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Pest Risk Analysis for

***Bactrocera latifrons* (Diptera: Tephritidae)**

September 2017

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This risk assessment follows the EPPO Standard PM 5/5(1) *Decision-Support Scheme for an Express Pest Risk Analysis* (available at http://archives.eppo.int/EPPOStandards/pra.htm) and uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at https://www.ippc.int/index.php). This document was first elaborated by an Expert Working Group and then reviewed by the Panel on Phytosanitary Measures and if relevant other EPPO bodies.

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Photos: *Bactrocera latifrons* adult. Courtesy: Natasha Wright, Cook's Pest Control, Bugwood.org

Based on this PRA, *Bactrocera latifrons* was added to the A1 Lists of pests recommended for regulation as quarantine pests in 2017.

Pest Risk Analysis for *Bactrocera latifrons* (Diptera: Tephritidae)

This PRA follows EPPO Standard PM 5/5 *Decision-Support Scheme for an Express Pest Risk Analysis*. It is a follow-up of the EPPO Study on Pest Risks Associated with the Import of Tomato Fruit (EPPO, 2015). Four PRAs for tomato pests were performed in parallel, in a new procedure by which they were prepared in a shorter time and reviewed together by one Expert Working Group. This implies among others that the final PRAs contain more uncertainties, which could not be resolved in the framework of this new procedure.

PRA area: *EPPO region*
Prepared by: EWG on PRAs for tomato
Date: 2015-12-07/11 (the PRA was further reviewed and amended by other EPPO bodies, see below)

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Prior to the EWG, the PRA was reviewed and comments provided by the following experts: Dr Maulid Mwatawala (Sokoine University of Agricultural, Tanzania), Dr Grant McQuate (USDA-ARS, Hawaii, USA) and Dr Nicador Liquido (USDA-APHIS, Hawaii, USA).
Following the EWG, the following PRA core members provided comments: Alan MacLeod (UK), Dirk Jan van der Gaag (The Netherlands), José Maria Guitian Castrillon (and colleagues; Spain), Lucio Montecchio (Italy), Robert Steffek (Austria), Salla Hannunen (Finland), Silvija Pupelienė (and Henrikas Ostrauskas; Lithuania).

The Panel on Phytosanitary Measures considered the management options in 2016-11 and 2017-03. EPPO Working Party on Phytosanitary Regulation and Council agreed that *Bactrocera latifrons* should be added to the A1 Lists of pests recommended for regulation as quarantine pests in 2017.

<table>
<tr><td colspan="4">Summary of the Pest Risk Analysis for Bactrocera latifrons (Diptera: Tephritidae)</td></tr>
<tr><td colspan="4">PRA area: EPPO region</td></tr>
<tr><td colspan="4">Describe the endangered area: The endangered area is considered to be the Mediterranean Basin, Portugal and the South of the Black Sea coast. There is a high uncertainty on the limits of the endangered area because of lack of data on the adaptability of the pest.
Establishment in protected cultivation is considered unlikely.</td></tr>
<tr><td colspan="4">Main conclusions
Overall assessment of risk: B. latifrons is a fruit fly native to South-East Asia which has spread to Africa, Hawaii and to new areas within Asia. It is mostly a pest of Solanaceae, although it also attacks some Cucurbitaceae and is reported on a few hosts in other families.
B. latifrons infests only fruits. Entry is considered possible, especially on fruit of Solanaceae, but also Cucurbitaceae, Mangifera indica and Psidium guajava. Spread is expected to be by both natural means and by trade in fruit (or plants carrying fruit). B. latifrons is a strong flyer and this would facilitate the finding of suitable hosts. The risk of entry is higher if fruit is imported close to production sites and private gardens, and fruiting hosts are available.
In some parts of its current distribution, it has an impact on Capsicum, but so far it has had only minor impacts in areas where it was introduced (Hawaii, southern Japan, Tanzania, Kenya). In comparison with other Bactrocera spp. such as B. dorsalis, reported damage is lower.

Phytosanitary Measures to reduce the probability of entry: Risk management options were determined for host fruit (e.g. Capsicum, Lycianthes, Solanum and Physalis), and plants for planting of cultivated hosts with fruit.</td></tr>
<tr><td>Phytosanitary risk for the <u>endangered area</u> (Individual ratings for likelihood of entry and establishment, and for magnitude of spread and impact are provided in the document)</td><td>High ☐</td><td>Moderate ☒</td><td>Low ☐</td></tr>
<tr><td>Level of uncertainty of assessment (see Q 17 for the justification of the rating. Individual ratings of uncertainty of entry, establishment, spread and impact are provided in the document)</td><td>High ☐</td><td>Moderate ☒</td><td>Low ☐</td></tr>
<tr><td colspan="4">Other recommendations: Raising awareness and inspection of luggage for travellers carrying fruits or plants for planting of main hosts</td></tr>
</table>

Stage 1. Initiation

Reason for performing the PRA:
Bactrocera latifrons was identified during the EPPO Study on pests risks associated with the import of tomato fruit ('EPPO tomato study' hereafter; EPPO, 2015) and was later selected as a priority for PRA by the EPPO Panel on Phytosanitary Measures based on a number of criteria including its impact on tomato, biological criteria, consideration of entry and transfer from commodities to hosts at destination. *B. latifrons* is native to South-East Asia, and has spread to Africa, Hawaii and to new areas within Asia. It is a pest of Solanaceae crops, especially *Capsicum*.
PRA area: EPPO region (map at www.eppo.int).

Stage 2. Pest risk assessment

1. Taxonomy

Taxonomic classification. Order: Diptera; Family: Tephritidae; Sub-family: Dacinae; Tribe: Dacini; Genus: *Bactrocera* Macquart, 1835; Species*: Bactrocera latifrons* (Hendel).

Synonyms. *Chaetodacus latifrons* Hendel, 1915; *Chaetodacus antennalis* Shiraki, 1933; *Dacus latifrons* (Hendel) and *Dacus parvulus,* Hendel, 1912.

Common names. Malaysian fruit fly (although does not originate from Malaysia). 'Solanum fruit fly' is sometimes used, but this is incorrect as it is common to both *B. latifrons* and *B. cacuminata* (McQuate and Liquido, 2013).

2. Pest overview

B. latifrons is mostly a pest of Solanaceae, although it also attacks some Cucurbitaceae and is reported on a few hosts in other families (see section 7).

***Life cycle*.** *B. latifrons* has egg, larval, pupa and adult stages. The life cycle is described in CABI CPC, based on Vargas and Nishida (1985): elongate eggs (0.8 mm long) are laid below the skin of the host fruit. At a temperature of 26.6°C (with 60% relative humidity and 12 h photoperiod), eggs hatch within a few days (mean 2.3 days). There are three larval instars, and the larvae feed for about a week (mean 8.5 days) in the fruit. Third instar larvae measure ca. 8 mm. Pupation occurs in the soil in the top layer under the host plant, and the pupal stage lasts about one and a half weeks (mean 10.2 days). Adults occur throughout the year and females begin oviposition after 6-17 days, and continue laying eggs for 6-117 days. Females lay between 9-587 eggs (mean 256), and mean female longevity is about 64 days, with 136 days as the maximum recorded longevity (Vargas and Nishida, 1985). No specific information was found on the life habits of *B. latifrons* adults. There is still incomplete knowledge on the foraging behaviour of fruit flies, although adults are known to feed on foliage and fruit (Prokopy, 2013).

Temperature requirements. A number of studies have been conducted on the life cycle and development of *B. latifrons*.

- The pest is negatively affected below 16°C and above 32°C, and the optimum temperature is 24°C (Vargas et al., 1996). *B. latifrons* is adapted to a narrower range of temperature than *B. cucurbitae* or *C. capitata* (its range is more similar to that of *B. dorsalis*), and has also lower population reproduction rates than others.
- Using individual temperature thresholds for the development of eggs, larvae and pupae (10.9°C, 6°C and 9.4°C respectively), Vargas *et al.* (1996) calculated that 421.2 accumulated degree days was required for development from egg to adult in Hawaii. Different results are given in Ma et al. (2012) (investigations of potential distribution in China), with 415.4 degree-days for a generation, and a lower threshold temperature of ca. 15.7°C in China. The lowest overwintering temperature and highest over-summering temperature are -3.7°C and 36°C, respectively (the original source is a Chinese thesis, not available).

In Yonaguni Isl. (Japan, southern part of the Ryukyu archipelago, close to Taiwan), *B. latifrons* was observed to overwinter as adults, and the hypothesis was made that those may enter in reproductive diapause (Shimizu et al., 2007). Takano (2014) assessed the overwintering ability under constant and fluctuating temperatures, and concluded that *B. latifrons* is not capable of overwintering in the north of Tanegashima Isl. (30 km to the south of Kyushu Isl. – the southernmost 'large' Japanese island). They conclude that *B. latifrons* is not tolerant of cold temperatures. Females survived better than males at constant temperatures. At

14-15°C, over 30% females survived for 90 days. At 8°C, 13 days were needed to kill 95% of females. Survival increased when fluctuating temperatures were used (11°C during 22 h, and 20°C during 2 h).

