Repubblica Italiana

REGIONE SICILIANA

GIUNTA REGIONALE

Deliberazione n. 466 del 22 novembre 2023.

“Piano di azione per il contenimento ed il controllo della *Solenopsis invicta* - Apprezzamento”.

La Giunta Regionale

VISTO lo Statuto della Regione;

VISTE le leggi regionali 29 dicembre 1962, n. 28 e 10 aprile 1978, n. 2;

VISTA la legge regionale 16 dicembre 2008, n. 19 e successive modifiche e integrazioni;

VISTO il D.P.Reg. 5 aprile 2022, n. 9 concernente: “Regolamento di attuazione del Titolo II della legge regionale 16 dicembre 2008, n. 19. Rimodulazione degli assetti organizzativi dei Dipartimenti regionali ai sensi dell'articolo 13, comma 3, della legge regionale 17 marzo 2016, n. 3”;

VISTO il proprio Regolamento interno, approvato con deliberazione della Giunta regionale n. 82 del 10 marzo 2020;

VISTO il Regolamento (UE) n. 1143/2014 del Parlamento europeo e del Consiglio, del 22 ottobre 2014, recante disposizioni volte a prevenire e gestire l’introduzione e la diffusione delle specie esotiche invasive;

VISTO il Decreto legislativo 15 dicembre 2017, n. 230: “Adeguamento della normativa nazionale alle disposizioni del Regolamento (UE) n. 1143/2014 del Parlamento europeo e del Consiglio del 22 ottobre 2014, recante disposizioni volte a prevenire e gestire l'introduzione e la diffusione delle specie esotiche invasive” ed, in particolare, l’art.19;

VISTA la nota prot. n.12592 del 21 novembre 2023 e atti acclusi, con la quale l’Assessore regionale per il territorio e l’ambiente trasmette, condividendone i contenuti, la nota prot. n.84864 del 21 novembre 2023 del Dirigente generale del Dipartimento regionale dell’ambiente, per l’apprezzamento da parte della Giunta regionale;

CONSIDERATO che nella richiamata nota prot. n.84864/2023 il Dirigente generale del Dipartimento regionale dell'ambiente espone, preliminarmente, le risultanze del lavoro svolto in data 28 settembre u.s. dal Tavolo tecnico istituito per affrontare le problematiche relative alla diffusione della specie *Solenopsis invicta* (formica di fuoco), a cui erano presenti il Libero Consorzio Comunale di Siracusa, l'Università di Catania, ISPRA, il Servizio 4 Fitosanitario regionale e l'Unità Fitosanitaria di Siracusa del Dipartimento regionale dell'agricoltura, specificando che: al predetto Tavolo tecnico sono state fornite le informazioni sulla presenza della specie, pervenute informalmente dai ricercatori di Barcellona e di Parma che hanno curato e pubblicato la ricerca sulla presenza della specie in Sicilia, nonchè le segnalazioni pervenute da parte dei cittadini del Siracusano in ordine alla presenza della "formica di fuoco" da diversi anni nei giardini delle proprie abitazioni negli abitati costieri di Ognina, Arenella e Fontane Bianche; il gruppo di ricerca, responsabile della prima segnalazione della specie in Sicilia, ha fornito un'ulteriore lista di avvistamenti della specie in argomento, dalla quale si desume che, rispetto al luogo della prima scoperta, la distribuzione della formica di fuoco si è estesa e sembrerebbe che la sua presenza in Sicilia ci sia da almeno quattro anni;

CONSIDERATO che, sempre nella nota prot. n.84864/2023, il Dirigente generale rappresenta che: come sollecitato dal Ministero dell'Ambiente e Sicurezza Energetica (MASE), l'eradicazione della specie in argomento dal territorio, da parte della Regione, è obbligatoria, ai sensi dell'art.17 del citato Reg. UE 1143/2014 e del parimenti citato art.19 del D.lgs. n.230/2017 e, tuttavia, si ritiene che, in base ai dati acquisiti sulla distribuzione della specie, nonché alle evidenze che indicano una presenza di lunga data sul territorio regionale, ci siano le condizioni per una deroga all'obbligo di eradicazione rapida, di cui all'art.18 del richiamato Reg.UE n.1143/2014 e, pertanto, risulta opportuno agire con un piano di controllo della popolazione della specie, essendo non attuabile una eradicazione della stessa in tempi brevi; per quanto evidenziato, nelle more che il MASE, con il supporto dell'Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), disponga le misure di eradicazione rapida, viene proposto, per l'apprezzamento della Giunta regionale, il Piano di azione per il contenimento e il controllo della *Solenopsis invicta* che preveda: l'individuazione dell'Assessorato regionale del territorio e dell'ambiente, quale soggetto capofila, cui compete l'eventuale individuazione di un Commissario straordinario, la creazione di una rete di monitoraggio della specie che coinvolgerà il predetto Assessorato, l'Assessorato regionale dell'agricoltura, dello sviluppo rurale e della pesca mediterranea e l'Assessorato regionale della salute, il coinvolgimento delle Università siciliane e di esperti per il necessario supporto scientifico (Comitato scientifico di supporto), l'adozione e attuazione del Piano in argomento con mezzi fisici e presidi sanitari disponibili e verifica delle prove attestanti da quale anno è presente la *Solenopsis invicta* in Sicilia;

RITENUTO di apprezzare il superiore Piano di azione per il contenimento ed il controllo della *Solenopsis invicta*;

SU proposta dell'Assessore regionale per il territorio e l'ambiente,

D E L I B E R A

per quanto esposto in preambolo, di apprezzare il Piano di azione per il contenimento ed il controllo della *Solenopsis invicta* in premessa specificato, in conformità alla nota prot. n.84864 del 21 novembre 2023 e atti acclusi del Dirigente generale del Dipartimento regionale dell'ambiente, trasmessi con nota prot. n.12592 del 21 novembre 2023 dell'Assessore regionale per il territorio e l'ambiente, costituenti allegato alla presente deliberazione.

Il Segretario — Il Presidente

BUONISI — SCHIFANI

ER

REPUBBLICA ITALIANA

REGIONE SICILIANA
Assessorato Territorio e Ambiente
L'Assessore
Via Ugo La Malfa n. 169 – 90146 Palermo
Tel. 091/7077226 – fax 091/6891086
assessore.territorioambiente@regione.sicilia.it

Prot. n. 12592/Gab.

Palermo 21 NOV 2023

Presidenza Regione Siciliana
On. Le Presidente della Regione siciliana
Ufficio di Gabinetto

Segreteria di Giunta

p.c. **Al Dirigente Generale**
del Dipartimento regionale dell'Ambiente

LORO INDIRIZZI DI POSTA CERTIFICATA

OGGETTO: Piano di azione per il contenimento ed il controllo della Solenopsi invicta.

Per l'apprezzamento da parte della Giunta Regionale, si trasmette la nota – a firma del Dirigente Generale del Dipartimento Regionale dell'Ambiente - prot. n. 84868 del 21 novembre 2023, acquisita al nostro protocollo in pari data al n. 12591/Gab., con allegata documentazione, di cui si condividono i contenuti.

L'Assessore
Elena Pagana

ASSESSORATO REGIONALE TERRITORIO E AMBIENTE

REPUBBLICA ITALIANA
Regione Siciliana
Assessorato del Territorio e dell'Ambiente
Dipartimento dell'Ambiente
DIRIGENTE GENERALE

Prot. n. 84864 del 21/11/2023

OGGETTO: *Risultanze del Tavolo tecnico sulla specie Solenopsis invicta e Piano di azione per il controllo della popolazione della stessa specie*

Dott.ssa Elena Pagana
Assessore del Territorio e dell'Ambiente
SEDE

In data 28 settembre u.s. come da VS convocazione si è riunito il Tavolo tecnico sulla specie *Solenopsis invicta*, detta "Formica di fuoco", erano presenti il Libero Consorzio Comunale di Siracusa, l'Università di Catania, ISPRA, il Servizio 4 Fitosanitario regionale e l'Unità Fitosanitaria di Siracusa del Dipartimento regionale dell'Agricoltura.

Il Servizio 3 di questo Dipartimento - come rappresentato con nota prot. 84784 del 21/11/2023 - ha portato al tavolo ulteriori informazioni sulla presenza della specie pervenute informalmente da parte dei ricercatori di Barcellona e di Parma che hanno curato e pubblicato la ricerca sulla presenza della specie in Sicilia, tra le quali segnalazioni da parte di cittadini del Siracusano che segnalavano la presenza della "*formica di fuoco*" da diversi anni nei giardini delle proprie abitazioni, negli abitati costieri di Ognina, Arenella e Fontane Bianche.

Come emerso nel corso del confronto, le problematiche più evidenti, relative alla diffusione della specie, sono legate principalmente a due aspetti:

1. sanitari, dovuti agli attacchi diretti da parte delle formiche quando si entra in contatto con queste nei pressi di un loro nido, che possono avere anche gravi conseguenze su soggetti fragili o allergici;

2. socio-economici legati al mondo vivaistico e agronomico, per via dell'embargo al commercio di piante, che potrebbe scattare da parte dell'UE al fine di evitare il propagarsi della specie al di fuori dell'isola ma anche per gli effetti fitosanitari indiretti che la specie potrebbe avere sulle colture.

In seguito, con nota assunta al protocollo DRA n. 75378 del 16/10/2023 (All. 1) è pervenuta, da parte del gruppo di ricerca, responsabile della prima segnalazione della specie in Sicilia, una ulteriore lista di avvistamenti, arrivate loro da parte di privati, che estende di oltre 10 km a sud la distribuzione della specie rispetto al luogo della prima scoperta e dalla quale sembrerebbe desumersi la sua presenza in Sicilia da almeno 4 anni.

Secondo quanto riportato nelle pubblicazioni scientifiche inviate da ISPRA con nota prot. 0052762/2023 del 3 ottobre 2023 (All. 2), risulterebbe che "nel suo habitat non nativo (la formica) dimostra una forte preferenza per ambienti urbani ed agricoli (Tsvhinkel, 2006)".

Come sollecitato dal Ministero dell'Ambiente e Sicurezza Energetica (MASE), l'eradicazione della specie dal territorio da parte della Regione è obbligatoria, ai sensi dell'art.17 del Reg. UE 1143/14 e dell'art.19 del D. Lgs. N. 230/17. Si ritiene tuttavia che, alla luce dei nuovi dati acquisiti sulla distribuzione della specie e sulla base delle evidenze che indicano una presenza di lunga data sul territorio regionale, che si possa ricadere nelle fattispecie previste dall'art. 18 del Reg. UE 1143/14, ovvero che si agisca con un piano di controllo della popolazione della specie, essendo non attuabile una eradicazione della stessa in tempi brevi.

Peraltro si ha notizia di interventi analoghi attuati in altri Paesi (Stati Uniti, Australia, etc.) usando dei principi attivi non autorizzati in Italia, ma rivelatisi efficaci. A tal riguardo potrebbe essere certamente utile interessare le Autorità competenti per autorizzare - anche soltanto per un periodo limitato - l'uso di tali principi attivi anche in Italia.

Per quanto sopra espresso, nelle more che il MASE, con il supporto di ISPRA, disponga le misure di eradicazione rapida, così come previsto dall'art. 19 comma 2 del D.Lgs. 230/17, dal quale emerge anche la rilevanza del coinvolgimento a livello nazionale del Ministero dell'Agricoltura della Sovranità Alimentare e delle Foreste, si sottopone alla SV, al fine dell'apprezzamento da parte della Giunta di Governo, la seguente proposta di "*Piano d'azione per il contenimento ed il controllo della Solenopsis invicta*":

1. individuazione nell'Assessorato regionale del Territorio e dell'Ambiente soggetto capofila; cui compete l'eventuale individuazione di un Commissario straordinario;
2. creazione di una rete di monitoraggio della specie che veda coinvolti, l'Assessorato del Territorio e dell'Ambiente, l'Assessorato dell'Agricoltura, dello Sviluppo Rurale e della Pesca mediterranea e l'Assessorato della Salute;
3. coinvolgimento delle Università Siciliane e di esperti per il necessario supporto scientifico (Comitato Scientifico di supporto);
4. adozione ed attuazione del "Piano d'azione per il contenimento e il controllo della *Solenopsis invicta*" con mezzi fisici (vapore, fuoco, … etc.) e presidi sanitari disponibili;
5. verifica delle prove attestanti da quale anno è presente la *Solenopsis invicta* in Sicilia.

Si rappresenta di valutare la necessità di interloquire con il Ministero competente per avviare l'iter autorizzativo dei p.a. già adoperati con successo all'estero.

Regione Siciliana - Ass.to Reg. del Territorio e dell'Ambiente

Patrizia Valenti

ALL. 1

dipartimento ambiente prot. 75378 del 16.10.2023

Enrico Schifani
Viale delle Palme, 25 - 90149 Palermo

Al
Servizio 3 - Aree Naturali Protette
Assessorato Regionale Territorio Ambiente Dipartimento Ambiente

Al
Servizio 4 - Servizio Fitosanitario Regionale
Assessorato Regionale Agricoltura, Sviluppo rurale e Pesca mediterranea
Dipartimento dell'Agricoltura

Alla
Unità Periferica Fitosanitaria di Siracusa (UO S4.010)

OGGETTO: Nuovi dati sulla distribuzione in Sicilia della "Formica di fuoco", *Solenopsis invicta*, specie invasiva di Interesse Unionale.

In merito alla presenza in Sicilia della "Formica di fuoco" (*Solenopsis invicta*), il sottoscritto, da parte del gruppo di ricerca responsabile della prima scoperta di cui è membro, vi invia segnalazioni di ulteriori siti di presenza della specie ricevute da cittadini che ci hanno contattato a seguito dell'eco mediatico della pubblicazione "The invasive ant *Solenopsis invicta* is established in Europe" sulla rivista *Current Biology*. La presenza nei nuovi siti appare credibile sulla base del materiale fotografico inviatoci e/o dei resoconti riguardanti le punture seguite da pustule casusate da formiche, considerando la prossimità geografica dei siti di nuova segnalazione con la popolazione da noi accertata come *Solenopsis invicta* attraverso le analisi presentate su *Current Biology*. Ogniqualvolta possibile, abbiamo chiesto ai cittadini che ci hanno trasmesso le segnalazioni di indicarci una stima minima del tempo in cui ricordano che la specie sia stata presente nelle rispettive aree, in maggioranza giardini e aree private, sulla base delle punture. Uno dei dati che vi inviamo è pubblicamente accessibile anche sulla piattaforma di citizen science www.inaturalist.org.

Con la presente si trasmettono tutte le informazioni pervenuteci per il seguito di competenza, al fine di agevolare la lotta alla specie.

Nella tabella sono riportati i dati dei nuovi siti segnalatici e quanto i cittadini ci hanno riferito per quel che riguarda la loro stima temporale di presenza della specie nell'area.

Restiamo a disposizione nel caso fosse necessaria qualche ulteriore informazione.

Cordiali saluti,
Enrico Schifani

Palermo, 10.10.2023

Enr. Schifani

Indirizzo	Località	Provincia	Numero nidi	Data del repor	Stime degli osservatori su presenza anche negli anni precedenti	Foto	Commenti	Osservatore	Fonte
Via Isole della Sonda 45	Arenella	Siracusa	>4	ago-23	almeno dal 2022	sì	Maschi rinvenuti nell'Agosto 2023	Stefano Nicolosi	Report pubblico su iNaturalist + contatto diretto nel Settembre 2023
Asparano, Via dell'Anguilla	Ognina	Siracusa	>3	set-23	almeno dal 2021	sì	In diverse proprietà	Giusi Cappello	Contatto diretto
Via Isole delle Molucche 71	Aranella	Siracusa		set-23	almeno dal 2019	sì		Francesco Quartarone	Contatto diretto
Viale dei Lidi, 302	Fontane Bianche	Siracusa		set-23	almeno dal 2020		Menzionato caso di Pronto Soccorso	Francesco Diara	Contatto diretto
	Fontane Bianche	Siracusa		set-23	almeno dal 2020			Luisa Laudani	Social network report
zona Cubano Tenda	Fontane Bianche	Siracusa	multipli	set-23			Menzionato caso di Pronto Soccorso	Stefano La Sala	Social network report
Via Mar Ionio	Fontane Bianche	Siracusa	>4	set-23	almeno dal 2019	sì		Massimiliano Tiralongo	Social network report + contatto diretto
Via Pegaso	Fontane Bianche	Siracusa	multipli	set-23				Antonio Dipietro	Social network report + contatto diretto
Via delle Muse 50	Fontane Bianche	Siracusa		set-23				Concetto Di Pace	Social network report
Residence Selenia	Fontane Bianche	Siracusa		set-23				Enrica De Melio	Social network report
Via delle Muse. N 68	Fontane Bianche	Siracusa	multipli	set-23	almeno dal 2021			Giallongo Mariagrazia	Social network report + contatto diretto
C/da Asparano in via dell'Orata	Ognina	Siracusa		ott-23	almeno dal 2020			Nello Ferrante	Contatto diretto
Via Mar Rosso	Fontane Bianche	Siracusa	multipli	ott-23		sì	Osservate molte regine		Contatto diretto

ALL. 2

Regione Siciliana
Assessorato del Territorio e dell'Ambiente
Dipartimento dell'Ambiente
Servizio 3 – Aree Naturali Protette, Rete Natura 2000, Sviluppo Sostenibile
Dott. Francesco Picciotto
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Ministero dell'Ambiente e della Sicurezza Energetica
Direzione Generale Patrimonio Naturalistico e Mare
PNM@Pec.Mite.Gov.it

Oggetto: Prima segnalazione della presenza di una nuova specie esotica invasiva di interesse unionale sul territorio regionale siciliano.

Responsabile dell'istruttoria: Dott.ssa Lucilla Carnevali (Tel. 06/50072650 - e-mail: lucilla.carnevali@isprambiente.it).

In riferimento alla segnalazione in oggetto, inviata con prot. n. 60780 del 4 agosto u.s., alla luce della riunione del tavolo tecnico sulla gestione della formica di fuoco tenutasi lo scorso 28 settembre 2023, ribadendo quanto già discusso nei numerosi contatti informali intercorsi in questi ultimi due mesi, questo Istituto comunica quanto segue.

L'eradicazione della specie dal territorio è obbligatoria ai sensi dell'art.17 del Reg. UE 1143/14 e dell'art.19 del D. Lgs. N. 230/17. Le tecniche applicabili sul campo (dal controllo meccanico a quello chimico) sono illustrate nel documento redatto dalla Commissione e trasmesso in allegato. Si raccomanda pertanto l'immediato avvio della distruzione dei nidi già identificati.

Nel caso della specie interessata, come emerge dal documento allegato, risulta inoltre essenziale definire misure di biosicurezza che prevengano la diffusione accidentale tramite movimentazione di suolo e materiale florovivaistico al di fuori dell'area di presenza accertata della specie. In caso di stretta necessità si raccomanda di prevedere controlli accurati e pulizia profonda dei materiali trasportati per evitare l'ulteriore diffusione della specie. Tali controlli andrebbero eseguiti anche da tutti i cittadini che vivono o frequentano le aree infestate.

Si trasmette inoltre lo studio del rischio della specie redatto a livello comunitario che contiene dati e riferimenti utili per la gestione della problematica.

Si rimane a disposizione per ogni eventuale supporto tecnico.

Distinti saluti.

IL RESPONSABILE DELL'AREA PARERI TECNICI
E STRATEGIE DI CONSERVAZIONE E GESTIONE DEL PATRIMONIO
FAUNISTICO NAZIONALE E MITIGAZIONE DANNI E IMPATTI

(Dott. Roberto Cocchi)

LC/Rif. int. 43476/2023

All. n. 02

IL RESPONSABILE DEL SERVIZIO PER IL COORDINAMENTO
DELLE ATTIVITA' DELLA FAUNA SELVATICA

Dott. Piero Genovesi
(firmato digitalmente)

Ai sensi dell'art. 19-bis del D.Lgs. n. 74/2017 inerente la partecipazione dei cittadini e degli altri utenti finali al processo di misurazione delle *performances* organizzative, questo Istituto ha adottato un modello di scheda di rilevazione della soddisfazione dell'utente. Si chiede cortesemente di compilare il questionario inerente il gradimento dei servizi erogati da ISPRA in relazione alla presente pratica collegandosi al seguente link https://survey.isprambiente.it/index.php/475114?lang=it, selezionando la struttura BIO-CFN, servizio erogato: Pareri tecnici.

Solenopsis geminata. © Meghan Cassidy, (CC BY-SA) via iNaturalist

The management of Fire Ants (*Solenopsis geminata, Solenopsis invicta, Solenopsis richteri*)

Information on measures and related costs in relation to species on the Union list

Scientific name(s)	*Solenopsis geminata* (Fabricius, 1804); *Solenopsis invicta* Buren, 1972; *Solenopsis richteri* Forel, 1909
Common names (in English)	Tropical Fire Ant (*S. geminata*), Red Imported Fire Ant (RIFA) (*S. invicta*), Black Imported Fire Ant (BIFA) (*S. richteri*)
Author(s)	Wolfgang Rabitsch
Reviewer(s)	Angulo, E., Blight, O., Boser, C., Buczkowski, G., Demetriou, J., Hoffman, B., Kenis, M., Klenovsek, A., Lach, L., Montgomery, M., Morton, G., Oi, D., Peacock, L., Plentovich, S., Roy, H., Stevens, N., Sunamura, E., Costello, K., Nunes, A., Scalera, R., Smith, K.
Date of completion	09/10/2022

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Summary of the measures, emphasizing the most cost-effective options.

Prevent intentional introduction into the territory
Addition of the three *Solenopsis* species on the list of species of Union concern in July 2022 entails application of provisions of Regulation (EU) 1143/2014. This includes a ban of intentional introductions, e.g. as a pet. However, implementation of the Regulation requires enforcement by each Member State and this has not yet been fully achieved.

Prevent intentional release or unintentional escape into the environment
It cannot be ruled out that the three *Solenopsis* species are kept in containment as a pet or for other reasons in the EU, but since this is rather unlikely, no measures to prevent release or escape are suggested.

Prevent reproduction in captivity
It cannot be ruled out that the three *Solenopsis* species are kept in containment as a pet or for other reasons in the EU, but since this is rather unlikely, no measures to prevent release or escape are suggested.

Prevent unintentional introduction into the territory
There are several active pathways of unintentional introduction into the EU. The species can travel as stowaway in containers and with vehicles, and contaminant of plants. Inspections at EU-borders by plant health authorities are currently not qualified for considering ants, but it would be most efficient to declare ants as “harmful organisms” and to enlarge the legal competence of plant health authorities to check for ants within their regular work. Also, Article 13 of Regulation (EU) 1143/2014 requires Member States to develop and adopt Action plans on the priority pathways of unintentional introduction, ensuring appropriate checks at the Union borders other than official controls for intentional introductions. Inspections should be based on a risk management approach, i.e. focusing on commodities, products and goods from countries in which the species is present, and should be prioritized, e.g. based on volume of imports or likelihood of entry into the wild.

Inspections (including surveillance) and treatments to prevent contamination at high-risk ports of departure, i.e. outside the EU, have much added value (towards unintentional introduction of other invasive alien species) and are likely cost-efficient, but have so far not been executed. Detailed knowledge of major import routes and contaminated commodities and products is necessary for implementation.

Prevent secondary spread
There are several possible pathways of secondary spread within the EU. The species can spread as stowaway in containers and with vehicles, and contaminant of plants and soils. Article 13 of Regulation (EU) 1143/2014 requires Member States to develop and adopt Action plans on the priority pathways of unintentional spread. Because of the presence in (sub)urban environments and likely encounters with the public, it is important to increase public awareness via dedicated information campaigns. This is also required to increase acceptability of management measures, which might include access to private land.

Achieve early detection
Measures to support early detection include active surveillance at points of introduction (e.g. airports, seaports, marinas, and areas of potential concern, such as plant quarantine facilities, buildings and disturbed lands, nurseries, garden centres) and points of entry into the wild. Surveillance (and monitoring) of *Solenopsis* species should be executed with attractant baits (e.g. peanut butter or tuna fish), and visual surveys of preferred micro-habitats. The use of trained detection dogs can be helpful. Environmental DNA analysis of soil or other substrates has much potential, but needs further research before it can be widely applied for early detection. Dedicated immunoassay tests to identify *S. invicta*, *S. richteri* and their hybrid, are available.

Rapid eradication
Contingency plans are considered essential elements for a successful rapid response. This includes clarification of the legal responsibilities, applicability of methods, funding and public approval. Measures for rapid eradication are identical or similar to management measures (e.g. chemical control), but should be applied as early as possible, when population densities and the infested area are small. A dedicated decision support system would help to prioritize whether to respond and how (or not) to an ant incursion event. The establishment of an “Invasive Alien Species Rapid Eradication Fund” is suggested.

Management (e.g. eradication, population control, containment)
Chemical control is the most widely used and most efficient management measure. A variety of products are available, including different active compounds. The method of choice must comply with EU- and Member State legislation and minimize negative side effects. Insecticides are usually applied via granular baits or contact insecticides, broadcasted with dedicated equipment. Efficiency

increases when both methods are combined ("Two-Step-Method"). Standard operating procedures are available, but need to be tailored to the context of the incursion. Success of eradication attempts decreases with increasing size of the infestation, with most successful attempts covering an area of not more than 10 ha. Chemical control via horizontal transfer (transfer of insecticides through physical contact between workers of a colony) has much potential and has been tested for *Solenopsis* species. Classical biological control using flies, fungi and viruses is also available for *S. invicta* and *S. richteri*. For small areas and in proximity to protected species or habitats, where the use of insecticides is prohibited, hot water treatment of mounds is recommended. *Solenopsis* species prefer habitats with a high level of disturbance, therefore, supporting extensive land-use practices in cultural land, habitat restoration of damaged ecosystems, and associated conservation measures increase resilience of natural habitats and help limiting invasion success. General awareness and knowledge about the impacts of invasive ants in the wider public must be improved, specifically with stakeholders providing pathways of introduction, entry into the wild and spread within a territory, specifically the horticulture and ornamental garden sector.

Measures for preventing the species being introduced, intentionally and unintentionally.

