Some authorities of importing countries (including Customs and NPPOs as well as Veterinary Services) require sanitary (veterinary) certification, confirming invertebrate shipments are free from disease vectors and/or listed mammalian, avian and/or aquatic pests, even when used only for plant protection. These are frequently required for shipments of bumblebees (*Bombus* spp) and other invertebrates, despite not falling under OIE guidance.

The use of such certificates originates from misinterpretation of the World Organisation for Animal Health (OIE), *Terrestrial Animal Health Code* (17) (see Torres *et al*., 18, for which insects are covered by OIE, this issue) and IATA LAR guidelines. Shipments within the EU originating from EU Member States are exempt from certification requirements (19), however, occasionally some Member State authorities still erroneously insist on veterinary certification for shipments within the EU. However, not all national governments have the local structures to issue such certification (Box 1). Blanket prerequisites can undermine the true value of veterinary certificates, as they end up being issued simply to tick the requirement box, rather than provide real value. Certification of IBCAs against diseases such as foot-and-mouth, vesicular stomatitis, etc., is irrelevant as these beneficial insects are neither hosts nor vectors of these pathogens. Similarly, bumblebee consignments often require certification as being free from diseases which they do not host.

Some Central American, African, and Asian countries require phytosanitary certification for IBCAs (19). Moreover, under R&D activities, shipped invertebrates originating from the wild are often sent for identification or to confirm presence of pathogens; in which case the process described under ISPM 3 is not as easy to follow due to unknown identity, unknown disease status and lack of related local capacity at the site of issuance/inspection. Globally the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) of the World Trade Organisation (WTO) makes provision for relevant certification

of imports and exports, but guards against use as artificial trade barriers (20). The challenges to some shippers to obtain the appropriate documentation is reaching the point of barriers to the trade in live insects.

Inconsistency in this regard can result in an importing country to require particular sanitary certification, whereas an exporting country may not issue it. As an example, the Canadian impasse described in Box 1, required regulatory adaptation by the Federal Parliament before any shipment could commence.

Certification of invertebrates for biocontrol should be fit-for-purpose, confirming that the organisms in question are 'beneficials', e.g. predators or parasitoids of agricultural and/or domestic pests, or in the case of SIT, rendered safe through sterilization treatments. Release authorization delivered by national authority confirms that these invertebrates are safe and of no danger to non-target organisms. Particularly in the case of SIT, although intrinsically plant, animal, or human pests and/or disease vectors, the conferred reproductive sterility and for some species additional male-only selection they undergo, remove the risks related to potential escape.

As sanitary and phytosanitary policy enforcement can rest with a variety of competent authorities such as NPPOs, agricultural ministries, customs, trade, and industry authorities, etc. many countries already use mutually recognized electronic certification systems to speed the issuance of standardized documentation. Effective communication by the competent authorities with carriers could resolve the current lack of procedural understanding by the latter (Box 1).

Recommendation for specific labelling

Even when all required documentation for import is in place, stakeholders along the shipping route handling packages, may be faced with procedural uncertainties, especially when transport delays or other unforeseen situations are incurred. Since July 2012, all health care related product shipments are furnished with a Time & Temperature (T&T) Sensitivity label, in order to maintain consignment integrity

(21). This label makes provision for the shipper to indicate the suitable temperature range of the consignment. A preferred delivery window (time from sending to receiving) is, however, not indicated.

A combination of privately produced labels for temperature parameters and 'rush' transport are already used by various senders, yet no single all-encompassing label specific to insects and arachnids exists. We propose such a dedicated label (Fig. 2) which includes six sections; A declaration of CITES or non-CITES status, table for details on shipping and last viable arrival date & time, temperature range and guidelines for safe destruction of the package (should it be necessary). Users would simply, mark the relevant criteria and disclaimer, ensuring a truthful completion of the details (Fig. 3). A QR code is also provided (not active in the Figures), which could be consulted by any user along the route to obtain more clarity and/or specific details on the various sections of the label.

Insert Figures 2 and 3 here

Conclusions

The transport of live insects suffers from four main issues: (1) unwillingness by several express carriers or integrators to transport, (2) lack of appropriate routes to allow timely delivery, (3) disproportionate costs compared to classic goods, and (4) inconsistence of inspection requirements.

Existing guidelines (ISPM 3, IATA LAR) address some of the challenges to invertebrate shipping, but increased awareness on the relevant requirements of live invertebrates is needed at all stages of the logistics and inspection chains. Suggested improvements could entail global harmonization of rules (while retaining useful distinctions between types of trade) and the creation of a specific universal checklist for this trade, combined with a live-invertebrate-specific label.