- The life cycle on *Capsicum* in Thailand is studied in Wingsanoi and Siri (2012).

Damage. Damage is caused by larvae, which feed and develop inside fruit. Mc Quate and Liquido (2013) give details on infestation rates reported in the literature for different hosts (with a warning on the possible different methodologies used to obtain those). The rates of infestation on Solanaceae vary but may reach several hundreds of emerged adults per kg of fruit, depending on the fruit species (Mc Quate and Liquido, 2013). The highest field infestation rate for non-Solanaceae was much lower (below 30 per kg). In Tanzania, incidence of *B. latifrons* was reported to be 90% in *Solanum anguivi*, over 60% in *S. aethiopicum* and *S. scabrum*; the lowest incidence levels were recorded on *Capsicum annuum*, *S. macrocarpon* and *S. sodomeum* (Mziray et al., 2010a).

Detection. Trapping can be used to detect adults. IAEA (2013) recommends trapping with a protein attractant in McPhail or multilure traps. *B. latifrons* adults do not respond to cue-lure or methyl eugenol. It is attracted to alpha-ionol, which is not a strong attractant according to Plant Health Australia (2011), but whose efficacy can be increased by using synergists from cade oil (McQuate and Peck, 2001; McQuate et al., 2004). In Hawaii, McQuate et al. (2013) has shown that catch in traps baited with 2.0 ml alpha-ionol + 1.0 ml cade oil was significantly greater than in protein hydrolysate baited traps. In addition, for trapping based on protein baits, the source of the bait can significantly affect the trap catch, with catch found to be significantly higher in traps baited with a Solulys AST–based bait as compared to a Torula yeast–based bait, which has commonly been used for general tephritid fruit fly detection trapping in California.
During detection surveys in Tanzania, it was impractical to use cade oil + alpha-ionol, because of low attractiveness and the longer time of exposure required in the field. The surveys, in most parts, were done by collecting suspected hosts of *B. latifrons*, mostly Solanaceae and Cucurbitaceae, for rearing in the laboratory (Dr M. Mwatawala, Sokoine University, Tanzania; pers. comm.).

Larvae of *B. latifrons* are inside fruits and can only be seen by cutting the fruit open. Larval instars damaging the fruits can make symptoms on the fruit (rotting, pitting) and create exit holes when emerging to pupate. Females may make little spots on the fruit when they lay eggs.

Identification. Identification of adults based on morphological characters is not easy, because of the likeness with other *Bactrocera* species. Morphological descriptions of adults and larvae are available in Carroll et al. (2002 onwards) and Carroll et al. (2004 onwards), respectively. Balmès (2014) refers to a new simplified identification key to separate larvae of nine species of the family Tephritidae that are regularly intercepted during import controls in Europe. Molecular methods and PCR tests have been developed for species identification (Yu et al., 2004; Zhang et al., 2007).

3.	**Is the pest a vector?**	**Yes** ☐	**No**	✓
4.	**Is a vector needed for pest entry or spread?**	**Yes** ☐	**No**	✓

5. Regulatory status of the pest

B. latifrons is not mentioned specifically in the phytosanitary regulations of EPPO countries, according to EPPO Global Database (at December 2015). However, it is a quarantine pest under 'Tephritidae (non-European)' for the EU, Norway, Switzerland, Morocco, Algeria and Serbia (specific requirements on *Citrus* fruit); as 'Trypetidae' for Tunisia and as *Bactrocera* sp. for Israel. *B. latifrons* was added to the EPPO Alert List in October 2015.

B. latifrons is a quarantine pest for New Zealand (2000; PQR); Korea Rep. (2011), Seychelles (2010), Trinidad and Tobago (2010), Japan (2013) (from the IPP), USA (*Bactrocera* sp.; USDA, 2009) and China (Ma et al., 2012). The EPPO Secretariat checked only a limited number of quarantine lists for non-EPPO countries, and *B. latifrons* may be regulated in more countries.

6. Distribution

B. latifrons is native to South-East Asia and has been introduced to Kenya, Tanzania and Hawaii.

Table 1. Distribution of *B. latifrons.* All records are from EPPO Global Database. For EPPO Global Database records, references can be found in the database

Region	Distribution	Additional comments
EPPO region	**Absent**	Absent, unreliable record: **Jordan**
Africa	**Kenya**, **Tanzania**	**Kenya:** first finding 2007 - De Meyer et al., 2014 citing Ekesi unpublished records **Tanzania**: first finding 2006 – Mwatawala et al., 2007
Asia (native)	**Brunei Darussalam**; **China** (Fujian, Guangdong, Guanxi, Hainan, Yunnan, Xinggang (Hong Kong)); **India** (Karnataka, Keraka, Tamil Nadu, West Bengal ; also Himachal Pradesh); **Indonesia** (Kalimantan, Sulawesi); **Japan** (Okinawa isl., Ryukyu, first finding 2010, 500 km North-East of the first finding, see next column); **Lao**; **Malaysia**; **Myanmar**, **Pakistan**; **Singapore**; **Sri Lanka**; **Taiwan**; **Thailand**; **Vietnam**	Absent, unreliable record: **Cambodia** Uncertain record: **Bangladesh** [only mentioned in Dacine Fruit Flies of the World (2012), and not in major reviews on this species, e.g. McQuate and Liquido, 2013]. Considered as an unreliable record (based on interceptions) in EPPO Global Database. Eradicated: Yonaguni Isl., far south of Ryukyu (**Japan**) (found in 1984 then disappeared. Found again in 1999, eradicated in 2011 – Kuba et al., 2006; Takano, 2014)
North America	**USA** (Hawaii, first finding 1983). California: under eradication in 2016 (USDA 2016) (first findings 1998, declared eradicated in 2006)	

Note: to date, there are no other records for Africa (Dr. Mwatawala, pers. comm.).

7. Host plants and their distribution in the PRA area

In a bibliography on *B. latifrons* hosts, McQuate and Liquido (2013) mention field infestation data for 59 species from 14 families (incl. 34 Solanaceae and 9 Cucurbitaceae), as well as some other host records. Table 2 lists all hosts as in McQuate and Liquido (2013) and De Meyer et al. (2014). These two publications give additional details, in particular on hosts in the various areas where the pest occurs. Indications on species cultivated in the EPPO region and species possibly traded as fruit are also given in Table 2.

Solanaceae are the main hosts of *B. latifrons* throughout its range. In Hawaii and Tanzania, where it was introduced, *B. latifrons* outcompeted or outnumbered other Tephritidae on these hosts (Liquido, 1994, cited in CABI CPC; Mziray et al., 2010a). *B. latifrons* attacks major cultivated Solanaceae such as *Solanum lycopersicum*, *Capsicum* spp. and *Solanum melongena*. These are the main hosts in Asia (De Meyer et al., 2014), but other host preferences were found elsewhere. In Hawaii, *S. torvum* and *S. linnaeanum* (Peck and McQuate, 2004) were preferred; in Tanzania, high infestation rates were found in *S. nigrum*, *S. scabrum*, *S. aethiopicum* and *S. anguivi* (Mziray et al., 2010a).

Some **Cucurbitaceae**, including cultivated species, were identified as hosts when it was introduced into Hawaii and Africa, but these are minor hosts, on which the pest causes occasional infestation (Mziray et al., 2010a; De Meyer et al., 2014). In India, it has apparently been recorded in cucurbits in Himachal Pradesh (Prabhakar et al., 2012).

Finally, in Asia, a few hosts are reported in **other families** (McQuate and Liquido, 2013; De Meyer et al., 2014). Many host records relate to 1 published host record (see Table 2). Although these hosts are probably not major, some of the interception reports relate to some of these hosts (e.g. *Psidium guajava*). The pest has also been intercepted on fruit not identified as hosts: *Mangifera indica*, *Syzygium samarangense* (EPPO interceptions); *Dimocarpus longan*, *Lablab purpureus*, *Mangifera altissima* and *M. indica*, *Passiflora* (McQuate and Liquido, 2013). For some hosts in this list, there were only 1 or few reported interceptions, but there were multiple interceptions on *Mangifera indica*.

Table 2. Host plants (from McQuate and Liquido, 2013; De Meyer et al., 2014)

In **bold**, considered to be widely cultivated in the EPPO region.

* hosts whose fruit is known to be used, and to be traded (or possibly traded). It is not excluded that others also are in this category, but this was not fully verified.