This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

Implementation of Regulation (EU) 1143/2014

MEASURE DESCRIPTION

The three *Solenopsis* species *S. geminata*, *S. invicta* and *S. richteri* are listed as "Invasive Alien Species of Union Concern" according to Commission Implementing Regulation (EU) 2022/1203 of 12 July 2022. According to Article 7 of Regulation (EU) 1143/2014, several restrictions apply for species on this "Union list", including the ban of intentional introduction (import) into the territory of the EU, keeping and breeding (including in contained holdings), placing on the market and releasing into the environment. However, execution of these restrictions is not always straightforward, specifically in the context of the mostly unrestricted and unregulated worldwide trade of living organisms, including ants (e-commerce). It has been shown that animal and plant species that had been listed as of Union concern several years ago, still can be ordered online (IUCN, unpubl.).

The relevance of ants as pets has increased significantly in recent years. Gippet & Bertelsmeier (2021) investigated the ant trade market, identifying 520 species for sale worldwide with 57 species considered invasive, including *Solenopsis*. The authors stress the urgency "to put in place international policies regulating the global trade of live animals (including invertebrates)." Although *Solenopsis* species probably are not ideal pets, considering their painful sting, interest in keeping them and trade cannot be ruled out. Further, considering the difficulties of ant identification, improper offerings (intentionally or unintentionally) of other (similar) species might happen.

Rabitsch & Blight (2021) recommended a complete ban for the intentional introduction of ants into the EU, except for authorized cases (e.g. for research or education), but this seems not realistic. Instead, more invasive ant species could be added to future additions of the Union list. Further, Article 12 of the Regulation provides Member States the opportunity to execute the restrictions (or a selection of them) to other invasive species in their territory, they consider as of Member State concern.

SCALE OF APPLICATION

Regulation (EU) 1143/2014 provides restrictions for all three *Solenopsis* species and applies to the EU territory. It has to be mentioned that these restrictions do not apply for the EU outermost regions: [A1]French Guiana, [A1]Guadeloupe, [A1]Martinique, [A2]Mayotte, [A2]Reunion Island and [B]Saint-Martin (France), Azores and Madeira (Portugal), and the [A2]Canary Islands (Spain) [[A1]*S. geminata* native (or historic introduction), [A2]*S. geminata* alien, [B]*S. invicta* alien]. It is known that invasive ants do not only arrive from the native range, but also from the non-native range (bridgehead effect, Bertelsmeier *et al.,* 2018). In particular, *Solenopsis* species may be present in shipments from European outermost regions (see above) or overseas territories, such as the Netherlands Antilles, Nouvelle Calédonie or French Polynesia, which are not regularly inspected. *Solenopsis geminata* and *S. invicta* are also present in the Caribbean UK Overseas Territories and the Leeward Antilles (Aruba, Bonaire, and Curaçao) with strong economic (and tourism) links to the EU.

EFFECTIVENESS OF THE MEASURE

Unknown or not yet applied.

Only recently added to the Union list; effectiveness is unknown.

EFFORT REQUIRED

Adding a species to the Union List requires availability of a Risk Assessment according to Article 5 of the Regulation, that has been approved by independent peer-reviews, the Scientific Forum (according to Article 28 of the Regulation) and the Committee (according to Article 27 of the Regulation). The process takes two years minimum, but can take longer in case of different opinions between the involved stakeholders.

RESOURCES REQUIRED

No estimate for the procedure is available.

SIDE EFFECTS (INCL. POTENTIAL) – BOTH POSITIVE AND NEGATIVE

Environmental effects: Unknown
Social effects: Unknown
Economic effects: Unknown
Only recently added to the Union list; no side effects (e.g. on trade) are known. The obligation to establish an early warning and rapid response system should have positive side effects for the environment as well as for socio-economic impacts.

ACCEPTABILITY TO STAKEHOLDERS

Mixed.
The acceptability of adding new species to the list of Union Concern is mixed and depends on the species, its actual or potential damage, interests of stakeholders in its use and the availability of efficient management methods.

LEVEL OF CONFIDENCE*

Established but incomplete.
Only recently added to the Union list; no studies exist yet to address the question.

Solenopsis geminata. © Didier Levasseur, (CC BY-NC) via iNaturalist

Prevention of escape or release into the environment

MEASURE DESCRIPTION

It cannot be ruled out that the three *Solenopsis* species are kept in containment as pets or for other reasons in the EU, but since this is rather unlikely and even more so in the foreseeable future, no measures to prevent escape or release into the environment are suggested here for the time being.

Prevention of reproduction of contained specimens

MEASURE DESCRIPTION

Article 31 and 32 of the IAS Regulation refer to non-commercial and commercial stock of the species. It cannot be ruled out that the three *Solenopsis* species are kept in containment as pets or for other reasons in the EU, but since this is rather unlikely and even more so in the foreseeable future, no measures to prevent reproduction are suggested here for the time being.

* See Appendix

Plant health inspections

MEASURE DESCRIPTION

The *Solenopsis*-Risk Assessments for the EU (Kenis *et al*., 2019; Blight, 2019, 2020) identified the following pathways of unintentional introduction into the EU:

a) Transport-Stowaway (hitchhikers in or on airplane)
b) Transport-Stowaway (nests transported in container/bulk, including sea freight, airfreight, train, etc.)
c) Transport-Contaminant (nursery material and other matters from horticultural trade)

It has to be mentioned that other pathways have been identified in other countries. For example, *S. invicta* was introduced to Taiwan with imported logs and wastepaper from the USA (Ma *et al*., 2010; Wylie *et al*., 2020). Pathways of introduction can change over time and should be re-assessed and updated in regular intervals to not miss current pathway trends. It is also essential to have robust interception data available to identify possible new pathways.

This measure deals with the unintentional introduction of small *Solenopsis* colonies into the EU with airplanes, contaminated nursery material, as stowaways within containers or any other transport means. The measure relates to plant health inspections at the EU-borders in contrast to national (and subnational) plant health inspections within a Member State that are considered in the "Prevention of secondary spread" section further below.

This measure should be routinely executed by plant health authorities at points of introduction (e.g. airports, seaports, marinas, and areas of potential concern, e.g. plant quarantine facilities, buildings and disturbed lands; but also including plant distribution centers, i.e. nurseries, garden centres) and can target specific commodities (e.g. containers, potted plants). It is therefore necessary to declare ants as "harmful organisms" and to enlarge the legal competence of plant health authorities to check for ants within their regular work. If this is not possible within the Plant Protection legislation, alternative ways must be found. Article 13 of Regulation (EU) 1143/2014 requires Member States to develop and adopt Action plans on the priority pathways of unintentional introduction (and spread), also ensuring appropriate checks at the Union borders other than official controls for intentional introductions.

While plant health authorities have an obligation to inspect goods imported from outside the EU under the plant protection legislations, their capacity does not match the ever increasing amount of products and it is only possible to check a tiny fraction of goods. The use of trained sniffer dogs or soil-DNA analyses during plant health inspections can be useful for increasing surveillance capacities (see below). For efficiency, this needs being based on a risk management approach, i.e. focusing on imports from infested regions and goods (e.g. potted plants). According to legislation, however, these inspections do cover only a selection of goods (e.g. agricultural products, ornamental plants). For example, the holding space of personal or cargo airplanes, is rarely (if ever) inspected; this is also due to the fact that companies try to keep the time of these airplanes on the ground as short as possible and any inspections would cause delays (and loss of money). If, as rare as this might be, a small colony nests in the cargo holding of an airplane, and moves out during the airplane is on ground, this most likely goes unnoticed.

Whenever a nest/colony is found, it should be destroyed by heat or freezing, or other treatments. USDA (2015) provides different chemical treatments for nursery stock in containers, e.g. immersion or dip, drench or topical treatment, or placing granular insecticides into potting media. It is essential to kill any *Solenopsis* nest/colony in contaminated garden plants before they are distributed and sold; hence, the use of contact insecticides for quarantine treatment is recommended.

Ant identification is difficult and the correct name of the species found is relevant for some analysis, but from a biosecurity point of view, all ants, regardless which species, should be destroyed at border inspections. If there is opposition, dedicated immunoassay tests to identify *S. invicta*, *S. richteri* and their hybrid, are available (e.g. Valles *et al*., 2018). Such tests, however, should not delay action beyond reasonable limits.

Surveillance should be executed with ant attractant baits (e.g. peanut butter, see below) and combined with visual surveys, supported by e.g. sniffer dogs or soil eDNA samples (see below). This measure could also be part of a broader Pathway Action Plan dedicated towards invasive ants in general (see e.g. Rabitsch & Blight, 2021), similar to other initiatives (e.g. Australian Invasive Ant Biosecurity Plan 2018–2028, Environment and Invasives Committee 2019; Biosecurity Plan for Invasive Ants in the Pacific Region, Vanderwoude *et al*., 2021).

SCALE OF APPLICATION

The measure should be applied within the legal obligations of Member States or at the relevant provincial levels.

EFFECTIVENESS OF THE MEASURE

Unknown or not yet applied.

Because ants are not listed as "harmful organisms" to plants or plant products, i.e. quarantine pests in the EU (Council Directive 2000/29/EC), records rarely appear in the national and international lists of intercepted harmful organisms. From 2005 to 2019, only 16 records of Formicidae out of 29,148 records of harmful organisms are mentioned in the EUROPHYT (European Union Notification System for plant Health Interceptions) database, with highest numbers of interceptions reported from the Netherlands. It is safe to say that there is a large number of unrecorded and undocumented ant introductions to (and within) the EU (see also Rabitsch & Blight, 2021). At the global scale, the number of introduced species in temperate regions is considered to be three and half times higher than the numbers so far detected (Miravete *et al.,* 2014), which highlights the need for an improved common detection method at ports and airports at a European scale.

Interception data are available for other countries (e.g. USA, Australia, New Zealand, China) and confirm that ants are regularly found during inspections (e.g. Harris *et al.*, 2005; Ward *et al.*, 2006; Bertelsmeier *et al.*, 2018; Suhr *et al.*, 2019; Yang *et al.*, 2019; Lee *et al.*, 2020). It has to be mentioned, however, that not all established alien species turn up in plant inspections: Boer & Vierbergen (2008) counted 37 established alien ant species (indoor and outdoor) in the Netherlands that have never been intercepted in 83 years.

EFFORT REQUIRED

Inspections for ants should be based on a risk management approach, i.e. focusing on commodities (e.g. machinery), products and goods (e.g. potted plants, fruits) from currently infested countries. These inspections should be prioritized, e.g. based on volume of imported commodities.

Based on the experience from Australia and Asia, Wylie *et al.* (2020) summarized *S. invicta* management in these countries and concluded: (a) *S. invicta* can be eradicated if detected early enough, (b) there has been a level of unpreparedness and under-resourcing of quarantine agencies in some countries to deal with the pest, (c) strict controls on the movement of products likely to harbor *S. invicta* are essential in preventing or slowing the spread of the pest and has a major influence on the success or failure of eradication efforts and (d) a coordinated agency response is necessary to prevent treatment failure. Currently, cargo container traffic is the main mechanism for movement of *S. invicta* around the world and can only be addressed by international collaboration. Given the recent fire ant propagule pressure on Japan and South Korea via container traffic from China, it is likely that China may be a new bridgehead for the invasion of its neighbours in Asia and beyond.

RESOURCES REQUIRED

No detailed information found on the topic. However, inspection services in Europe are insufficiently equipped to cope with the vast and increasing amount of materials imported, resulting in only a small part of the materials actually inspected. An increased investment in manpower for inspection is needed, combined with a more risk-based approach to inspection to better target high risk items.

SIDE EFFECTS (INCL. POTENTIAL) – BOTH POSITIVE AND NEGATIVE

Environmental effects: Positive
Social effects: Positive
Economic effects: Positive

Plant health inspections for ants should generate positive side effects as there are many invasive ants that would be intercepted, not just *Solenopsis* species, including another species from the Union list, the little fire ant *Wasmannia auropunctata*.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

If the additional workload for plant health authorities is covered (new staff, equipment) and standard operating procedures are established, as well as stakeholder interests from affected businesses considered, the measure should be acceptable.

LEVEL OF CONFIDENCE*

Inconclusive.

There is not much information available on ants and plant health inspections in the EU.

* See Appendix

Inspections at high-risk ports of departure

MEASURE DESCRIPTION

To increase the efficiency of prevention efforts, the before mentioned inspections at the EU-borders should be combined with careful inspections of goods at high-risk ports of departure to prevent contamination (e.g. Hoffmann *et al*., 2017). Treating containers in the country of origin has been successfully implemented in New Zealand and greatly increased efficiency (e.g. Nendick, 2008). It is worth mentioning that due to the so-called bridgehead effect, i.e. invasive ants do not only arrive from their native range, but also from their non-native range (Bertelsmeier *et al*., 2018), high-risk ports can harbour invasive alien ant species from all around the globe and not only from the native range. Setting up a surveillance system (e.g. prophylactic baiting) in both, high-risk ports of departure and points of introduction (and surroundings) is recommended (e.g. container terminals) (see below).

Pre-border restrictions are in place against "harmful organisms", e.g. for wood packing material (ISPM no 15 requires heat or chemical treatments), but ants are not considered in this framework. High rates of ant interceptions on live plant and wood products or packaging worldwide tend to confirm the relative inefficiency of such restrictions imposed to exporters to Europe. However, knowledge of the occurrence of high-risk species in any given port of departure would be extremely useful. This measure would pose an additional financial burden to the exporter, but it could increase efficiency and save costs in the long run on both sides. While implementation of such a measure on a small island seems straightforward, it is more difficult in an EU context with several large import hubs and very many possibly high-risk ports of departure.

This measure could also be part of a broader (regional or global) Pathway Action Plan dedicated towards invasive ants in general (see e.g. Rabitsch & Blight, 2021).

SCALE OF APPLICATION

This measure has been successfully applied in New Zealand (e.g. Nendick, 2008). There is no possibility to apply it to all Member States, but a targeted and strategic approach towards major pathway import routes or commodities seems possible. Rabitsch & Blight (2021) show that there are several preferred points of introduction in Europe, e.g. seaports in the United Kingdom, the Netherlands and Germany, which are associated with historic and recent pathways of introduction (the plant trade). Similarly, preferred ports of departure should be identified and possibilities for this measure worked out.

EFFECTIVENESS OF THE MEASURE

Unknown or not yet applied.

This measure has been successfully applied by New Zealand (e.g. Nendick, 2008). If a successful application in an EU-context is possible, warrants further investigations.

EFFORT REQUIRED

In an ideal scenario, i.e. plant health staff checking prioritized commodities in ports of departure, this measure should be applied on a permanent basis.

RESOURCES REQUIRED

In an ideal scenario, i.e. plant health staff checking prioritized commodities in ports of departure, this measure requires quite some permanent investment in costs for staff and equipment. According to Nendick (2008), this measure has reduced inspection actions at the point of introduction by 850 hours per annum, freeing staff for other vital work; significant cost reductions for importers and faster container clearance in New Zealand.

SIDE EFFECTS (INCL. POTENTIAL) – BOTH POSITIVE AND NEGATIVE

Environmental effects: Positive

Social effects: Positive

Economic effects: Positive

Pre-border inspections at ports of departure could search for different species, relevant in other contexts (e.g. invasive species detrimental for the environment, harmful species and pests detrimental for plant health, organisms detrimental for animal and human health), which could create positive side effects to all sectors.

ACCEPTABILITY TO STAKEHOLDERS

Mixed.

Because of the permanent investment/costs of the measure, it might be not favoured by decision-makers.

LEVEL OF CONFIDENCE*

Inconclusive.

There is no experience available on this measure in the EU.

* See Appendix

Measures to prevent the species spreading once they have been introduced.

Inspections and treatments of goods

MEASURE DESCRIPTION

The *Solenopsis*-Risk Assessments for the EU (Kenis *et al.*, 2019; Blight, 2019, 2020) identified the pathways of secondary spread between and within Member States as:

a) Transport-Contaminant (Contaminant nursery material)
b) Transport-Stowaway (Container/bulk, including road transport, sea freight, airfreight, train, etc.)

It has to be mentioned that other pathways have been identified in other countries. For example, *S. invicta* was spread within China with potted plants and turf transportation (Lu *et al.*, 2008). Pathways of spread can change over time and should be re-assessed and updated in regular intervals to not miss current pathway trends.

This measure deals with the unintentional transport of small colonies between and within Member States with contaminated nursery material, and as stowaways within containers or any transport means. The nursery trade appears as the highest priority for measures as potted plants provide excellent conditions for nests and brood development of *Solenopsis* species. The measure relates to plant health inspections at the national (and subnational) level in contrast to plant health inspections at the EU-borders (and the pathways of introduction).

This measure could be applied between-EU and within-MS. Secondary spread of *Solenopsis* species within and between MS of the EU must be avoided. This measure could also be part of a broader Pathway Action Plan dedicated towards invasive ants in general (see e.g. Rabitsch & Blight, 2021).

SCALE OF APPLICATION

The measure should be applied within the legal obligations of Member States or at the relevant provincial levels.

EFFECTIVENESS OF THE MEASURE

Unknown or not yet applied.

So far, ants are rarely intercepted (or at least rarely reported) during plant inspections at the EU-borders. It is assumed that there is a large number of unreported (and unidentified) cases in Europe. This transmits to the MS-levels, where little (actually no) information about translocated ants within a MS is available. Providing sufficient resources (workpower, methodologies) and standard operating procedures (including clear responsibilities) in case of a detection, increased inspections of nursery material, and transport infrastructure facilities, through plant health authorities at the MS-level is necessary. The effectiveness of such an intensification of inspections, however, is largely unknown.

EFFORT REQUIRED

The necessary effort to make this measure effective is unknown, but probably high. It starts with regular surveillance and monitoring at points of introduction and requires methods and techniques to act fast (see above and below).

RESOURCES REQUIRED

The necessary costs to make this measure effective is unknown, but probably high. It starts with regular surveillance and monitoring at points of introduction and requires methods and techniques to act fast (see above and below).

SIDE EFFECTS (INCL. POTENTIAL) – BOTH POSITIVE AND NEGATIVE

Environmental effects: Positive
Social effects: Positive
Economic effects: Positive

Increasing intensity of plant health inspections at the MS-level increases the likelihood of detecting other invasive animals travelling under similar conditions (e.g. flatworms) and might have general positive side-effects.

ACCEPTABILITY TO STAKEHOLDERS

Mixed.

Plant inspection authorities already struggle with the large amounts of transported goods, little human resources and additional tasks without strengthening their work force is likely met with opposition. Also, changes to national or provincial legislation might be necessary to provide a legal basis for the measures.

LEVEL OF CONFIDENCE*

Inconclusive.

There is not much information available on ants and plant health inspections within the EU.

* See Appendix

Restricted movement of soil, turf, and potted plants treatment

MEASURE DESCRIPTION

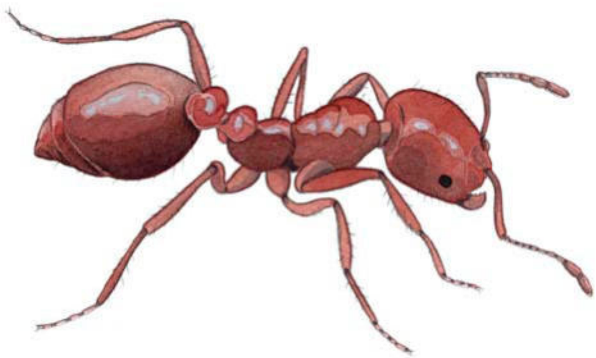
This measure deals with the restriction of the movement of soil, turf, and potted plants within the EU. Although not (yet) considered a relevant pathway in the EU, it is elsewhere (e.g. USDA, 2015; Liu *et al.*, 2020).

Nests of *Solenopsis* might be unintentionally translocated with the transport of soil, turf or potted plants. Therefore, these materials need being treated before transportation by private garden owners or public garden caretakers as well as commercial businesses (nurseries, turf producers). Treatment might include measures described further below (e.g. hot water, chemical).

SCALE OF APPLICATION

The measure should be applied at the local or provincial level with instructions provided for private and public garden owners and commercial businesses.

Solenopsis invicta. © Massimiliano Lipperi, Studio Wildart



EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

The measure could be part of an awareness campaign. The effectiveness of such interventions, however, is unknown.

EFFORT REQUIRED

The necessary effort to make this measure effective is unknown, but probably high.

RESOURCES REQUIRED

The necessary costs to make this measure effective is unknown, but probably high.

SIDE EFFECTS

Environmental: Positive

Social: Positive

Economic: Positive

The measure increases the likelihood of detecting other invasive animals travelling under similar conditions (e.g. flatworms) and might have general positive side effects.

ACCEPTABILITY TO STAKEHOLDERS

Unknown.

Raising awareness might increase acceptability for private garden owners.

LEVEL OF CONFIDENCE*

Inconclusive.

It is inconclusive if this will become a relevant and active pathway of secondary spread of *Solenopsis* spp. in the EU in the future.

* See Appendix

Raising public awareness and community engagement

MEASURE DESCRIPTION

Solenopsis stings are painful and it is assumed that there is interest of the public and communities, where the species is present and where it causes negative impacts to agriculture, human health or as a nuisance. Although not directly comparable, similar initiatives elsewhere have been success stories (e.g. Liu *et al*., 2020; Wang *et al*., 2020).

Public awareness is raised by producing leaflets, posters, press releases, presentations, social and classic media outlets. The aim of raising awareness is to increase the number of observers (and hear back of new infestations as rapid as possible), decrease the likelihood of secondary spread from any possible unintentional pathway (see above). Ultimately, the goal is to engage with the local (affected) community, providing information on impacts, spread and management options that might include the use of chemical control and access to private lands. A dedicated (telephone or email) point-of-contact per Member State (or at the regional levels) could help to inform about biosecurity issues, including introduced ants.

This measure could also be part of a broader Pathway Action Plan dedicated towards invasive ants in general (see e.g. Rabitsch & Blight, 2021).

SCALE OF APPLICATION

This measure should be applied in general at the EU-level (dealing with all invasive ants on the Union list) targeting jump-dispersal events, and specifically at infested sites in Member States and local surrounding areas, which are most likely being colonized in the near future.

EFFECTIVENESS OF MEASURE

Effective.

Although there are no quantitative data available, it is generally assumed that raising the profile of biological invasions in general, and of selected invasive species in particular, is an effective mean to change opinions and behaviour of private individuals and public stakeholders. It is recommended to coordinate campaigns at the EU-level.

EFFORT REQUIRED

The high turnover of news and information in digital societies requires messages being repeatedly and actively communicated via different channels, both traditional and digital, including social media to reach an as wide as possible audience.

RESOURCES REQUIRED

No specific cost estimates available.

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Positive

Raising awareness of the impacts of invasive species increases the understanding of the problem of biological invasions in general and this might have positive side effects.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

No conflict of interest foreseen.

LEVEL OF CONFIDENCE*

Well established.

Raising awareness has a proven value to flag the impacts invasive alien species can have, specifically for species where there is a high likelihood of negative personal encounters in private and public gardens and parks, and agricultural fields.

Solenopsis geminata. © Judy Gallagher (CC BY 2.0) via Flickr

* See Appendix

Measures to run an effective surveillance system for achieving an early detection of a new occurrence.

Surveillance at points of introduction and entry

MEASURE DESCRIPTION

Surveillance is an essential element in ant management planning. Surveillance measures apply to i) monitoring at and around points of introduction and ii) points of entry. In accordance with the terminology used in the EU-Risk Assessments (Kenis *et al*., 2019; Blight, 2019, 2020), "introduction" here means the movement of the species into the risk assessment area (e.g. into an airport or seaport) and "entry" means the arrival in the environment ("in the wild"), which not necessarily has to be a natural habitat and can be highly disturbed. In an ideal world, surveillance measures also include iii) monitoring at the port of departure (which is dealt with in the prevention section above).

It is generally acknowledged that early detection and rapid response are key strategies to prevent greater impact of invasive alien species. However, with limited budgets for such activities and an endless and increasing influx of goods, early warning and rapid response measures must be well planned with clear responsibilities (who is doing what) and needs well-trained personnel and might make use of new technologies (e.g. soil eDNA, see below) (see also contingency planning in the next section). A dedicated decision support system would help to prioritize whether to respond and how (or not) to an ant incursion event.

i) surveillance at points of introduction

This measure should be routinely executed by plant health authorities at points of introduction (e.g. airports, seaports, marinas, and areas of potential concern, e.g. plant quarantine facilities, buildings and disturbed lands; but also including plant distribution centers, i.e. nurseries, garden centres) and can target specific commodities (e.g. potted plants). To take action, it is necessary to define the area under investigation including a safety (buffer) margin. This surveillance can also include prophylactic toxic baiting at points of introduction known to receive high numbers of ants.

It is necessary to declare ants as "harmful organisms" and to enlarge the legal competence of plant health authorities to check for ants within their regular work. If this is not possible within the Plant Protection legislation, alternative ways must be found.

The use of trained sniffer dogs during plant health inspections can be useful for surveillance activities at the wider premises of airports or seaports and can include other commodities that are not usually inspected or that are unregulated (Lin *et al*., 2011). For efficiency, this needs being based on a risk management approach, i.e. focusing on commodities (e.g. machinery), products and goods (e.g. potted plants, fruits) from currently infested countries. These inspections should be prioritized, e.g. based on volume of imported commodities. It is acknowledged that such a system will never intercept 100% of all introductions, which is why surveillance needs to extend beyond points of introduction. Hoffmann *et al*. (2022) found detection rates of 86% within 2 m and 28% within 25 m (for the yellow-crazy ant *Anoplolepis gracilipes*) in the field, noted different outcomes depending on the transect spacing (covering areas of approx. 5–9 ha in one hour), and provided a protocol how to improve the utility of detector dogs for invasive ant surveillance.

ii) surveillance at points of entry

Setting up of an active surveillance system to achieve early detection and rapid response is required according to Article 16 of the EU Regulation. However, such a dedicated monitoring system beyond points of introduction, covering natural habitats or (sub)urban sites is not in place in any European country and it is unlikely to ever be for ants. Different strategies exist to bypass this gap, e.g. making use of the increasing force of citizen scientists using smartphones and available platforms such as iNaturalist. While this is a promising and efficient solution for conspicuous groups with large communities (e.g. birds, mammals and plants), it is less efficient for invertebrates and especially ants, which identification requires voucher specimens (sometimes specific castes), high magnification and taxonomic experience. However, with the increasing popularity, quality of photographs and advanced tools (e.g. artificial intelligence in species ID), it should not be ruled out as one tool in the invasive alien species management tool box. This also applies to other new technologies (e.g. soil eDNA) with promising potential that still have to prove their usefulness (see below).

