

International live insect trade: a survey of stakeholders

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Summary

There are significant amounts and diverse types of transboundary shipments of live insects for pollination, pest management, industrial processes, research, and other uses. The range of purposes and parties involved in this trade makes data collection and analysis of this trade difficult. The OIE and Collectif TIS, a French think tank, carried out a stakeholder survey to better understand the nature of live insect (and

related arthropod) trade and potential challenges to safety and efficiency. Target respondents had experience in the areas of biocontrol, sterile insect technique, entomological research, and regulatory affairs. Although the survey was sent globally, the perimeter of answers was unintentionally biased towards Europe and European-related trade. Interest in Europe is high, as this region is developing a comprehensive framework to promote the use of beneficial insects to replace pesticides.

The survey also explored knowledge and relevance of some international agreements on movement and risk management of beneficial or invasive insects, benefits sharing, and liability. Knowledge of the various regulations was generally poor, and those responding to the questionnaire highlighted a perceived lack of clarity regarding live insect shipments in existing international regulations and guidelines. Almost two thirds of the participants reported reluctance by couriers and carriers to accept live insects for shipment, and three quarters described occasional to systematic delays or rerouting that resulted in reduction in quality or viability. As a result, some respondents reported that they hand-carry live insects, mostly when dealing with small quantities.

Respondents described being directly involved in trade covering 70 species of live insects and ticks being transported amongst 37 countries, with volumes that ranged from less than ten to over a million insects per shipment. Of these insects, 30% were potential vectors of pathogens to humans or animals, 42% were potential plant pest species (including, some used for biocontrol), and 17% were classical biocontrol agents. The results of this survey begin to define the current scope, scale, and issues for those exporting, carrying, importing, regulating, or otherwise involved in shipping live insects and ticks across political boundaries; the survey seeks to attract support from regulatory bodies and shipping operators to facilitate safety, efficiency, and consistency in this underdeveloped sector.

Keywords

Live insects – Regulation – Shipment – Trade –Transport.

Introduction

The topic of live insect transport has been attracting more attention as the need internationally for such shipments has grown. Among the reasons for this emerging interest are: limiting risks related to invasive species or protecting biodiversity and facilitating trade activities related to biocontrol. Live insect shipments can cover a wide range of purposes, mainly biocontrol, pollination, and research activities, but also feed and food industry stock, insect product industries (e.g. silk, live bait), and personal or commercial collections (hobby, zoos and butterfly houses, pets). The overall volume of insect trade, however, has been unknown except for specific cases such as shipments of biocontrol agents by large companies or sterile insects as part of area-wide pest management programmes (1, as discussed in Enkerlin and Pereira [2], this issue). Shipments of live insects for research projects are often infrequent and of limited numbers, although they might be of considerable value, sometimes being unique samples.

Be it for research or ongoing biocontrol programmes, it is paramount that shipments are handled according to good practice to improve the chance that a consignment arrives alive and in good condition to the recipients. Dominiak & Fanson (3) reported how stress related to transport conditions may affect the viability of sterile flies released as part of pest management programmes, which has a direct impact on the success of the protection services to growers. Shipping conditions also determine in many cases the appropriate life stage for transporting insects and the way in which they must be packed to travel well. Documentation, labelling, and logistics can affect the duration of shipments.

A scoping meeting on insect shipment issues held in 2018 reported the general views that (a) the current practices and regulations in place often differ between countries and there is a lack of consistent guidance for both senders and freight agents; (b) there were numerous constraints on shipping live insects (few carriers, delays, costs) for some stakeholders; and (c) that actions circumventing existing rules were

sometimes taken to avoid administrative effort, loss, delays and costs (Quinlan *et al.* [4], this issue).

The survey

A survey was designed to explore solutions to facilitate, improve and secure insect shipments, and assess the risks associated with human, animal or plant health related to international live insect shipments. The World Organisation for Animal Health (OIE) was interested in the survey results because of its role to help protect animal health (5). The Collectif TIS, a French think tank on the deployment of the Sterile Insect Technique (SIT), initiated the survey because the research and industrial community it represents identified this issue as one of the main leverages to facilitate the increased use of SIT or other biocontrol insects in Europe. This has resulted in a greater focus on European examples in this survey.

The survey organisers sought observations and experiences from the field to better understand the variety and volume of live insect shipments, usual practices, difficulties encountered, level of knowledge, and perceptions of applicability of current regulations or guidelines by stakeholders. Additional emphasis on relevant European regulations was included in the survey for the stakeholders involved in trade to and from European Union member states.

This survey was only an initial exploration of the issues of live insect shipment and was not intended to be representative of the many stakeholders likely to be involved in such shipments. The aim was to identify a broad range of interests and experiences, which could form the basis of a more representative analysis in the future. The results provide insights on the wide range and complexity of live insect shipments worldwide, which should be conveyed to the freight transport community, as well as national and international official bodies. Moreover, the survey supports the need to investigate further the potential risks associated with animal or plant health and the need to provide more guidance to help to mitigate these risks.

Materials and methods

Survey structure

An online survey was conducted from July to October 2019 using a structured semi-qualitative questionnaire to seek information on trade practices, knowledge, and awareness of the regulatory frameworks around the international movement of insects and ticks. The main aim was to obtain information on any insect species being traded, excluding honeybees (since their shipment conditions are already covered by OIE activities and international standards), that may have animal, human, or plant health implications. Ticks were also included in the survey, despite belonging to the class Arachnida, since they were previously identified as major disease vector species that are commonly being shipped for research activities. While identifying potential risks for animal health was one of the primary perspectives in carrying out the survey, it was recognised that there are many other relevant dimensions and objectives for management and guidance of international live insect shipping. The target trade was transboundary, which could include exchanges between continental and overseas territories as they may involve different regulations or potential risks (relevant primarily for European countries, including France, Spain, and Portugal).

The key areas covered by the survey were (a) the nature, purpose, and conditions of shipments, (b) the experience, including any difficulties, of shipping, and (c) the knowledge of shippers about relevant regulatory texts and international guidelines. The survey was divided into three independent sections according to the main roles in shipment: exporters, importers, or regulators.