\+ Record from Asia, 1 reference only, found in 1-2 samples from several years' surveys in Malaysia and Thailand

Solanaceae			
***Capsicum annuum**	*Solanum anguivi	Solanum mammosum+	Solanum sisymbriifolium
***Capsicum chinense**	Solanum erianthum or S. donianum (previously S. verbascifolium)	***Solanum melongena**	Solanum sodomeum (=S. linnaeanum)
***Capsicum**	Solanum granulosoleprosum+	Solanum nigrescens	Solanum stramoniifolium+
***Capsicum frutescens**	Solanum incanum	Solanum nigrum	*Solanum torvum
Lycianthes macrodon (=L. biflora)	Solanum lasiocarpum (=S. indicum)	*Solanum pimpinellifolium	Solanum trilobatum
*Physalis peruviana	***Solanum lycopersicum**	Solanum pseudocapsicum	Solanum viarum
Physalis pubescens	*Solanum macrocarpon	Solanum santiwongsei (=S. violaceum)	
*Solanum aculeatissimum		Solanum sarmentosum (=S. dulcamaroides)	
*Solanum aethiopicum		Solanum scabrum	
Solanum americanum			

Cucurbitaceae		
*Benincasa hispida	Cucumis dipsaceus	*Diplocyclos palmatus
***Citrullus lanatus**	***Cucumis melo**	*Lagenaria siceraria
*Coccinia grandis	***Cucumis sativus**	Momordica trifoliata

Other families	
Combretaceae: *Terminalia catappa*	Rhamnaceae: **Ziziphus nummularia* (=*Z. rotundifolia*)+, **Z. jujuba*
Euphorbiaceae: **Baccaurea motleyana*	Rutaceae: ****Citrus aurantiifolia***+, *Murraya paniculata*+
Lythraceae: *Lagerstroemia indica*+	Sapindaceae *Sapindus rarak*+
Myrtaceae: **Psidium guajava*+	Verbenaceae: *Gmelina philippensis*+
Oleaceae: *Linociera parkinsoni*+, *L. xanthocarpum*+	
Passifloraceae: *Passiflora foetida*+	
Punicaceae: ****Punica granatum***+	

Uncertainties/undetermined hosts:

- *Mangifera indica*. The records in White and Elson-Harris (1992) and other publications are considered as doubtful/erroneous in McQuate and Liquido (2013). However, there were interceptions in the USA (McQuate and Liquido, 2013) and in EPPO countries.
- *Cucurbita maxima*, *Momordica charantia* (listed in McQuate and Liquido, 2013). These have been suggested as hosts based on unpublished data; there are no published data supporting this (Dr McQuate and Liquido, pers.comm.).
- *Euphorbia* (McQuate and Liquido, 2013, referring to a general publication on California). No supporting published field data (Dr Grant and Liquido, pers.comm.).
- *Coffea arabica*. 1 adult was found (understood to be emerged adult) during one survey of over 1000 *C. arabica* fruit (McQuate and Liquido, 2013).
- There was one interception in France on *Annona cherimola* (French NPPO, unpublished).
- *Averrhoa carambola, Citrus* spp., *Citrus limon*, *Citrus sinensis*, *Coffea*, *Litchi sinensis*, *Malus domestica*, *Musa* x *paradisiaca*, *Solanum virginianum (S. xanthocarpum, S. surratense)*, *Trichosanthes cucumerina* (*angurna*). Identified as undetermined hosts in McQuate and Liquido (2013) (some of these are mentioned as hosts in White and Elson-Harris, 1992); there are no field data documenting these species as being hosts (Dr McQuate and Liquido, pers. comm.). Some are considered as 'possible' host species in some publications (e.g. Papadopoulos et al., 2013, annexes), but have not been covered in this PRA.

8. Pathways for entry

B. latifrons has been introduced into other regions from its Asian origin: Hawaii (around 1983), Africa (first found in Tanzania in 2006, then Kenya in 2007), Japan (Yonaguni, first found in 1984, then again 1999; Okinawa, in 2010; Kuba et al., 2006), and California (first findings in 1998, declared eradicated in 2006).

There have also been many interceptions. Papadopoulos et al. (2013) report 72 interceptions of *B. latifrons* at Charles de Gaulle airport (Paris, France) in 2007-2009. Many interceptions of *B. latifrons* are mentioned in various EPPO countries; the USA and Japan (McQuate and Liquido, 2013); and China (Ma et al. 2012, Bian et al. 2012). Details on interceptions on specific commodities, where available, are given in Table 4.

The pathways in Table 3 were studied in details (see Table 4).

Table 3. Species or genera covered for different commodities

Pathway	Hosts covered
Fruit (in the botanical sense, incl. vegetables) of cultivated hosts in the families Solanaceae, Cucurbitaceae and other families	For both Solanaceae and Cucurbitaceae, there is an uncertainty on which hosts are cultivated and traded as fruit. Non-Solanaceae and non-Cucurbitaceae were considered, as well as species that are not on the host list but for which there were interceptions.
Plants for planting of hosts with fruits	Hosts in Table 2. A full analysis was not made of which hosts may be traded as plants for planting
Packaging	Pupae are formed in soil, and they may be formed in packaging (McQuate and Liquido, 2013, report interceptions of puparia in fruit consignments, and pupae may remain in packaging).

In addition, fruit or plants may be transported by travellers in luggage. There were some findings of *B. latifrons* in fruit in luggage (USDA, 2009; McQuate and Liquido, 2013). These are not detailed here, but measures are considered in Section 16.

For all pathways, the following is taken into account:

-Eggs and larvae are inside the fruit, and detection is difficult.

-All stages are expected to survive transport, as the pest has been intercepted alive on various fruits, but not to develop if fruit are refrigerated. Multiplication is considered unlikely, as the lowest threshold for development of eggs and adults is 10.9°C and 9.4°C, and adults need particular conditions for mating -normally mate in the crown of host plants and mating behaviour is strongly influenced by light intensity (Jackson, and Long, 1997). Fruits may be transported at temperatures above this threshold. Fruits are often transported under refrigeration (e.g. for ripe tomatoes 7-10°C, sometimes higher for less ripe stages; EPPO, 2015). For other fruit hosts, UK PI (2006) indicates an optimal transit temperature of 10°C for capsicum, melon, watermelon. Takano (2014) found that 13 days at 8°C were needed to kill 95% of females of *B. latifrons*, and time taken for fruit transport may be much shorter.

Table 4. Consideration of pathways

Packaging: If the population of the pest carried with commodities is in the late instar, pupation can occur in packaging (e.g. in paper tissue). Pupae (perhaps also final instar larvae seeking pupation sites) may be present in the packaging. Multiplication in transport is considered unlikely. If adults emerge from pupae, they may transfer to a host if the packaging is imported (or discarded) close to facilities where hosts are grown. **Likelihood of entry**: moderate, if imported (or discarded) close to production sites; **uncertainty**: moderate.

Pathway	Fruit – Solanaceae hosts	Fruit – Cucurbitaceae hosts	Fruit - other families hosts	Plants for planting with fruit
Pathway prohibited in the PRA area?	No	No	Partly e.g. *Psidium* (into Israel)	Partly, in some EPPO countries. e.g. EU: Solanaceae, Citrus. Art 39, 41 plants for planting should be 'free from plant debris, flowers and fruits' However, import of these hosts is permitted in some other EPPO countries, e.g. ornamental Citrus in Turkey
Pathway subject to a plant health inspection at import?	Partly e.g. EU for specified fruit, e.g. *Solanum melongena*, *Capsicum*	Partly e.g. EU *Momordica*	Partly e.g. EU *Mangifera*, *Passiflora*, *Psidium*, *Syzygium*, *Annona, Citrus.*	Most probably partly in many EPPO countries. e.g. EU: all
Pest already intercepted?	Yes (*Capsicum*, *C. annuum*, *Solanum*, *S. aculeatissimum*, *S. lycopersicon*, *S. melongena*, *S. sisymbrifolium*) (not all in EPPO, also from other regions)	No records found. No interceptions reported in McQuate and Liquido (2013)	Yes, on *Psidium guajava.* Also *Mangifera indica* (multiple interceptions - not reported as a host); and few on other non-reported hosts: *Syzygium samarangense*, *Dimocarpus longan*, *Lablab purpureus*, *Mangifera altissima*, *Passiflora*. *Annona cherimola* is also mentioned once, but from a country in South America, where *B. latifrons* is not reported as being present.	No records found
Most likely stages that may be associated	Eggs and larvae in fruit. Pupae and adults have also been found associated with consignments (McQuate and Liquido, 2013), but these probably developed in transport.	Eggs and larvae in fruit	As for Solanaceae fruit	Plants for planting are usually not traded with fruit. However, if the plant carries fruit (e.g. ornamental *Capsicum*, *Physalis*), eggs and larvae may be present in fruit and pupae in the soil. Adults may be present if emerged during transport. If there are no fruits, there might be pupae in the soil but this is very unlikely
Important factors for association with the pathway	These are the main hosts. Rates of infestation reported in the literature are high (McQuate and Liquido, 2013) (see 2.). For tomato, Capsicum and eggplant, rates of 75, 160 and 30 adults per kg fruit are mentioned (where these were measured).	The association would be lower than for Solanaceae as these are only reported as occasional hosts (Mziray et al., 2010a; De Meyer et al., 2014) Rates of infestation are also lower (McQuate and Liquido, 2013)	The association would be lower than for Solanaceae as these are only reported as occasional hosts. However, the pest is considered more likely to be associated with: - *Baccaurea motleyana*, *Terminalia catappa*: cultivated hosts with more than 1-2 records	Requirements on growing media accompanying plants would prevent presence of pupae before transport (but they may be formed during transport and storage if plants carry fruit). The importance of most plants concerned as