Solenopsis invicta. © birdingtexan, (CC BY) via iNaturalist

Surveillance (and monitoring) of *Solenopsis* spp. in the field is usually performed using baited or non-baited pitfall traps, but effectiveness is limited by the fact that foragers use tunnels below the soil surface and often only travel short distances above ground. Foraging distance, however, is known to depend on many different factors, including colony size (larger colonies need larger foraging areas). Traps effectiveness depends on the baits attractiveness. Pitfall traps, however, can be difficult to apply in solid soil, in wet weather and (depending on the size) can produce a lot of by-catch. Ross (2018) suggested a relatively cheap 3D-printed dome trap on the ground surface that can be used for detection and for treatment. Bao *et al*. (2021) developed a new baited trap system that possibly can also catch underground workers; they tested 21 different food lures, with hotdogs being most preferred, as *Solenopsis* spp. prefer protein-rich food. Other references mention shrimp crackers and potato chips as bait (e.g. Vogt *et al*., 2003), mixed protein food (hotdogs or ground meat combined with peanut butter) (e.g. Stringer *et al*., 2011), tuna, cat food, sugar water, or other sugar/protein-products. Stringer *et al*. (2011) conclude that pitfall traps are the best method for detecting small nests. Established populations can be monitored visually by counting the ant mounds. As above, it is necessary to define the area under investigation including a safety (buffer) margin before starting surveillance activities. Apart from visual surveys for large mounds, food baits appear to be the best of the traps tested for detecting *Solenopsis* ants.

SCALE OF APPLICATION

This measure should be applied at the EU-level as part of the implementation of the EU Regulation.

EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

Currently no ant surveillance takes place in Europe. There are several case studies demonstrating the effectiveness of early warning (achieved through active surveillance) and rapid response against invasive alien species, including in the EU and species of the Union list.

EFFORT REQUIRED

In an ideal scenario, surveillance at points of introduction should be applied on a permanent basis, whereas surveillance at points of entry could be retired after a successful eradication campaign.

For example, after the introduction and establishment of *S. invicta* in China, approx. 2,500 surveillance sites were set up, covering more than 0.6 million hectares, serving as alert system (Wang *et al*., 2020).

RESOURCES REQUIRED

The necessary costs to make this measure effective is unknown, but probably high. In an ideal scenario, this measure requires permanent investments in costs for staff and equipment.

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Positive

Increasing surveillance increases the likelihood of detection of other invasive alien species, including species from the Union list, with the possibility to prevent their establishment.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

No obvious conflict of interest from stakeholders expected.

LEVEL OF CONFIDENCE*

Inconclusive.

There is no experience available on this measure in the EU.

* See Appendix

Environmental DNA detection

MEASURE DESCRIPTION

Environmental DNA (eDNA) analysis detects short fragments of DNA in environmental samples. With the increasing availability of genetic information from an increasing number of species, and the rapid development in eDNA research, capacity and resolution (NGS), this method has gained much attention and has promising potential for future monitoring and surveillance. Triggered by successful applications in the aquatic environments (including species on the Union list, e.g. Ficetola *et al.*, 2008), new avenues include the use of eDNA in soil, air or bark and leave samples (e.g. Valentin *et al.*, 2020; Clare *et al.*, 2022).

Recently, Yasashimoto *et al.* (2021) successfully applied the method to detect the Argentine ant from soil samples using a newly designed real-time PCR assay. In theory, it is possible to develop specific primers for dedicated and specific assays for most ant species where CO1 sequences are known that then could be used in detection. Additionally, this partly might help overcome the problem of ant species identification.

It has to be mentioned that the method needs further research regarding its applicability, especially with soil from natural habitats (e.g. DNA persistence in increasing distance from the nest, relations to abundance, seasonality, DNA extraction from different soil types), but for the dedicated purpose of detection of ants in soil samples from potted plants, most of these limitations do not apply. A metabarcoding approach, i.e. detecting several species within one sample and analysis, currently is not available for ants, but this might be an additional avenue for future research and could target for example the genus *Solenopsis* that includes several invasive species.

SCALE OF APPLICATION

The measure is applicable at the local scale, at potential points of introduction and entry, and ports of departure.

EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

The measure has not yet been applied, and needs more development and testing to specifically target species or species-groups of interest.

EFFORT REQUIRED

Dedicated immunoassay tests to identify *S. invicta*, *S. richteri* and their hybrid, are available (e.g. Valles *et al.*, 2018). Limitations are the cost, time for the analysis, and knowledge about degradation of eDNA in the substrate.

RESOURCES REQUIRED

No specific cost estimates are available.

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Positive

Any plant health inspection causes delays in distribution of the traded organisms. If the industry is hold accountable for any damage their activities might create, they should be interested in new methodologies to fast-track goods through import in a biosecure way.

Potential positive side effects are limited if the assay is species specific. But in case of a metabarcoding approach, the methodology might have positive side effects as it could detect more than one invasive species at the same time.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

See above.

LEVEL OF CONFIDENCE*

Inconclusive.

The method still needs development and specific adjustments to target *Solenopsis* species detection.

Solenopsis geminata. © Massimiliano Lipperi, Studio Wildart

* See Appendix

Measures to achieve rapid eradication after an early detection of a new occurrence.

Contingency planning and emergency funds

MEASURE DESCRIPTION

The benefits of initiating management measures as early as possible are obvious. Surprisingly, there is a notable gap in developing contingency plans against invasive alien species in Europe. It is well documented that unclear or scattered responsibilities can delay action and counteract success. Therefore, depending on the likelihood of introduction, entry, establishment and spread, as laid out in the corresponding Risk Assessments of the species of Union concern, every Member State (or groups of Member States) should prepare such plans for selected species of Union concern. These contingency plans should include inter alia i) who is in charge, ii) who pays, iii) what method(s) shall be applied and iv) should consider environmental and socio-economic factors. Ideally, such plans are prepared before an introduction occurs to allow for efficient rapid response without substantial delays. A similar system is already in place within the EU-Plant Health legislation, and could be used as a template or guidance for contingency planning for invasive alien species.

Particularly the lack of immediately available funds must be considered as a major obstacle for rapid eradication. Similar to catastrophe funds at the EU and the Member State levels, a dedicated Invasive Alien Species Rapid Eradication Fund would support necessary actions be taken without much delay.

SCALE OF APPLICATION

A contingency plan should cover at least the territory of a Member State, as it concerns competent authorities, responsibilities and funding, but could also extend to neighbouring countries, or e.g. biogeographic regions. An Invasive Alien Species Rapid Eradication Fund should be made available for all Member States.

EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

A dedicated contingency plan for the Asian hornet *Vespa velutina* works well in the United Kingdom with hornets regularly coming in from the continent, all of which have been eradicated until now. Adequate funding often is a barrier to execution of conservation actions. In addition, raising funds can be a long-lasting process, which contradicts the needs of rapid eradication with usually very narrow windows of opportunity.

EFFORT REQUIRED

Writing the plan, discussing with stakeholders and updating when new information becomes available. Setting up an Invasive Alien Species Rapid Eradication Fund – if kept to a limited total budget and low threshold application procedures, i.e. low administrative burdens – would require some lead time and coordination.

RESOURCES REQUIRED

Costs to cover the expenses of writing and discussing the plan (and ultimately executing it). The budget for an Invasive Alien Species Rapid Eradication Fund does not need to be high. The purpose would be to provide funds in the amount of approx. 10,000 to 50,000 Euro to allow taking immediate action at one site of infestation.

SIDE EFFECTS

Environmental: None
Social: None
Economic: None
No side effects known.

ACCEPTABILITY TO STAKEHOLDERS

Mixed.

The contingency plan needs be discussed and agreed with all partners involved. Measures taken need approval and support by authorities and the public (including land owners).

LEVEL OF CONFIDENCE*

Inconclusive.

There are a lot of uncertainties associated with such a measure due to lack of information, but also due to often institutionalized responsibilities within Member States.

* See Appendix

Chemical control (see next section)

MEASURE DESCRIPTION

The measures available for rapid response after detection of an incursion do not differ from the measures for control and containment, which are described in the next sections. However, assuming that population size and infested area are smaller at the beginning of an invasion, the likelihood of successful eradication is higher than at any later stage of the invasion.

Hot water and other immersion treatments

MEASURE DESCRIPTION

Applying hot water to soil of potted plants can be an efficient control measure if an infestation of *Solenopsis* is detected at a point of introduction (plant quarantine facilities, plant nurseries). Immersion treatments (including other substances, e.g. potassium oleate, Chen *et al.*, 2010) can help reducing the amount of insecticides. Tschinkel & King (2007) developed an application for use under field conditions to contain/control *Solenopsis invicta* (see below).

SCALE OF APPLICATION

This eradication measure applies to the local scale of infestation in closed facilities and is not applicable in the wild, where it can be useful as a containment measure.

EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

There is not much information available on the effectiveness of this measure. Hara *et al.* (2011) applied it to *Wasmannia auropunctata* and a single treatment with hot water per pot resulted in reductions of ant numbers between 89 and 99%. Chen *et al.* (2010) achieved high mortality of a potassium oleate/water immersion treatment only after elevating the temperature to 50 °C. However, for eradication, even 99% effectiveness for one measure might not be enough and supplementary treatment might be needed to achieve full eradication.

A comparison of different treatments that were applied once on *Solenopsis saevissima* colonies in urban environments of southeastern Brazil, revealed that a liquid insecticide (K-othrine®) was the most efficient in eliminating > 91% of the colonies, followed by hot water (60%), granular insecticide (40%) and water with detergent (30%) (Fernandes *et al.*, 2020).

EFFORT REQUIRED

Single treatments are sufficient to result in significant reductions of ant numbers (Chen *et al.*, 2010; Hara *et al.*, 2011), but supplementary treatment might be needed to achieve full eradication of brood and queens.

RESOURCES REQUIRED

No estimates are provided by Chen *et al.* (2010) and Hara *et al.* (2011), but there are costs for staff and equipment to consider. The Pacific Invasive Ant Toolkit provides costs to some management activities (PIAT, 2016), but these are difficult to transfer to the EU-context.

SIDE EFFECTS

Environmental: Positive
Social: Mixed
Economic: Mixed

Hot water treatment is also recommended for infestations with other soil organisms, particularly flatworms. Damage to the plants is possible and can cause a conflict of interest.

ACCEPTABILITY TO STAKEHOLDERS

Mixed.

The measure might interfere with the interests of the horticultural or ornamental plant industry.

LEVEL OF CONFIDENCE*

Inconclusive.

There is not much information available beyond the results provided by Chen *et al.* (2010) and Hara *et al.* (2011; for *Wasmannia auropunctata*).

* See Appendix

Chemical control – Granular baits and contact insecticides

MEASURE DESCRIPTION

The purpose of chemical control using insecticides is to kill insects. There is a certain variety of commercially available products, based on different compounds, compositions and combinations, especially outside the European Union. The use of some of these compounds is restricted or forbidden in the EU, at the national or subnational levels and corresponding legislation needs to be considered. For example, fipronil is banned in the EU from use in agriculture since 2017 (according to Regulation (EC) No 1107/2009 concerning plant protection products), but still available and sold in household stores to control insects in private houses and gardens (as it is not covered in Regulation (EU) No 528/2012 on the use of biocidal products).

The common practice to apply insecticides to ants is in combination with a bait. There are different possibilities to do this, e.g. via granular baits, gel baits, or liquid baits, but usually the product consists of the active toxicant, a solvent and/or carrier and a substance that makes it attractive to the ants (the bait). In most products, this phagostimulant is soybean oil. Chemical control can be used to completely eradicate small populations or single colonies, but also to contain or control larger populations over larger areas. Depending on the size of the targeted area, there are different ways of broadcasting the baits (aerial, e.g. by helicopters, drones, or manual, e.g. by hand or spreaders mounted on any kind of vehicles).

The attractiveness of most products decreases when the compound gets wet, therefore application to wet ground or before rain is not preferred (Oi *et al*., 2022). However, baits that use a corn grit carrier absorb moisture and turn mushy, but fire ants will still feed on them and are killed. Thus, bait that gets rained on or is irrigated can still be effective if not washed away.

Worker ants usually cannot discriminate substances and readily carry the poisoned bait back into the colony. Most toxicants act slowly so that worker ants have sufficient time to carry the bait back into the nest, where it is distributed within the colony members (trophallaxis). The target is the reproductive caste, the queen(s) of a colony, which usually lives inside the nest, protected by their workers and the ultimate goal is to stop reproduction of the colony. Worker ants often have a short life span and life-expectation and survival of an ants' colony depends on regular supply of new workers produced by the queen(s). Although high densities are less likely in Europe, it demonstrates the difficulties posed for management aiming to remove all queens from any given area. However, ant colonies usually occur at a restricted (local) range (even supercolonies that range over thousands of kilometres can be separated into more manageable units) allowing more targeted management actions.

A different approach is the use of contact insecticides against single nests (mounds) and/or the surrounding surface areas, applied as a liquid mound drench, granules applied to the mound surface and watered in, granules or dusts applied to the mound surface, direct liquid or aerosol mound injections (Drees *et al*., 2013). However, not all methods are feasible in different contexts (see e.g. Wang *et al*., 2020). Surface treatments are applied as liquid sprays or granular formulations, which may need to be watered in, broadcasted over the treatment area (Drees *et al*., 2013). Also, combinations of contact insecticides and granular baits have been applied (e.g. the "Two-Step-Method", i.e. broadcast bait followed by individual mound treatment, Drees *et al*., 2008). Drees *et al*. (2013) also discuss the limitations of chemical treatments and their integration into an IPM system (see below).

Toxicants can act as neurotoxins (e.g. fipronil), metabolic inhibitors (e.g. hydramethylnon) or as insect growth regulators (IGR) (e.g. methoprene, pyriproxyfen). According to Hoffmann *et al*. (2016) fipronil, hydramethylnon, and methoprene were used in the majority of successful *Solenopsis* spp. eradications. Sakamoto & Goka (2021) found fipronil as best toxicant for controlling *S. invicta*. Recently, different plant extracts were tested and found causing 100% mortality under lab conditions, e.g. from *Lantana camara* and *Michelia alba* (Zhong *et al*., 2008; Qin *et al*., 2018).

In Taiwan, an infested area of 650 ha (1,100 ha including a buffer zone) was treated using the "two-step-method" from 2004-2006 with spinosad, fipronil, and pyriproxyfen four times per year and individual mound treatments using 85% carbaryl wettable powder; in 2007 pyriproxyfen and indoxacarb bait was applied four times per year in areas with high ant density and pyriproxyfen was applied twice per

Solenopsis invicta. © Joe MDO, (CC BY-NC) via iNaturalist

year in the regular treatment area; interventions continued from to 2017, including aerial bait treatments to 35 ha of inaccessible land; in 2017, *S. invicta* was declared as successfully eradicated (see Liu *et al*., 2020, who provide additional case studies of successful eradication in Taiwan, using other methods, e.g. mound drenches and baiting the infested areas once every month with pyriproxyfen bait and granular fipronil).

Hwang (2009) reported another case study from Taiwan: An infestation of 13 ha (with 1,578 mounds) was treated with pyriproxyfen at a rate of 2 kg/ha for four years. Populations were significantly reduced within one month, and were considered eradicated after one year.

S. invicta was detected and eradicated on several occasions in New Zealand (e.g. Corin *et al*., 2008; Christian 2009) and a national surveillance system was established in 2003 (Peacock 2011). For example, *S. invicta* has been successfully eradicated in New Zealand (e.g. from Auckland International Airport in 2001, from Ports of Napier in 2004, at Whirinaki in 2006). The 3 year eradication program at Whirinaki included visual inspections and the use of baits with a mix of peanut butter, sausage meat and cotton wool soaked in a sugary water solution to check for ants' presence. A minimum of four baits per 10 m x 10 m were laid out in a 2 km radius of the place of first detection of the single nest. More than 900,000 bait samples were collected and checked over the 3 years. Areas that could not be surveyed were aerially treated with insecticidal ant baits. Pitfall traps were used to survey surrounding areas.

Suggestions and recommendations for fire ant (and other invasive ants) eradication are provided by the Pacific Invasive Ant Toolkit (http://piat.org.nz/index.php?page=red-imported-fire-ant-response), including products, training and required tools. The global eradication and response database (GERDA) includes several examples of ant eradication attempts (Kean *et al*., 2022).

Wylie *et al*. (2016) summarized the rapid response actions after the detection of *S. invicta* in Queensland and the details of the eradication plan are not repeated here. In short, a 5-year eradication plan was developed for the incursion at the Port of Brisbane, including baiting (using insect growth regulators methoprene or pyriproxyfen or a metabolic inhibitor hydramethylnon) the infested area (8,000 ha, excluding a 2 km buffer) 3 to 4 times per year for 3 years. Baits were broadcasted by hand-held granular spreaders, by quad bikes, or from helicopters. Within another 3 km buffer area, surveys were done once a year. Surveillance was conducted after the treatments for two more years, also including the use of sniffer dogs. No ants were found after the five years and the eradication declared successful. A 3-year eradication plan was developed for the incursion in Yarwun, including movement restrictions to limit secondary spread with infested materials, treatment of colonies (mounds) by injection of fipronil and baiting using pyriproxyfen (and methoprene near waterways). Hand spreaders and aerial treatment were used. Treatment and buffer areas were 1,028 ha, the area of infestation was 71 ha. Approximately 18 months after the final treatment visual surveillance within the treatment zone and a 2 km buffer area revealed no ant nests or workers. After 4 years, surveillance by sniffer dogs was conducted and confirmed the eradication.

Wylie *et al*. (2016) provide a checklist of successful ant eradications:

- Resources must be adequate, and there must be a commitment to see the project through to completion. Most eradication programmes are carried out on a large scale, cost millions of dollars and are sometimes protracted if the pest has a sizeable established foothold before eradication commences.
- Clear lines of authority must be established. An extensive programme is only feasible if the lead agency has a clear mandate to carry out required procedures at all affected sites.
- The biology of the species must be appropriate and make it susceptible to control procedures. Detailed scientific knowledge is required of the dispersal ability, reproductive biology and life history of the target species to determine the ease of population reduction.
- The target species must be detectable at low densities. Early detection can reduce the likelihood of spread, and the ability to detect at low densities is important at the 'tail-end' of an eradication programme.
- Subsequent intensive management of the system may be necessary, such as restoration following eradication of the target species, if prominent or 'keystone' native species have been removed.
- Re-invasion must be prevented. Eradication will only be temporary if rapid re-invasion is likely.
- Protective measures should be in place for rare, threatened or susceptible non-target species and/or habitats.

In 2017 it was agreed to fund an expanded National Red Imported Fire Ant Eradication Program (NRIFAEP, see also https://www.fireants.org.au/) to eradicate *S. invicta* over an approx. area of 600,000 ha in South East Queensland. The program is funded until 2027 with a budget of 400+ millions AUD. Wonder (2019) provided a detailed analysis of the effectiveness of the program after 2 years. Currently, in its fifth year and having spent half of the money, concerns were expressed that more money is needed to achieve the targets of the program until 2027.

Eradication of *S. geminata* was possible across 3 ha in northern Australia for at least two years mainly because small colonies were readily located within a relatively restricted disturbed habitat (Hoffmann & O'Connor, 2004). The species was treated with toxic granular baits delivered by hand.

Ants use cuticular hydrocarbons (CHC) in nestmate recognition and some components of native ant species CHC's have been found having repellent and neural effects on alien ant species (Uebi *et al*., 2022). Pheromones can also be used to disrupt ant trail integrity and therefore recruitement effficiency (Suckling *et al*., 2008, 2010).

SCALE OF APPLICATION

The minimum scale is the size of one colony. Most successful ant eradications have been conducted in Australia and targeted areas smaller than 10 ha, but more recently larger areas were cleared from invasive ants (see Hoffmann *et al*., 2016 and Wylie *et al*., 2016 for more examples and https://www.fireants.org.au/ for the most recent activities), often employing multiple methods. In general, the larger the infested area, the more complex and expensive the management strategy becomes, with decreasing likelihood of success.

Directly related to the area/scale of the management action is the mode of broadcasting the bait. Aerial application of baits from helicopters comes with logistic and legal complexities (and approval seems highly unlikely in Europe). Manual application by hand or spreaders can be laborious and time-consuming, but probably is the only option in smaller areas.

Solenopsis invicta. © Julian, (CC BY-NC) via iNaturalist

EFFECTIVENESS OF MEASURE

Effective.

Chemical control is effective if applied repeatedly and consequently and monitoring and surveillance (see above) of the infested sites continues for at least a few years. Depending on the active ingredient, ant activity can be eliminated quickly or over time.

A key component of successful eradication programs is financial support and good cooperation between the stakeholders.

Wylie *et al*. (2016) conclude that "Of the five known incursions of the highly invasive Red Imported Fire Ant in Australia, two are regarded to have been eradicated. As treatment efforts continue, and the programme evolves and new tools become available, eradication is still considered to be feasible for the remaining Red Imported Fire Ant populations with long-term commitment and support".

Some eradication attempts failed, and according to Drees *et al*. (2006, 2013) the primary reasons (for the USA) are: (i) the inability to attain absolute (100%) control using available products; (ii) the large area of infestation; (iii) high cost of treatment; (iv) inability to uniformly treat an entire area of infestation and (v) the ability of fire ants to rapidly spread even before eradication efforts are put in place (Drees *et al.,* 2013).

EFFORT REQUIRED

Depending on the scale and goals of the measures.

RESOURCES REQUIRED

The National Red Imported Fire Ant Eradication Program commenced in September 2001 (in the same year when the ant was discovered!) with a budget of AUD 123 million and over 400 staff. The Program consisted of repeated treatment of infested and putatively infested areas with baits containing insect growth regulators, widespread surveillance, movement controls on materials likely to harbour the ant, strong community engagement and supporting research (Vanderwoude *et al*., 2003). The subsequently declared Ten Year Plan to eradicate *S. invicta* from South East Queensland has a budget of > 400 mio AUD.

The eradication of *S. invicta* in early 2000s in Auckland covered less than 1 ha and costed NZD 1.4 million (Christian, 2009).

Costs for conventional bait insecticides including cost of application amounted to approx. 17 USD per 0.4 ha (Barr *et al*., 2005). Mound treatments with contact insecticides are more expensive when there are high densities of mounds and should be used after baits have reduced populations before (Wang *et al.*, 2013).

Post-management monitoring is considered key to a successful eradication/control campaign and needs being factored in the budgets.

SIDE EFFECTS

Environmental: Negative
Social: Positive
Economic: Positive

Chemical control usually is not species specific and can negatively affect other wildlife (including livestock and humans), accumulate in trophic networks and can have a long half-life in terrestrial ecosystems (especially in soils). It is often emotionally discussed between advocates and opponents from the industry and nature conservation. The development and use is legally regulated at different levels, in Europe at the EU, the national and sometimes provincial levels and different practices can also apply at the local level .e.g. in protected areas. The unabated use of insecticides (e.g. neonicotinoids, see Schläppi *et al.*, 2020) is without doubt (in combination with other factors) partly responsible for the insect decline syndrome (Rabitsch & Zulka, in press).

Hoffmann *et al.* (2016) mention that documentation of non-target impacts in the field is limited, which likely is a consequence of the fact that the majority of management actions have been executed in urban or industrial areas so far. Taking advantage of the peculiarities of ant biology (social insects, life in discrete colonies) and ant management (baiting), targeted management strategies are available and possible negative side-effects can be minimised by smart planning of the actions.

Although generally used in extremely low concentrations, fipronil is highly toxic to aquatic animals, and should not be used near aquatic bodies. It is also a potential threat to other invertebrates and to vertebrates, such as some birds, mammals and reptiles (see review in Hoffman *et al.*, 2016). Hydramethylnon breaks down quickly and is water insoluble, having low persistence in the environment. A non-target study conducted in Hawaii suggests that relatively few non-ant arthropod groups were impacted by its use (Krushelnycky *et al.*, 2005) and it is usually of low toxicity to vertebrates, except fish (see review in Hoffman *et al.*, 2016).

Socio-economic effects of this measure should be generally positive, as controlling or eradicating ant species, which can be a nuisance, from public places, private houses, or agricultural fields is beneficial to the general public and farmers.

The eradication measures in Brisbane did not seriously impact native ant genera (McNaught *et al.*, 2014).

ACCEPTABILITY TO STAKEHOLDERS

Mixed.

The use of chemicals in cultural lands and natural habitats, especially in protected areas, is a controversial topic and has pros and cons (see above). The EU/national/local legislation of the compounds mentioned above needs to be considered. An in-depth assessment goes beyond this document, but there is general agreement that benefits for biodiversity should outweigh non-target impacts for acceptability.

ADDITIONAL COST INFORMATION

Costs for the EU, including implementation of the specifications of the IAS-Regulation 1143/2014, are not available. Currently, within the EU, the species are considered as absent (*S. richteri*), intercepted (*S. invicta*) and introduced, but not established in Greece, Italy, Netherlands and Cyprus (*S. geminata*) (Kenis *et al.*, 2019; Blight, 2019, 2020).

In a recent overview of the observed and potential economic costs of invasive alien ants worldwide, *Solenopsis* spp. ranked first. Costs have been estimated at about 32 billion USD between 1930 and 2021 (Angulo *et al.*, 2022). It was also confirmed that costs increased over time.

LEVEL OF CONFIDENCE*

Established but incomplete.

There is ample evidence and experience using this method and it can be assumed that it will also work with the aim to control or reduce impacts in the long term. However, nothing is known about possible adaptations of the ants towards the active ingredients (resistance?) or the management itself (behavioural adaptations?).

* See Appendix

Chemical control – Horizontal transfer

MEASURE DESCRIPTION

Horizontal transfer refers to the acquisition of insecticides through physical contact with a treated individual. Buczkowski & Wossler (2019) recently tested this new approach on the Argentine ant *Linepithema humile* in laboratory studies and in the field in South Africa: 10,000 worker ants were collected in the field, treated (sprayed with 1.5 mL 0.0.6% fipronil solution using an atomizer) and immediately released in invaded plots (plot size was 100 m^2). The treated donor workers stayed alive for ca. 2 hours and distributed the toxicant within the colony to multiple recipients. Ant abundance was reduced by > 90% within 24 hours and no ants were found in the test plots after one week. A single treated worker ant was found capable of killing more than 300 nestmates. Further research is needed to test if such a treatment would finally eradicate a colony, but it proved to successfully control or contain the invasive ant.