Regular and 'known consignor' shipments are generally handled efficiently by freight forwarders and aircraft operators, but sometimes with limited available direct or compatible routes serviced. Express

carrier companies have sufficient experience in dealing with rapid transportation and careful handling of sensitive or perishable products and could offer significant shipping flexibility thanks to their end-to-end multimodal logistic chain. If the buy-in of express delivery providers could be obtained, their integrated model could finally result in competitive transport pricing, addressing issues of routing and costs.

To date, several stakeholders suffer from being underserved, affecting their R&D activities, commercial development, and expansion of biocontrol approaches. The safe and efficient transport of IBCAs, pollinators and R&D material is in the interest of all stakeholders. For policy makers and authorities, resolving this basic issue is a key factor that would boost the integration of biocontrol and other beneficial uses of insects, thus empowering the reactivity and quality of science to respond to pathogen transmission and risks posed by invertebrate invasions. Opening new routes and contributing to biocontrol deployment and biodiversity protection creates new opportunities for express carriers and integrators, and should be viewed as positively impactful, for example, promoting green label initiatives.

Well communicated and understood guidelines that confirm consignment safety should foster consistency of inspection requirements and prevent unnecessary holdups at the port of entry that negatively affect the organisms' survival.

This is a call to the transport stakeholders to recognize the many fitting procedures already put in place by competent authorities. Further discussions could be facilitated and conveyed by leading international organisations such as OIE, IAEA, IPPC, and the International Biocontrol Manufacturers Association (IBMA) in consultation with competent national authorities to harmonise these sometimes disparate guidelines and regulations into a more accessible framework for safe and efficient carriage of insects. Resolving this issue will contribute significantly to reaching some of the UN Sustainable Development Goals.

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Table I

Categories of live IBCAs and other invertebrates shipped

Categories of invertebrates, mites, and nematodes		**Field of use**	**Stakeholders**	**Typical volumes**	**Typical frequency**	**Risk of shipment failure**
IBCAs	Classical biocontrol	Agriculture, Environment protection	Commercial Sustainable agriculture Environmental health	Medium (Thousands of insects per consignment)	Weekly/monthly	Ineffective, inefficient crop protection service; use of pesticide
	Augmented biocontrol	Agriculture, Environment protection	Commercial Sustainable agriculture Environmental health	High (Millions-Billions of insects per consignment)	Daily to weekly	Ineffective, inefficient crop protection service; Use of pesticide
Animal health products (vector control)		Agriculture	Commercial Sustainable agriculture	Medium (Thousands-Millions of insects per consignment)	Daily to weekly	Ineffective, inefficient animal health protection service; Use of pesticide

Categories of invertebrates, mites, and nematodes	**Field of use**	**Stakeholders**	**Typical volumes**	**Typical frequency**	**Risk of shipment failure**
Sterile insects	Agriculture, Environment protection Vector control programmes (mosquito, tsetse fly, etc.)	Commercial Sustainable agriculture Environmental health Public health	High (millions-billions of insects per consignment)	Weekly/ biweekly	Ineffective, inefficient pest control; Use of pesticide
Invertebrates for R&D activities	Agriculture, Environment protection Human/ animal health Rearing for food and feed	Research on pest management. Research on pathogens transmitted/ risks. Colony starters	Low-Medium (hundreds-millions insects per consignment)	Irregular, a few times/ year	Delayed, inefficient research; Loss of unique samples; Delay in colony establishment

Table II

How the main issues are currently dealt with and propositions for improvement

Issues	Current systems in place	Calls for improvements
Refusal of carriage by several express carriers	- IATA LAR demonstrates some acceptable conditions, for aircraft transportation - Express carriers' policy to accept live insect cargo is country dependant - Some national authorities have clarified that live insects transport should not fall under live animal transport requirements [a]	- Increased awareness of sector importance and positive contributions to health and biodiversity protection - Harmonization of carriage conditions requirements from shippers for live insects - Rapid access risk checklist to reduce uncertainty regarding packaging and handling; the LAR check list [b] could be adapted to serve this purpose. - Live insect label with a clear destruction guideline
Inefficient routes	- Freight forwarders and brokers optimize available routes by mixing transport modes, often resulting in high costs, several intermediaries and long transit times. - Dedicated road transport, often resulting in high costs and long transport duration.	- Access express carriers which manage end-to-end multimodal supply chains, thus securing tracking and time-sensitive deliveries - Open live cargo to low-cost aircraft operators to benefit from more direct routes - Greater integration and cooperation along the logistic chain to facilitate transit operations and ensure priority treatment
High handling charges	- Insurance on liability is often a limiting element for express carriers - Complex logistic routes involving several operators increase the cost	- Clarified workflow and responsibility statements for each party