The questionnaire (provided as supplementary material [link to be added]), named ‘International movement of live insects and ticks – practices and regulations’, was disseminated through organisational e-mail lists, as well as to other individual contacts of the authors. Effort was made to include a diverse group of initial, targeted respondents who were broadly identified as likely to be involved in or aware of live insect shipping activities, in order to cover the various fields of insect shipments: plant or environment protection or disease vector related

research, biocontrol activities using macro-organisms, and insect production such as feed and food. The questionnaire was sent as a hyperlink to the online platform SurveyMonkey®, along with an explanatory note. The cover note explained the reasons for the questionnaire and the global aims of the coordinators.

Respondents were asked to define their involvement with the shipment of live insects and/or ticks as mainly Exporting/Sending, mainly Importing /Receiving, both (exporting and importing), or neither (e.g. Regulating body). They were then directed to different sections of the questionnaire. Participants were asked to list up to 10 species most regularly shipped (thereby limiting reports on some less important trade) and to describe the conditions and directions of shipment for the most common three species. They could write in the difficulties encountered when shipping and the areas to develop for improvements. A final section allowed the participants to rate their knowledge and understanding or applicability of various regulatory texts or guidelines.

Respondents were given the opportunity to provide their name and institution, although this was not required for completion of the questionnaire. All results shown here are anonymized, and no survey participant details are published.

Survey analysis

Analysis of the responses is primarily descriptive. Detailed statistical analysis is not appropriate with an unknown response rate and an unrepresentative sample. The number and diversity of responses proved sufficient to show a wide range of issues and scales of shipments. It is not possible to determine how many potential respondents were aware of the survey, but 164 initiated a response while only 72 completed the survey. All respondents except two identified their institution and location, indicating that repeat voting is not a concern for interpretation of the results. One participant who reported being involved only in dead insect transport was removed from the analysis.

Maps of insect movements described by respondents, described below, were made using TradeMapper (<http://trademapper.co.uk/>), developed by TRAFFIC and WWF to visualise wildlife trade.

Limitations of the study

The study only focuses on live insects and ticks. The movement of dead insects or parts of insects, bees, spiders, and other arthropods is out of the scope of the survey. The study does not distinguish the health status of the insects being traded. It focuses on the shipping conditions of the insects and not on the rearing procedures or husbandry details of the insects, which may also affect risk.

As regulations and guidelines are different between regions, some of the presented data might not be scalable at the global level. The survey study population is also more biased towards the EU countries in comparison to the rest of the world, due to the sampling approach.

The survey is unintentionally more biased towards the biological control sector, as well, because the authors belonged mostly to this field and the questionnaire was disseminated towards their network extensively. The community using insects for recreational purposes (pets, collections) was not reached by the survey dissemination. The insects for food and feed sector were limited in our survey since they are primarily traded as processed insect products rather than living insects.

Results

Global data

In total, 45 participants answered as mainly 'importer' or 'exporter', while 26 participants responded 'neither'. This last group is then referred to as regulator/advisor.

Importers or exporters

The 45 respondents in this group were from 34 organisations, 14 countries and one oversea territory. The participants were mainly from

research organisations (63%) or commercial industries (14%) (Fig. 1). Of these, 61% have been involved in shipment of live insects and/or ticks for more than ten years, indicating a substantial level of experience.

They were asked if their organisation was certified as a ‘known consignor’; which was described in the survey text as follows:

The Known Consignor scheme means a consignor who originates cargo or mail for its own account and whose procedures meet common security rules and standards sufficient to allow carriage of cargo or mail on any aircraft. Regardless of destination, international outbound cargo that originates from a Known Consignor does not require further examination before uplift onto an aircraft. [6]

The majority of the respondents did not know (59%, N=44). Only two respondents answered positively, one was mainly exporting (Biological control), the other mainly importing (Research); they reported to be involved in live insect transport for six to ten years.

[Insert Figure 1 here]

Regulators or advisors

The participants declaring to be neither directly involved in export or import shipment belonged to various categories: Government or regulatory bodies, United Nations organisations, non-governmental organisations (NGOs), industry federations, grower organisations, consultants, or research centres. They are referred to hereafter as ‘Regulators or advisors’.

Diversity of insect shipped

Participants could rank up to ten species of live insects and/or ticks that they regularly ship, according to volume. A total of 70 species were reported. Eleven species were cited by multiple participants. Table I describes some characteristics of the ones shipped by more than two different participants

Insert Table 1 here

Of the insect species listed, three main categories of insects emerged (based on risks or use): 30% were potential vectors for human and/or animal diseases, 42% were (potential) plant pests, and 17% were biological control agents (Fig. 2).

Insert Figure 2 here

Three cases involved weekly shipment of sterile insects, shipped as adults, maintained at a specific temperature. One of these shipment sets was reported at a weekly frequency for an annual number of specimens shipped of over a million, representing an estimated 500–1,000 kg in total annual shipments. The other two were weekly or seasonal shipments, representing annually under a million individuals for an annual total of 10 to 100 kg of insects. One case involved shipment at the pupal stage, but no information was given on the shipment conditions.

Among the plant pest insects, five species represent exotic biocontrol agents usually used against invasive plant pests. Insects shipped for biocontrol activities were described to be shipped as eggs, larvae, or adults. Another respondent reported the shipment of adults from a plant pest (Aphid species) intentionally infected with a plant pathogen; they were transported via hand-carriage at a specific temperature range, in small numbers of insects (10 to 100 annually) and declared as live insects for research. Six species of ticks (from the genera *Dermacentor*, *Ixodes* and *Rhipicephalus*) and samples to be identified were reported to be sourced from wild or confined rearing (or a combination of both); they were shipped mostly as adults and sometimes as eggs. Potential insect vectors of human and animal pathogens (e.g. mosquitoes, culicoides, tsetse flies) were sourced from the wild or confined rearing, and were shipped within and across continents.

Insects transport worldwide

The conditions of shipment were examined for each case of shipment described, that is, for given respondents and given species (up to three

species described per respondent). Most of the cases involved transport by air (85%, N=52), while 4% were by rail and 4% by road; none involved transport by sea.

Transboundary movement

The shipments described involved a diversity of routes between neighbouring countries or between continents (Fig. 3). The countries represented in the map are limited to the ones with which the respondents to the survey were directly involved, and should be considered only as a sample of the actual global trade/movement of live insects. The map on movement of live insects that are potential vectors of human/animal pathogens (Fig. 4) shows that countries with high biodiversity and higher endemicity of pathogens or vector insects, such as in the South American, African, or Asian regions, are sending or receiving insects. The map of plant pest insects or biocontrol agent movement (Fig. 5) shows a high intensity of routes between Europe and North America. Most shipments described are from or shipped toward Europe (particularly France), which is a bias due to reaching more stakeholders from this region.