Zhang *et al*. (2022) tested the methodology on *S. invicta* using cycloxaprid (a neonicotinoid), imidacloprid and bifenthrin and confirmed the contact and horizontal toxicities.

EU/national/local legislation needs to be respected and authorities should ensure that chemicals are licensed for use in their respective countries.

SCALE OF APPLICATION

The plot size in the described case study was set at 100 m^2 (Buczkowski & Wossler, 2019). Treated ants survived for ca. 2 hours, but in theory, horizontal transfer should work from the single colony level up to a scale that is only limited by feasibility of treating donor ants and their mobility.

EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

Chemical control of *Solenopsis* spp. is effective and if applied via horizontal transfer, there is no reason why this measure should not be effective. However, it remains to be tested, specifically with regard to ideal treatment area, number of donor ants needed, number of replications, and other details.

EFFORT REQUIRED

Buczkowski & Wossler (2019) applied donor ants once and used six experimental plots and four control plots in their study.

RESOURCES REQUIRED

No cost estimates are provided by Buczkowski & Wossler (2019).

SIDE EFFECTS

Environmental: Unknown
Social: Unknown
Economic: Unknown

This new, target-specific management strategy provides benefits compared to broadcasting granular or paste/gel baits in the open environment. Because treated ants distribute the toxicant directly in the colony, there is no risk of harm to non-target species, which is why Buczkowski & Wossler (2019) suggest that this method could also be suitable for ecologically sensitive environments as in conservation areas. Research is needed to optimize the method (e.g. treating brood instead of workers) and test the effectiveness for other invasive ant species, including *Solenopsis* spp.

ACCEPTABILITY TO STAKEHOLDERS

Unknown.

The use of chemicals, even if packed inside of ants, in cultural lands and natural habitats, especially in protected areas, is a controversial topic and has pros and cons. The EU/national/local legislation of the compounds mentioned above needs to be considered. This new, target-specific approach, and the possibility of none or few side-effects on non-target species (and habitats), provides a new tool in the ant management toolkit that deserves further research.

LEVEL OF CONFIDENCE*

Some prerequisites of successfully applying this method in *Solenopsis* colonies are given (e.g. trophallaxis), others need more research and testing (e.g. influence of mobility of workers).

* See Appendix

Classical biological control

MEASURE DESCRIPTION

Classical biological control (CBC) of *Solenopsis invicta* and *S. richteri* in the USA has a long tradition and a very rich literature (for a recent review see Oi *et al.*, 2015; Oi & Porter, 2022). CBC, i.e. the introduction of non-native natural enemies for their permanent establishment and long-term control of a target species, is considered a cost-effective method since no action is required after releases and successful establishment.

The main natural enemies of *Solenopsis* spp. that have been released are parasitoid flies of the genus *Pseudacteon* (Phoridae), the so-called decapitating flies, native to South America, with more than 20 known species, and currently six considered established in the USA (Oi *et al.*, 2015). *Pseudacteon* spp. have been introduced, established and spread in the USA since 1997 (Graham *et al.*, 2003; Williams *et al.*, 2003; Morrison, 2012). These flies parasitize a small percentage of workers and affect colonies indirectly by reducing foraging activities of workers. Other enemies that have been used include the microsporidium *Kneallhazia solenopsae* (first found in the US in 1996), entomopathogenic fungi *Beauveria bassiana* s.l., *Matarhizium anisopliae* and others, and several viruses (SINV-1, -2, and -3) (Bextine & Thorvilson, 2002; Briano *et al.*, 2012; Oi & Valles, 2012). Williams *et al.* (2003) assume that "collectively, these natural enemies are expected to provide sustainable suppression of fire ant populations", but Drees *et al.* (2013) argue that "levels of fire ant suppression required in sensitive urban and ecological environments may not be achievable" using CBC only, and that it is necessary to combine different methods (see IPM, below).

CBC of *S. geminata*, in contrast, has not yet been tested and is at the stage of identification of natural enemies in the native range for subsequent testing (e.g. Plowes *et al.*, 2009).

CBC is a management option, but not intended for eradication, and therefore not considered an option in Australia and New Zealand, aiming at eradication of fire ants. See also Sheppard *et al.* (2019) for an evidence-based assessment of best practice use of classical biological control (CBC) for the management of established invasive alien species that threaten biodiversity and ecosystem services.

SCALE OF APPLICATION

CBC has a long history (see e.g. Kenis *et al.*, 2017). The scale of application usually starts at a selected test site, and – if successful – can be enlarged to cover large areas, e.g. the whole territory of the EU and Europe.

Bextine & Thorvilson (2002) successfully inactivated up to 80% of the ant mounds treated with *B. bassiana* in a field experiment covering an area of 700m^2.

EFFECTIVENESS OF MEASURE

Effective.

Biological control is passionately discussed between proponents and opponents, due to some well-known failures in the past, most often due to the lack of rigorous testing of host specificity. However, no test can ever rule out unexpected evolutionary changes in the behaviour of species, which always leaves a certain amount of risk connected to biological control. If it works, biological control can be extremely effective. Kenis *et al.* (2017) found that until 2010, 6,175 introductions of insect CBC agents were made against 588 insect pest species of which 33% led to establishment and 10% resulted in satisfactory control against 29% (172 species) of the pest species being targeted.

The effectiveness of released and established *Pseudacteon* spp. in the USA has not been demonstrated so far, possibly because average parasitism rate per colony are too low (e.g. Callcott *et al.*, 2011; Morrison, 2012).

The effectiveness of *B. bassiana* s. l. has been demonstrated under laboratory conditions, but only few data have validated its use in the field. Bextine & Thorvilson (2002) successfully inactivated up to 80% of the mounds in a field experiment. Kafle *et al.* (2011) inactivated 70% of the mounds treated. In both studies, the most efficient delivery form was the use of baits (e.g. fungal pellets coated with peanut oil) instead of a direct application of the fungus. Ants possess an advanced form of social immunity towards pathogens (e.g. Liu *et al.*, 2019; Malagocka *et al.*, 2019) that probably limits effectiveness. A new microencapsulation method to apply *M. anisopliae* was developed by Qiu *et al.* (2019).

A molecular analysis revealed that *Kneallhazia solenopsae* also infects *S. geminata* but its impacts on colony survival are unknown (Ascunce *et al.*, 2010).

Effectiveness can be improved by combining measures, e.g. the combination of CBC with chemical control seem to be a promising control strategies against *S. invicta* (Oi *et al.*, 2008).

These biological control agents are host specific and negatively impact fire ants to varying degrees. Fire ant populations in the presence of biological control agents are often reduced (based on number of ants per nest), but


Solenopsis richteri. © Luciano Peralta, (CC BY-NC) via iNaturalist

the number of nests may not decline (Oi *et al.*, 2015). It is assumed that in the southern USA, collectively, natural enemies help reducing the frequency of insecticide applications required to maintain *S. invicta* control, but are subtle, and not sufficiently effective to achieve control on their own (Oi *et al.*, 2008; Drees *et al.,* 2013).

EFFORT REQUIRED

Establishing a fully operational CBC programme in Europe requires many steps and takes at least 10 years of development, including legal compliance.

RESOURCES REQUIRED

Drees *et al*. (2013) provided some data on the costs of releasing *Pseudacteon* spp. in the USA, but they do not include pre-release investigations that would be required before release in Europe. The production cost of *Pseudacteon* is estimated at 1 USD per fly. Five thousand flies were released in Florida in 1997 and by 2005 they spread to over 90,000 km^2. The cost of this release was estimated at 10,000 USD, but considering the natural subsequent spread of the species, treatment cost estimates dropped to approx. 0.0001 USD per hectare.

SIDE EFFECTS

Environmental: Unknown
Social: Unknown
Economic: Unknown

Negative side effects of failed biocontrol programmes feature prominently in the literature and – as mentioned above – there will never be a 100% guarantee for safety. However, as explained by Kenis *et al*. (2017, and others) the negative perception is largely unwarranted given the very low percentage of non-target impacts. In the specific case of CBC of *Solenopsis* spp., no information on actual or potential side effects are available for Europe.

Established natural enemies may help reduce the amount of insecticides required to maintain control (Oi *et al*., 2008).

ACCEPTABILITY TO STAKEHOLDERS

Mixed.

CBC is a controversial topic and has pros and cons (see above). The EU/national/local legislation needs to be considered. An in-depth assessment goes beyond this document, but there is general agreement that benefits for biodiversity should outweigh non-target impacts for acceptability.

Pseudacteon spp. and the pathogens could possibly be considered for introduced to Europe since they are specific to one or a few exotic *Solenopsis* spp. and should therefore have limited side effects on the environment, with maybe the exception of native *Solenopsis* spp. (Oi and Valles, 2012).

LEVEL OF CONFIDENCE*

Inconclusive.

There is a lot of information on the possibilities of CBC against *Solenopsis* species. It has proven to be a difficult management option in terms of duration, costs and efficacy, and it can be assumed that with the currently limited and restricted impacts in Europe, it is not seen as a high priority for the industry (with limited resources for research and funding).

* See Appendix

Integrated pest management

MEASURE DESCRIPTION

Integrated pest management (IPM) approaches use a combination of different measures to reduce populations of the target organism below damage thresholds. Drees *et al.* (2013) summarize IPM strategies for *S. invicta* and *S. richteri* and conclude that "optimally, elegant IPM programs are target specific, threshold driven, environmentally friendly and cost-effective". Drees *et al.* (2013) further argue "… there is no single best IPM program for imported fire ants. Programs designed and implemented using IPM concepts will vary due to multiple factors including presence and abundance of fire ants and other ant species, level and seasonality of control desired, established natural enemies in the management area, availability of registered insecticide products for the use sites involved, environmental concerns, and cost of application(s) that include time and labour." Details of the IPM approach are therefore site- and context-specific, and other factors can be added, e.g. the planned outcome (eradication or suppression), the size and accessibility of the site and other factors. EU/national/local legislation needs to be respected and authorities should ensure that chemicals are licensed for use in their respective countries.

SCALE OF APPLICATION

This measure applies to the local scale.

EFFECTIVENESS OF MEASURE

Effective.

Oi *et al.* (2008) compared the effectiveness between sites treated with insecticides (fipronil) only and sites treated with insecticides and biological control agents (*Kneallhazia solenopsae* and *Pseudacteon tricuspis*). Populations of *S. invicta* at the integrated sites were suppressed by > 95% for 3 years, whereas at the chemical control sites effectiveness was < 85% after 1.4 years.

Also, the combination of methods, e.g. entomopathogenic fungi with pesticides, seem to be one of the best control strategies against *S. invicta*.

EFFORT REQUIRED

The necessary effort to make this measure effective is unknown, but probably high.

RESOURCES REQUIRED

No cost estimates were given.

SIDE EFFECTS

Environmental: Negative
Social: Positive
Economic: Positive

Side effects are similar to those mentioned before for the other treatments.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

IPM appears being more acceptable to stakeholders than CBC. Acceptability depends on the details of the measures foreseen.

LEVEL OF CONFIDENCE*

Established but incomplete.

IPM is a well-established management strategy and several case studies demonstrate a higher effectiveness when different measures are combined.

* See Appendix

Hot water and liquid nitrogen treatment

MEASURE DESCRIPTION

Hot water is an effective management measure to kill *Solenopsis* colonies, but applicability in the field is limited. Tschinkel & King (2007) developed an operating procedure, including use of a charcoal-fired kiln made from an oil drum lined with a sand-fireclay mixture, powered from a 12V battery. Dual bilge pumps pump water from a large tank through a long coil of copper tubing within the kiln to produce 4 to 5 litres of hot water per min, which is collected in buckets and poured into *Solenopsis* nests previously opened by piercing with a stick. The assembly operates from the back of a pickup truck. Colonies of *S. invicta* were treated twice over two years, which reduced their numbers to zero. New colonies were formed subsequently and neighbouring colonies expanded into the areas. After a third treatment, populations were suppressed for over a year. Overall, a 70% reduction in number of colonies and a 93% reduction of large, mature colonies was achieved. The method was patented in the US in 2020 (US patent no. 10,716,302 B2) and also successfully applied in conservation areas (King, pers. comm.).

Lin *et al*. (2013) injected liquid nitrogen into the nests and found that -15 °C caused 100% mortality of workers within 24 hours. Nine out of ten colonies were no longer active after 2 weeks and none was considered functional after 3 weeks. Lin *et al*. (2013) suggest that liquid nitrogen is useful for areas of high human activity or when chemical control is not possible.

SCALE OF APPLICATION

This measure applies to the local scale. The size of the experimental area treated by Tschinkel & King (2007) was approx. 0.8 ha and single colonies by Lin *et al*. (2013).

EFFECTIVENESS OF MEASURE

Effective.

Both treatments successfully reduced numbers of *S. invicta* colonies (Tschinkel & King, 2007; Lin *et al*., 2013). In infested regions, re-colonization from adjoining colonies will limit the effectiveness at larger scales. Killing one colony (mound) takes about 2 minutes time; with increasing area, effectiveness decreases, and should be accompanied by other methods (King, pers. comm.).

EFFORT REQUIRED

Treatment was executed twice within a year, with a third treatment in the following spring to kill off queenless fragments of workers to avoid these being taken over by emerging sexuals on their mating flights from nearby localities (Tschinkel & King, 2007). The liquid nitrogen treatment was applied once.

RESOURCES REQUIRED

The equipment costs range from 3,000–15,000 USD, depending on the size of the set-up, with additional costs for fuel, water, and staff time (including training).

SIDE EFFECTS

Environmental: Unknown
Social: Positive
Economic: Positive

Negative environmental side effects of pouring hot water or liquid nitrogen into ant nests are reduced by the targeted application of releasing the substances directly into the nest, but cannot be completely ruled out. It is assumed that liquid nitrogen has a bigger impact on the soil fauna than hot water. Socio-economic effects are estimated as positive, considering the known detrimental impact of *Solenopsis* ants.

For small areas and in proximity to protected species or habitats, where the use of pesticides is prohibitive, the hot water method is recommended.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

The measure provides an alternative to using insecticides that could be applied at local scales. However, it is assumed that application of hot water is more acceptable to stakeholders than liquid nitrogen.

LEVEL OF CONFIDENCE*

Established but incomplete.

There is evidence for the applicability of the measure at the local scale, but it needs more testing under different environmental and habitat variables.

* See Appendix

Land-use practice and restoration of damaged ecosystems (cf. Article 20)

MEASURE DESCRIPTION

Invasive ants often prefer habitats with a high level of disturbance. Supporting extensive land-use practices in cultural land, habitat restoration of damaged ecosystems, and associated nature conservation measures (e.g. reduction of habitat loss and degradation, fragmentation, invasive alien plants, pollution) all promote native biodiversity, increase resilience of natural habitats and help limiting invasion success.

This is in accordance with Article 20(2) of the EU-Regulation demanding Member States to increase the ability of ecosystems exposed to disturbance by *Solenopsis* species to resist and recover from the effects and to support the prevention of reinvasion following an eradication campaign.

These very general measures to support biodiversity must be tailored to the specific needs in a given local or regional context. For example, the degree of disturbance while broadcasting the bait must be limited (disturbance of mounds causes colonies to move) and any unintentional translocation of ants with the equipment or vehicles between sites must be avoided.

The combination of management approaches, including IPM, requires a deep understanding of the often complex interactions between species in their habitats. The risk of unexpected and unwanted outcomes of measures (e.g. mesopredator release) needs being considered in management planning.

SCALE OF APPLICATION

This "soft" (i.e. very general, and not specific) management measure applies to the whole EU, but activities are executed at the local scale.

EFFECTIVENESS OF MEASURE

Unknown or not yet applied.

It can be assumed that nature-friendly land-use practices and restoration measures support the objective of reducing the impact of *Solenopsis* species. Concrete evidence, however, is not available, and any measure requires a careful pre-management planning and post-management monitoring to be able to learn lessons from the activities.

An adaptive management approach (Hoffman & Abbott, 2010) should be employed whenever management actions are taken.

EFFORT REQUIRED

The required effort depends on the details of the measure.

RESOURCES REQUIRED

Cost estimates depend on the details of the measure.

SIDE EFFECTS

Environmental: Unknown
Social: Unknown
Economic: Unknown

Negative side effects of nature-friendly land-use practices and restoration measures are not expected, but cannot be completely ruled out. Ecological systems are complex, so are species interactions, and predictability is limited, especially under a multitude of synergistic and antagonistic environmental, social and economic variables.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

There is wider political and stakeholder interest in restoration measures, although there can be conflicts of interest depending on the type, intensity, and costs of the measure.

LEVEL OF CONFIDENCE*

Established but incomplete.

While there are examples of positive effects of this measure, no specific information on the topic in relation to *Solenopsis* species could be found.

Solenopsis richteri. © Massimiliano Lipperi, Studio Wildart

* See Appendix

Raising awareness (of acceptance) of management measures

MEASURE DESCRIPTION

Although the negative impacts of *Solenopsis* species are well known to people being affected by their stings, and to agriculture, the general awareness and knowledge about the impacts of invasive ants in the wider public can be improved, specifically with stakeholders providing pathways of introduction, entry into the wild and spread within a territory, i.e. the horticulture and ornamental garden sector, fruit and vegetable importers, and the pet sector.

Public awareness is raised by producing leaflets, posters, press releases, presentations, social and classic media outlets. The aim of raising awareness for management is to increase understanding of the mechanisms, the damage and possible solutions. It is also helpful and necessary for acceptance of management measures, e.g. on the use of chemical control and access to private land. Engagement with the local (affected) community is considered essential.

Liu *et al*. (2020) summarize "essential eradication lessons" from the invasion of *S. invicta* in southeast Asia as: (1) Immediate action through partnership with universities and the private sector, (2) engagement with the public and community with an interest in control through technology, (3) establishment of multi-level horizontal networks of response teams, (4) strategy implementation ranging from large-scale prevention to precise treatment and (5) adoption of technology and social media.

SCALE OF APPLICATION

Awareness campaigns and materials can be produced and distributed at the EU-level (with consideration of the different language barriers), but also at the Member State, regional and provincial levels and should specifically deal with the management actions taken at the infested sites. Naturally, such materials should inform about all invasive ants on the Union list.

EFFECTIVENESS OF MEASURE

Effective.

Although there are no quantitative data available, it is generally assumed that raising the profile of biological invasions in general, and of selected invasive species in particular, is an effective mean to change opinions and behaviour of private individuals and public stakeholders. This includes understanding and acceptance of measures taken in (sub)urban settings, natural habitats and protected areas.

EFFORT REQUIRED

The measure requires a dedicated and targeted information campaign in relation to the planned management activity.

RESOURCES REQUIRED

No cost estimates available.

SIDE EFFECTS

Environmental: Positive
Social: Positive
Economic: Positive

Negative side effects of awareness campaigns are not expected. Positive side effects are possible as raising awareness of the impacts of invasive species increases the understanding of the problem of biological invasions in general and this might have general positive side effects, including on other ant species on the Union list.

ACCEPTABILITY TO STAKEHOLDERS

Acceptable.

No conflict of interest foreseen.

LEVEL OF CONFIDENCE*

Well established.

Raising awareness has a proven value to flag the impacts invasive alien species can have, specifically for species where there is a high likelihood of negative personal encounters in private and public gardens and parks, and agricultural fields.

Solenopsis richteri. © Nicolas Olejnik, (CC BY-NC) via iNaturalist

* See Appendix

Bibliography

Angulo, E., Hoffmann, B.D., Ballesteros-Mejia, L., Taheri, A., Balzani, P., Bang, A., Renault, D., Cordonnier, M., Bellard, C., Diagne, C., Ahmed, D. A., Watari, Y. & Courchamp, F. (2022). Economic costs of invasive alien ants worldwide. *Biological invasions*, 24, 2041–2060.

Ascunce, M. S., Valles, S. M., Oi, D. H., Shoemaker, D., Plowes, R., Gilbert, L., LeBrun, E. G., Sanchez-Arroyo, H. & Sanchez-Pena, S. (2010). Molecular diversity of the microsporidium *Kneallhazia solenopsae* reveals an expanded host range among fire ants in North America. *Journal of invertebrate Pathology*, 105, 279–288.

Bertelsmeier, C., Ollier, S., Liebold, A., Brockerhoff, E. G., Ward, D. & Keller, L. (2018). Recurrent bridgehead effects accelerate global alien ant spread. *Proceedings of the National Academy of Sciences USA*, 115, 5486–5491.

Bextine, B. R. & Thorvilson, H. G. (2002). Field applications of bait-formulated *Beauveria bassiana* alginate pellets for biological control of the red imported fire ant (Hymenoptera: Formicidae. *Environmental Entomology*, 31, 746–752.

Blight, O. (2018a). Template for Annex with evidence on measures and their implementation cost and cost-effectiveness. *Solenopsis geminata*. Study on Invasive Alien Species – Development of Risk Assessments: Final Report, 12 pp.

Blight, O. (2018b). Template for Annex with evidence on measures and their implementation cost and cost-effectiveness. *Solenopsis richteri*. Study on Invasive Alien Species – Development of Risk Assessments: Final Report, 11 pp.

Blight, O. (2019): Risk assessment *Solenopsis geminata*. Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention. https://circabc.europa.eu/ui/group/98665af0-7dfa-448c-8bf4-e1e086b50d2c/library/c7173234-4118-481d-a8c8-f25fea155762/details

Blight, O. (2020): Risk assessment *Solenopsis richteri*. Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention. https://circabc.europa.eu/ui/group/98665af0-7dfa-448c-8bf4-e1e086b50d2c/library/f00528ff-19a0-4efe-8c83-3b50adf314a6/details

Briano, J., Calcaterra, L. & Varone, L. (2012). Fire ants (*Solenopsis* spp.) and their natural enemies in Southern South America. *Psyche*, 2012, 19 pp.

Buczkowski, G. & Wossler, T. C. (2019). Controlling invasive Argentine ants, *Linepithema humile*, in conservation areas using horizontal insecticide transfer. *Scientific Reports*, 9, 19495.

Callcott, A.-M. A., Porter, S. D., Weeks, R. D. Jr., Graham, L. C., Johnson, S. J. & Gilbert, L. E. (2011): Fire ant decapitating fly cooperative release programs (1994–2008): two *Pseudacteon* species, *P. tricuspis* and *P. curvatus*, rapidly expand across imported fire ant populations in the southeastern United States. *Journal of Insect Sciences*, 11, 19.

Chen, J., Shang, H.-W. & Jin, X. (2010). Response of *Solenopsis invicta* (Hymenoptera: Formicidae) to potassium oleate water solution. *Insect Science*, 17, 121–128.

Christian, S. (2009). Red imported fire ant eradicated from Napier. *Biosecurity*, 92, 28–29.

Clare, E. L., Economou, C. K., Bennett, F. J., Dyer, C. E., Adams, K., McRobie, B., Drinkwater, R. & Littlefair, J. E. (2022). Measuring biodiversity from DNA in the air. *Current Biology*, 32, 693–700.

Corin, S. E., Ritchie, P. A. & Lester, P. J. (2008). Introduction pathway analysis into New Zealand highlights a source population hotspot in the native range of the red imported fire ant (*Solenopsis invicta*). *Sociobiology*, 52, 129–143.

Drees, B. M., Calixto, A. A. & Nester, P. R. (2013). Integrated pest management concepts for red imported fire ants *Solenopsis invicta* (Hymenoptera: Formicidae). *Insect Science*, 20, 429–438.

Environment and Invasives Committee (2019). National Invasive Ant Biosecurity Plan Australian Government, Canberra. Available at: www.environment.gov.au/biodiversity/threatened/publications/tap/invasive-ants

Fernandes, E. F., Santos-Prezoto, H. H., Mendonça, R., De Castro, M. M. & Prezoto, F. (2020). Comparisons between different fire ants control methods in urban environments. *Annals of Environmental Science and Toxicology*, 4(1), 45–49.

Ficetola, G. F., Miaud, C., Pompanon, F. & Taberlet, P. (2008). Species detection using environmental DNA from water samples. *Biology Letters*, 4, 423–425.

Gippet, J. M. W. & Bertelsmeier, C. (2021). Invasiveness is linked to greater commercial success in the global pet trade. *Proceedings of the National Academy of Sciences USA* ,118, e2016337118.

Graham, L. C., Porter, S. D., Pereira, R. M., Dorough, H. D. & Kelley, A. T. (2003). Field releases of the decapitating fly *Pseudacteon curvatus* (Diptera: Phoridae) for control of imported fire ants (Hymenoptera: Formicidae) in Alabama, Florida and Tennessee. *Florida Entomologist*, 86, 334–339.

Hara, A. H., Cabral, S. K., Niino-DuPonte, R. Y., Jacobesen, C. M. & Onuma, K. (2011). Bait insecticides and hot water drenches against the little fire ant, *Wasmannia auropunctata* (Hymenoptera:Formicidae), infesting containerized nursery plants. *Florida Entomologist*, 94, 517–526.

Harris, R., Abbott, K., Barton, K., Berry, J., Don, W., Gunawardana, D., Lester, P., Rees, J., Stanley, M., Sutherland, A. & Toft, R. (2005). *Invasive ant pest risk assessment project for Biosecurity New Zealand*, 41 pp.

Hoffmann, B. D. & O'Connor, S. (2004). Eradication of two exotic ants from Kakadu National Park. *Ecological Management & Restoration*, 5(2), 98–105.

Hoffmann, B. D. & Abbott, K. L. (2010). Active adaptive management for invasive ant management. In: Lach, L., Parr, C. L. & Abbott, K.L. (eds), Ant Ecology. Oxford Univ. Press, Oxford, 297–298.

Hoffmann, B. D., Luque, G. M., Bellard, C., Holmes, N. D. & Donlan, J. (2016). Improving invasive ant eradication as a conservation tool: A review. *Biological Conservation*, 198, 37–49.

Hoffmann, B. D., Graham, R. & Smith, D. (2017). Ant species accumulation on Lord Howe Island highlights the increasing need for effective biosecurity on islands. *NeoBiota*, 34, 41–52.

Hoffmann, B. D., Faulkner, C., Brewington, L. & Lawton, F. (2022). Field quantifications of probability of detection and search patterns to form protocols for the use of detector dogs for eradication assessments. *Ecology and Evolution*, 12, e8987.