Pathway	Fruit – Solanaceae hosts	Fruit – Cucurbitaceae hosts	Fruit - other families hosts	Plants for planting with fruit
	(It is not known if some hosts are cultivated and traded, such as *Lycianthes macrodon* and many Solanum host species).		(or not known): - *Psidium guajava*, 1 host record, but EPPO interceptions. - *Syzygium samarangense*, *Mangifera indica*: not on host list, but interceptions (EPPO and elsewhere) For other hosts, there are 1 or a few findings (and no known interceptions), association is considered less likely. In particular, it is not considered likely to be associated with *Punica granatum*, *Ziziphus*. It is also not considered likely to be associated with species with few interceptions in McQuate and Liquido (2013)	hosts is unknown.
Survival during transport and storage	Likely	Likely	Likely	Likely. All life stages may survive transport and storage, and may continue their development.
Trade	At least small volumes for tomato (EPPO, 2015 – e.g. China, India, Malaysia, Kenya, Thailand), eggplant, *Capsicum* (at least Thailand, interceptions), probably smaller volumes of more 'exotic' Solanaceae such as *S. aethiopicum*, *Physalis peruviana*, *S. torvum* etc.	At least watermelon, melon (data searched for the EU project Dropsa), possibly cucumber, or 'exotic' vegetables such as *Benincasa hispida*, *Coccinia grandis.* *Cucumis dipsaceus* (used as leaves only?) and *Momordica trifoliata* (wild?) are likely not traded.	No details searched, but there is a trade of some species at least: *Mangifera indica* (high volumes - data searched for the EU project Dropsa), *Syzygium samarangense*, *Psidium guajava*, and some with which the pest is less likely to be associated, such as *Psidium guajava*, *Punica granatum*, *Ziziphus*. *Terminalia catappa* is not known to be traded.	Not known.
Transfer to a host	Transfer would require the presence of fruiting hosts (however, adults may be able to survive for several weeks; the mean lifespan of females is 64 days, with the max 136 days, which is comparable with the whole growing season of tomatoes). Adults fly and may actively search host plants. Transfer is more likely if packing and handling facilities are located near production areas of hosts (but this is a known situation for at least tomato, pepper and eggplants) or private gardens with hosts, in the presence of hosts with fruit. Transfer with fruit directly provided to the consumer or used for processing is generally unlikely (the pest will be destroyed at processing or discarded by the final consumer). However, there are circumstances for discarding fruit that	Transfer is more likely if packing and handling facilities are located near production areas of hosts and private gardens with hosts, in the presence of hosts with fruit. No information is available on whether this is the case. See also additional comments in Solanaceae fruit	Transfer is more likely if packing and handling facilities are located near production areas of hosts, or private gardens with hosts, in the presence of hosts with fruit.. No information is available on whether this is the case See also additional comments in Solanaceae fruit	Plants for planting will be planted in favourable conditions for their development. Transfer to another host will depend on where the plants will be used, and the presence of hosts with fruit.

Pathway	Fruit – Solanaceae hosts	Fruit – Cucurbitaceae hosts	Fruit - other families hosts	Plants for planting with fruit
	may not eliminate the pest, such as domestic compost in private gardens, 'green bins', discarding prior to processing.			
Likelihood of entry	High if imported close to production areas of hosts and private gardens, and fruiting hosts are available Low otherwise	Moderate if imported close to production areas of hosts and private gardens Low otherwise	For *Mangifera indica*, *Psidium guajava*, moderate if imported close to production areas of hosts; low otherwise For *Terminalia catappa*, *Syzygium samarangense*, low in all cases (assumed lower volumes, uncertain association) For all others: low (low association)	Moderate for plants with fruit: at most moderate volumes, not main hosts, but higher likelihood of survival and transfer Low otherwise
Uncertainty	Moderate (trade volume and which species are traded)	Moderate (trade volume and which species are traded)	High (association, volumes, whether *T. catappa* traded)	High for plants with fruit (volume of trade of plants with fruit) Low otherwise

Pathways considered unlikely and not considered further.

- **Soil or growing media from areas where *B. latifrons* occurs.** Only pupae will be associated with soil. Soil associated with plants for planting of hosts is covered under the 'plants for planting' pathway. Regarding soil on its own, the importation of soil into many EPPO countries (at least the EU, Turkey, Israel) from countries where the pest occurs is forbidden. Finally, entry with soil associated with plants for planting of non-host is considered unlikely (pupae will preferably be formed in the soil under host plants, and have a limited life span (about 10 days at 26°C). **Uncertainty***:* low
- **Leaf vegetables:** A number of host species are used as leaf vegetable (e.g. *S. nigrum*, *S. scabrum, C. dipsaceus*?). No life stage of *B. latifrons* is associated with green parts. **Uncertainty***:* low.
- **Hitch-hiking, natural spread.** There is no evidence that hitch-hiking (as contaminant of non-host commodities, conveyances etc.) could be a pathway. Natural spread is unlikely from countries where the pest is present: in Asia, the current distribution is separated from the EPPO region by mountains and areas of cold climate or deserts; in Africa by the Sahara. **Uncertainty**: low.
- **Seeds, tissue cultures, processed commodities made from hosts, etc.**: *B. latifrons* is not associated with those.

Uncertainty: moderate (association of B. latifrons with its non-Solanaceae hosts).

The ratings of the likelihood of entry and the uncertainty are given in Table 4.

9. Likelihood of establishment outdoors in the PRA area

Host plants in the EPPO region

Many hosts are grown in the EPPO region (see Table 2), and some hosts are also present in the wild (e.g. *S. nigrum*). A number of Solanaceae (incl. tomato, capsicum and eggplant) and Cucurbitaceae hosts are grown commercially in the field or under protected conditions (glasshouse, tunnels, plastic), as well as in gardens. Tomato is cultivated throughout the PRA area, whilst sweet pepper and eggplant have a more southern and eastern distribution (EPPO, 2014). Details on tomato are provided in the EPPO tomato study (EPPO, 2015).

Together, the host crops are expected to be present throughout the EPPO region, although some are more southerly than others (e.g. *Citrullus lanatus*), and the production systems may vary (i.e. grown only in the field, only under glasshouse, or both).

The abundance of plants and the type of plants will influence the suitability of the area for establishment (e.g. all-year tomato crops, mixed tomato-other host, solely other hosts, mix of host plants). In some parts of the PRA area, solanaceous hosts (possibly others) are grown all year round (e.g. at least North Africa and some Mediterranean countries like Turkey or Spain), which will favour establishment. As for the other tomato pests *Keiferia lycopersicella* and *Neoleucinodes elegantalis*, it is not considered likely that the existing management practices in the field will prevent establishment (EPPO, 2012, 2014). Details of the management practices for tomato and eggplant are given in EPPO (2012).

Climatic conditions

According to the classification of Köppen Geiger (see map in Annex 1), *B. latifrons* occurs mostly in countries of equatorial climates. It also occurs in Okinawa (Japan) and regions of China, which have a climate similar to part of the EPPO region (Cfa). In a study of the potential distribution in China, Ma et al. (2012), taking into account dry and cold stress, estimate its potential distribution to be the whole of South-East China, up to 32.4°N, corresponding to an area also classified as Cfa climate.

The current distribution also includes countries with a limited temperate climatic zones (which are also present in the PRA area), such as part of Kenya and Tanzania. The infranational data available is not sufficient to evaluate whether it occurs in temperate climatic zones in these countries. In Morogoro (first finding in Tanzania; 'equatorial' type climate), surveys showed that it was more abundant in low to medium altitude areas compared to high altitude areas (Mziray et al., 2010b), but it is now considered widespread in Tanzania. The pest was found in Arusha and Kilimanjaro which are considered "cold" areas in Tanzania (Dr. M. Mwatawala, pers. comm.). In the highlands, temperatures range between 10 and 20°C during cold and hot seasons respectively. Findings in Tanzania have occurred at altitudes between 381 and 1650 m, (Dr. M. Mwatawala, pers. comm.).

In the USA, probability maps were developed for several fruit flies (Margosian et al., 2007) taking into account predicted number of generations, cold weather tolerance and hosts, and using data from Vargas et al. (1996) (see 2.). Taking into account a cold tolerance threshold (and the areas where establishment would not be possible due to cold temperatures), they predicted one to nine generations of *B. latifrons* in an area extending from the coast of the Pacific North West through to California, Arizona, Texas and South-Eastern USA. The highest risk area was in Florida (in an area of Cfa-type climate in Köppen-Geiger) and moderate-low risk south of a line North Carolina-New Mexico, West to Arizona and California.The pest was already detected in California (1 single fly, 1 location in 1998 - considered eradicated; PQR, Papadopoulos et al., 2013; 2 adult females in one trap in 2016 – under eradication, USDA 2016).