Insert Figures 3, 4, 5

Sourcing

Wild sourced (harvested) accounted for 33% of the shipment described, while another 33% were from confined rearing (with no free movement outside the designated farm or laboratory premises) (Fig. 6A). The sourcing could differ for a given species, as reported by 23% of the respondents. Among the shipment of wild sourced insects, 56% were insects of agricultural interest and 44% were potential human/animal disease vectors. Some respondents indicated shipping them as eggs, larvae, pupae, or adults; however, most respondents did not report this information.

Physical conditions

There were few answers regarding the developmental life stage of the insect and the physical conditions of shipment. However, the data

indicate similar proportions of refrigerated packages, at a specific range of temperature or without any specific temperature requirement (Fig. 6B).

Hand-carrying

Most respondents (64%) reported that they never hand-carry their insect packages (Fig. 6C). The ones reporting routinely hand-carrying were from the 'mainly importers' category. Another 13% of participants reported to hand-carry only when potential carriers would not accept a package. Respondents involved in hand-carrying are mostly transporting small quantities of insects: 8 out of 14 described packages under 50g of insects, 10 out of 14 reported carrying between 10 to 100 individuals per shipment. Some respondents indicated transporting at the adult stage, but most of them did not give any detail on the life stage. One respondent from the Food and Feed sector reported routinely hand-carrying packages of the black soldier flies *Hermetia illucens*, stating that no declaration would be required; their average shipments comprised 10,000 to 100,000 insects (1–10kg package) but the stage was not indicated. Of those hand-carrying routinely, 64% reporting that they declared their package as containing live insects.

Insert Figure 6 here

Undeclared shipments

Some respondents (21%) reported that an official declaration (paperwork accompanying the parcel) of the live insect status was not required for their shipment (Fig. 6D); half were mainly involved in exporting. The shipments described by these respondents involved in insect movement between European countries; between European Overseas Territories and mainland Europe; between Central and North American countries; or between neighbouring African countries. The species shipped were biocontrol agents (Pteromalidae and Braconidae species of parasitic wasps and *Cetonia aurata*), potential vectors of human diseases (*Aedes albopictus*), and a tick species (vector of pathogens in dogs).

For 15% of the shipments described, the 'live insects' status was not declared because otherwise the carrier would not accept the package; these were reported only by the Exporter category. Respondents described cases of undeclared shipments of (potential) plant pests (transported as pupae or eggs), mosquitoes (potential vectors of human diseases *An. gambiae* and *Ae. aegypti*, transported as eggs), adult ticks (potential vectors of human diseases *Ixodes ricinus* or animal diseases *Dermacentor marginatus*, *D. marginatus*). These shipments were mostly monthly, then quarterly or seasonally (so could be repetitive shipments during a season). They were done between European countries (continental and overseas) and between continents.

Shippers have a responsibility to be aware of when declarations are legally required. Reasons given as to why to avoid this declaration are discussed elsewhere.

Declared shipments

The majority of the shipments described (54%) were done with declarations regarding the status of live insects. About a third of them were shipments of under 100 individuals, and another third were shipments between 100 to 10,000 individuals, while one shipment concerned over a million insects. Of those shipments with declarations, 29% were annual, 39% were seasonal, 14% monthly, while 18% were weekly.

Import and export documentation

The most common documentation reported as accompanying shipments was a material transfer agreement (MTA) (43%, n=19) and import permit (41%, n=18). However, it is important to note that 23% (n=10) of the participants often do not provide any documents; one of those participants considers that no declaration is required. Another 9% (n=4) indicated that they are not aware of the documents required, among which an e-commerce shipper sent weekly shipments of 10,000–100,000 specimens of two species of biocontrol agents within Europe.

It should be noted that failing to provide required documentation for international shipments, whatever the material, could lead to fines or prosecution, depending on the case.

For 23% of the shipments, a sanitary/veterinary certificate was attached. A wide range of alternative documents were also provided by some respondents, such as: CITES declaration (n=4), mutual agreed terms (MAT; n=4), quarantine license (n=5), letter of authority (LOA; n=8), but also invoices, insurance forms, origin of goods statement, packing list, etc. Exporters and importers described a similar range of documentation.

Regulatory knowledge and applicability

Regarding the regulations section, the questionnaire focused on the relevant regulatory texts and international guidelines in the field as listed in Table II (details on these texts and guidelines can be found in Quinlan *et al.* [3]). Respondents indicated low levels of proficiency and a lack of familiarity with the relevance of these agreements to their work.

Insert Table II here

The Nagoya Protocol to the Convention on Biological Diversity (CBD) (7) was the text for which respondents indicated the greatest familiarity, with 6% considering they have an average or complete knowledge. Of the respondents rating average to complete knowledge, 85% considered that the protocol is important for their activity (rated as 3 to 5), 77% of them were primarily involved in research, 85% have more than six years of experience in shipping (either import or export), 42% traded over six different species annually, and 58% traded insects sourced from the wild or a combination of wild and rearing. On the other hand, of the respondents reporting no or very basic knowledge of the Nagoya protocol, 69% declared not knowing if it applied to their activities, although most of them (77%) had more than six-years of experience in insect shipments and almost half were involved in wild sourcing.

The Nagoya–Kuala Lumpur Supplementary Protocol (8), dealing with transboundary movement of live modified organisms, was unknown to 59% of the respondents. Six respondents out of 34 considered that this text was important to their activities; of those, two had a good knowledge of it, while one declared having no prior knowledge of the text.

The CBD Supplementary Voluntary Guidance for Avoiding Unintentional Introductions of Invasive Alien Species Associated with Trade in Live Organisms (9) was unknown to 65% of the respondents, and 54% reported not knowing if it was applicable to their field. This text was considered highly relevant for their activity by 24%, mainly importers of insects for research purposes; their knowledge of the text varied from basic to complete.

The applicability of the ISPM No. 3 (10), an international standard under the International Plant Protection Convention (IPPC), which gives guidelines regarding trade in living biocontrol agents or other beneficial organisms associated with plant health (e.g. pollinators), is unknown to 34% of the respondents, mainly involved in human/animal vector insect research activities. Six respondents out of 38 declared no applicability of this text to their field, although three of them were involved in the shipment of biocontrol macroorganisms for over six years. Of the respondents dealing with agricultural research or biocontrol, 60% reported a good to complete knowledge of the standard. The ones declaring strong applicability of ISPM 3 to their activities all also provide import permits and other relevant documentation with shipments.