Hwang, J.-S. (2009). Eradication of *Solenopsis invicta* by pyriproxyfen at the Shihmen Reservoir in northern Taiwan. *Insect Science*, 16, 493–501.

Kafle, L., Wu, W.-J., Kao, S.-S. & Shih, C.-J. (2011). Efficacy of *Beauveria bassiana* against the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae), in Taiwan. *Pest Management Science*, 67, 1434–1438.

Kean, J. M., Suckling, D. M., Sullivan, N. J., Tobin, P. C., Stringer, L. D., Smith, G. R., Kimber, B., Lee, D. C., Flores Vargas, R., Fletcher, J., Macbeth, F., McCullough, D. G., Herms, D. A. *et al.* (2022). Global eradication and response database. http://b3.net.nz/gerda (accessed 30 August 2022).

Kenis, M., Hurley, B. P., Hajek, A. E. & Cock, M. J. W. (2017). Classical biological control of insect pests of trees: facts and figures. *Biological Invasions*, 19, 3401–3417.

Kenis, M., Rabitsch, W. & Roy, H. (2019): Risk assessment *Solenopsis invicta*. Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention. https://circabc.europa.eu/ui/group/98665af0-7dfa-448c-8bf4-e1e086b50d2c/library/c85936ca-6832-4789-af7c-d46e0b505270/details

Kenis, M., Rabitsch, W., Roy, H. & Robertson, P. (2017). Template for Annex with evidence on measures and their implementation cost and cost-effectiveness. *Solenopsis invicta. Study on Invasive Alien Species – Development of Risk Assessments: Final Report*, 9 pp.

Lee, C. C., Weng, Y. M., Lai, L. C., Suarez, A. V., Wu, W. J., Lin, C. C., Yang, C. C. (2020). Analysis of recent interception records reveals frequent transport of arboreal ants and potential predictors for ant invasion in Taiwan. *Insects*, 11, 356.

Lin, H. M., Chi, W. L., Lin, C. C., Tseng, Y. C., Chen, W. T., Kung, Y. L., Lien, Y. Y. & Chen, Y. Y. (2011). Fire ant detecting canines: a complementary method in detecting red imported fire ants. *Journal of Economic Entomology*, 104, 225–231.

Lin, H.-M., Tseng, Y.-C., Chen, C.-T., Lin, C.-C., Lee, Y.-T. & Chen, Y.-Y. (2013). Use of liquid nitrogen to treat *Solenopsis invicta* (Hymenoptera: Formicidae) nests. *Florida Entomologist*, 96, 871–876.

Liu, L., Zhao, X.-Y., Tang, Q.-B., Lei, C.-L. & Huang, Q.-Y. (2019). The mechanisms of social immunity against fungal infections in eusocial insects. *Toxins (Basel)*, 11(5), 244.

Liu, H. K., Lin, C.-C., Huang, L.-H., Huang, S.-A. & Huang, R.-N. (2020). Eradication and control strategies for red imported fire ants (*Solenopsis invicta*) in Taiwan. *Sustainability*, 12, 3951.

Lu, Y., Liang, G. & Zeng, L. (2008). Study on expansion pattern of red imported fire ant, *Solenopsis invicta* Buren, in South China. *Scientia Agricultura Sinica*, 41, 1053-1063.

Ma, J., Hu, X., Wu, J., Zhao, J. & Chen, N. (2010). An analysis for the interception dynamic of *Solenopsis invicta* Buren at ports in Guangdong. Journal of *Environmental Entomology*, 32, 122–124.

Malagocka, J., Eilenberg, J. & Jensen, A. B. (2019). Social immunity behaviour among ants infected by specialist and generalist fungi. *Current Opinion in Insect Science*, 33, 99–104.

McNaught, M. K., Wylie, F. R., Harris, E. J., Alston, C. L., Burwell, C. J. & Jennings, C. (2014). Effect of broadcast baiting on abundance patterns of red imported fire ants (Hymenoptera: Formicidae) and key local ant genera at long-term monitoring sites in Brisbane, Australia. *Journal of Economic Entomology*, 107, 1307–1315.

Miravete, V., Roura-Pascual, N., Dunn, R. R. & Gomez, C. (2014). How many and which ant species are being accidentally moved around the world? *Biology Letters*, 10, 20140518.

Morrison, L. W. (2012). Biological control of *Solenopsis* fire ants by *Pseudacteon* parasitoids: theory and practice. *Psyche*, 424817.

Nendick D (2008) Win-win from offshore container management programme. *Biosecurity* 84:12

Oi, D. H. & Valles, S. M. (2012). Host specificity testing of the *Solenopsis* fire ant (Hymenoptera: Formicidae) pathogen, *Kneallhazia* (= *Thelohania*) *solenopsae* (microsporidia: thelohaniidae), in Florida. *Florida Entomologist*, 95, 509–512.

Oi, D. H. & Porter, S. D. (2022). Parasitoids and pathogens used against imported fire ants in the southern United States. In: Van Driesche, R. G., Winston, R. L., Perring, T. M. & Lopez, V. M. (eds) Contributions of Classical Biological Control to the U.S. Food Security, Forestry, and Biodiversity. FHAAST-2019-05. USDA Forest Service, Morgantown, West Virginia, USA. https://bugwoodcloud.org/resource/files/23194.pdf (accessed 6 October 2022)

Oi, D. H., Williams, D. F., Pereira, R. M., Horton, P. M., Davis, T., Hyder, A. H., Bolton, H. T., Zeichner, B. C., Porter, S. D., Hoch, A. L., Boswell, M. L. & Williams, G. (2008). Combining biological and chemical controls for the management of red imported fire ants (Hymenoptera: Formicidae). *American Entomologist*, 54, 44–53.

Oi, D. H., Porter, S. D. & Valles, S. M. (2015). A review of the biological control of fire ants (Hymenoptera: Formicidae). *Myrmecological News*, 21, 101–116.

Oi, D. H., Atchison, R. A., Chuzel, G., Chen, J., Henke, J. A. & Weeks, R. D. (2022). Effect of irrigation on the control of Red Imported Fire Ants (Hymenoptera: Formicidae) by water-resistant and standard fire ant baits. *Journal of Economic Entomology*, 115, 266–272.

Peacock, L. (2011). The national invasive ant surveillance programme. *Surveillance*, 38, 51.

PIAT (2016). How much will it cost? http://piat.org.nz/index.php?page=how-much-will-it-cost#:~:text=Ballpark%20estimations,-Hoffmann%20and%20colleagues&text=The%20USD%20per%20hectare%20cost,5%25%20of%20the%20total%20cost (accessed 6 Oct 2022)

Plowes, R. M., Lebrun, E. G., Brown, B. V. & Gilbert, L. E. (2009). A review of *Pseudacteon* (Diptera: Phoridae) that parasitize ants of the *Solenopsis geminata* Complex (Hymenoptera: Formicidae). *Annals of the Entomological Society of America*, 102, 937–958.

Qin, D., Huang, R., Li, Z., Wang, S., Cheng, D. & Zhang, Z. (2018). Volatile component analysis of *Michelia alba* leaves and their effect on fumigation activity and worker behavior of *Solenopsis invicta*. *Sociobiology*, 65, 170–176.

Qiu, H. L., Fox, E. G. P., Qin, C. S., Zhao, D. Y., Yang, H. & Xu, J. Z. (2019). Microcapsuled entomopathogenic fungus against fire ants, *Solenopsis invicta*. *Biological Control*, 134, 141–149.

Rabitsch, W. & Blight, O. (2021). The threat posed by alien ants to EU agriculture and the potential for phytosanitary measures to prevent importation. Technical note prepared by IUCN for the European Commission.

Ross, A. (2018). 3D printing and biosecurity. *Surveillance*, 45, 33–34.

Sakamoto, H. & Goka, K. (2021). Acute toxicity of typical ant control agents to the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae). *Applied Entomology and Zoology*, 56, 217–224.

Schläppi, D., Kettler, N., Straub, L., Glauser, G. & Neumann, P. (2020). Long-term effects of neonicotinoid insecticides on ants. *Communications Biology*, 3, 335.

Sheppard, A.W., Paynter, Q., Mason, P., Murphy, S., Stoett, P., Cowan, P., Brodeur, J., Warner, K., Villegas, C., Shaw, R., Hinz, H., Hill, M. and Genovesi, P. (2019). IUCN SSC Invasive Species Specialist Group. The Application of Biological Control for the Management of Established Invasive Alien Species Causing Environmental Impacts. The Secretariat of the Convention on Biological DiversityTechnical Series No. 91. Montreal, Canada 88 pages.

Stringer, L. D., Suckling, D. M., Baird, D., Vander Meer, R. K., Christian, S. J. & Lester, P. J. (2011). Sampling efficacy for the Red Imported Fire Ant *Solenopsis invicta* (Hymenoptera: Formicidae). *Environmental Entomology*, 40, 1276–1284.

Suckling, D. M., Peck, R. W., Manning, L. M., Stringer, L. D., Cappadonna, J. & El-Sayed, A. M. (2008). Pheromone disruption of Argentine ant trail integrity. *Journal of Chemical Ecology*, 34, 1602–1609.

Suckling, D. M., Stringer, L. D., Bunn, B., el-Sayes, A. M. & Vander Meer, R. K. (2010). Trail pheromone disruption of Red Imported Fire Ant. *Journal of Chemical Ecology*, 36, 744–750.

Suhr, E. L., O'Dowd, D. J., Suarez, A. V., Cassey, P., Wittmann, T. A., Ross, J. V. & Cope, R. C. (2019). Ant interceptions reveal roles of transport and commodity in identifying biosecurity risk pathways into Australia. *NeoBiota*, 53, 1–24.

Tschinkel, W. R. (2006). The fire ants. Harvard University Press, Cambridge.

Tschinkel, W. R. & King, J. R. (2007). Targeted removal of ant colonies in ecological experiments, using hot water. *Journal of Insect Science*, 7, 41.

Uebi, T., Sakita, T., Ikeda, R., Sakanishi, K., Tsutsumi, T., Zhang, Z., Ma, H., Matsubara, R., Matsuyama, S., Nakajima, S., Huang, R.-N., Habe, S., Hefetz, A. & Ozaki, M. (2022). Chemical identification of an active component and putative neural mechanism for repellent effect of a native ant's odor on invasive species. *Front Physiol.*, 13, 844084.

USDA (2015). Imported fire ant: quarantine treatments for nursery stock, grass sod, and related materials. Program Aid No. 1904, updated January 2015. *USDA, Animal and Plant Health Inspection Service*, 18 pp.

Valentin, R.E., Fonseca, D.M., Gable, S., Kyle, K.E., Hamilton, G.C., Nielsen, A.L. & Lockwood, J.L. (2020). Moving eDNA surveys onto land: Strategies for active eDNA aggregation to detect invasive forest insects. *Molecular Ecology Resources* 20, 746–755.

Valles, S.M., Strong, C.A. & Callcott, A.-M.A. (2018). Multiplexed lateral flow immunoassay to discriminate *Solenopsis invicta*, *Solenopsis richteri*, and *Solenopsis invicta × richteri* hybrids. *Insectes Sociaux*, 65, 493–501.

Vanderwoude, C., Elson-Harris, M., Hargreaves, J. R., Harris, E. J. & Plowman, K. P. (2003). An overview of the red imported fire ant (*Solenopsis invicta* Buren) eradication plan for Australia. *Records of the South Australian Museum Monograph Series*, 7, 11–16.

Vanderwoude, C., Boudjelas, S., Gruber, M., Hoffmann, B., Oi, D. & Porter, S. (2021). Biosecurity Plan for Invasive Ants in the Pacific Region. In: Pullaiah, T. & Ielmini, M. R. (eds), Invasive Alien Species: Observations and Issues from Around the World, *Volume 2: Issues and Invasions in Asia and the Pacific Region*, 275–288.

Vogt, J. T., Smith, W. A., Grantham, R. A. & Wright, R. E. (2003). Effects of temperature and season on foraging activity of red imported fire ants (Hymenoptera: Formicidae) in Oklahoma. *Environmental Entomology*, 32, 447–451.

Wang, L., Lu, Y. Y., Xu, Y. J. & Zeng, L. (2013). The current status of research on *Solenopsis invicta* Buren (Hymenoptera: Formicidae) in Mainland China. *Asian Myrmecology*, 5, 125–138.

Wang, L., Zeng, L., Xu, Y. & Lu, Y. (2020). Prevalence and management of *Solenopsis invicta* in China. *NeoBiota*, 54, 89–124.

Ward, D. F., Beggs, J. R., Clout, M. N., Harris, R. J. & O'Connor, S. (2006). The diversity and origin of exotic ants arriving in New Zealand via human mediated dispersal. *Diversity Distribution*, 12, 601–609.

Williams, D. F., Oi, D. H., Porter, S. D., Pereira, R. M. & Briano, J. A. (2003). Biological control of imported fire ants (Hymenoptera: Formicidae). *American Entomologist*, 49, 150–163.

Wonder, B. (2019). Efficiency and Effectiveness Review of the National Red Imported Fire Ant Eradication Program. *Consultancy Report for the Steering Committee for the National Red Imported Fire Ant Eradication Program*. 98 pp.

Wylie, R., Jennings, C.., McNaught, M. K., Oakey, J. & Harris, E. J. (2016). Eradication of two incursions of the Red Imported Fire Ant in Queensland, Australia. *Ecological Management & Restoration*, 17, 22–32.

Wylie, R., Yang, C.-C. S. & Tsuji, K. (2020). Invader at the gate: The status of red imported fire ant in Australia and Asia. *Ecological Research*, 35, 6–16.

Yang, X., Ning, D., Ni, M., Hassan, B., Wu, J. & Xu, Y. (2019). Interception of exotic ants and survey of the ant fauna at Gaoming Port, China. *Asian Myrmecology*, 11, 1–11.

Yasashimoto, T., Sakata, M. K., Sakita, T., Nakajima, S., Ozaki, M. & Minamoto, T. (2021). Environmental DNA detection of an invasive ant species (*Linepithema humile*) from soil samples. *Scientifc Reports*, 11, 10712.

Zhang, L., Wang, L., Chen, J., Zhang, J., He, Y., Lu, Y., Cai, J., Chen, X., Wen, X., Xu, Z. & Wang, C. (2022). Toxicity, horizontal transfer, and physiological and behavioral effects of cycloxaprid against *Solenopsis invicta* (Hymenoptera: Formicidae). *Pest Management Science*, 78, 2228–2239.

Zhong, P., Zhao, J., Zhang, S. & Feng, J. (2008). Indoor toxic study of several plant extracts on red imported fire ant. *Journal of Huizhou University*, 28, 41–44.

Appendix

Level of confidence provides an overall assessment of the confidence that can be applied to the information provided for the measure.

- **Well established:** comprehensive meta-analysis or other synthesis or multiple independent studies that agree.
- **Established but incomplete:** general agreement although only a limited number of studies exist but no comprehensive synthesis and/or the studies that exist imprecisely address the question.
- **Unresolved:** multiple independent studies exist but conclusions do not agree.
- **Inconclusive:** limited evidence, recognising major knowledge gaps.

Your feedback is important. Any comments that could help improve this document can be sent to ENV-IAS@ec.europa.eu

Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention

Contract No 07.0202/2016/740982/ETU/ENV.D2

Final Report

Annex 7: Risk Assessment for *Solenopsis invicta* Buren, 1972

Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention" Contract No 07.0202/2016/740982/ETU/ENV.D2

Based on the Risk Assessment Scheme developed by the GB Non-Native Species Secretariat (GB Non-Native Risk Assessment - GBNNRA)

Name of organism: *Solenopsis invicta* Buren, 1972

Author(s) of the assessment:
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Risk Assessment Area: The geographical coverage of the risk assessment is the territory of the European Union (excluding the outermost regions)

Peer review 1: Olivier Blight, Dr, Institut Méditerranéen de Biodiversité et d'Ecologie, University of Avignon, France
Peer review 2: Anne-Marie Callcott, Dr**,** USDA, APHIS, PPQ, CPHST, Biloxi Station, USA
Peer review 3: Robert Tanner, Dr, European and Mediterranean Plant Protection Organization (EPPO/OEPP), PARIS, FRANCE

This risk assessment has been peer-reviewed by three independent experts and discussed during a joint expert workshop. Details on the review and how comments were addressed are available in the final report of the study.

Completed: 17/11/2017

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Entry	**likely**	**medium**	The most important pathway of introduction for *S. invicta* in Europe is the entry of nests as contaminant of nursery material (including soil) and as stowaway/hitchhiker in container/bulk or other commodities (e.g. vehicles, machinery, packaging material). However, the propagule pressure of nests is largely unknown. Queen ants are also likely to arrive as hitchhikers, but only aircrafts will allow a fast transfer that will allow a successful establishment.
Summarise Establishment	**likely**	**high**	According to different models, *S. invicta* could become established in all countries around the Mediterranean Sea, on the Southern Atlantic Coast from Southern France to Portugal. Beyond that, establishment in the Macaronesian region is also very likely. Predictions on the geographic extent of potential establishment vary with the models. It is likely that if established, the ant will have a patchy distribution in Southern Europe, with high densities and extent in suitable habitats in direct contact with permanent water bodies and in irrigated areas.
Summarise Spread	**moderately**	**medium**	In all potentially infested biogeographical regions, *S. invicta* will probably spread moderately rapidly compared to other insects. Although *S. invicta* can spread by natural means over several kilometres per year, its spread will occur mainly through human-assisted transport, in particular with soil and infested items, but its distribution will be constrained by climate and habitat suitability.
Summarise Impact	**major**	**medium**	The species has a major to massive environmental, economic and social impacts elsewhere in the world.

			Similar impacts may occur in Southern Europe. However, the transferability to Europe is hindered by uncertain data on habitat/climatic suitability that may limit the geographic area that is most favourable to the insect. In other words, if only limited zones in the Mediterranean region will be favourable for the ant, impacts will be largely restricted to these zones.
Conclusion of the risk assessment	**high**	**medium**	*Solenopsis invicta* is among the most damaging invasive insects on earth. There is little doubt that it can enter Europe through a variety of pathways, but its establishment and impact will be constrained by climatic and habitat suitability. It is likely that it may become a serious environmental, economic and social pest in some areas of southern Europe, but the extent of its potential distribution remains unclear.

Distribution Summary (for explanations see EU chapeau and Annex IV):

Member States

	Recorded	Established (currently)	Established (future)	Invasive (currently)
Austria	–	–	?	–
Belgium	–	–	-	–
Bulgaria	–	–	-	–
Croatia	–	–	yes	–
Cyprus	–	–	yes	–
Czech Republic	–	–	-	–
Denmark	–	–	-	–
Estonia	–	–	-	–
Finland	–	–	-	–
France	–	–	yes	–
Germany	–	–	-	–

Greece	–	–	yes	–
Hungary	–	–	-	–
Ireland	–	–	-	–
Italy	–	–	yes	–
Latvia	–	–	-	–
Lithuania	–	–	-	–
Luxembourg	–	–	-	–
Malta	–	–	yes	–
Netherlands	yes	–	-	–
Poland	–	–	-	–
Portugal	–	–	Yes	–
Romania	–	–	-	–
Slovakia	–	–	-	–
Slovenia	–	–	yes	–
Spain	–	–	Yes	–
Sweden	–	–	-	–
United Kingdom	–	–	-	–

EU biogeographical regions

	Recorded	Established (currently)	Established (future)
Alpine	-	-	-
Atlantic	yes	-	?
Black Sea	-	-	-
Boreal	-	-	-
Continental	-	-	-
Mediterranean	-	-	yes
Pannonian	-	-	-
Steppic	-	-	-

EU CHAPEAU		
QUESTION	**RESPONSE**	**COMMENT**
Ch1. In which EU biogeographical region(s) or marine subregion(s) has the species been recorded and where is it established?	Workers of *S. invicta* have been intercepted occasionally during import inspections and, in at least one occasion in the Netherlands (Atlantic Region) in 2002, a nest was found in soil of imported ficus plants from the USA (Boer and Vierbergen 2008; Noordijk 2010). No established populations are recorded in the EU, nor in Western Palaearctic in general.	In the Netherlands, the first interception record of workers was in 1958 and 2 to 5 interceptions were made until 2008 (Boer and Vierbergen 2008; Noordijk 2010). Data from other countries were not found.
Ch2. In which EU biogeographical region(s) or marine subregion(s) could the species establish in the future under current climate and under foreseeable climate change?	According to various climate and ecophysiological models, *S. invicta* could become established in the Mediterranean Biogeographical region under current climate, although the geographic extent of current or future establishment varies with the models and there is no clear consensus. For more details see Qu. 1.13. Beyond that, establishment on the Southern Atlantic biogeographical region, in particular the coast from Southern France to Portugal is considered possible (e.g. Morrison et al. 2004). However, according to Bertelsmeier et al. (2015), *S. invicta* will not establish widely in Europe under current climate, but may have the capacity to do so under future climatic conditions until 2080 in Ireland, Spain, Italy, Germany, Slovenia, and Hungary. Beyond that, the model indicated Switzerland as suitable for *S. invicta* at that date.	One reason for the different predictions of these models is that they use different methodological approaches (ecophysiological vs climatic data) in modelling the potential distribution of the species.
Ch3. In which EU member states has the species been recorded? List them with an indication of the timeline of observations.	Workers have been found occasionally during import inspections and, in at least one occasion in the Netherlands in 2002, a nest has been found in	Ants are not listed as quarantine pests in the EU and, therefore, records rarely appear in the national and international lists of intercepted

	the soil of imported ficus plants from the USA (Noordijk 2010).	pests.
Ch4. In which EU member states has this species established populations? List them with an indication of the timeline of establishment and spread.	No established populations recorded in the EU, nor in Western Palaearctic in general.	
Ch5. In which EU member states could the species establish in the future under current climate and under foreseeable climate change?	According to various climate and ecophysiological models, *S. invicta* could become established in all EU member states around the Mediterranean biogeographical region under current climate, including the following countries: Portugal, Spain, France, Italy, Slovenia, Croatia, Greece and Cyprus (e.g. Morrison et al. 2004). Beyond that, establishment on the Southern Atlantic Coast from Southern France to Portugal is considered possible. However, according to Bertelsmeier et al. (2015) *S. invicta* will not establish in Europe outside some areas in the Mediterranean biogeographical region, but under current climate, but may have the capacity to do so under future climatic conditions until 2080 in Ireland, Spain, Italy, Germany, Slovenia, and Hungary. Beyond that, the model indicated Switzerland as suitable for *S. invicta*. The geographic extent of current or future establishment varies with the models and there is no clear consensus. For more details see Qu. 1.13.	
6. In which EU member states has this species shown signs of invasiveness?	None. There are no established populations recorded in the EU, nor in Western Palaearctic in general.	
7. In which EU member states could this species become invasive in the future under current climate and under foreseeable climate change?	Based on the information available, the species may become invasive in any country, where it is able to establish, e.g. in the Mediterranean biogeographical region (Portugal, Spain, France, Italy, Slovenia,	

	Croatia, Greece and Cyprus) under current climate, and the Mediterranean, Atlantic (Ireland), Continental (Germany) and Pannonian (Hungary) biogeographical regions under foreseeable climate change.	

SECTION A – Organism Information and Screening		
Organism Information	**RESPONSE**	**COMMENT**
A1. Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	Scientific name: *Solenopsis invicta* Buren 1972 Class: Insecta Order: Hymenoptera Family: Formicidae Genus: *Solenopsis* Westwood, 1840 Synonyms: *Solenopsis wagneri* (Santschi), *Solenopsis saevissima* var. *wagneri* Taber (2000) provided a history of the taxonomic status of *S. invicta*. A comprehensive and regularly updated list can be found at www.antweb.org. Common names: Red imported fire ant, Rote importierte Feuerameise, Hormiga roja de fuego, Fourmi de feu. No varieties or breeds are known, but hybridization between *Solenopsis* species is regularly observed. While *S. invicta* and *S. richteri* are reproductively isolated in the native range (Ross & Shoemaker 2005), extensive hybridization between *S. invicta* x *S. richteri* is documented in the southern U.S.A. (e.g. Ross et al. 1987). The hybrid taxon is excluded from this assessment.	Genetic data indicate that *S. invicta* is a polyphyletic, cryptic species group composed of several species that cannot be distinguished morphologically (Martins et al. 2014).
A2. Provide information on the existence of other	The genus *Solenopsis* contains about 200 species,	There are over 20 native *Solenopsis* species

species that look very similar	among which 18 to 20 are "true fire ants", which all look very similar and have the potential of becoming invasive. In particular, *S. richteri* is very similar to *S. invicta* and, in North America, where both species are invasive, hybrids are observed. There is considerable uncertainty about species delimitation in the native range and morphological separation is notably difficult and sometimes considered impossible, certainly in the field. A key for separation of the taxa in the *S. geminata* species-group was provided by Trager (1991).	occurring in Europe and in the risk assessment area, most of which live an elusive subterranean life with small populations. Therefore, confusion with native species cannot be completely ruled out, and specific taxonomic expertise is needed to confirm ant species identity, but life-history and colony structure might be helpful indicators with regard to invasive non-native *Solenopsis* species.
A3. Does a relevant earlier risk assessment exist? (give details of any previous risk assessment and its validity in relation to the EU)	A risk assessment has been made for fire ants (*Solenopsis* spp.) in the Netherlands, which concludes that, although they are regularly found during import inspections in the Netherlands, it is unlikely that they can establish outdoors in the country. However, establishment in permanently heated buildings is possible, and can cause nuisance to humans through their sting and the destruction of equipment such as electrical equipment (including air conditioner units, computers, etc.) (Noordijk 2010). Another RA has been carried out for New Zealand, which classified *S. invicta* as having the highest risk of the 75 non-native ant species assessed (MAF Biosecurity 2002; Harris, undated).	
A4. Where is the organism native?	*Solenopsis invicta* is native to (sub-) tropical South America, including parts of Argentina and Brazil, Bolivia, Paraguay, Peru and Uruguay (CABI 2017). It prefers tropical and subtropical climates with warm temperatures and high annual precipitation,	

	but tolerates savanna climates with dry summers, temperate climates without extended winter frost periods, and arid to semi-arid climates (Tschinkel 2006). It occurs in a wide range of, mostly, disturbed/developed habitats, including roadsides, in the vicinity and inside of buildings, grasslands, crop fields, pastures, lawns, gardens, and parks, where colonies are established in the soil or other suitable media. In its native range it also occurs in rainforests, secondary forests and plantation but, in the non-native range, it demonstrates a strong preference for urban and agricultural environments (Tschinkel 2006).	
A5. What is the global non-native distribution of the organism (excluding the Union, but including neighbouring European (non-Union) countries)?	It was unintentionally introduced (and subsequently spread) in southern US States (from California to Florida), Mexico, Panama and many Caribbean islands (e.g. Virgin Islands, Bahamas, etc.), Australia (Queensland) and New Zealand (eradicated), China (South East), Malaysia, Singapore and Taiwan (CABI 2017).	The first confirmed records of *S. invicta* outside its native range are documented from 1942, when it was collected by E.O. Wilson in the area of Mobile, Alabama (USA); already abundant at that time, the time of arrival was estimated to be within 1933 and 1942 (Tschinkel 2006). In Australia it was first discovered in Brisbane in 2001 (Nattrass and Vanderwoude 2001). It was introduced but did not establish in New Zealand (Ward 2009). Introduced in Taiwan and mainland China in the early 2000s (Chen et al. 2006, Zhang et al. 2007).
A6. Is the organism known to be invasive (i.e. to threaten organisms, habitats or ecosystems) anywhere in the world?	Yes. It is considered to be amongst the 100 most invasive species on earth and it is the invasive insect that has been most studied for its ecological impact worldwide (Kenis et al. 2009).	Negative impacts have been studied mainly in Southern USA and include competition with and displacement of native ants, predation on hatchlings of birds and reptiles (see Qu. 2.18). In addition, fire ants can have negative effects on

		agriculture, as well as animal and human health, ranging from minor allergic reactions to lethal allergic reactions (see Qu. 2.26 – 2.32). Data derived from the IUCN Red List and the IUCN Global Invasive Species Database show that globally *S. invicta* has a known or suspected negative impacts on 3 endangered species, more specifically: *Cyclura lewisi*, Grand Cayman Blue Iguana (IUCN: EN). *Holbrookia lacerata*, Spot-tailed Earless Lizard (IUCN: NT) ("*S. invicta* likely to constitute a threat to this species"). *Podomys floridanus*, Florida Deermouse (IUCN: VU) ("Red imported fire ants (Solenopsis invicta) are a potential predatory threat to gopher tortoises and might be a direct threat to Podomys as well (Wetterer and Moore 2005)").
A7. Describe any known socio-economic benefits of the organism in the risk assessment area.	At present there are no socio-economic benefits in the RA area as the species is not present in the RA area.	In invaded areas, *S. invicta* is a predator of some pest arthropods such as ticks and caterpillars. It can feed on crop pests and in sugarcane production and it is occasionally preserved to reduce sugarcane borer population levels (e.g. Charpentier et al. 1967, Rossi and Fowler 2002). Its mound-building activities are sometimes considered to improve soil quality, e.g. by reducing soil compaction or increasing NH4+ levels (e.g. Lafleur et al. 2005).