Issues	Current systems in place	Calls for improvements
		- Access express carriers which manage end-to-end multimodal supply chains, thus limiting intermediaries
Unnecessary inspections	- "Known consignor" status - Various documentation attached with packages to explain content - Mutually recognized electronic certification systems to facilitate a speedy process	- Increased awareness of live insect packages requirements and risks mitigation by handling and customs agents - Prior notification to custom inspectors - Consistent documentation requirements for all invertebrates - Live insect label with clear document and authorization checklist

(a) Example: Technique Instruction from the French Ministry of Agriculture DGAL/SDSPA/2017-742 dated 18/09/2017 https://oaba.fr/PDF/instruction%20DGAL2017_rappel_reglementation.pdf
(b) LAR 47th Edition IATA Live Animals Acceptance Checklist https://www.iata.org/contentassets/d7c512eb9a704ba2a8056e3186a31921/en-lar-47-acceptance-checklist.pdf

Table III

A comparison of existing requirements between vaccine and IBCA shipping, and transferability to other invertebrates shipping*

Key steps for an optimal shipment	Shipping of vaccine	Shipping IBCAs	How can invertebrate shipping be improved
Prevent environmental/health risks: Safe packaging	Shipper is responsible for the vaccine to be packaged carefully, to ensure no breakage/leakage during shipping. Strict protocols apply.	Shipper is responsible for the IBCAs to be packaged securely to ensure their conditions during the shipping period are maintained as needed and that the package is secured against any escape. There are strict protocols used in packaging invertebrates for shipment.	Strict protocols (IATA LAR) used in packaging invertebrates for successful shipment to address handling conditions.
Ensure quality and survival: Suitable transport conditions	Shipper is responsible for the vaccine to be packaged in a manner that temperature extremes encountered during shipping will not be a detriment to the vaccine.	Shipper is responsible for the IBCAs to be packaged in a manner to cope with temperature extremes encountered during shipping to ensure their viability will not be affected negatively.	
Ensure flawless logistics: Proper documentation	Proper documentation for approval to import the vaccine must be in place for customs inspection. Freight brokers or shippers are responsible to provide this to the carrier.	Proper documentation (Sanitary or Phytosanitary certificates) for approval to import the invertebrates must be in place for customs inspection. Freight brokers or the shippers are responsible to provide this to the carrier.	Through the IPPC and NPPOs and their respective competent authorities, regulations and protocols are in place to accommodate the approval and authorization of importation of IBCAs. Similar procedures can be followed for other invertebrates. “Known consignor” status or prior notification may facilitate quick passage.

Key steps for an optimal shipment	**Shipping of vaccine**	**Shipping IBCAs**	**How can invertebrate shipping be improved**
Opportunities for carriers	Express carriers will accept vaccine for international shipment and delivery.	Express carriers sometimes prohibit shipment of invertebrates.	Based on the protocols and regulatory approval processes in place, shipping invertebrates by express carriers is no different from shipping vaccine and should be accepted.

* WHO (10) specifies labelling, packaging, and temperature monitoring procedures for vaccines. Responsibilities of shippers/receivers are outlined. Various labels on delivery time temperature range requirements are listed. Route and advance notification advice is also given. Shipping packaging and monitoring device specifications are provided for many common examples of vaccines. A similar model Guidance document could be produced for insects.

Table IV

Transport & Logistics Glossary. Terms definitions extracted from the ICAO-WCO Joint Publication on Air Cargo Security and Facilitation: Moving Air Cargo Globally (2016)