The participants involved in trade with or within Europe were asked about their knowledge of European regulations. The Directive 2008/61/CE (11) is poorly known by the surveyed community with 68% reporting no or little knowledge. This text deals with the conditions of introduction or movement of harmful organisms, plants, or plant products. However, three respondents involved in research or sterile insect technique on vectors of human diseases report it as being relevant to their activity, although it is directed at organisms harmful to

plants. The EU Regulation 2016/2031 (12) relates to protective measures against pests of plants; 79% declare not knowing it. Four respondents out of 21 considered that it was relevant to their activities, although one was involved only in research on insect vectors of human diseases.

The Commission Delegated Regulation 2019/829 (13) concerning the delivery of temporary derogations for the use of pests of plants in certain conditions (official testing, scientific or educational purposes, trials, varietal selections, or breeding) is known only by two out of 19 respondents, who are involved in biocontrol or research activities with plant pests. The Regulation 1143/2014 (14) dealing with the prevention and management of the introduction and spread of invasive alien species was known to 21%, half of whom worked with plant pests and half with vectors of human or animal diseases.

Finally, Regulation (EU) 2015/2283 (15), which relates to production of insects for food and feed, was unknown to all respondents and considered not relevant for their activity of shipping live insects.

National regulatory context

Regulation of insect movement

Some 43% of respondents declared that the country in which they are based has a national regulation relevant to insect shipping, while an equal proportion did not know about their national regulation status. Four respondents declared that there was no national regulation in their field, and that they had no private or academic guidelines either.

Sterile Insect Technique and Genetically Modified Organisms

Respondents from nine countries reported being involved in shipping live insects for SIT. Regarding sterile insect shipment, only two organisations (dealing with vectors of human diseases), however, reported the existence of a national regulation related to SIT, one based in Europe and another one in the Caribbean.

Difficulties faced during the international movement of insects/ticks

Finding a shipper

Just over half (55%) of respondents considered that their main difficulty came from the unwillingness or reluctance of the shipping companies to ship live insects/ticks (Fig. 7); there was no trend related to importer or exporter role, plant or human health field, or stage of the insects to be shipped. Of the 26 types of shipments described by this group of respondents, six were reported to be exceptionally or frequently hand-carried, as a result of commercial agents or carriers being unwilling to take shipments.

Insert Figure 7 here

Around half (48%) considered that the rates proposed for shipping are frequently or always high as compared to other materials of the same weight and volume. Half of these respondents are importers, and 60% of the insect shipments they received or sent were declared as live insects. On the other hand, seven of the eight respondents reporting that rates are not too high are exporters, and six of them reported not declaring that packages contained live insects, either because it would not be required (three respondents) or because the agents/carriers would not accept live insects.

Rates and restrictions imposed by the same agent/carrier for the same type of shipments are judged (sometimes to always) to be inconsistent by 67% of the respondents. The ones reporting no restriction also declared having few issues related to costs, unwillingness to accept a shipment, or misclassification.

Shipments are sometimes misclassified as a hazardous substance, according to 36% of the respondents; there is no clear explanatory variable related to continent, sourcing, export/import, or category of insect (vector/pest). One respondent from South America involved in agricultural (quarantine) pest export to European countries for research objectives declared always undergoing misclassification; this

respondent also reported high costs, unwillingness to ship, and having to hand carry the insects when agents/carriers would not accept the shipments.

Concerning insect species which have undergone treatment or modification that makes them no longer a pest/vector but a biocontrol tool (such as sterile insects), the majority (76%) of respondents declare not encountering any particular restrictions. Two respondents reported always having issues, however, while two others reported sometimes facing restrictions, for exports of large numbers of sterile insects (i.e. 10,001–100,000 insects per shipment).

Procedures and regulations

Difficulties were also reported due to the unavailability or the lack of guidelines for insect/tick shipments (70%), and the lack of a regulatory body for the authorisation of those shipments (80%). Many respondents (64%) agreed with the proposition that there is ‘a lack of harmonised international trade regulations with unfair trade barriers, such as diverse requirements between different international, regional and national technical or regulatory bodies, as well as private transport service providers’, presented in the survey.

Confusion with illegal trade in endangered or wild collected species did not appear as a parameter of importance in this survey. Only two respondents declared suffering from this confusion sometimes or always; they both are commercial exporters of biocontrol agents for commercial or research purposes.

The lack of clear mechanisms to share benefits, transfer ownership or protect proprietary research and development in the country of origin or receiving country (in relation to the Nagoya Protocol) was reported by 59% of respondents. Those reporting always facing this issue are involved in commercial or intercontinental research movement of agricultural pests or biocontrol agents.

Technical problems during shipment

Almost two thirds (65%) reported never having had their package held or destroyed by Customs. The three importers declaring frequently or always having their packages held or destroyed, were variously shipping either by air, road or railway, small packages of live insects (under 50g). A majority (73%) reported problems due to delays or rerouting (which reduces quality or leads to death of the insects/ticks during transport), and 55% reported loss, damage, or a break in the temperature regime of the package.

High mortality of insects and ticks during movement was reported by 64% of the respondents, of which five are commercial exporters or importers. Four respondents declared always or frequently facing this issue, they also reported always enduring loss, damage, or a break in temperature.

The lack of appropriate commercial insurance covering living biological products (insects) was reported as never being a difficulty by 73% of respondents. It was sometimes considered an issue for 13% of participants.

Regulators or advisors' perception of international movement of live insects/ticks

Only 27% of the respondents in this group belonged to institutions in charge of drafting, implementing, or enforcing legislation or protocols related to international movement of live insects/ticks (Fig. 8A). Over half (57%) reported knowing the national institution regulating the authorisation of the international movement of live insects/ticks in their country (Fig. 8B). When asked whether they considered that there is a need for more specific guidelines and/or support, at the national or international level, for the international movement of live insects/ticks, 88% of respondents agreed (Fig. 8C). The only two responding negatively did not belong to regulatory bodies but were in the advisor category.