SECTION B – Detailed assessment

Important instructions:

- In the case of lack of information the assessors are requested to use a standardized answer: "No information has been found."
- For detailed explanations of the CBD pathway classification scheme consult the IUCN/CEH guidance document.
- With regard to the scoring of the likelihood of events or the magnitude of impacts see Annex.
- With regard to the confidence levels, see Annex.

PROBABILITY OF INTRODUCTION and ENTRY

Important instructions:

- Introduction is the movement of the species into the EU.
- Entry is the release/escape/arrival in the environment, i.e. occurrence in the wild. Not to be confused with spread, the movement of an organism within Europe.
- For organisms which are already present in Europe, only complete this section for current active or if relevant potential future pathways. This section need not be completed for organisms which have entered in the past and have no current pathway of introduction and entry.

QUESTION	RESPONSE [chose one entry, delete all others]	CONFIDENCE [chose one entry, delete all others]	COMMENT
1.1. How many active pathways are relevant to the potential entry of this organism? (If there are no active pathways or potential future pathways respond N/A and move to the Establishment section)	**many**	**high**	*Solenopsis invicta* is suspected of having arrived in the USA in the 1930s in the ballast of cargo ships from Paraguay (Vinson 1997). However, soil ballast is not used anymore for intercontinental shipping and this pathway is here considered not active. There have been indications that the species is sold online by terrarium keepers.
1.2. List relevant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways as well as a description of the associated commodities.	a) Transport-Stowaway (Hitchhikers in or on airplane)		*Solenopsis invicta* is termed a "tramp" ant, it can hitchhike with many commodities through many pathways. However, only the entry of queen ants and nests present a risk of establishment. Furthermore,

For each pathway answer questions 1.3 to 1.10 (copy and paste additional rows at the end of this section as necessary). Please attribute unique identifiers to each question if you consider more than one pathway, e.g. 1.3a, 1.4a, etc. and then 1.3b, 1.4b etc. for the next pathway.	b) Transport-Contaminant (nursery material and other matters from the horticultural trade) c) Transport-Stowaway (nests transported in container/bulk, including sea freight, airfreight, train, etc.)		queens must find a nest quickly after mating. These restrictions limit the number of active pathways. MAF Biosecurity (2002) provides a very detailed analysis of potential pathways of introduction of *S. invicta* in New Zealand, which is also highly relevant for Europe. Noordijk (2010) provides a brief assessment of pathways for the Netherlands as well as interception data.
Pathway name:	a) Transport-Stowaway (Hitchhikers in or on airplane)		
1.3a. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	
1.4a. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	**moderately likely**	**low**	Newly-mated queens start forming a nest within 6-7 hours. After that time, their chance of survival and of establishing a nest decreases. Considering that ships from the nearest infested areas take more than a week to reach the EU, newly-mated queens can only arrive successfully in airplanes. However, it cannot be ruled out that newly mated queen ants establish a nest on a ship (see Qu. 1.5).
1.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**moderately likely**	**medium**	Considering the fact that a flight from infested areas (e.g. Southern US or China) takes at least 10 hours, not considering embarking and disembarking of containers, commodities, etc., a queen may not arrive in its best condition for establishing nests. Likelihood of survival will decrease with increasing travel duration, but is possible. However, multiplication and the establishment

			of a small nest during such an intercontinental flight is highly unlikely.
1.6a. How likely is the organism to survive existing management practices during passage along the pathway?	N/A		There are no management practices against hitchhiking ants or ant queens in or on airplanes in place.
1.7a. How likely is the organism to enter Europe undetected?	**likely**	**high**	A single queen ant or even several queens or small nests are not easy to detect in cargo airplanes.
1.8a. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**likely**	**high**	Nuptial flights of ant queens have been recorded throughout the year and commodities with which ants can enter Europe occur throughout the year.
1.9a. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**high**	Many airports in the Mediterranean region are surrounded by suitable habitats including irrigated/watered gardens and parks. Indeed this species simply requires soil as a substrate in which to establish a nest and has been found to occur in diverse habitats from roadside verges to forests.
1.10a. Estimate the overall likelihood of entry into Europe based on this pathway?	**moderately likely**	**medium**	The likelihood is scored moderately likely because the number of queen ants travelling through this pathway is probably relatively low and the duration of the transportation would be unlikely to favour survival of the queen. MAF Biosecurity (2002) scored the likelihood of introduction of a queen ant by aircraft as "low".
Pathway name:	b) Transport-Contaminant (nursery material and other matters from the horticultural trade)		
1.3b. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	This concerns both fully developed nests (with active workers) and newly-founded nests (before workers are developed and start foraging) transported in nursery material by the horticultural trade. Newly-founded nests can also be formed by queens transported in ships

			before the nursery material arrives at destination.
1.4b. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	**likely**	**low**	There are very limited data on ant nests arriving through the horticultural trade in Europe. At least some nests have reached Europe (the Netherlands) and New Zealand. Ants are not listed as quarantine pests in the EU and, therefore, records rarely appear in the national and international lists of intercepted pests. However, millions of plants arrive with soil or in pots (with substrates) from infested areas (Southern US, Mexico, Caribbean islands and China) every year in Europe and, although the soil/substrate is supposed to be sterile, infestation by ants can occur just before or during transport. Flower pots are one of the preferred habitats for *S. invicta* in invaded regions, in particular because of their humidity and because they are usually in contact with the ground. Other horticultural material such as mulch, hay and other plant material can harbour ant nests. Both polygynous and monogynous nests occur in *S. invicta.* Polygynous colonies are particularly large since they include many queens and may contain thousands of workers. The maximum size of a fully developed colony may reach more than 200,000 workers (Tschinkel 2006). Ant nests might get onto the pathway in large numbers as contaminant of horticultural materials including soil. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
1.5b. How likely is the organism to survive during	**very likely**	**high**	Once sealed in a newly-founded nest, a queen is able to

passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.			survive 13 to 95 days on her own reserves, i.e. much longer than before nest establishment (Markin et al. 1972; Porter 1988). Likelihood of survival nevertheless will decrease with increasing travel duration. However, multiplication of a small nest during intercontinental translocation is highly unlikely.
1.6b. How likely is the organism to survive existing management practices during passage along the pathway?	**likely**	**medium**	Horticulture plants and soils/substrates are usually chemically treated before shipment but can be easily infested after treatment either before departure or during transport.
1.7b. How likely is the organism to enter Europe undetected?	**likely**	**high**	Fully developed nests are quite visible. In contrast, newly-founded nests with few queen(s) and workers in the soil/substrate can easily arrive undetected.
1.8b. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**likely**	**high**	The horticultural trade is active throughout the year.
1.9b. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**high**	Potted plants and plant materials are likely to be transported outdoors in gardens, which may adjoin to a suitable habitat. It is expected that suburban and urban habitats are most at risk at the beginning of an invasion.
1.10b. Estimate the overall likelihood of entry into Europe based on this pathway?	**likely**	**medium**	We consider this pathway as the most likely pathway of introduction of *S. invicta* into Europe. Similarly, Noordijk (2010) and MAF Biosecurity (2002) also consider the horticultural trade as the most likely pathway for introduction in the Netherlands and New Zealand. MAF Biosecurity (2002) classifies "commercial importation of untreated soil that undergoes no inspection or post-arrival quarantine" as the single pathway presenting a very high likelihood.
Pathway name:	c) Transport-Stowaway (nests transported in container/bulk, including sea freight, airfreight, train, etc.)		
1.3c. Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	This section includes travelling nests that are not directly associated with the horticultural trade. Virtually any article of commerce can host hitchhiking nests of

			all sizes and ages, including newly-founded and fully developed nests. There are very many articles of commerce and container types that are grouped here together. This includes, e.g. sea containers but also vehicles (incl. used car parts), machinery, building material, packaging materials, bark, aquaculture material, used electric equipment.
1.4c. How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year? Subnote: In your comment discuss how likely the organism is to get onto the pathway in the first place. Subnote: In your comment discuss the volume of movement along this pathway.	**likely**	**low**	There are very limited data on ant nests arriving in Europe. See containers and all articles of commerce cited above were scored by MAF Biosecurity (2002) as presenting a high likelihood of introduction for nests of *S. invicta*. Ants are not listed as quarantine pests in the EU and, therefore, records rarely appear in the national and international lists of intercepted pests. Polygynous nests include many queens and may contain thousands of workers. The maximum size of a fully developed colony may reach more than 200,000 workers (Tschinkel 2006). Ant nests might get onto the pathway in large numbers as stowaway in containers or other bulk freight, including soil. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
1.5c. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e. much longer than before nest establishment (Markin et al. 1972; Porter 1988). This is sufficient to survive longer trips to Europe from any origin. Likelihood of survival nevertheless will decrease with increasing travel duration.
1.6c. How likely is the organism to survive existing	**very likely**	**high**	In most of the commodities in this pathway, there are no

management practices during passage along the pathway?			management practices in place.
1.7c. How likely is the organism to enter Europe undetected?	**likely**	**high**	Many of these commodities are not carefully inspected. While established nests are usually obvious, newly-founded nests are often inconspicuous. In contrast, newly-founded nests with few queen(s) and workers can easily arrive undetected.
1.8c. How likely is the organism to arrive during the months of the year most appropriate for establishment?	**likely**	**high**	Commodities that can carry *S. invicta* are active throughout the year.
1.9c. How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	**likely**	**high**	Several of the potential commodities and items in which nests can hide can be transported to suitable habitats since the ant particularly likes disturbed soils, which are found everywhere, specifically in urban and semi-urban habitats.
1.10c. Estimate the overall likelihood of entry into Europe based on this pathway?	**likely**	**high**	Given the high numbers and types of containers, commodities and items that can be associated with *S. invicta*, this pathway can be considered as having a high likelihood of introduction, as determined by MAF Biosecurity (2002) and Noordijk (2010).
End of pathway assessment, repeat as necessary.			
1.11. Estimate the overall likelihood of entry into Europe based on all pathways in relevant biogeographical regions in current conditions (comment on the key issues that lead to this conclusion).	**likely**	**medium**	The species has been recorded/intercepted already in Europe and it is likely that this will happen again, specifically with contaminated soil in the horticultural trade and/or as stowaway with container/bulk imports in sea or air freights.
1.12. Estimate the overall likelihood of entry into Europe based on all pathways in relevant biogeographical regions in foreseeable climate change conditions?	**likely**	**medium**	Climate change is not changing the risk of introduction or likelihood of entry based on the mentioned active pathways.

PROBABILITY OF ESTABLISHMENT

Important instructions:

- For organisms which are already established in parts of the Union, answer the questions with regard to those areas, where the species is not yet established. If the species is established in all Member States, continue with Question 1.16.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
1.13. How likely is it that the organism will be able to establish in the EU based on the similarity between climatic conditions in Europe and the organism's current distribution?	**likely**	**medium**	Various climatic models have been developed to assess climatic preferences for *S. invicta*, which can be used to assess the likelihood of establishment of the ant related to climate preferences. However, they do not all agree in their conclusions. Morrison et al. (2004) used the model of Korzukhin et al. (2001) to map suitable areas for the reproduction of *S. invicta* worldwide. The model used a dynamic, ecophysiological model of colony growth, superposing temperature and precipitation requirements to predict the potential global range distribution of the ant. The model showed that large parts of the Mediterranean region fall in the area suitable for *S. invicta* establishment (Fig. A1 in Annex 4) Sutherst and Maywald (2005) used the CLIMEX climate modeling software to assess the potential geographic range of *S. invicta* based on an ecoclimatic index (EI). For Europe, the analysis showed that climate per se will not constrain the ant from colonizing countries bordering the Mediterranean and western France. Two versions of the model are available that show some differences in the distribution range, i.e. the original from Sutherst and Maywald (2005) and an

			improved but unpublished version included as template in the CLIMEX software V4. (Fig. A2 and A3 in Annex 4). In both cases, EI for Europe was significantly lower than for the regions where the ant is highly invasive (e.g. in North America and East Asia), suggesting that, in Europe, establishment and population growth may be less straightforward, except in irrigated lands and in habitats in direct contact with permanent water bodies. Indeed, the model shows much higher EIs when irrigation is added (Fig. A4, as compared to Fig. A2, in Annex 4). Bertelsemeier et al (2014), using a climate matching model (Maxent) based on present distributions, mapped suitable areas globally for 15 of the worst invasive ant species (incl. *S. invicta*), both currently and with predicted climate change (in 2080). They showed that less than 2% of the European continent is presently suitable for *S. invicta*, but predicted that the potential distribution of *S. invicta* will until 2080 in Ireland, Spain, Italy, Germany, Slovenia, and Hungary. Beyond that, the model indicated Switzerland as suitable *for S. invicta* (Fig. A5 in Annex 4).
1.14. How likely is it that the organism will be able to establish in the EU based on the similarity between other abiotic conditions in Europe and the organism's current distribution?	**likely**	**high**	Other abiotic conditions should not be a constraint for the establishment of *S. invicta* in Europe, maybe except for high-altitude environments. The ant particularly likes disturbed soils, which are found everywhere, specifically in urban and semi-urban habitats.
1.15. How likely is it that the organism will become established in protected conditions (in which the environment is artificially maintained, such as wildlife parks, glasshouses, aquaculture facilities, terraria, zoological gardens) in Europe?	**moderately likely**	**high**	*Solenopsis invicta* frequently invades buildings in its invaded range. In regions with unsuitable climates, it may survive under warm conditions in buildings or greenhouses as well as in gardens and parks in cities. The ant has shown temporary

Subnote: gardens are not considered protected conditions			indoor colony establishments including at least once in the Netherlands (Noordijk 2010, see also Morril 1977, Tschinkel 2006). However, indoor colonies often can be eradicated easily.
1.16. How widespread are habitats or species necessary for the survival, development and multiplication of the organism in Europe?	**widespread**	**medium**	*Solenopsis invicta* prefers disturbed habitats, which are found everywhere in Europe. However, in dry areas, it reproduces preferably in habitats associated with waters, including irrigated areas, which may limit its distribution in the Mediterranean region, at least in natural areas.
1.17. If the organism requires another species for critical stages in its life cycle then how likely is the organism to become associated with such species in Europe?	**N/A**	**very high**	*Solenopsis invicta* does not require another species for establishment.
1.18. How likely is it that establishment will occur despite competition from existing species in Europe?	**moderately likely**	**medium**	*Solenopsis invicta* is a highly competitive species. In its invaded range, it has locally displaced native ants but also highly invasive ants such as the Argentine ant (Holway et al. 2002). However, Tschinkel (2006) suggests that, at range margins, the competition with local ant species that are better adapted to the climate might impede *S. invicta* establishment and/or reproduction. In several suitable areas it will have to face the competition with the Argentine ant. This species is able to limit *S. invicta* establishment and confrontations will be asymmetric as the Argentine ant already forms colonies of many hundred thousands of individuals.
1.19. How likely is it that establishment will occur despite predators, parasites or pathogens already present in Europe?	**likely**	**medium**	Only few *Solenopsis* spp. are native to Europe, and no specific natural enemy of *Solenopsis* spp. occurs in Europe. Thus, only generalist natural enemies of ants may affect the establishment of the ant.
1.20. How likely is the organism to establish despite existing management practices in Europe?	**likely**	**medium**	No specific management practices are in place against invasive ants in the wild in Europe.

			Eradication of single nests is straightforward in buildings but much less so outdoors. However, some eradication programmes have succeeded, such as in New Zealand (Christian 2009).
1.21. How likely are existing management practices in Europe to facilitate establishment?	**likely**	**medium**	Disturbed habitats, in particular irrigated areas, are favourable for *S. invicta* and so increases in urbanization will be beneficial for this species.
1.22. How likely is it that biological properties of the organism would allow it to survive eradication campaigns in Europe?	**likely**	**medium**	The eradication of *S. invicta* outdoors is difficult, especially when polygynous *S. invicta* colonies are present with many nests and many queens per nest (Noordijk 2010).
1.23. How likely are the biological characteristics of the organism to facilitate its establishment?	**likely**	**high**	*Solenopsis invicta* has monogynous and polygynous populations. The polygynous form can more easily establish because the higher number of queens increases reproduction potential, especially in the critical early stages of establishment. For other characteristics, see also Q1.25. Inseminated females (queens) lay up to 200 eggs per hour (Tschinkel 1988). Within one year, the colony can grow to several thousands of workers, within three years it can reach 50,000 (Markin et al. 1973) or even up to 230,000 workers (Tschinkel 1988). The peculiar, almost unique, reproductive caste system of eusocial ants can facilitate establishment. For the Argentine ant, it was shown that as few as 10 workers are sufficient for a colony to grow quickly (Hee et al. 2000).
1.24. How likely is the capacity to spread of the organism to facilitate its establishment?	**moderately likely**	**medium**	At introduction, *Solenopsis invicta* will not spread far by itself. However, if arriving in soil or other substrates (e.g. potted plants), then spread may be facilitated by the movement of soil and plants to suitable places.

1.25. How likely is the adaptability of the organism to facilitate its establishment?	**likely**	**high**	*Solenopsis invicta* is highly adaptable. It can live in a variety of habitats, especially those that are related to humans, and it is also considered an opportunistic omnivore. Also, in contrast to many ants, it does not have a restricted flight period. Nuptial flights have been recorded throughout the year and foraging can occur over a wide soil surface temperature range (12-51 °C) while maximum worker ants foraging occurs between 22-36 °C (Porter and Tschinkel 1987). This indicates that *S. invicta* has a high adaptability to new circumstances.
1.26. How likely is it that the organism could establish despite low genetic diversity in the founder population?	**likely**	**high**	Most invasive ants, which are among the most invasive insects worldwide, establish following the entry of single nests or queens (Holway 2002). Therefore, low genetic diversity does not seem a barrier to establishment.
1.27. Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Europe? (If possible, specify the instances in the comments box.)	**likely**	**high**	*Solenopsis invicta* has been introduced and become established in Southern US and various Caribbean Islands (Tschinkel 2006), and more recently Australia (Nattrass and Vanderwoude 2001) and China and Taiwan (Chen et al. 2006, Zhang et al. 2007). It was also introduced and eradicated in New Zealand (Ward 2009), the Netherlands (Noordijk 2010) and probably other parts of the world. Furthermore, *Solenopsis geminata*, a closely-related species has been even more successful in invading several continents (albeit they may have slightly different biotic and abiotic requirements). Thus, should the climate of Southern Europe be suitable and habitats available for the species, the history of invasion elsewhere clearly shows that it is likely to be introduced and establish in Europe.
1.28. If the organism does not establish, then how likely is	**moderately likely**	**high**	As shown with interception data from countries

it that casual populations will continue to occur? Subnote: Red-eared Terrapin, a species which cannot re-produce in GB but is present because of continual release, is an example of a transient species.			such as the Netherlands and New Zealand, *S. invicta* and related *Solenopsis* spp. are regularly intercepted at ports of entry. However, in most cases, these are sterile workers that cannot establish in the wild. Ants are not listed as quarantine pests in the EU and, therefore, interception data are not good indicators of their frequency of entry because they do not have to be mentioned in the national and international lists of intercepted pests. It has to be assumed that there are a considerable number of unreported cases.
1.29. Estimate the overall likelihood of establishment in relevant biogeographical regions in current conditions (mention any key issues in the comment box).	**likely**	**medium**	In the Mediterranean and Macaronesian biogeographical regions, establishment under current conditions is likely, at least in the most humid or irrigated habitats. Also, the southern Atlantic region from Southern France to Portugal is considered to be potentially susceptible, but there is no agreement across climate models (see e.g. Bertelsmeier et al. 2015).
1.30. Estimate the overall likelihood of establishment in relevant biogeographical regions in foreseeable climate change conditions	**likely**	**high**	Under foreseeable climate change, *S. invicta* may establish in the Atlantic, Mediterranean, Continental and Pannonian biogeographic region (according to Bertelsmeier et al. 2015). Bertelsmeier et al. (2015), who are the least positive about a wide establishment in the Mediterranean region, predict an increase of the potential range for *S. invicta* in Europe in the future.

PROBABILITY OF SPREAD

Important notes:

- Spread is defined as the expansion of the geographical distribution of an alien species within the assessment area.
- Repeated releases at separate locations do not represent spread and should be considered in the probability of introduction and entry section.