Aircraft operators	Aircraft operators, also known as airlines and air carriers, provide air transportation for goods. A transport contract (air waybill) binds an aircraft operator with the relevant contracted parties for the safe and secure transport of cargo and mail from one location (e.g. the airport of departure) to another (e.g. the airport of arrival). The air cargo may be transported on passenger aircraft or all-cargo aircraft. In some instances, particularly for short distances, aircraft operators may also transport air cargo by road. The transport contract remains an air waybill, however, and the road segment is considered as a flight, with a designated flight number. This type of operation is known as a 'road feeder service'.
Air waybill	A document prepared by or on behalf of a shipper that evidences the contract between the shipper and aircraft operator(s) for the carriage of goods over routes of the operator(s). Air waybills have several purposes, but their two main functions are as a contract of carriage (behind every original air waybill are the conditions of contract for carriage), and as evidence of the receipt of goods.
Consignment	One or more items accepted by the carrier from one shipper at one time and at one address, receipted in one lot and moving on one air waybill or shipment record to one consignee at one destination address.
Express carriers/ Integrators	Express carriers combine the work of a broker, haulier, freight forwarder, ground handler and aircraft operator into one single company or group, which is why they are also sometimes referred to as 'integrators'. Express delivery has thus become a specific business model in the cargo industry. Express carriers manage end-to-end multimodal supply chains. They operate sophisticated track-and-trace information technology systems, which allow them to monitor the progress of an individual shipment through their chain, from pick up to delivery. Express carriers typically transport high-value-added, time-sensitive cargo, with a time definite delivery.

Freight broker	A broker is an independent agent who facilitates the movement of goods from buyer to seller, for instance by arranging air transport or meeting Customs requirements, such as goods declarations. Brokering functions are often integrated with forwarding, consolidation and even warehousing functions within a single entity.
Freight forwarders	Freight forwarders are part of the transport logistics process within the supply chain and their main task is to arrange for air shipments to be managed in such a way that they are ready for transportation by aircraft operators. Such arrangements might include the consolidation of cargo. A freight forwarder and logistics service provider may offer a service relating to the preparation, storage, carriage, and final delivery of goods, including the applicable documentary and facilitation formalities. A forwarder rarely acts as carrier of the goods. A forwarder's prime responsibility is to safeguard the interests of its customer, the consignor or shipper.
Ground handlers	Ground handlers are subcontracted and act on behalf of freight forwarders and/or aircraft operators. This occurs when the freight forwarder or aircraft operator does not have the necessary facilities. Ground handling services can include the provision of warehouses to accept, handle, prepare, and tag cargo and mail, as well as loading/unloading, transit, and storage of cargo and mail. Ground handlers are responsible for dealing with operational aspects, based on the instructions of freight forwarders and aircraft operators.
Known consignors	An entity may act as a known consignor when it originates cargo or mail for its own account and when its procedures meet common security rules and standards sufficient to allow the carriage of cargo or mail on commercial aircraft. Once a known consignor has accounted for the security status of cargo, the consignment may be delivered to a regulated agent, other approved entity, or directly to the aircraft operator, who then takes over the responsibility for keeping it secure until it is loaded on to an aircraft.
Receiver/ Recipient/ Consignee	The consignee is the party designated on the invoice or packing list as the recipient of the goods at the end of the transport movement.

Regulated agents	A regulated agent is a freight forwarder or any other entity (e.g. ground handler) that conducts business with an aircraft operator and provides security controls that are accepted or required for cargo or mail by the appropriate authority. Once approved as a regulated agent, an entity may conduct security controls for cargo, including the screening of goods. An aircraft operator may receive cargo secured by a regulated agent, which accounts for the security status of consignments.
Shipper/ Sender/ Consignor	A consignor is the entity or individual who initiates the movement or transport of the goods. In other words, it is the sender. (A 'known consignor' is an entity recognized in some States as meeting specified security requirements). The term 'shipper' is often used to describe the entity or individual who initiates the trade in goods. Consignor and shipper are separate roles but can be the same entity or individual.

Box 1

Shipping challenges that prohibit SIT initiatives from collaborating

The Okanagan-Kootenay Sterile Insect Release (OKSIR) Program in Canada employs sterile insects to control codling moths in pome fruit production. Over the past 25 years a 96% reduction in pesticide-use has been achieved (8).

Sterile insects have successfully been shipped to South Africa and New Zealand for pilot projects to implement SIT. However, shipping costs prohibit expansion to regular commercial shipping due to these consignments being restricted to 'air cargo' only, and excluding couriers or other integrated options covering the entire route with expedited delivery for a perishable product. Particularly for emerging interests in European countries, shipping costs have been prohibitive.

Collaboration between OKSIR and a commercial partner in the USA to deliver SIT to growers has also been hampered by policy. Although distribution on either side of the international border is handled by respective couriers, the actual cross-border shipping has only been practical when conducted by permitted hand-carriage.