No information was found on humidity requirements for *B. latifrons*. In the USA, some drier areas and areas of Mediterranean climate are included in the area at risk (Margosian et al., 2007). Note that, in field studies in Hawaii (Liquido et al. 1994), it was noted that "*B. latifrons* can establish population clusters in marginal (e.g. arid and windswept range and ranch lands) habitats where other tephritids are less or not successful." Ma et al. (2012) reported that moisture requirements of *B. latifrons* are mediated through its host plants (and therefore they use the wilting point of plants as a threshold in their modelling). Although the role of humidity, and the effects of irrigation in hot, dry areas in the south of the EPPO region is not known, establishment is considered possible where its hosts survive, including under irrigation. There is an uncertainty with this, as well as on the soil humidity necessary for pupae survival (Jackson et al., 1998 on a study on depth of pupae in the soil for several *Bactrocera* incl. *latifrons* and *C. capitata,* concluded that *C. capitata* is better adapted to dry conditions).

It is considered that it can establish outdoors in part of the EPPO region. There are uncertainties (high) regarding the exact limits of establishment. *B. latifrons* is also not likely to establish where fruiting host plants are not present all year round (although Shimizu et al. (2007) envisaged that adults may overwinter and generally fruit fly adults can survive for many weeks (e.g. up to 136 days - see section 2) if they find nutrients (water, sugar, proteins)). *B. latifrons* has a wide host range, and may use wild hosts (such as *Solanum nigrum*) to maintain populations, but survival would require that some host fruit is present nearly all or a large part of the year. It may also form transient populations in other areas and may survive in glasshouses (transient) in absence of its hosts outdoors. Given the short development time, it may be possible to have several transient generations within a growing season where conditions are favorable outdoors.

Populations from areas where the climatic conditions are more similar to those of the EPPO region have a higher likelihood of establishment than other populations.

Climex models using the parameters defined by Ma et al. (2012), and those extrapolated from Vargas et al. (1996) give provisional maps for the EPPO region (see Annex 3). The most likely areas at risk of establishment outdoors in the EPPO region are the Mediterranean Basin, Portugal and the South of the Black Sea coast.

Other considerations

In Hawaii and Tanzania, *B. latifrons* was observed to outcompete other fruit flies on Solanaceae, but not on non-Solanaceae. In Hawaii, it outcompeted *B. dorsalis*, *B. cucurbitae* and *Ceratitis capitata* in its solanaceous hosts, but not in its non-solanaceous hosts; it was outnumbered by *B. cucurbitae* on Cucurbitaceae (Liquido et al., 1994, cited in CABI CPC). In Tanzania, Mziray et al. (2010a) reported that it outnumbered *B. invadens*, *B. cucurbitae* and *Ceratitis capitata* in most of the common solanaceous hosts.

Uncertainty: High (Adaptability to climate outdoors in different areas of the EPPO region, impact of humidity).

Mediterranean Basin, Portugal and the South coast of the Black Sea

Rating of the likelihood of establishment outdoors	*Low* ☐	*Moderate* ✓	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ☐	*High* ✓

Rest of the EPPO region

Rating of the likelihood of establishment outdoors	*Low* ✓	*Moderate*	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

10. Likelihood of establishment in protected conditions in the PRA area

Many hosts are grown under protected cultivation (plastic, tunnel, glasshouse) in the EPPO region, including *S. lycopersicum*, *S. melongena*, *Capsicum*, *Citrullus lanatus*, *Cucumis sativus*, *Cucumis melo*. The possibility is not excluded that transient populations could be present in glasshouses, but it is very unlikely that the pest establishes in a glasshouse. Even though there are no official reports for establishment in glasshouses, fruit flies may develop in significant numbers under glasshouse conditions. There is often a crop-free period in glasshouses, and adults cannot survive for a long time in the absence of nutrients (however, they have a longer longevity if nutrients are available). Shimizu et al. (2007) observed that on Yonaguni Island, Japan, adults overwinter, speculating that it may be because of a reproduction diapause.

Whole EPPO region

Rating of the likelihood of establishment indoors	*Low* ✓	*Moderate* ☐	*High* ☐
Rating of uncertainty	*Low* ✓	*Moderate* ✓	*High* ☐

11. Spread in the PRA area

B. latifrons is likely to spread naturally and through human-assisted pathways. In mark-release recapture study in the field, Peck and McQuate (2004) found dispersal abilities similar to other fruit flies (200 m – mark-release-recapture in an area with patches of *S. torvum*). Adults may have a long life time (a few months). Many *Bactrocera* can fly 50-100 km (EPPO/CABI, 1997, referring to Fletcher, 1989). Noda et al. (2015) studied the flight ability (duration, frequency, velocity) of *B. latifrons* in a flight mill (i.e. estimates would be higher than for natural spread), and estimated the 12 h flight distances to be 9.1 and 12.7 km (measured flight velocity multiplied by flight duration), for males and females respectively. The spread would be highest if it is introduced into an area where it can establish outdoors and from which host commodities (especially fruit) are traded. Transport of fruit within countries (e.g. markets, private use, passengers) may also play an important role.

Rating of the magnitude of spread	*Low* ☐	*Moderate* ☐	*High* ✓
Rating of uncertainty	*Low* ✓	*Moderate* ☐	*High* ☐

12. Impact in the current area of distribution

There are few detailed references on impact. *B. latifrons* is a pest of Solanaceae throughout its range (CABI CPC). It is an occasional pest of Cucurbitaceae especially in Africa (De Meyer et al., 2014). In Hawaii, it is also found on Cucurbitaceae (34 Solanaceae, 9 Cucurbitaceae: McQuate & Liquido, 2013). One impact mentioned is that Tephritidae are highly regulated worldwide, and presence of fruit flies has consequences for exports. No mention of environmental or social impact was found in the literature.

In Asia, *B. latifrons* is considered to be a major pest; it caused up to 60-80% loss on red pepper in Malaysia (Ma et al., 2012, citing others). In Thailand, it is a pest of *Capsicum* (Wingsanoi and Siri, 2012; Wingsanoi et al., 2013) and Wasee et al. (2013) studied resistance of various pepper accessions to several pests under net tunnels. *B. latifrons* was the only insect included in this study, and caused damage to peppers and yield losses. 17 of 357 host plant accessions were tested and considered ‘resistant’, with fruit yield losses of 1-25%. 151 accessions were susceptible, with 75-100% fruit yield losses. For India, NBAIR (2013) rate *B. latifrons* as ‘minor, sporadically serious’ (for Solanaceae).

Where introduced, *B. latifrons* has outcompeted other fruit flies (or became predominant) on Solanaceae (Liquido, 1994; Mziray et al., 2010a). In Tanzania, it was expected to remain a minor pest due to low populations (Mziray et al., 2010b). In Tanzania, Solanaceae, except tomato, are either harvested green (when they are not attacked – e.g. *S. aethiopicum* which is a preferred host in Tanzania or *S. anguivi*), or consumed as leaves (*S. scabrum*); the impact of *B. latifrons* is thus not felt (because ripe fruits are mostly attacked by the pest) (Dr. M. Mwatawala, pers. comm.). No recent data was found on the situation in Kenya. In Africa, *B. latifrons* has a host range that is not fully exploited by other fruit fly species, which could aggravate the problems already encountered by local farmers, by attacking crops that were relatively fruit fly pest free (De Meyer et al., 2014).

In Hawaii, Vargas and Nishida (1985) considered it had a lower biotic potential and was less injurious than other invasive fruit flies such as *B. cucurbitae* and *B. dorsalis*, and that eradication might be possible (however, since then, the pest has spread to all of the main Hawaii islands). Liquido (1994) reported that it maintains relatively low populations, even if abundant biomass is available. Although it is a less common fruit fly, it is still of economic importance (Vargas et al., 2008). It is associated primarily with patches of wild and cultivated Solanaceae, with extensive economic damage in community gardens and farms growing tomato, eggplant and capsicum. However, such damage is confined to isolated areas; the pest has not caused much direct economic damage in Hawaii overall, but is important for quarantine considerations.

In conclusion, there is little evidence of damage on Solanaceae other than Capsicum (although high levels of infestation are reported in McQuate et al. (2013) for some species), nor on Cucurbitaceae and other hosts. The fact that there are few reports of damage may indicate that the pest has lower impact than other fruit fly species.

An overall rating on *Capsicum* was made based on the worst impacts, i.e. in Malaysia, recognizing that such impacts are recorded only in part of the distribution of the pest.

Uncertainty: impact on hosts other than Solanaceae. Impact in countries where no information is available.

Capsicum

Rating of the magnitude of impact in the current area of distribution	*Low* ☐	*Moderate* ☐	*High* ✓
Rating of uncertainty	*Low* ✓	*Moderate* ☐	*High* ☐

Other hosts

Rating of the magnitude of impact in the current area of distribution	*Low* ✓	*Moderate* ☐	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate* ✓	*High* ☐

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? **No**

Damage is expected to be lower as climatic conditions outdoors are not optimal. There is an uncertainty on whether *B. latifrons* would survive periods without the crop, but it could probably develop several generations in transient populations in part of the PRA area. *B. latifrons* may cause an impact mostly on its solanaceous hosts (especially capsicum, tomato and eggplant). Specific control measures will be needed. IPM strategies are widely used in the EPPO region, and may have to be modified as they currently do not cover fruit flies. Area-wide suppression may need to be applied. *B. latifrons* causes yield and quality loss, it increases production costs and disrupts IPM programmes. Tephritidae are highly regulated worldwide, and the introduction of *B. latifrons* would have consequences for exports.