Insert Figure 8

Type of support to improve international movement of live insects/ticks

Most respondents, whether involved in the shipment or in the regulators group, would recommend greater harmonisation of policy, guidelines or international standards and national legislation regulating live insect shipments. Regulators and advisors, in addition, agree on needs for better enforcement and stakeholder training (Fig. 9).

Insert Figure 9

Discussion

A high diversity of shipments

This small sample of participants showed that international live insect movement and trade are at a global scale for research and commercial activities. Respondents reported they were involved with seventy different insect species, being traded between 37 countries (or overseas territories), from small sample sizes for research purposes to some millions of insects shipped as part of operational SIT programmes.

Most insects shipped belonged to three main categories: potential vectors for human and/or animal diseases, plant pests, and biological control agents. They were traded or shipped either for research or commercial activities. The higher volumes (100,000 individuals to over a million per shipment) relate to commercial transfers of sterile insects or biocontrol products. Package characteristics (numbers of specimen and weight) vary with the stage of the insect being shipped. Several participants reported sending or importing quantities from 10,000 to 100,000 individuals, which can weigh less than 50g for eggs (usually sent to start rearing activities) and up to a few kg for pupal stages. For commercial shipping the price varies with weight and size of the package; which may render low-weight shipment of little commercial interest for agents/carriers, especially at a low frequency.

Shipping practices reflect a lack of clarity and obvious difficulties

Most participants indicated some or several difficulties when shipping insects (or ticks), starting from the reluctance of some agents and carriers to transport this category of shipment. The most common difficulties encountered were loss and deterioration of the packages (including temperature breaks) and delays or rerouting, which may affect the quality or survival of the insects. It is common for insects to arrive dead, and this can have serious consequences, both for research activities when it is a unique field sample, and for pest management programmes when the protection service is impaired (not to mention the cost).

Users exporting or importing live insects often reported using only an MTA document, which is not related to the shipping procedure and would have little value for customs controls. Several users reported they hand carry and/or do not declare the content of their package to facilitate shipping. Refusal by couriers or carriers to transport live insects is often reported. However, undeclared, or uncontrolled shipment of live insects may also have unsatisfactory consequences. For users, this may lead to obvious risks of damages, delays, and loss of quality. For all stakeholders, including the national authorities, this increases the risks of invasive species (insects or pathogens) spread.

Risks associated with undeclared shipments

Human or animal health risks

This survey starts to identify the major species of insects being used and traded internationally that are potential disease vector insects and ticks with human and animal health implications. A more focused survey would be needed to identify more formally the extent of risks related to human or animal health. However, 30% of the species traded by the participants were insects that are potential vectors of human and/or animal pathogens. Their movement mostly related to research activities, only a small part was devoted to the deployment of the sterile insect technique (against mosquitoes).

Biodiversity risks prevention

The International Plant Protection Convention (IPPC) has recognized that the globalisation of trade and climate change increase the threat of species injurious to plants being introduced and have adopted measures to determine and manage phytosanitary risks. CBD Guidance (9) covers the risks to biodiversity when importing alien species, whether intentionally or not, and gives instructions for the preparation of live organism consignments. A similar approach might be taken to cover the scope of insects that can carry pathogens transmittable to humans or animals, which could result in official conditions imposed on import and scientific activities. This has been done for the trade of bees to prevent the spread of diseases between continents/countries, through the OIE *Terrestrial Animal Health Code* (5).

Knowledge of regulations and guidelines

Participants were asked to rate their knowledge and level of applicability of various international regulatory texts and guidelines related to live insect movements. The applicability of the Nagoya Protocol (7) to international insect movement should be high as several instances relate to wild samples. However, the results of the survey showed that there is still a lack of knowledge or compliance even from users involved in research activities from field-sourced samples. The Nagoya–Kuala Lumpur Supplementary Protocol (8), specific to transboundary movement of living modified organisms was largely unknown to the participants, however none reported they were dealing with GM insects. The CBD Supplementary Voluntary Guidance for Avoiding Unintentional Introductions of Invasive Alien Species Associated with Trade in Live Organisms (9) was also largely unknown, but even participants who had no prior knowledge of it reported to understand its applicability for their activities.

The most relevant guideline for live insect trade in the field of plant pest protection and biocontrol is ISPM 3 (10). It appears to be relatively well known and used among the plant pest control sector, although not universally considered relevant by shippers of biocontrol insects who responded. This internationally recognized standard presents clear

procedures for users, shippers, and national authorities to secure and facilitate shipments.

Overall, the users involved in European trade showed a poor knowledge and understanding of the various regional regulations in place: Directive 2008/61/CE [11]), EU Regulation 2016/2031 (12), Commission Delegated Regulation 2019/829 (13). Those regulations mostly relate to plant health and are a framework for import (including required documentation and related national authorities) and conditions of use and containment. The Regulation 1143/2014 (14) dealing with the prevention and management of introduction and spread of invasive alien species was also poorly known, however it may apply to various participants dealing with potentially invasive insect species. This regulation sets the conditions for import, including specific permits, authorisations, and containment measures.

Guidelines and standards are often needed by stakeholders to understand and follow regulations. There might be a need for international agencies and national regulatory bodies to update existing guidance or to bring those various regulations into a more comprehensible and/or comprehensive form that could be more easily followed by all users. This might also facilitate commercial shipping operators understanding the issues and requirements. Existing guidelines could be more widely publicised, given the relatively poor awareness by those involved in shipping.

Facilitate, improve, and secure shipment conditions

Users feel frustrated at the limited options and unclear procedures for live insect shipments. However, the diversity of shipments, low weight and irregular frequencies of most shipments may not seem very attractive for commercial shipping operators, who may think that they are taking some risk in accepting such consignments. On top of that, there seems to be confusion related to the administrative procedures for shipment and implementation of existing guidelines.

Shipping live insects is obviously time sensitive and requires good environmental control inside packages. Relevant procedures exist in the

International Air Transport Association (IATA) Live Animal Regulations (LAR; Section on ‘beneficials, insects, bees and bumblebees’) (16), which can make shipping those insects by commercial airline companies easier than through couriers. This LAR section emphasizes that the transport of those insects ‘has to occur in the shortest time possible to protect the vitality of these delicate organisms’. However, the packaging and operational requirements described in the LAR are quite specific for certain types of insects and stages, and may not fit, for example, when shipping mosquito eggs to start a colony or ticks to be identified by collaborators. Although those example activities usually have a high scientific and public health value, they have little or no commercial value. The definitions in the LAR could be improved to better differentiate insects, and/or conditions, that pose no risks as pests, vectors or invasives.