QUESTION	RESPONSE	CONFIDENCE	COMMENT
2.1. How important is the expected spread of this organism in Europe by natural means? (Please list and comment on each of the mechanisms for natural spread.)	**moderate**	**high**	Queen ants disperse during nuptial flights and for nesting. Most queens do not fly far from the colony of origin but some may fly up to 12 kilometres (Tschinkel 2006, Dhami & Booth 2008). Nuptial flights occur throughout the year. Polygynous colonies can also spread by "budding", i.e. alates mate in the nest and queens disperse only short distances and take workers with her to start a new colony (Tschinkel 2006). Such strategy does not allow a rapid spread but increase survival rates of queens and colonies. Sometimes, an entire colony can disperse by rafting/floating on water, e.g. after flooding of its habitat (e.g. Adams et al. 2011). The question is scored "moderate" because it is likely to spread more slowly by natural means than by human assistance.
2.2. How important is the expected spread of this organism in Europe by human assistance? (Please list and comment on each of the mechanisms for human-assisted spread) and provide a description of the associated commodities.	**major**	**high**	Human assisted pathways of spread are the agricultural and horticultural trade of plants, plant materials, and soil/substrate as well as other movements of commodities.
2.2a. List and describe relevant pathways of spread.	a) Transport-		

Where possible give detail about the specific origins and end points of the pathways. For each pathway answer questions 2.3 to 2.9 (copy and paste additional rows at the end of this section as necessary).	Contaminant (Contaminant nursery material) b) Transport-Stowaway (Container/bulk, including road transport, sea freight, airfreight, train, etc.) c) Unaided (Natural dispersal)		
Pathway name:	a) Transport-Contaminant (Contaminant nursery material)		
2.3a. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	
2.4a. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year?	**very likely**	**high**	Within Europe, movements of potted plants are unrestricted. Soil/substrate in potted plants is a favourite media for nesting (see entry section above). Thus, newly founded nests or parts of fully developed nests could easily be moved. Other horticultural material such as mulch, hey and other plant material can harbour ant nests. Polygynous nests include many queens and may contain thousands of workers. Ant nests might get onto the pathway in large numbers as contaminant of horticultural materials including soil. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
2.5a. How likely is the organism to survive during passage along the pathway (excluding management practices that	**likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e.

would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.			much longer than before nest establishment (Markin et al. 1972; Porter 1988). Likelihood of survival is high, nevertheless will decrease with increasing travel duration. Multiplication of a colony during spread within the EU cannot be ruled out, but is rather unlikely.
2.6a. How likely is the organism to survive existing management practices during spread?	**likely**	**high**	Horticultural plants and products and soils/substrates are usually not treated before translocation within the EU.
2.7a. How likely is the organism to spread in Europe undetected?	**likely**	**high**	Fully developed nests are quite visible. In contrast, newly-founded nests with few queen(s) and workers can easily travel undetected in soil or other horticultural products.
2.8a. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**very likely**	**high**	Potted plants and plant materials are often planted or stored in or close to highly suitable habitats, such as gardens, parks, road sides, etc. It is expected that spread facilitates occurrences in suburban and urban habitats.
2.9a. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**very likely**	**high**	We consider this pathway as the most likely pathway of spread of *S. invicta* within Europe.
Pathway name:	b) Transport-Stowaway (Container/bulk, including road transport, sea freight, airfreight, train, etc.)		
2.3b. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	Virtually any article of commerce can host hitchhiking ants within nests of all sizes and ages, including newly-founded and fully developed nests. There are very many transported items (e.g. vehicles (incl. used car parts), machinery, building material, agricultural equipment packaging materials, bark, aquaculture material, used electric equipment, non-agricultural soil, sand, gravel) that are suitable to carry nests and are grouped here together.
2.4b. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin over the course of one year?	**very likely**	**high**	There are very limited data on ant nests translocated within the EU. Polygynous nests include many queens and may contain thousands of workers. Ant nests might get onto transported items in large numbers as

			stowaways. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
2.5b. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**likely**	**high**	Once sealed in a newly-founded nest, a queen is able to survive 13 to 95 days on her own reserves, i.e. much monger than before nest establishment (Markin et al. 1972; Porter 1988). This is sufficient to survive longer trips within Europe. Likelihood of survival is high, nevertheless will decrease with increasing travel duration. Multiplication of a colony during spread within the EU cannot be ruled out, but is rather unlikely.
2.6b. How likely is the organism to survive existing management practices during spread?	**likely**	**high**	Most potential commodities that can carry ants or nests are not managed.
2.7b How likely is the organism to spread in Europe undetected?	**likely**	**high**	Fully developed nests are quite visible. In contrast, newly-founded nests with few queen(s) and workers can easily travel undetected in most potential transported items.
2.8b. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**very likely**	**high**	Several of the potential commodities and items in which nests can hide can be transported to suitable outdoor habitats since the ant particularly likes disturbed soils, which are found everywhere, specifically in urban and semi-urban habitats.
2.9b. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**very likely**	**high**	Given the high numbers and types of commodities and items that can be associated with *S. invicta*, this pathway can be considered as having a high likelihood of spread within the EU.
Pathway name:	c) Unaided (Natural dispersal)		
2.3c. Is spread along this pathway intentional (e.g. the organism is released at distant localities) or unintentional (the organism is a contaminant of imported goods)?	**unintentional**	**very high**	
2.4c. How likely is it that large numbers of the organism will spread along this pathway from the point(s) of origin	**moderately likely**	**medium**	Spread by nuptial flights can occur throughout the year in subtropical climates, and likely will be

over the course of one year?			restricted to the summer months in the risk assessment area; it will include small numbers of alates, while budding usually includes a larger number of queens and workers. Colonies can also spread through flood water (Hung and Vinson 1978). The species can also spread from indoor establishments. The likelihood of reinvasion after eradication is identical to the likelihood of introduction in the first place.
2.5c. How likely is the organism to survive during passage along the pathway (excluding management practices that would kill the organism)? Subnote: In your comment consider whether the organism could multiply along the pathway.	**very likely**	**very high**	Likelihood of survival during unaided spread is high. Alate ants do not multiply during spread but budding colonies do.
2.6c. How likely is the organism to survive existing management practices during spread?	**very likely**	**very high**	Management practices during unaided spread are not currently in place.
2.7c. How likely is the organism to spread in Europe undetected?	**moderately likely**	**high**	Low ant densities (e.g. single queens, small newly-founded nests) often remain undetected for longer periods. However, spread will mainly occur from well-established nests, which be noticeable and spread will be detected earlier.
2.8c. How likely is the organism to be able to transfer to a suitable habitat or host during spread?	**likely**	**very high**	Queen ants can fly or be taken by the wind up to 16 km, (Hung and Vinson 1978) and will likely find suitable habitats (e.g. humid or irrigated habitats).
2.9c. Estimate the overall likelihood of spread into or within the Union based on this pathway?	**very likely**	**very high**	*Solenopsis invicta* will spread unaided to all suitable habitats within its suitable climatic range. Alate females can fly up to 16 km and colonies can also be occasionally transported by water flood. However, as with most invasive insects, long distance spread will be more often due to accidental transportations by humans. There are a number of intrinsic and extrinsic

			factors that influence spread including availability of disturbed habitats and morphology of the queens (King and Tschinkel 2006).
End of pathway assessment, repeat as necessary.			
2.10. Within Europe, how difficult would it be to contain the organism?	**very difficult**	**medium**	It will probably be very difficult to contain the species by human means. Its spread will be constrained by climate and habitat suitability. If *S. invicta* become established in a European region, quarantine measures could be put in place to restrict the risk of long-distance spread, e.g. through nursery stock, as in USA (USDA 2015).
2.11. Based on the answers to questions on the potential for establishment and spread in Europe, define the area endangered by the organism.	Establishment and spread in the Mediterranean region is likely, at least in humid and irrigated habitats. Beyond that, establishment in the Macaronesian region is also likely.	**high**	See Ch2 and Ch5 of the Chapeau and Q1.13.
2.12. What proportion (%) of the area/habitat suitable for establishment (i.e. those parts of Europe were the species could establish), if any, has already been colonised by the organism?	**0-10**	**very high**	The species is not yet established in Europe.
2.13. What proportion (%) of the area/habitat suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	**0-10**	**high**	Even if it arrives in the next years it will probably not spread very fast, based on previous experiences in invaded areas. For example, Hung and Vinson (1978) measured that *S. invicta* has spread by 48 km /year in Texas between 1957 to 1977. However, Texas is eco-climatically more suitable than Europe (Sutherst and Maywald 2005), which surely influences spread potential.
2.14. What other timeframe (in years) would be	**40**	**low**	According to Bertelsmeier et al. (2015), under

appropriate to estimate any significant further spread of the organism in Europe? (Please comment on why this timeframe is chosen.)			predicted climate change in 2080, the proportion of suitable area for establishment will increase, but still not exceed 10% of the area in Europe. Repeated introductions into Europe via different pathways and without management in place increases likelihood of entry, but is highly unpredictable. A significant further spread might occur in the decades to come, but is highly uncertain.
2.15. In this timeframe what proportion (%) of the endangered area/habitat (including any currently occupied areas/habitats) is likely to have been invaded by this organism?	**0-10**	**low**	The species probably will not spread very widely in the EU and remain restricted to climatically preferred habitats in the Mediterranean region.
2.16. Estimate the overall potential for spread in relevant biogeographical regions under current conditions for this organism in Europe (using the comment box to indicate any key issues).	**moderately**	**medium**	Based on observations in North America and the lower ecoclimatic suitability in Europe (see Q1.13), we can estimate that it will spread to all potentially infested biogeographical regions, but possibly slower than in North America. Its spread will occur mainly through human transport but its distribution will be indirectly constrained by climate and habitat suitability.
2.17. Estimate the overall potential for spread in relevant biogeographical regions in foreseeable climate change conditions	**likely**	**low**	Climate change will not increase the potential or rapidity of spread directly, but may facilitate population growth with subsequently increasing potential for spread and widen the distribution range.

MAGNITUDE OF IMPACT

Important instructions:

- Questions 2.18-2.22 relate to environmental impact, 2.23-2.25 to impacts on ecosystem services, 2.26-2.30 to economic impact, 2.31-2.32 to social and human health impact, and 2.33-2.36 to other impacts. These impacts can be interlinked, for example a disease may cause impacts on biodiversity and/or ecosystem functioning that leads to impacts on ecosystem services and finally economic impacts. In such cases the assessor should try to note the different impacts where most appropriate, cross-referencing between questions when needed.
- Each set of questions above starts with the impact elsewhere in the world, then considers impacts in Europe separating known impacts to date (i.e. past and current impacts) from potential future impacts (including foreseeable climate change).
- Assessors are requested to use and cite original, primary references as far as possible.

QUESTION	RESPONSE	CONFIDENCE	COMMENTS
Biodiversity and ecosystem impacts			
2.18. How important is impact of the organism on biodiversity at all levels of organisation caused by the organism in its non-native range excluding the Union?	**major**	**high**	*Solenopsis invicta* is considered by the International Union for Conservation of Nature (IUCN) one of the "World's 100 worst" invasive alien species (Lowe et al. 2004). It is also the most studied invasive insect for its environmental impact, accounting, until 2007, for 18% of all primary research publications in this field (Kenis et al. 2009). Wang et al. (2013) provide an extensive review of studies on the environmental impact of the ant since its invasion in China. Environmental impacts caused by the ant in the invaded ranged excluding the Union are multiple: -<u>Impact on fauna</u>: In southern North America, it threatens several arthropods, molluscs, reptiles, birds, amphibians and mammals by direct predation, competition or stinging (see review by Holway et al. (2002) and more recent studies such as King and Tschinkel (2008); Allen et al. (2016)). In particular, it

			has been shown to displace or reduce populations of native and invasive ants (including the Argentine ant) (McGlynn 1999; Holway et al. 2002; King and Tschinkel 2008). It also attacks beneficial insects such as parasitoids and predators (Eubanks et al. 2002; Ness 2003). It must be noted, however, that data on direct effects on long term population declines of animals are largely lacking, even for impact on native ants. *Solenopsis invicta* mainly occupies niches in highly disturbed habitats and, in such situations, it is difficult to distinguish between the effects of disturbance and the effects of *S. invicta* on other ants (King and Tschinkel 2006). The native fauna is also indirectly affected through the intensive use of pesticides needed to control the pest (e.g. Mokkarala 2002). -Impact on plants: the impact on wild plants has been less studied than that on animals or cultivated plants. However, the flora can also be affected through various mechanisms, such as changes in soil properties (Lafleur et al. 2005), predation or tending of plant pests, direct seed predation and competition with native ant dispersers (Ness and Bronstein 2004). However, *S. invicta* may also facilitate seed dispersal (Stuble et al. 2010). -Alteration of ecosystem functions: Nest building and foraging activities of *S. invicta*, affect physical and chemical soil properties and strongly enhances plant growth through the increase of $NH4^{+}$ (Lafleur et al. 2005). It also affects mutualistic interactions between plants and insects by reducing numbers of plant mutualists that protect the plant or disperse plant seeds (Ness and Bronstein 2004). It is likely that impact on ecosystem functions may be locally major and similar

			to that observed in presently invaded areas elsewhere.
2.19. How important is the impact of the organism on biodiversity at all levels of organisation (e.g. decline in native species, changes in native species communities, hybridisation) currently in the different biogeographical regions or marine sub-regions where the species has established in Europe (include any past impact in your response)?	N/A		Because the species is not present in Europe, there is no current impact on biodiversity and related ecosystem services.
2.20. How important is the impact of the organism on biodiversity at all levels of organisation likely to be in the future in the different biogeographical regions or marine sub-regions where the species can establish in Europe?	**major**	**medium**	It is likely that, if *S. invicta* establishes and spreads in the Mediterranean region, the impact on native biodiversity, in particular on arthropods, molluscs and small vertebrates may be locally major and similar to that observed in presently invaded areas elsewhere.
2.21. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism currently in Europe?	N/A		Because the species is not present in Europe, there is no current impact on the conservation value of native species or habitats.
2.22. How important is decline in conservation value with regard to European and national nature conservation legislation caused by the organism likely to be in the future in Europe?	**moderate**	**Low**	Although *S. invicta* can inhabit a wide range of habitats, in invaded regions it particularly dominates highly disturbed habitats, such as forests edge, newly deforested areas, road sides, agricultural areas included irrigated soils, gardens, etc. (Morrison et al 2004; Ness and Bronstein 2004). Therefore, many natural habitats of high conservation value may not be threatened by the ant. However, some open natural habitats in the Mediterranean region may well be suitable, in particular those with permanent water supply.
Ecosystem Services impacts			
2.23 How important is the impact of the organism on provisioning, regulating, and cultural services in its non-native range excluding the Union?	**major**	**High**	<u>Provisioning-Nutrition</u>: *S. invicta* damages cultivated field crops by feeding on the seeds, seedlings and developing fruit (see Qu. 2.18). It also negatively affects cattle farming (Teal et al. 1999). <u>Regulating-Seed dispersal</u>: *S. invita* may interfere with seed dispersal of native ant species and directly predate (and therefore reduce) amount of seeds. However, *S. invicta* may also facilitate seed dispersal (Stuble et al.

			2010). Regulating-Pest and disease Control: *S. invicta* may interfere with beneficial insects that exert biocontrol activities in modified habitats. Cultural-Physical use of landscapes: *S. invicta* is a social nuisance in infested areas. Public areas such as parks and recreational areas may become unsafe for children and people have modified their behaviour to avoid the nuisance (Schinkel 2006).
2.24. How important is the impact of the organism on provisioning, regulating, and cultural services currently in the different biogeographic regions or marine sub-regions where the species has established in Europe (include any past impact in your response)?	**N/A**		Because the species is not present in Europe, there is no current impact on ecosystem services.
2.25. How important is the impact of the organism on provisioning, regulating, and cultural services likely to be in the different biogeographic regions or marine sub-regions where the species can establish in Europe in the future?	**major**	**medium**	It is likely that, if *S. invicta* finds suitable habitats and climates for its development in the Mediterranean region, the impact on ecosystem services may be locally major and similar to that observed in presently invaded areas. But its extent is very difficult to estimate considering the uncertainty related to habitat/climatic suitability.
Economic impacts			
2.26. How great is the overall economic cost caused by the organism within its current area of distribution, including both costs of damage and the cost of current management	**massive**	**High**	Various estimates of economic costs due to *S. invicta* in USA have been published, which range from half a billion to several billion dollars per year (Pimentel et al. 2000, Williams et al. 2001, Morrison et al. 2004). Some more specific accounts exist for regions and impact categories. For example, as cited in CABI (2017): "In 1998, the average household cost for imported fire ant problems per Texas household in urban areas was US $150.79, with US $9.40 spent on medical care. The total annual metroplex (Austin, Dallas, Ft. Worth, Houston and San Antonio) expenditures for medical care costs

			was 9% or US $47.1 million of the US $526 million total expenditure cost due to *S. invicta* (Lard et al. 2002)". In Australia, the Australian Bureau of Agriculture Resources Economics has calculated that costs due to *S. invicta* in rural industries have amounted to more than AU$ 6.7 billion over 30 years (ISSG 2017). Other regions have made estimations for potential economic costs in case of *S. invicta* invasion. For Hawaii, it was estimated that the impact on various economic sectors would be around US $211 million per year (Gutrich et al. 2007). Economic costs in invaded areas are mainly related to three impact categories: -<u>Impact on agriculture</u>: *S. invicta* can directly damage crops such as corn, sorghum, okra, potatoes and sunflowers by feeding on the seeds, seedlings and developing fruit (Stewart and Vinson 1991; CABI 2017). The impact may also be indirect through the tending of homopteran pests (aphids, scale insects, etc.), which they protect against natural enemies to collect honeydew. However, it must be noted that *S. invicta* also preys on plant pests and may provide benefits to crops. The ant also affects livestock by stinging particularly very young, old or confined animals. The ants move to moist areas of the body (eyes, genitals), the yolk of hatching birds and wounds, and begin stinging when disturbed. The stings result in injury such as blindness, swelling or death (CABI 2017). Finally, the ant can also affect the agriculture sector by

			stinging workers in the field and affecting agricultural equipment (see below). -<u>Health impacts</u>: *S. invicta* can sting people and may cause an allergic reaction that requires medical care and, sometimes, causes anaphylaxis. See social impact below for a description of the medical issue in south-eastern USA. -<u>Impacts on infrastructure and equipment</u>: Ants and their mounds damage roads and electrical equipment. Also domestic electrical equipment may be damaged such as computers, swimming pool pumps, cars or washing machines. Colonies move into buildings or vehicles seeking favourable nesting sites, particularly during flooding and very hot, dry conditions. Fire ant foraging and nesting activities can result in the failure of many types of mechanical (such as hay harvesting machinery and sprinkler systems) and electrical equipment (including air conditioner units and traffic box switching mechanisms) (CABI 2017).
2.27. How great is the economic cost of damage* of the organism currently in the Union (include any past costs in your response)? *i.e. excluding costs of management	N/A		Because the species is not present in Europe, there is no current cost of damage.
2.28. How great is the economic cost of damage* of the organism likely to be in the future in the Union? *i.e. excluding costs of management	**major**	**medium**	It is likely that, if *S. invicta* establish and spread in the Mediterranean region, the economic impact may be locally major and similar to that observed in presently invaded areas elsewhere. In the risk assessment for the Netherlands, Noordwijk (2010) also mentions potential ‘indirect’ effects caused by probable import restrictions if fire ants become established indoors in the Netherlands. Many countries,

			including the countries in the Mediterranean region, are susceptible for fire ants establishments. These countries will have strict regulations on imports of certain goods from infested countries. If the Netherlands harbours fire ants, this will have serious consequences on plant (material) export trade in Europe and worldwide.
2.29. How great are the economic costs associated with managing this organism currently in the Union (include any past costs in your response)?	N/A		Because the species is not present in Europe, there is no current cost of management.
2.30. How great are the economic costs associated with managing this organism likely to be in the future in the Union?	**major**	**medium**	It is likely that, if *S. invicta* establishes and spreads in the Mediterranean region, the management costs may be locally major, and similar to that observed in presently invaded areas elsewhere.
Social and human health impacts			
2.31. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism for the Union and for third countries, if relevant (e.g. with similar eco-climatic conditions).	**major**	**high**	*Solenopsis invicta* is a social nuisance in infested areas. Public areas such as parks and recreational areas may become unsafe for children and people have modified their behaviour to avoid the nuisance (CABI 2017). Ants also enter buildings, destroying various domestic equipment. *Solenopsis invicta* significantly affects human health. In south-eastern USA, an estimated 14 million people are stung annually (CABI 2017). A survey in Texas showed that 79% of inhabitants have been stung by the ant in the year of the survey (Drees 2000). While, for most people, the effect of stings is relatively minor, albeit painful, some people are hypersensitive to a protein contained in the venom and, for them, a sting can lead to an anaphylactic shock. Anaphylaxis occurs in 0.6 to 6% of persons who are stung and can be lethal. Several deaths are reported each year in south-eastern USA (deShazo et al. 1999). A survey in South Carolina showed that 0.94% of the people seek medical attention for *S. invicta* stings and 0.02% are treated for

			anaphylaxis (Caldwell et al. 1999).
2.32. How important is social, human health or other impact (not directly included in any earlier categories) caused by the organism in the future for the Union.	**major**	**medium**	It is likely that, if *S. invicta* establish and spread in the Mediterranean region, the social impact, including health impact, may be locally major, and similar to that observed in presently invaded areas elsewhere.
Other impacts			
2.33. How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	**minimal**	**medium**	*Solenopsis invicta* is not known for being used as food or feed, being a host or vector of other damaging organisms.
2.34. How important might other impacts not already covered by previous questions be resulting from introduction of the organism? (specify in the comment box).	**N/A**		No other impacts were found.
2.35. How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Europe?	**major**	**medium**	There are no specific natural enemies of *Solenopsis* spp. in Europe. Thus, only generalist natural enemies of ants may affect the ant and these are highly unlikely to regulate (control) populations.
2.36. Indicate any parts of Europe where any of the above impacts are particularly likely to occur (provide as much detail as possible).	Mediterranean region, but see comments.	**low**	The species has a major to massive environmental, economic and social impacts elsewhere in the world. However, the transferability to Europe is hindered by uncertain data on habitat/climatic suitability that may limit the geographic area that is most favourable to the insect. Similar impacts may occur locally in Southern Europe in favourable environments, where humidity is adequate, e.g. in direct contact with permanent water bodies and in irrigated areas.

ADDITIONAL QUESTIONS - CLIMATE CHANGE			
3.1. What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	increase of temperatures, changes in rainfall pattern	**low**	In their study on ant invasions under climate change, Bertelsmeier et al. (2015) predicts that the potential distribution of *S. invicta* will increase in all regions, including in Europe.
3.2. What is the likely timeframe for such changes?	50 years	**low**	
3.3. What aspects of the risk assessment are most likely to change as a result of climate change?	distribution range, likelihood of establishment	**low**	Establishment potential may be enhanced by climate change, i.e. more areas in Europe will be suitable for *S. invicta* invasion (Beltelsmeier et al. 2014) and, indirectly, if more areas are suitable for the ant, the magnitude of impact at continental and regional level will increase.
ADDITIONAL QUESTIONS - RESEARCH			
4.1. If there is any research that would significantly strengthen confidence in the risk assessment please summarise this here.	**yes**	**very high**	The main uncertainty in this risk assessment is the availability of suitable habitats and the tolerance and adaptability of *S. invicta* to current and foreseeable European climate. There is little doubt that the species is able to establish and spread in some areas in the Mediterranean region, but it is unclear if impact will remain at the local levels or if the species has the potential to multiply and colonize larger territories in the EU.

REFERENCES

Adams BJ, Hooper-Bui LM, Strecker RM, O`Brien DM (2011) Raft Formation by the Red Imported Fire Ant, *Solenopsis invicta*. Journalof Insect Science 11: 17.

Allen CR, Birge HE, Slater J, Wiggers E (2017) The invasive ant, *Solenopsis invicta*, reduces herpetofauna richness and abundance. Biological Invasion 19: 713-722.

Bertelsmeier C, Luque GM, Hoffmann BD, Courchamp F (2015) Worldwide ant invasions under climate change. Biodiversity & Conservation 24: 117-128.

Boer P, Vierbergen G (2008) Exotic ants in The Netherlands (Hymenoptera: Formicidae). Entomologische Berichten, Amsterdam 68: 121-129.

CABI (2017) *Solenopsis invicta* [original text updated by D Gunawardana]. In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

Caldwell ST, Schuman SH, Simpson WM Jr. (1999) Fire ants: a continuing community health threat in South Carolina. Journal of the South Carolina Medical Association 95: 231-235.

Charpentier, LJ, McCormick WJ, R. Mathes (1967) Beneficial arthropods inhabiting sugarcane fields and their effects on borer infestations. Sugar Bulletin 45: 276-277.

Chen JSC, Shen C-H, Lee H-J (2006) Monogynous and polygynous Red imported fire ants, *Solenopsis invicta* Buren (Hymenoptera: Formicidae), in Taiwan. Environmental Entomology 35: 167-172

Christian S (2009) Red imported fire ant eradicated from Napier. Biosecurity 92: 28-29.

deShazo RD, Williams DF, Moak ES (1999) Fire ant attacks on residents in health care facilities: a report of two cases. Annals of Internal Medicine 131: 424-429.

Drees BM (2000) The Scripps Howard Texas Poll: Fire Ants in Texas. Fire Ant Trails, 3(5), Texas Cooperative Extension, College Station,Texas, USA. http://fireant.tamu.edu/materials/newsletters/fatrails3.005.htm#scripps.

Eubanks MD, Blackwell SA, Parrish CJ, Delamar ZD, Hull-Sanders H (2002) Intraguild predation of beneficial arthropods by red imported fire ants in cotton. Environmental Entomology 31:1168–1174

Folgarait PJ (1998) Ant biodiversity and its relationship to ecosystem functioning: a review. Biodiversity and Conservation 7: 1221–1244.

Gutrich JJ, VanGelder E, Loope L (2007) Potential economic impact of introduction and spread of the red imported fire ant, *Solenopsis invicta*, in Hawaii. Environmental science & policy 10: 685-696.

Harris, (undated) Invasive ant pest risk assessment project: Preliminary risk assessment. Biosecurity New Zealand

Hee JJ, Holway DA, Suarez AV, Case TJ (2000) Role of propagule size in the success of incipient colonies of the invasive Argentine ant. Conservation Biology 14: 559–563

Holway DA, Lach L, Suarez A, Tsutsui N, Case TJ (2002) The causes and consequences of ant invasions. Annual Review of Ecology and Systematics 33: 181–233

Hung AC, Vinson SB (1978) Factors affecting the distribution of fire ants in Texas (Myrmicinae: Formicidae). The Southwestern Naturalist, 205-213.

Kenis M, Auger-Rozenberg M-A, Roques A, Timms L, Péré C, Cock MJW, Settele J, Augustin S and Lopez-Vaamonde C (2009) Ecological effects of invasive alien insects. Biological Invasions 11, 21-45.

King JR, Tschinkel WR (2006) Experimental evidence that the introduced fire ant, *Solenopsis invicta*, does not competitively suppress co-occurring ants in a disturbed habitat. Journal of Animal Ecology 75:1370–1378

Lafleur B, Hooper-Bu` LM, Mumma EP, Geaghan JP (2005) Soil fertility and plant growth in soils from pine forests and plantations: effect of invasive red imported fire ants *Solenopsis invicta* (Buren). Pedobiologia 49:415–423

Lard C, Willis DB, Salin V, Robinson S (2002) Economic assessments of red imported fire ant in Texas' urban and agricultural sectors. In: Drees BM, ed. Program Highlights of the Texas Imported Fire Ant Research and Management Project. Southwestern Entomologist Supplement 25: 123-137.

MAF Biosecurity (2002) Hazard identification and import release assessment: The introduction of red imported fire ants into New Zealand via the importation of goods and arrival of craft from Australia, the Caribbean, South America, and the USA. Biosecurity Authority Ministry of Agriculture and Forestry Wellington New Zealand

Mokkarala, P (2002) Effects of red imported fire ant baits on some non-target ants. Master's thesis, Texas A&M University. Available electronically from http : / /hdl .handle .net /1969 .1 /ETD -TAMU -2002 -THESIS -M65.

Markin GP, Collins H, Dillier JH (1972). Colony founding by queens of the Red imported fire ant, *Solenopsis invicta*. Annals of the Entomological Society of America 65: 1053-1058

Markin GP, Dillier JH, Collins HL (1973) Growth and development of colonies of the red imported fire ant, *Solenopsis invicta*. Annals of the Entomological Society of America 66: 803-808.

Martins C, de Souza RF, Bueno OC (2014) Molecular characterization of fire ants, *Solenopsis* spp., from Brazil based on analysis of mtDNA gene cytochrome oxidase I. Journal of Insect Science 14: 50.

McGlynn TP (1999) The worldwide transfer of ants: geographical distribution and ecological invasions. Journal of Biogeography 26: 535-548.

Morril WL (1977) Red imported fire ant foraging in a greenhouse. Environmental Entomology 6: 416- 418.

Morrison LW, Porteer SD, Daniels E, Korzukhin MD (2004) Potential global range expansion of the invasive fire ant, *Solenopsis invicta*. Biological Invasions 6:183-191.

Nattrass R, Vanderwoude c (2001) A preliminary investigation of the ecological effects of Red Imported Fire Ants (*Solenopsis invicta*) in Brisbane. Ecological Management and Restoration 2: 220-223.

Ness JH (2003) Contrasting exotic *Solenopsis invicta* and native *Forelius pruinosus* ants as mutualists with *Catalpa bignonioides*, a native plant. Ecological Entomology 28:247–251

Ness JH, Bronstein JL (2004) The effects of invasive ants on prospective ant mutualists. Biological Invasions 6: 445-461.