No environmental impact is expected, apart from if pesticide applications increase. Social impacts are expected to be minor overall, but possibly major locally.

Rating of the magnitude of impact in the area of potential establishment	*Low* ☐	*Moderate* ✓	*High* ☐
Rating of uncertainty	*Low* ☐	*Moderate*☐	*High* ✓

14. Identification of the endangered area

Outdoors, *B. latifrons* is most likely to establish in the Mediterranean Basin, Portugal and the South coast of the Black Sea. Hosts grown in these areas, especially capsicum, tomato and eggplant, are at risk of economic impacts.

15. Overall assessment of risk

B. latifrons infests only fruits. Entry is considered likely, especially on fruit of Solanaceae, but also Cucurbitaceae, *Mangifera indica* and *Psidium guajava* (with different likelihoods and uncertainties – see Table 4 in section 8). It is worth noting that there are records of interceptions of *B. latifrons* on many fruit species, including some that are not recorded as hosts. *B. latifrons* is very unlikely to establish in protected conditions. Spread is expected to be by both natural means and by trade in fruit (or plants carrying fruit). *B. latifrons* is a strong flyer and this would facilitate the finding of suitable hosts. The risk of entry is higher if fruit is imported close to production sites or private gardens, where fruiting hosts are available.

In Asia, *B. latifrons* is considered to be a major pest particularly on *Capsicum*, but so far it has had only minor impacts in areas where it was introduced (Hawaii, southern Japan, Tanzania, Kenya). There, in comparison with other *Bactrocera* spp. such as *B. dorsalis*, reported damage is lower. The endangered area is considered to be the Mediterranean Basin, Portugal and the South coast of the Black Sea. *B. latifrons* is expected to have a moderate impact especially on capsicum, tomato and eggplant.

Phytosanitary measures were elaborated for fruit (Solanaceae, Cucurbitaceae, *Mangifera indica*, *Psidium guajava*) and plants for planting with fruit.

Stage 3. Pest risk management

16. Phytosanitary measures

Measures were considered for fruits, plants for planting with fruit, as well as entry with travellers carrying host fruit and plants from countries where the pest occurs.

For fruit:
- Solanaceae are a major pathway. Given the large number of *Solanum* hosts, and the findings on new hosts when introduced to Africa and Hawaii, measures are proposed to cover the host genera: *Capsicum*, *Lycianthes* [note: it is not known if any are cultivated for fruit production], *Solanum* and *Physalis*. However, this would cover cultivated species that are not currently on the host list (in particular a number probably mostly grown in South America where the pest is absent), such as *S. muricatum* (pepino), *S. betaceum* (tamarillo), as well as cultivated species whose leaves are used (and not fruit).
- For Cucurbitaceae, measures cover host species (as in Table 2. However, it may be noted that *Cucumis dipsaceus* seems to be used only as leaves, and *Momordica trifoliata* seems to be wild).
- For other families, although there is a lower risk of introduction, *B. latifrons* was intercepted on species, as well as on some species not on the host list. Measures are suggested for hosts with more than 1-2 host records (or unknown) (*Baccaurea motleyana*, *Terminalia catappa*), *Psidium guajava* (1 host record, but interceptions), as well as *Syzygium samarangense*, *Mangifera indica* (not on host list, but interceptions).

Annex 2 summarizes the consideration of measures. Measures regarding packaging are not detailed in Annex 2, but combined below with those for the different commodities.
- For fruit, similar measures were identified for all categories above. However, for non-Solanaceae and non-Cucurbitaceae species, which are considered as minor hosts (or not listed as hosts), a PC requirement may be considered sufficient by the NPPO, depending on local circumstances, as it will ensure inspection of consignements. This may also be the case for Cucurbitaceae fruit.

- For plants for plantings, measures are recommended only for plants carrying fruit (i.e. not the seedlings).

Possible pathways ***(in order of importance)***	**Measures identified (see details in Annex 2)**
Fruit	Phytosanitary certificate and: - Pest Free Area Or - Pest-free production site/place of production under complete physical isolation (EPPO Standard PM 5/8) + appropriate packing/handling methods to avoid infestation during transport (on the basis of bilateral agreement) Or - Systems approach (on the basis of bilateral agreement): Treatment of the crop (area-wide management) + monitoring + appropriate packing/handling methods to avoid infestation during transport + inspection at packing + visual inspection of the consignment + separation of trade and production flows in the importing country Or - Treatment of the consignment (specific treatments need to be defined for *B. latifrons*) + appropriate packing/handling methods to avoid (re)infestation (on the basis of bilateral agreement) Or -import only in winter, for direct consumption or immediate processing in areas where the pest can not establish outdoors Or -surveillance in the importing country + separation of trade and production flows (only in countries where the pest cannot establish outdoors, on the basis of bilateral agreement) In all cases above: - only new packaging should be used at origin, and packaging should be destroyed or safely disposed of at import.
Plants for planting of cultivated hosts with fruit Note: for many EPPO countries, the import of Solanaceae plants for planting is prohibited but not other important host plants	Phytosanitary certificate and: - Pest Free Area (with survey, trapping and identification of fruit flies) + appropriate packing/handling methods to avoid infestation during transport Or - Pest-free production site under complete physical isolation (see EPPO Standard PM 5/8) (incl. appropriate measures for growing medium) + appropriate packing/handling methods to avoid infestation during transport Or - Free from fruits and replacement of the original growing media. In all cases above: - only new packaging should be used at origin, and packaging should be destroyed or safely disposed of at import.
Travellers carrying fruits or plants for planting of main hosts	Raising awareness and inspection of luggage

Eradication and containment. Eradication, as well as containment, of fruit flies is complex and costly. Rather it is considered here that introduction should be prevented. Male annihilation technique is not possible because there is no strong attractant.

The Sterile Insect Technique for *B. latifrons* was developed in Japan (incl. diet for mass rearing, irradiation dose/developmental stage, transport, release) and applied to eradicate the pest from the Yonaguni Isl. (Kuba et al., 2006; Kuriwada et al., 2014; Shimizu et al., 2007; Fukugasako and Okamoto, 2014). This was the first application of the SIT method for this pest, and it was successful.

Due to the nature of this PRA (short), it is not possible to provide detailed requirements for eradication and containment.

17. Uncertainty

The main uncertainties are as follows:

- host range and impact (damage) on the different hosts
- whether adults would survive during transport (for consignments of plants for planting), and whether they could survive at destination if host fruit are not available over some months (i.e. until fruits are in an appropriate stage for oviposition)
- why numerous interceptions in Europe has not lead to outbreaks so far.

18. Remarks

None.

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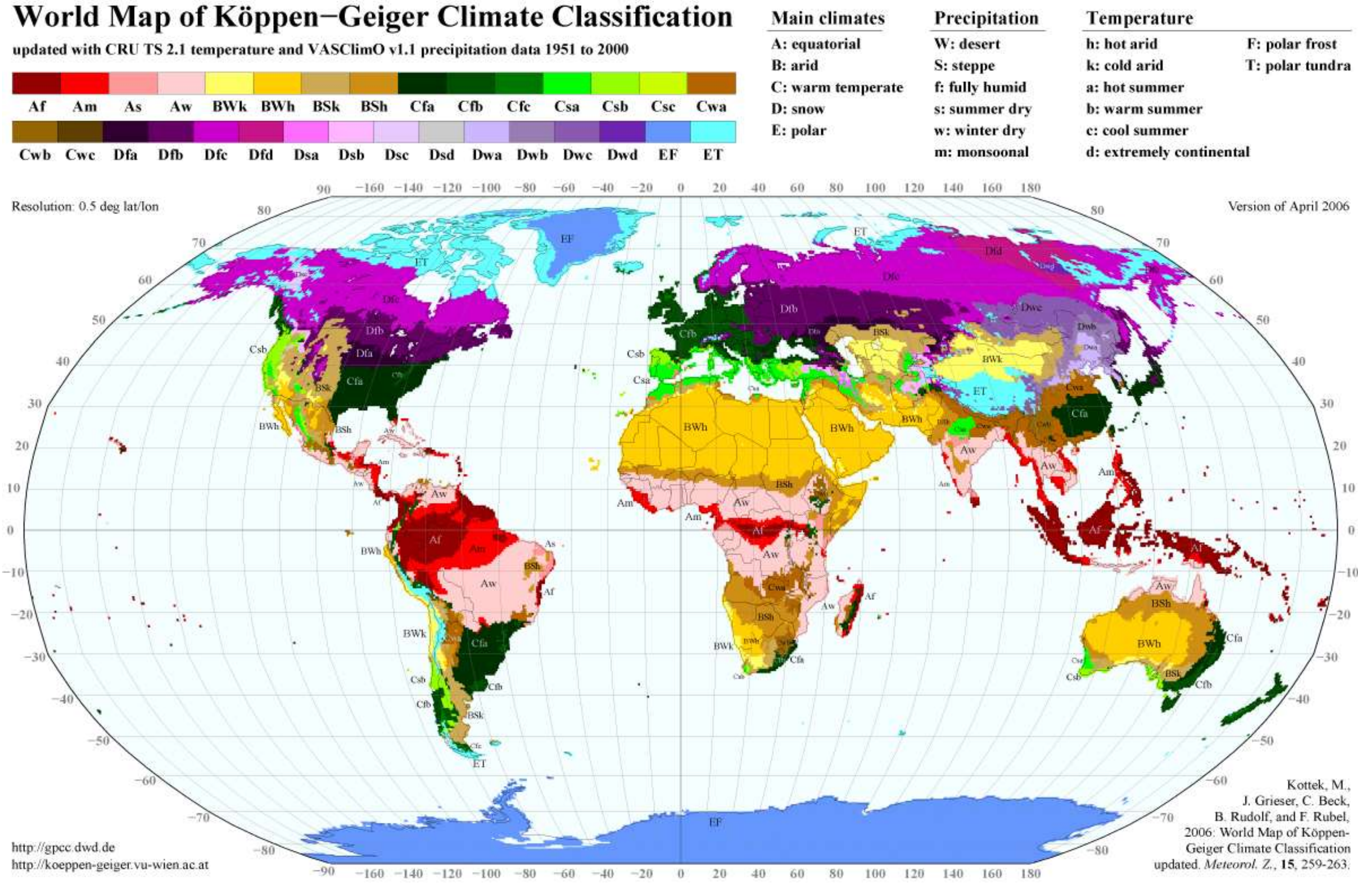
Annex 1