For agents/carriers, the profit margin may seem insufficient and/or seasonality of trade may make this business appear of little interest at first sight. The potential commercial risks during shipment due to lack of clear regulation may also be deterrent. This survey also aimed to show the variety of reasons for which users need to trade live insects and the global need from most research laboratories involved in public or animal health, agriculture, or environment preservation, as well as from biocontrol industries. This could help commercial shipping operators recognize the attractions of this market.

Most respondents indicated a need for more consistent policy, guidelines, or international standards to support and facilitate safe and efficient international movement of live insects and ticks. The concepts existing in ISPM 3 and the IATA LAR could serve as a base from which to implement a more comprehensive framework for best practices for all insects, including the categories of insects not yet covered.

Conclusions

Despite the long-established uses of insects, industrialisation, and commercialisation of the sector are still in their infancy, therefore to a large extent so is the trade that supports it. Thus, available information about the trade is scarce, including in scientific literature. The scarcity

of quantitative international insect trade data, records, and figures (volume, countries/regions involved, monetary value, etc.) makes it harder to gain attention from policy makers and international bodies; confusion around the appropriate and up to date guidance for the various types of insects in trade is not helping to make this sector attractive for commercial shipping operators. While not comprehensive or even representative of all insect trade, this survey provides sufficient data to change that landscape. Relevant international bodies and national or regional regulatory bodies should also recognize the importance of this particular trade.

There is a growing need for more consistent policies between countries, which may be supported through the development of comprehensive international guidance or standards on insect shipment that allow participants in the trade to understand requirements reliably and quickly and be ready to meet them. While simple, timely and accessible messaging around this will help support understanding and therefore compliance, any guidance will need to differentiate the risks that may be involved according to the characteristics of the proposed trade. It is especially important to identify and agree on conditions for shipments that have no or very low risk and are widely established as safe. The aim of this investigation is not to complicate procedures or add restrictions to sectors already moving large volumes successfully throughout the world. The limited awareness of current regulations and guidance indicates a need for improved publicity on the potential benefits of shipment of live insects and the proportionate risk management requirements to make it safe.

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Author contributions

All co-authors drafted the survey; RC created the online survey tool; CFO, RC, JM and JP did the data analysis; CFO drafted the manuscript and all co-authors contributed to and reviewed the final manuscript.

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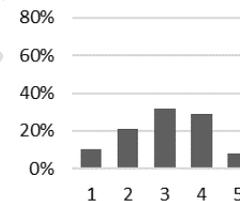
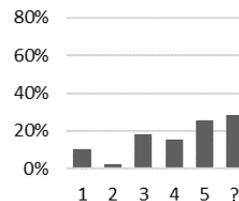
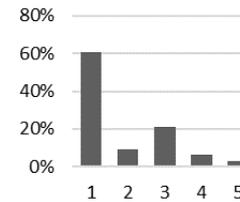
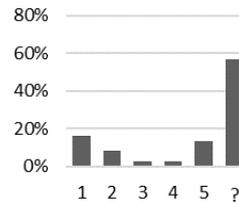
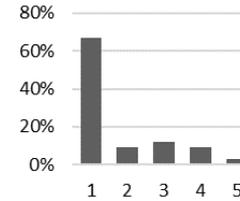
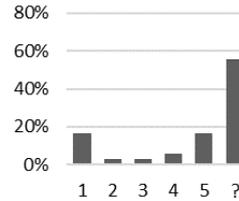
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Table I
Details of the shipments described by the respondents for the most cited species

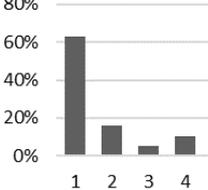
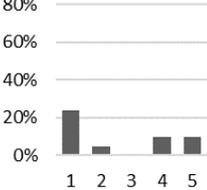
Species	Field of use or research	Number of respondents	Weight per shipment	Sourcing
<i>Aedes aegypti</i>	Medical	12	< 1 kg	Combination of sources or rearing confined
<i>Aedes albopictus</i>	Medical	11	< 1 kg	Wild or combination of sources
<i>Culex pipiens</i>	Medical	6	< 1 kg	Wild
<i>Culicoides sp.</i>	Medical	5	< 1 kg	Confined or wild
<i>Anopheles gambiae</i>	Medical	3	< 1 kg	Combination of sources, rearing confined or rearing non-confined
<i>Cydia pomonella</i>	Agriculture	3	< 10 kg	Combination of sources or rearing confined
<i>Ixodes ricinus</i>	Medical	3	< 1 kg	Combination of sources or wild

Table II

Regulatory texts and guidelines: level of knowledge and applicability for insect trade. The bars indicate the percentage of respondents. Level of knowledge from 1 = no knowledge to 5 = complete knowledge; level of importance towards own activity from 1 = not important to 5 = extremely important, and ? = unknown. The number of total respondents is indicated (N). European regulations questions were targeted only to respondents shipping insects/ticks to/from/within the European Union

Text/guideline	Relevance for the field	Level of knowledge (% of total answers)	Consideration of applicability (% of total answers)
International treaties or guidelines			
The Nagoya Protocol [7]	Wild sourcing		
	Biodiversity protection		
	Access to Genetic Resources		
	Commercial use		
	Fair and Equitable Sharing of Benefits		
		(N=39)	(N=40)
The Nagoya – Kuala Lumpur Supplementary Protocol on Liability and Redress to the Cartagena Protocol on Biosafety [8]	Transboundary movement of live modified macro-organisms		
		(N=34)	(N=38)
Supplementary Voluntary Guidance for Avoiding Unintentional Introductions of Invasive Alien Species Associated with Trade in Live Organisms (CBD COP	Invasive alien species		
	Trade recommendations		
		(N=34)	(N=37)

Text/guideline	Relevance for the field	Level of knowledge (% of total answers)	Consideration of applicability (% of total answers)
decision 14/11, Annex1 [9]			
FAO/IPPC International standards for phytosanitary measures (ISPMs): ISPM 3 [10]	Guidelines for the export, shipment, import and release Biocontrol macro-organisms and sterile insects.	<p>(N=34)</p>	<p>(N=38)</p>
European regulations			
Directive 2008/61/EC [11]	Import into European member states Conditions of introduction or movement for trial or scientific purposes and for work on varietal selections Harmful organisms to plants, plants, plant products and other objects	<p>(N=19)</p>	<p>(N=21)</p>
Regulation (EU) 2016/2031 [12]	Rules to determine the phytosanitary risks Protective measures Pests of plants	<p>(N=19)</p>	<p>(N=21)</p>
Commission Delegated Regulation (EU) 2019/829 of 14 March 2019. [13]	Temporary derogations in view of official testing, scientific or educational purposes, trials, varietal selections, or breeding Pests of plants	<p>(N=19)</p>	<p>(N=21)</p>