Lastly, misalignment of transport and certification related policies between exporting- and importing countries can cause a serious impasse. For import into New Zealand, codling moth consignments needed to be accompanied by a veterinary certificate. Yet, the mandated NPPO, the Canadian Food Inspection Agency (CFIA), was unable to issue such documentation, as the procedure for lepidoptera was not covered by Federal law in Canada.

Fig. 1

Malformation and mortality of sterile fruit flies shipped as pupae, due to the shippers' disregard for timeous delivery. Left - *Ceratitis capitata* transported for >48h from Spain to Corsica (courtesy of Benoit Cailleret, AREFLEC); Right - *Bactrocera dorsalis* transported for >5 days from Austria to Reunion Island (courtesy of Emma Dieudonné, Cirad)

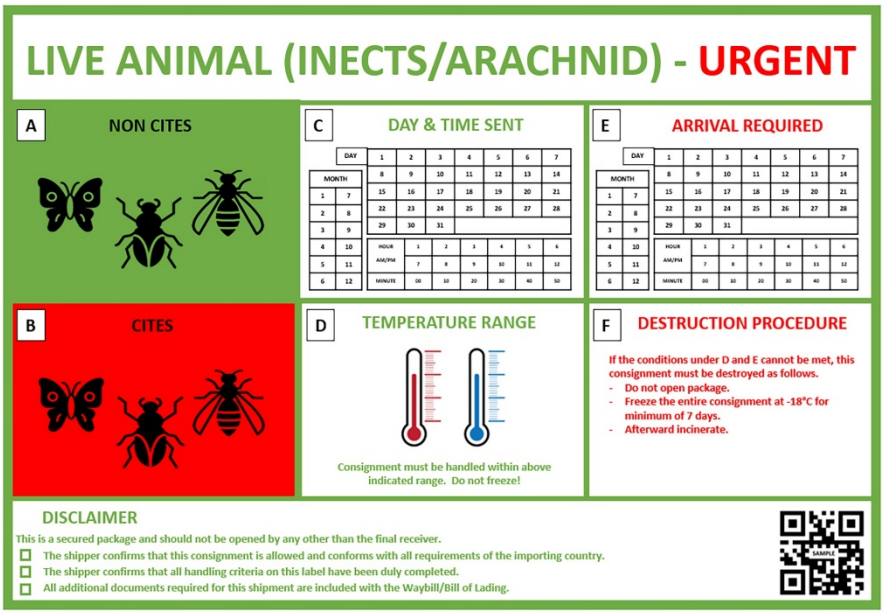

Fig. 2

Proposal of an informative label for the shipment of Insects or Arachnids (blank)

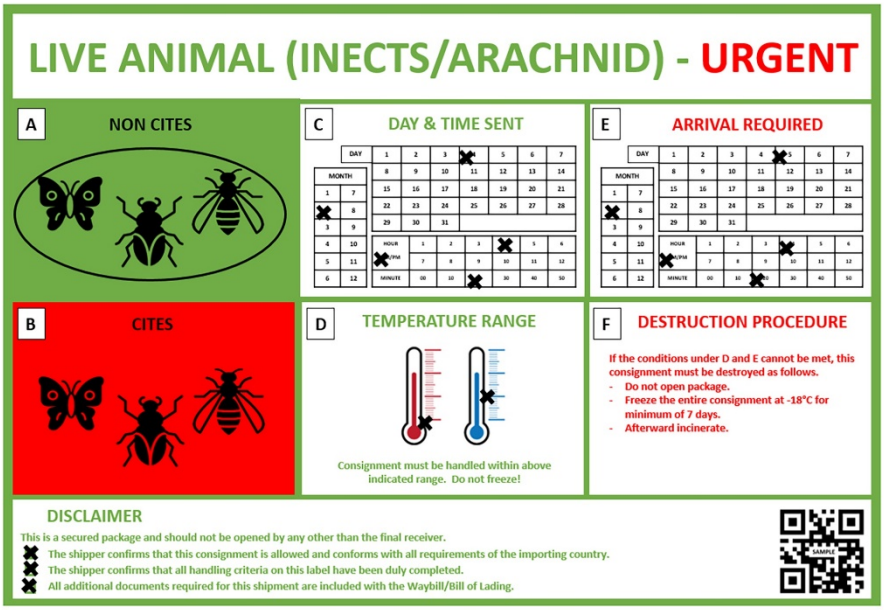

Fig. 3

Proposal of an informative label for the shipment of Insects or Arachnids (filled in for an example)