World Map of Köppen−Geiger Climate Classification
updated with CRU TS 2.1 temperature and VASClimO v1.1 precipitation data 1951 to 2000
Af Am As Aw BWk BWh BSk BSh Cfa Cfb Cfc Csa Csb Csc Cwa
Cwb Cwc Dfa Dfb Dfc Dfd Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd EF ET
Main climates
A: equatorial
B: arid
C: warm temperate
D: snow
E: polar
Precipitation
W: desert
S: steppe
f: fully humid
s: summer dry
w: winter dry
m: monsoonal
Temperature
h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
d: extremely continental
F: polar frost
T: polar tundra
Resolution: 0.5 deg lat/lon
Version of April 2006
http://gpcc.dwd.de
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Annex 2. Consideration of pest risk management options

The table below summarizes the consideration of possible measures for the different pathways (based on EPPO Standard PM 5/3). When a measure is considered appropriate, it is noted “yes”, or “not alone” if it should be combined with other measures in a systems approach. “No” indicates that a measure is not considered appropriate. A short justification is included.

Option	Fruit (Solanaceae)	Fruit (Cucurbitaceae)	Fruit (others)	Plants for planting (all hosts) with fruit
Existing measures in EPPO countries	The measures in place are not sufficient to prevent the risk of entry of the pest (at the scale of the whole EPPO region)			
Options at the place of production				
Visual inspection at place of production	Not alone. Fruit flies are difficult to see. Early infestation may be overlooked. Trapping with appropriate traps. Only a weak attractant is available.			
Testing at place of production	No. Not relevant.			
Treatment of crop	Not alone. Not reliable to guarantee pest freedom, but can be combined with other measures. As the eggs and larvae are inside the fruit, crop sprays are unlikely to reach the pest. Adults are most of the time out of host crops and would not be directly affected by insecticides. An area-wide management programme was applied in Hawaii (Vargas et al., 2008) for several fruit fly species, and its future implementation to *B. latifrons* was planned (Vargas et al., 2008). McQuate (2009 - abstract) investigated (cage trials) the efficacy of the GF120NF Fruit Fly Bait for the suppression of *B. latifrons*, and concluded it should be effective. It could be used in the framework of an area of low pest prevalence.			
Resistant cultivars	No. Not relevant (Wasee et al., 2013 found that some *Capsicum* cultivars are more resistant, but not fully).			
Growing the crop in glasshouses/ screenhouses	Yes. This would require complete physical isolation (see EPPO Standard PM 5/8). Possible, but difficult to implement in commercial production. Screenhouses should have an appropriate mesh size (larger than for thrips and whiteflies, so possible even in tropical climates). It should include requirements for growing media (to make sure it is free from pupae). Plants for planting should be appropriately packaged/handled to avoid infestation during transport out of the physical isolation.			
Specified age of plant, growth stage or time of year of harvest	No			
Produced in a certification scheme	No. Not relevant for an insect.			
Pest free production site	Yes. Only growing under complete physical isolation (see 3 rows above)			
Pest free area	Yes. PFA as described in ISPMs 4 and 26. It will require the use of traps (but the attractant is weak) and regular inspections. There should be controls on movement of all host fruit and plants, other hosts, equipment and packaging, etc. in and out of the area. Mziray et al (2010b) note that results suggest the possibility of establishing *B. latifrons* free areas where export solanaceous crops can be grown, but further research over longer periods would be needed to establish this. Plants for planting should be appropriately packaged/handled to avoid infestation during transport out of the PFA.			
Place of production freedom.	Yes. Only growing under complete physical isolation. Place of production freedom in the open is not considered an suitable option, due to high flight capacity			
Area of low pest prevalence	Not alone. ALPP as described in ISPM 30 *Establishment of areas of low pest prevalence for fruit flies (Tephritidae)*, provided this is feasible for the area considered and ensures pest-free fruit in a systems approach.			Not alone. ALPP should be combined with other measures, e.g. post-entry quarantine
Options after harvest, at pre-clearance or during transport				
Visual inspection of	Not alone. Detection is difficult in particular for early infestation. It			Not alone. Pupae may be in

Option	Fruit (Solanaceae)	Fruit (Cucurbitaceae)	Fruit (others)	Plants for planting (all hosts) with fruit
consignment	should include cutting the fruit open.			the growing media and therefore very difficult to detect.
Testing of commodity	No. Not relevant			
Treatment of the consignment	Yes (+ handling/packing preventing infestation) No specific data is available for treatments against *B. latifrons*. Irradiation: 150 GY in ISPM 28-PT 7 (FAO, 2009; *Irradiation treatment for fruit flies of the family Tephritidae* (generic)) (applying by extrapolation to all fruits and vegetables that are hosts). This dose also proved effective specifically against *B. latifrons* (Follett et al., 2011). This is not recommended as an option because the EPPO Council recommended that irradiation should not be used for food commodities. Vapour heat treatment: No specific PT for *B. latifrons*, but ISPM 28-PT15 may apply (Vapour heat treatment for *Bactrocera cucurbitae* on *Cucumis melo var. reticulatus*). The EWG considered that such treatment will not be applicable for tomato fruit. Cold treatment for Citrus (e.g. 0.3°C for 3 days for shipment from Turkey to Japan against Ceratitis) Fumigation with methyl bromide is a possibility in the US Treatment Manual but is not recommended (it was phased out in 2015) Note: the EU Directive, for *Citrus* fruit against Tephritidae, lists: 'any acceptable vapour heat treatment, cold treatment, or quick freeze treatment, which has been shown to be efficient against the relevant organism without damaging the fruit, and, where not availaible, chemical treatment as far as it is acceptable by Community legislation.'			No
Pest only on certain parts of plant/plant product, which can be removed	No. Eggs and larvae are in the fruit.			Yes. Removing fruit would ensure absence of eggs and larvae, and replacing growing medium (top layer) would ensure absence of pupae (both should be combined). It may be possible to only remove the top layer of the growing media but no information was sought to define the depth at which pupae may be found in the growing media. Removing fruit may reduce the value of the plants.
Prevention of infestation by packing/handling method	Not alone. Commodities may already be infested. Only new packaging should be used for fruit. For relevant measures, suitable packing/handling methods should be used to prevent reinfestation			Not alone. Commodities may already be infested. For relevant measures, suitable packing/handling methods should be used to prevent reinfestation