Text/guideline	Relevance for the field	Level of knowledge (% of total answers)	Consideration of applicability (% of total answers)
Regulation (EU) 1143/2014 [14]	Prevention and management of the introduction and spread of invasive alien species Threat to biodiversity and related ecosystem services Adverse impact on human health and the economy	 <p>(N=19)</p>	 <p>(N=21)</p>

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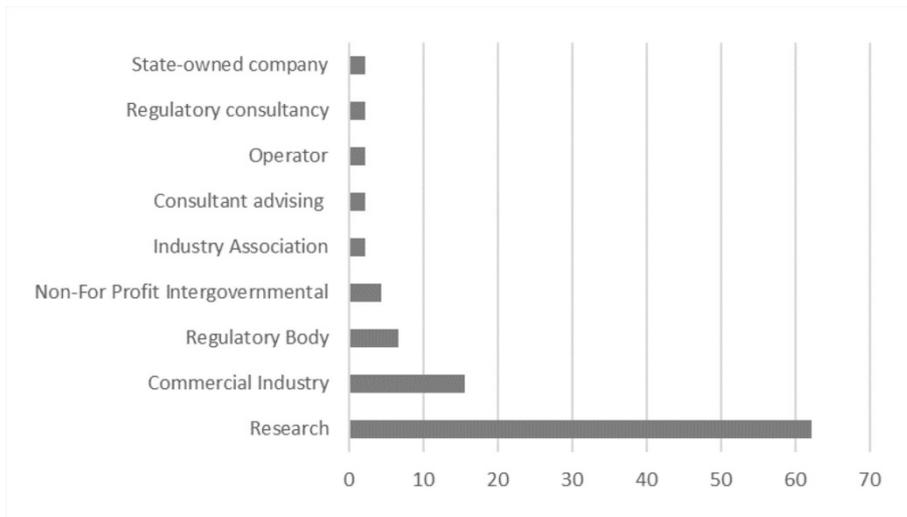


Fig. 1
Type of organisation to which the respondents belonged (% of total answers; N=45)

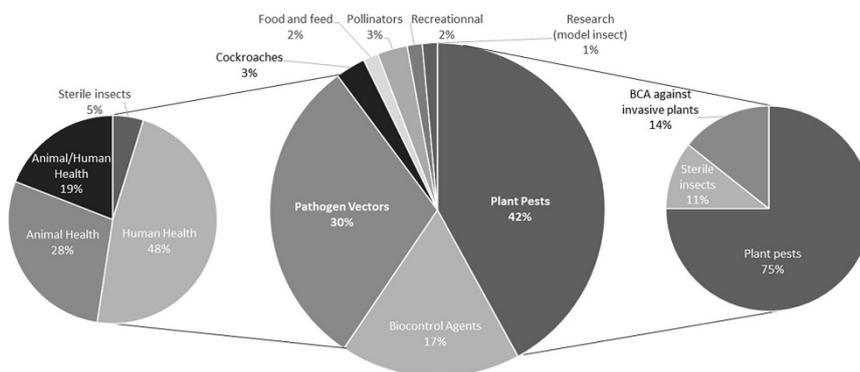


Fig. 2
Proportion of the insect species shipped by the respondents according to categories of nature or use (% of total answers; N=70). The ‘Pathogen vector’ and ‘Plant pest’ groups are further detailed in the satellite diagrams



Fig. 3
Map showing transport direction of all categories of insects mentioned by survey respondents. The thickness of the lines indicates the number of transfers on similar routes

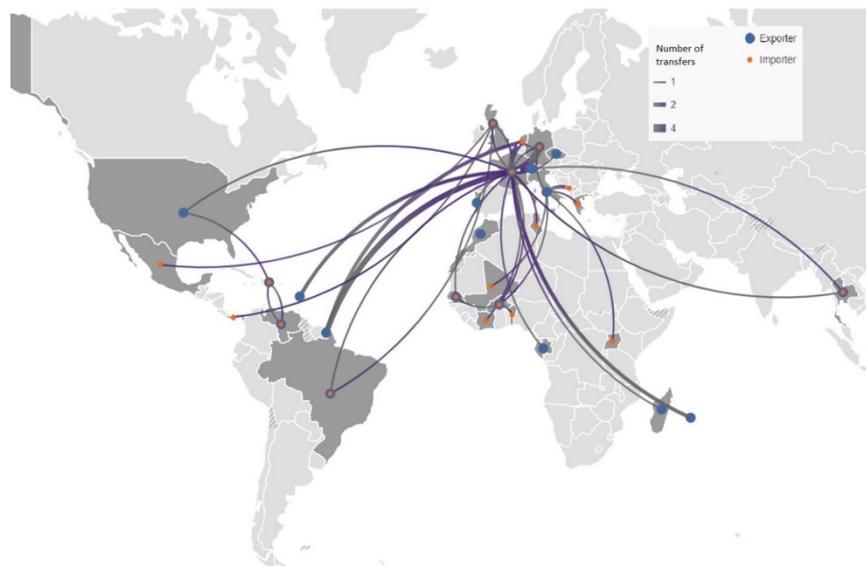


Fig. 4
Map showing transport direction of insects that are potential vectors of human and/or animal pathogens mentioned by survey respondents. The thickness of the lines indicates the number of transfers on similar routes



Fig. 5
Map showing transport direction of insects that are potential plant pest or used as biocontrol agents (against plant or insect pests) mentioned by survey respondents. The thickness of the lines indicates the number of transfers on similar routes

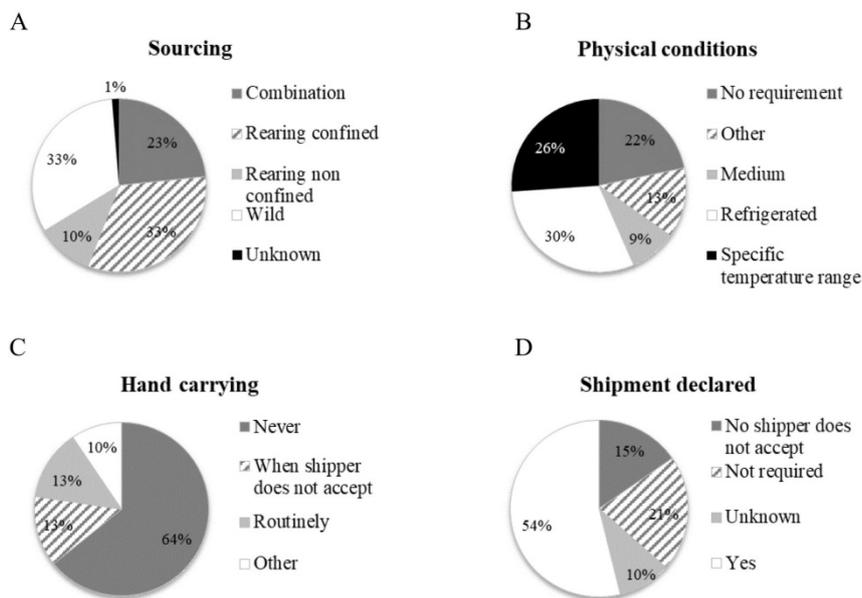


Fig. 6
Main characteristics of the reported shipments: sourcing origin (A; N=77), physical shipment conditions (B; N=23), hand-carrying shipment (C; N=53), declaration as live-insects (D; N=52)

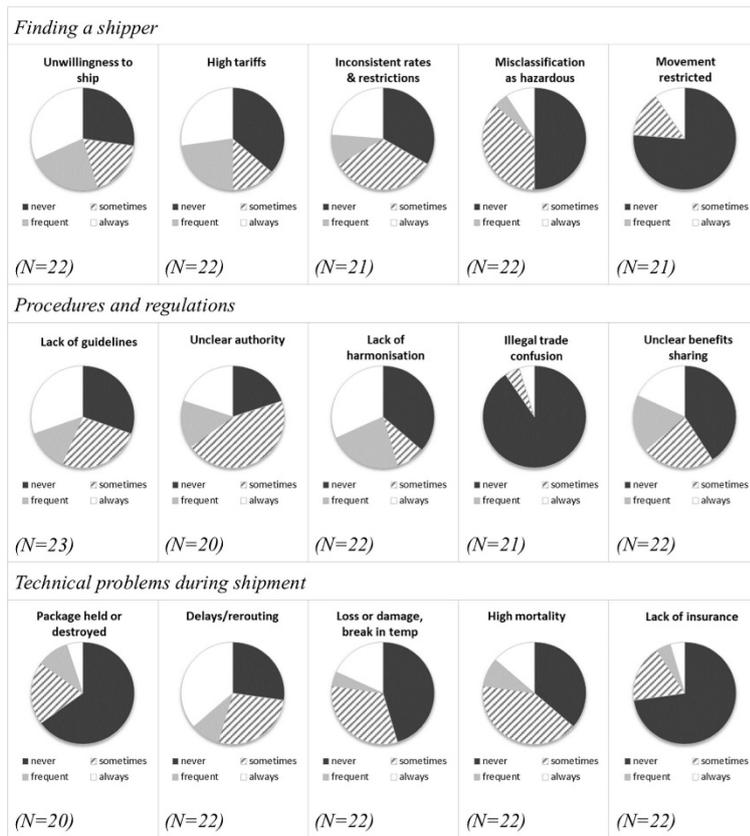


Fig. 7
Difficulties encountered by users during shipments of live insects or ticks. The number of total respondents is indicated (N)

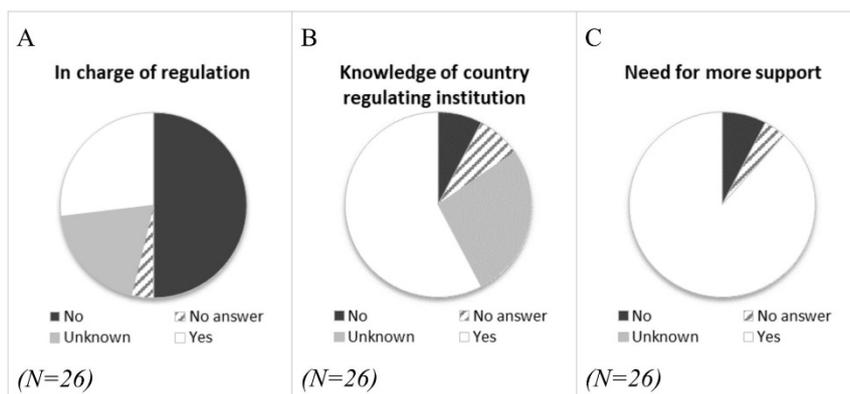


Fig. 8
Responses of the Regulators/Advisors group (N=26): own institution in charge of legislation or protocols (A), knowledge of institutions regulating the authorisation of shipment (B), need for more support regarding live insect/tick transport (C)

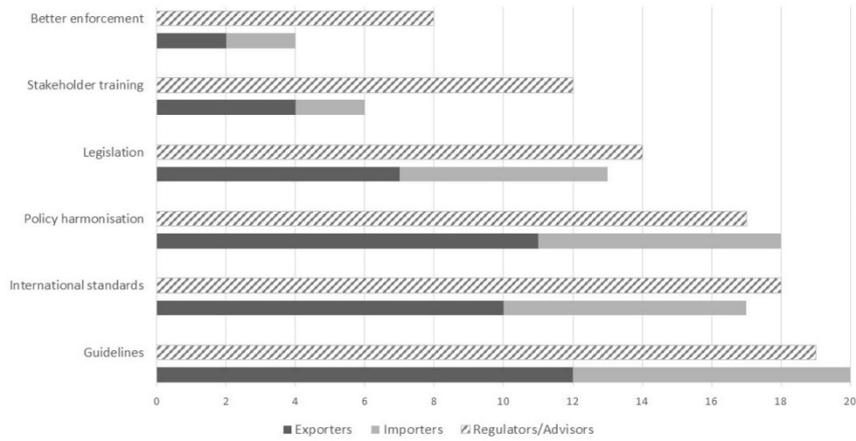


Fig. 9
Type of support needed according to Importers/Exporters or Regulators/Advisors (number of respondents)