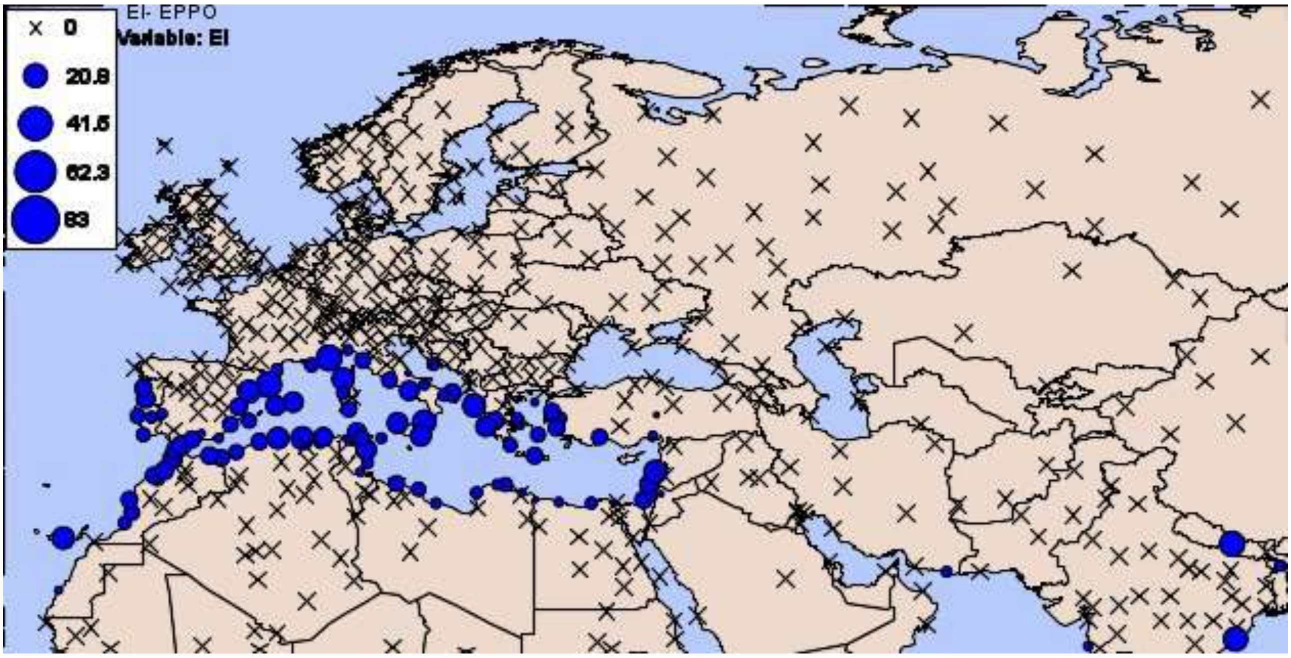
Options that can be implemented after entry of consignments		
Post-entry quarantine	No. Not relevant for fruit	Possible in theory, for small consignment of high value plants in the framework of bilateral agreements (but may not be practical/cost-effective)
Limited distribution of consignments in time and/or space or limited use	Difficult to implement in practice. Consignments may be imported when temperatures are cold for immediate processing or direct consumption, where the pest cannot survive outdoors. However, there is limited knowledge on the conditions under which the pest may survive outdoors. Immediate processing of the fruit and destruction of the waste (e.g. burning, deep burial, solarization) is possible, but it is not practical and difficult to control in practice. Rapid disposal of packaging material will reduce the chances of adults emerging from any puparia that have formed during transit. Adults that have emerged during transport might also escape and reach a glasshouse with hosts.	No. Not applicable for plants as the intended use is for planting.
Only surveillance and eradication in the importing country	Possible in individual EPPO countries in the northern part (where the pest can not establish outdoor), but difficult to implement in practice. In the part of the EPPO region where the pest cannot establish outdoors (not precisely defined), infested fruit consignments could in theory be imported. This would require the separation of trade and production flows (separate facilities for imported consignments and for growing hosts) and a good surveillance system to detect any occurrence of the pest in crops. Eradication is considered possible in greenhouses in that part of the PRA area. This would be possible only as long as the trade volumes are very low.	No

Annex 3 Maps of potential area of establishment according to CLIMEX models

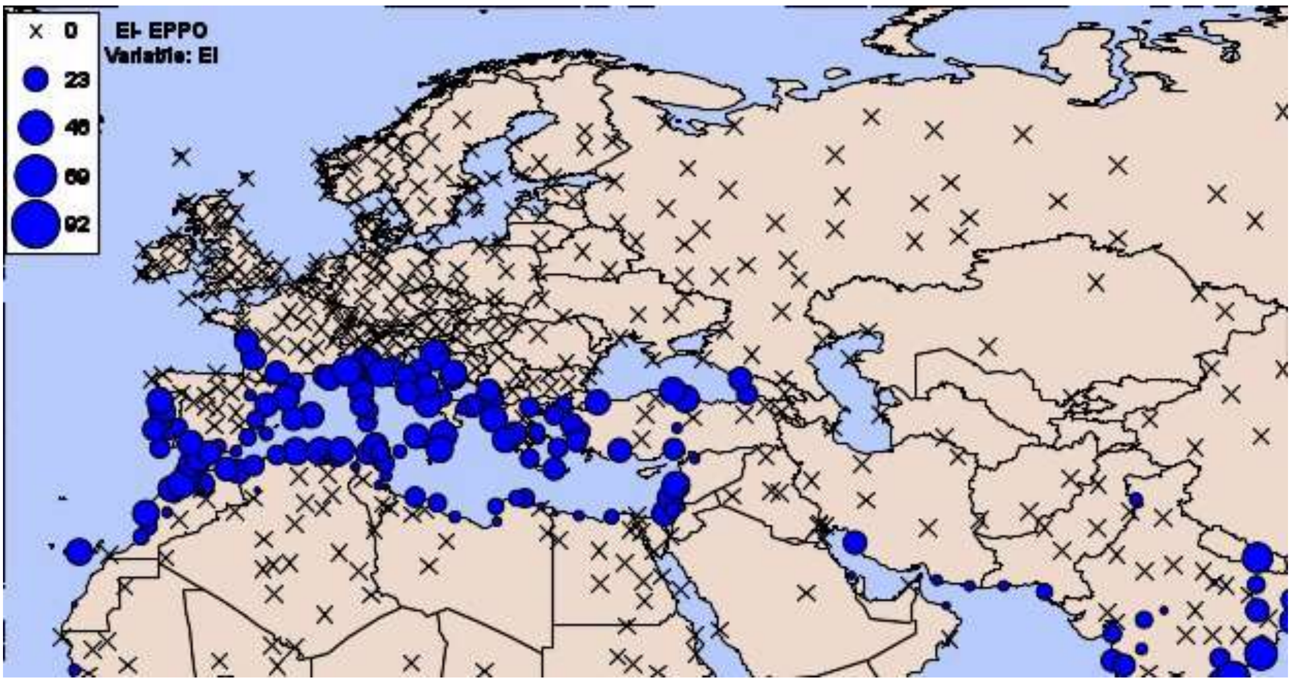
Maps of potential establishment in the EPPO region according to the parameters extrapolated from Vargas et al. (1996) –a; and parameters as defined by Ma et al (2002) – b.

For a, parameters were based on Vargas et al. for maximal and minimal temperature and the degree-days per generations. Based on the current distribution of *B. latifrons,* a preliminary attempt was made to adjust the CLIMEX model parameters in such a way that the resulting ecoclimatic suitability map ressembled the geographic distribution pattern as good as possible. EI is an "ecoclimatic index" Blue dots indicate locations where climate is suitable for establishment outdoors based on ecoclimatic index (EI>35 is considered very favourable for establishment)

a



b



According to these models, the number of generations would be 1-3 in the North of the Mediterranean Basin, and up to 5 in the South. Model b suggested a larger zone for establishment toward the North of the Mediterannean Basin, including South-western France, and the Balkans.

Parameters of the CLIMEX models (extrapolated from data in Vargas et al. on the left, as in Ma et al. on the right)

Parameters: Bactrocera latifrons_ Vargas

		Edit Comments...		Copy to Clipboard	
☑ Moisture Index					
SM0	SM1	SM2	SM3		
0.1	0.25	1	1.5		
☑ Temperature Index					
DV0	DV1	DV2	DV3		
16	24	30	32		
☐ Light Index					
☐ Diapause Index					
☑ Cold Stress					
TTCS	THCS	DTCS	DHCS	TTCSA	THCSA
2.5	-0.0012	8	-0.002	0	0
☑ Heat Stress					
TTHS	THHS	DTHS	DHHS		
32	0.005	0	0		
☑ Dry Stress					
SMDS	HDS				
0.1	-0.0024				
☑ Wet Stress					
SMWS	HWS				
1.5	0.007				
☐ Cold-Dry Stress					
☐ Cold-Wet Stress					
☐ Hot-Dry Stress					
☐ Hot-Wet Stress					
Day-degree accumulation above DV0					
DV0	DV3	MTS			
16	32	7			
Day-degree accumulation above DVCS					
DVCS	*DV4	MTS			
10	100	7			
Day-degree accumulation above DVHS					
DVHS	*DV4	MTS			
36	100	7			
Degree-days per Generation					
PDD					
421.2					

Parameters: Bactrocera latifrons

		Edit Comments...		Copy to Clipboard	
☑ Moisture Index					
SM0	SM1	SM2	SM3		
0.1	0.5	1	1.8		
☑ Temperature Index					
DV0	DV1	DV2	DV3		
15.7	18	33	36		
☐ Light Index					
☐ Diapause Index					
☑ Cold Stress					
TTCS	THCS	DTCS	DHCS	TTCSA	THCSA
2	-0.1	0	0	0	0
☑ Heat Stress					
TTHS	THHS	DTHS	DHHS		
36	0.005	0	0		
☑ Dry Stress					
SMDS	HDS				
0.1	-0.005				
☑ Wet Stress					
SMWS	HWS				
1.8	0.002				
☐ Cold-Dry Stress					
☐ Cold-Wet Stress					
☐ Hot-Dry Stress					
☐ Hot-Wet Stress					
Day-degree accumulation above DV0					
DV0	DV3	MTS			
15.7	36	7			
Day-degree accumulation above DVCS					
DVCS	*DV4	MTS			
12	100	7			
Day-degree accumulation above DVHS					
DVHS	*DV4	MTS			
36	100	7			
Degree-days per Generation					
PDD					
415.4					