Noordijk J (2010) A risk analysis for the fire ants in the Netherlands. Stichting European Invertebrate Survey, Leiden, the Netherlands.

Pimentel D, Lach L, Zuniga R, Morrison D (2000) Environmental and economic costs of nonindigenous species in the United States. BioScience 50: 53-64.

Porter SD (1988) Impact of temperature on the colony growth and development rates of the ant, *Solenopsis invicta*. Journal of Insect Physiology 334: 1127-1133.

Porter SD, Tschinkel WR (1987) Foraging in *Solenopsis invicta* (Hymenoptera: Formicidae): effects of weather and season. Environmental Entomology 16: 802-808.

Ross KG, Shoemaker DD (2005) Species delimitation in native South American fire ants. Molecular Ecology 14: 3419-3438.

Ross KG, Vander Meer RK, Fletcher DJC, Vargo EL (1987) Biochemical phenotypic and genetic studies of two introduced fire ants and their hybrid (Hymenoptera: Formicidae). Evolution 41: 280 –293.

Rossi, MN, Fowler HG (2002) Manipulation of fire ant density, *Solenopsis* spp., for short term reduction of *Diatraea saccharalis* larval densities in Brazil. Sci. agric. (Piracicaba, Braz.) 59: 389-392.

Stuble KL, Kirkman LK, Carroll CR (2010) Are red imported fire ants facilitators of native seed dispersal? Biological invasions 12: 1661-1669.
Stewart JW, Vinson SB (1991) Red imported fire ant damage to commercial cucumber and sunflower plants. Southwestern Entomologist 16: 168-1760.
Sutherst RW, Maywald G (2005) A climate model of the red imported fire ant, Solenopsis invicta Buren (Hymenoptera: Formicidae): implications for invasion of new regions, particularly Oceania. Environmental Entomology: 34: 317-335.
Taber SW (2000) Fire Ants. College Station, Texas: Texas A&M University Press.
Teal S, Segarra E, Barr C, Drees B, 1999. The cost of red imported fire ant infestation: The case of the Texas cattle industry. Texas Journal of Agriculture and Natural Resources 12: 88-97.
Trager JC (1991) A revision of the fire ants, Solenopsis geminata group (Hymenoptera: Formicidae, Myrmicinae). Journal of the New York Entomological Society 99: 141-197.
Tschinkel WR (1988) Colony growth and the ontogeny of worker polymorphism in the fire ant, *Solenopsis invicta*. Behavioral Ecology and Sociobiology 22: 103-115.
Tschinkel WR (2006) The fire ants. Harvard University Press, Cambridge.
USDA (2015) Imported fire ant: quarantine treatments for nursery stock, grass sod, and related materials. Program Aid No. 1904, updated January 2015. USDA, Animal and Plant Health Inspection Service.
Vinson SB (1997) Invasion of the red imported fire ant (Hymenoptera: Formicidae): spread, biology, and impact. American Entomologist: 43:23-39;
Wang L, Lu YY, Xu YJ, Zeng L (2013) The current status of research on *Solenopsis invicta* Buren (Hymenoptera: Formicidae) in Mainland China. Asian Myrmecology 5: 125-138.
Ward D (2009) The potential distribution of the red imported fire ant, Solenopsis invicta Buren (Hymenoptera: Formicidae), in New Zealand. New Zealand Entomologist 32: 67-75
Wetterer JK (2013) Exotic spread of *Solenopsis invicta* (Hymenoptera: Formicidae) beyond North America. Sociobiology 60: 50-55.
Wetterer JK. Moore JA (2005) Red imported fire ants (Hymenoptera: Formicidae) at gopher tortoise (Testudines: Testudinidae) burrows. Florida Entomologist 88: 349-354
Williams DF, Collins HL, Oi DH (2001) The red imported fire ant (Hymenoptera: Formicidae): an historical perspective of treatment programs and the development of chemical baits for control. American Entomologist 47:146-159.
Zhang R, Li Y, Liu N, Porter SD (2007) An overview of the Red imported fire ant (Hymenoptera: Formicidae) in mainland China. Florida Entomologist 90: 723-731.

ANNEX I - Scoring of Likelihoods of Events

(taken from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	**Description**	**Frequency**
Very unlikely	This sort of event is theoretically possible, but is never known to have occurred and is not expected to occur	1 in 10,000 years
Unlikely	This sort of event has not occurred anywhere in living memory	1 in 1,000 years
Possible	This sort of event has occurred somewhere at least once in recent years, but not locally	1 in 100 years
Likely	This sort of event has happened on several occasions elsewhere, or on at least one occasion locally in recent years	1 in 10 years
Very likely	This sort of event happens continually and would be expected to occur	Once a year

ANNEX II - Scoring of Magnitude of Impacts

(modified from UK Non-native Organism Risk Assessment Scheme User Manual, Version 3.3, 28.02.2005)

Score	**Biodiversity and ecosystem impact**	**Ecosystem Services impact**	**Economic impact (Monetary loss and response costs per year)**	**Social and human health impact**
	Question 2.18-22	*Question 2.23-25*	*Question 2.26-30*	*Question 2.31-32*
Minimal	Local, short-term population loss, no significant ecosystem effect	No services affected[1]	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Some ecosystem impact, reversible changes, localised	Local and temporary, reversible effects to one or few services	10,000-100,000 Euro	Significant concern expressed at local level. Mild short-term reversible effects to identifiable groups, localised.
Moderate	Measureable long-term damage to populations and ecosystem, but little spread, no extinction	Measureable, temporary, local and reversible effects on one or several services	100,000-1,000,000 Euro	Temporary changes to normal activities at local level. Minor irreversible effects and/or larger numbers covered by reversible effects, localised.
Major	Long-term irreversible ecosystem change, spreading beyond local area	Local and irreversible or widespread and reversible effects on one / several services	1,000,000-10,000,000 Euro	Some permanent change of activity locally, concern expressed over wider area. Significant irreversible effects locally or reversible effects over large area.
Massive	Widespread, long-term population loss or extinction, affecting several species with serious ecosystem effects	Widespread and irreversible effects on one / several services	Above 10,000,000 Euro	Long-term social change, significant loss of employment, migration from affected area. Widespread, severe, long-term, irreversible health effects.

[1] Not to be confused with „no impact“.

ANNEX III - Scoring of Confidence Levels

(modified from Bacher et al. 2017)

Confidence level	**Description**
Low	There is no direct observational evidence to support the assessment, e.g. only inferred data have been used as supporting evidence *and/or* Impacts are recorded at a spatial scale which is unlikely to be relevant to the assessment area *and/or* Evidence is poor and difficult to interpret, e.g. because it is strongly ambiguous *and/or* The information sources are considered to be of low quality or contain information that is unreliable.
Medium	There is some direct observational evidence to support the assessment, but some information is inferred *and/or* Impacts are recorded at a small spatial scale, but rescaling of the data to relevant scales of the assessment area is considered reliable, or to embrace little uncertainty *and/or* The interpretation of the data is to some extent ambiguous or contradictory.
High	There is direct relevant observational evidence to support the assessment (including causality) *and* Impacts are recorded at a comparable scale *and/or* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and/or* Data/information are not controversial or contradictory.
Very high	There is direct relevant observational evidence to support the assessment (including causality) from the risk assessment area *and* Impacts are recorded at a comparable scale *and* There are reliable/good quality data sources on impacts of the taxa *and* The interpretation of data/information is straightforward *and* Data/information are not controversial or contradictory.

ANNEX IV - Species Distribution Models

The following climate models have been considered in the risk assessment. See Q. 1.13. for explanations.

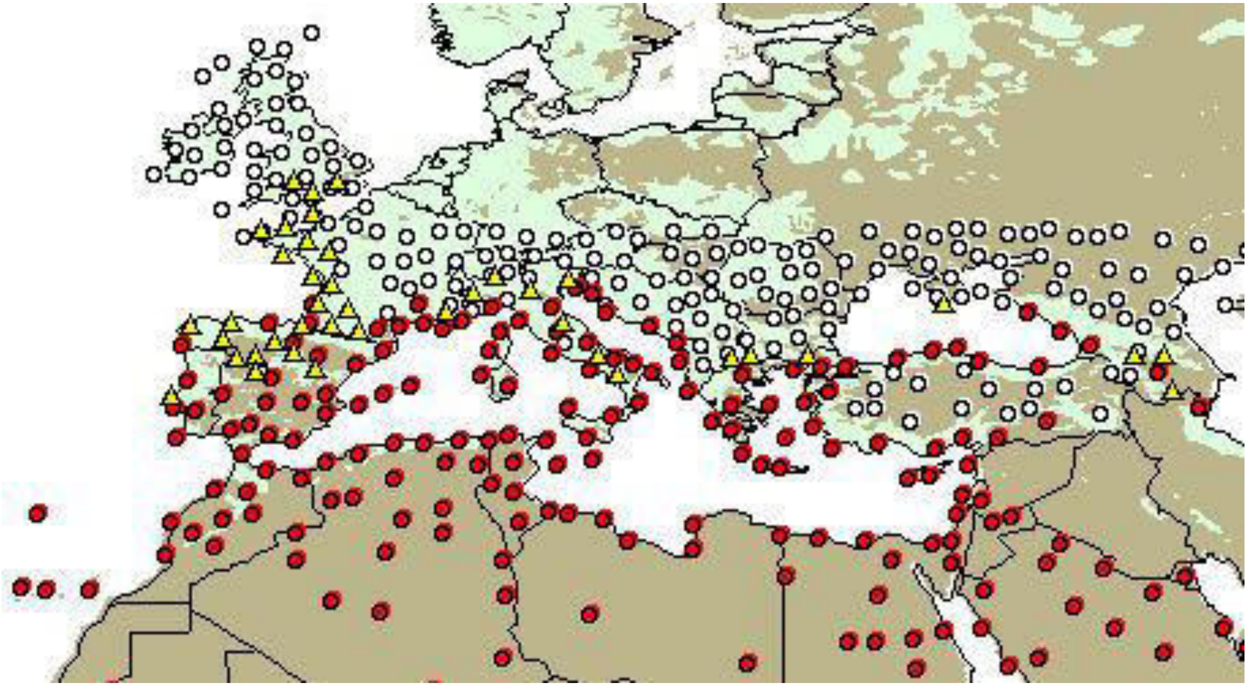

Fig. A1. Potential range of *Solenopsis invicta* in Europe, the Middle East and North Africa from Morrison et al. (2004). Symbols represent potential reproduction: full circle: certain; triangle: possible; empty circle: unlikely. Background represents precipitation: green: adequate; brown: inadequate.

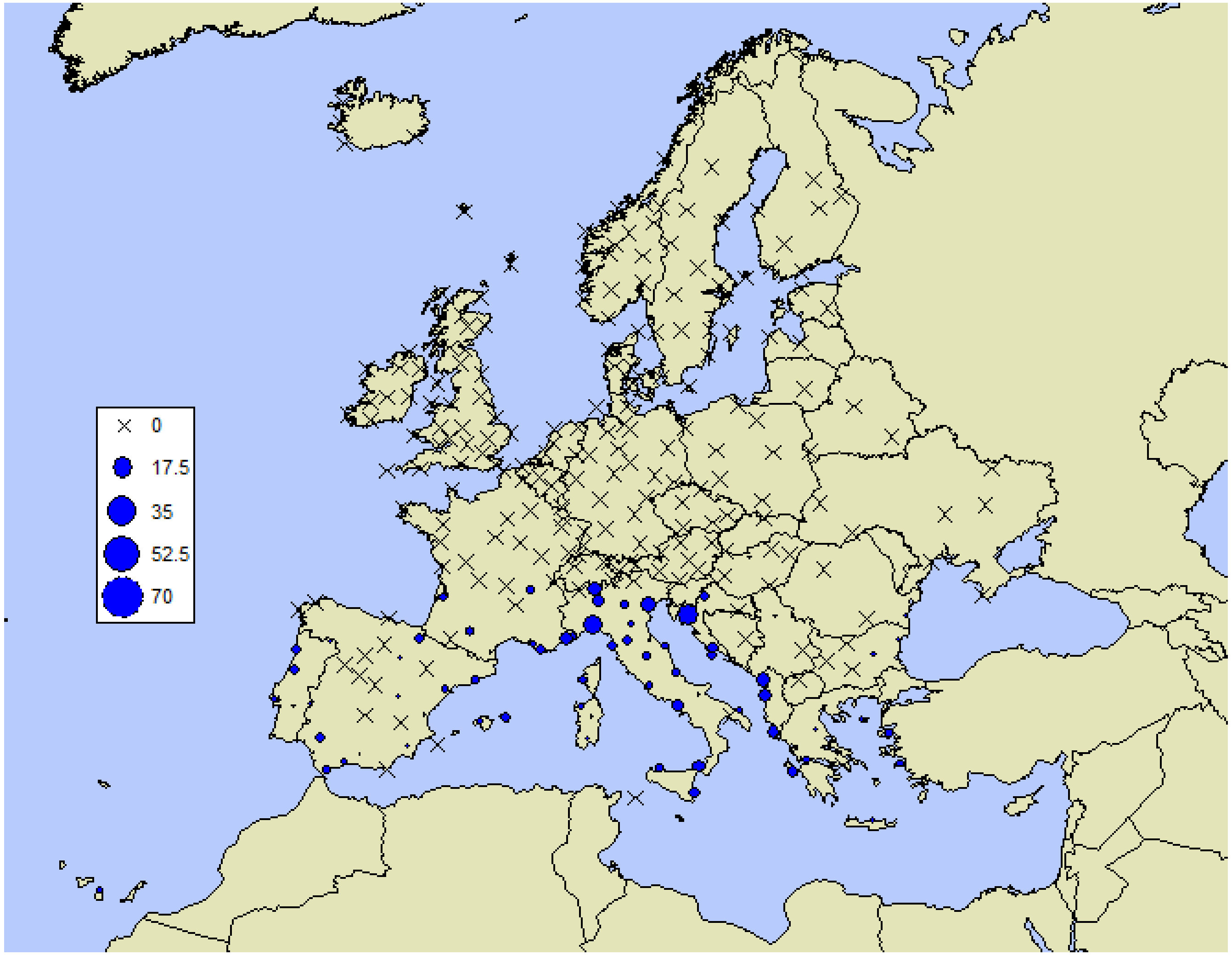

Fig. A2. Ecoclimatic index (EI) for *Solenopsis invicta* using the original CLIMEX parameters from Sutherst and Maywald (2005). Note the differences with the modified version included in the CLIMEX software version 4 (Kriticos et al 2015) shown in Fig. A3.

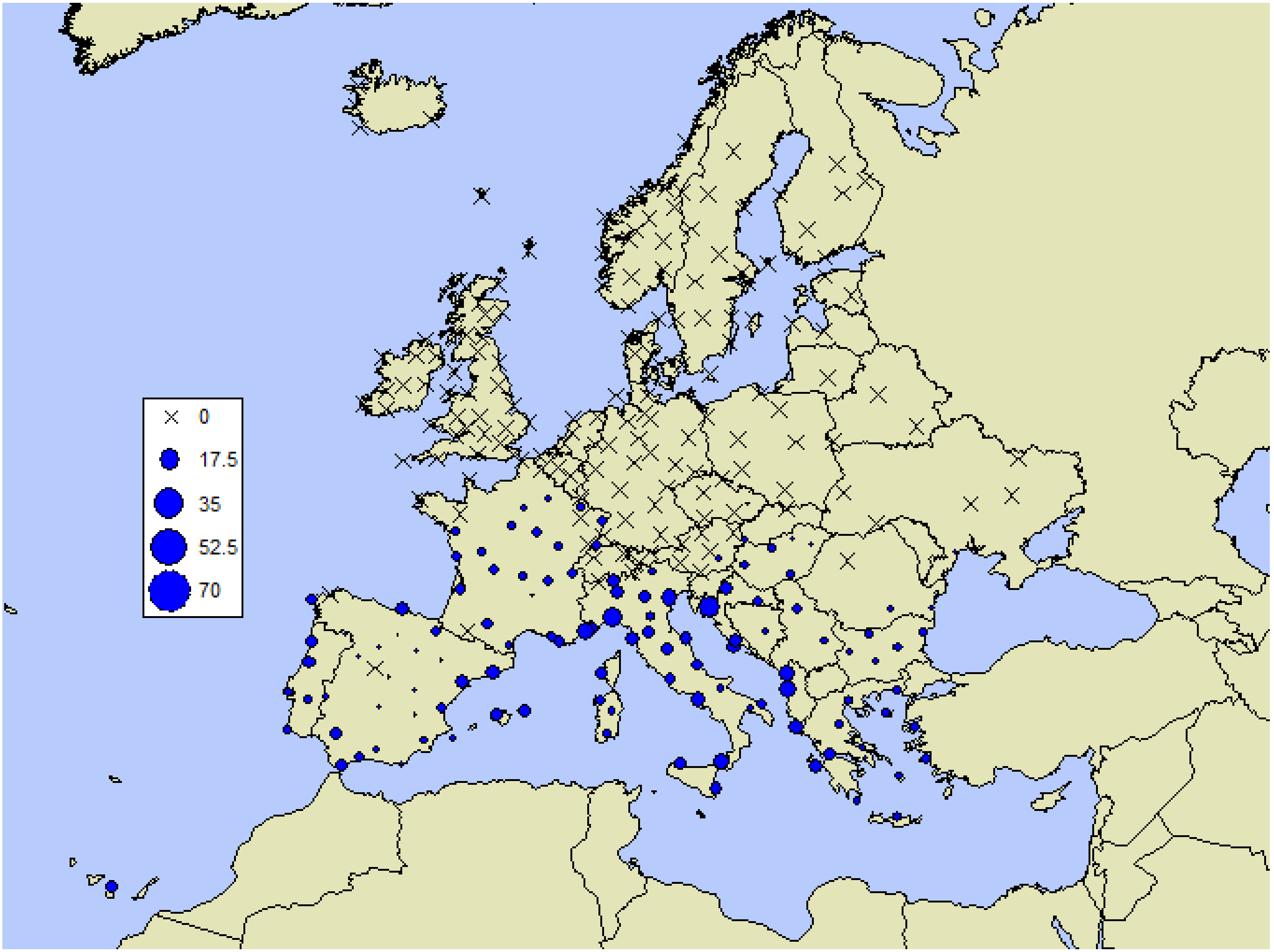

Fig. A3. Ecoclimatic index for *Solenopsis invicta* using CLIMEX parameters from the *S. invicta* parameters included in the CLIMEX software version 4 (Kriticos et al 2015), modified from Sutherst and Maywald (2005). Note differences with Fig. A2.

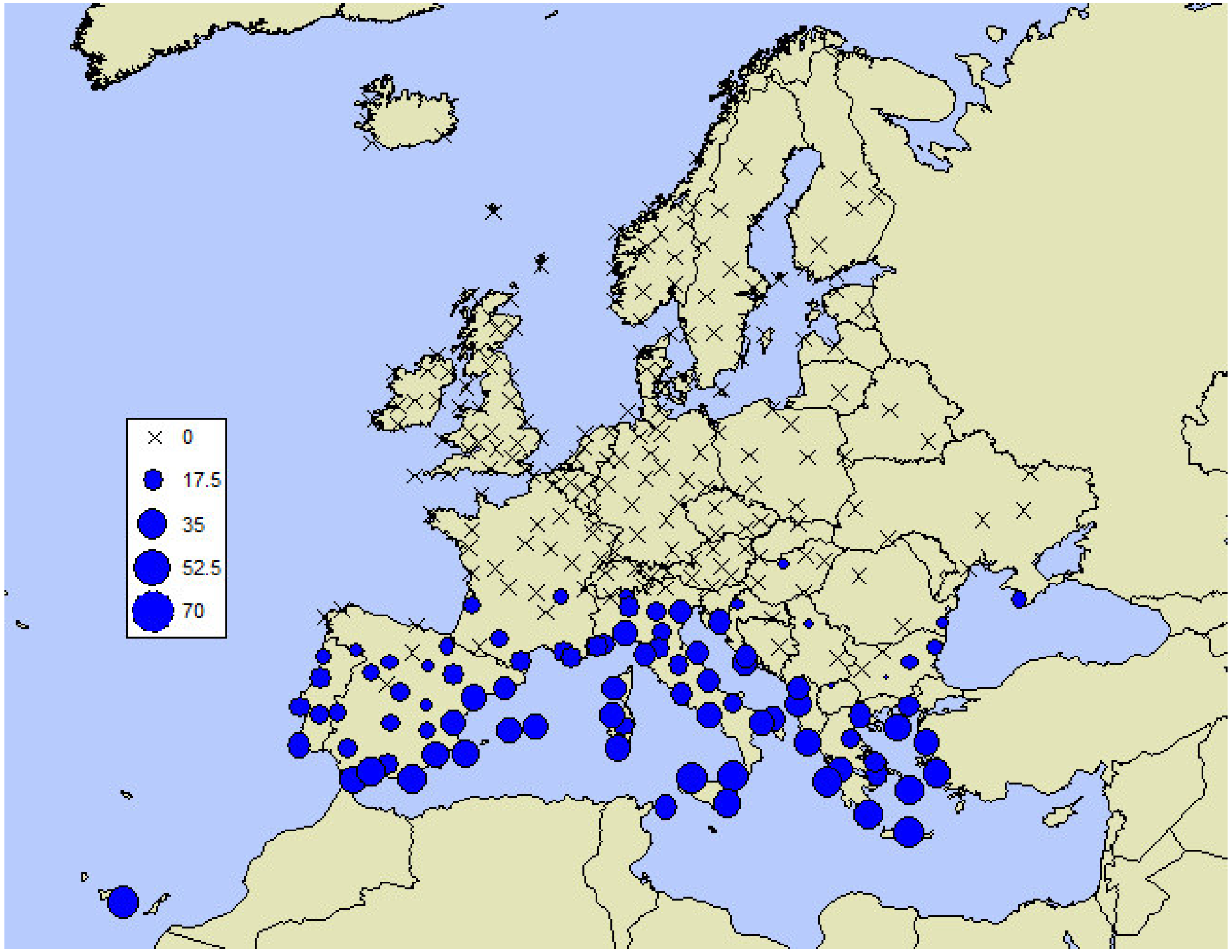

Fig. A4. Ecoclimatic index for *Solenopsis invicta* using the original CLIMEX parameters from Sutherst and Maywald (2005) (as in Fig. A2) with irrigation (30mm/week or 4.3mm/day, al seasons).

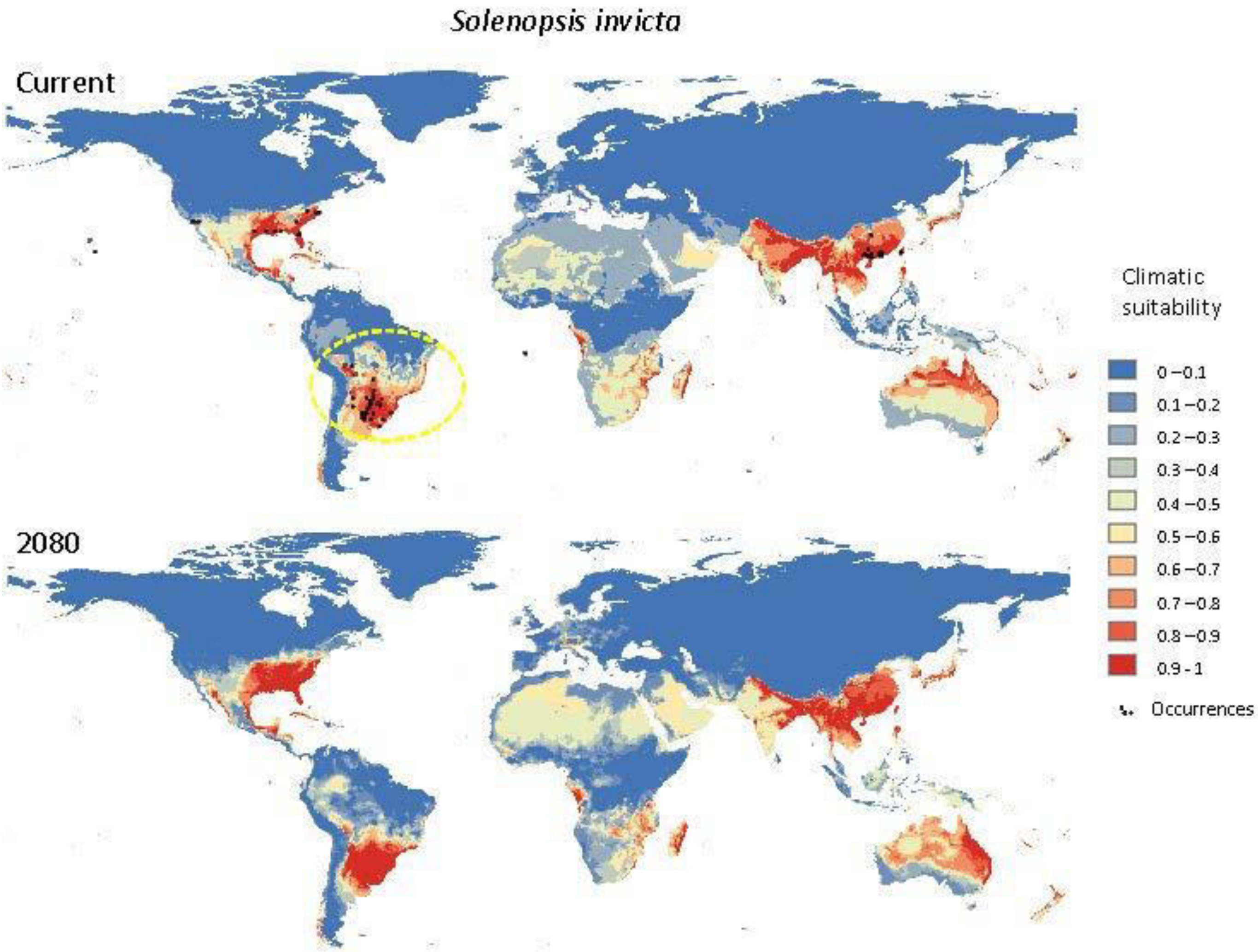

Fig. A5. World climatic suitability of *Solenopsis invicta* in current climate and 2080, from Bertelsmeier et al. (2015).

References

Barr CL, Davis T, Flanders K, Smith W, Hooper-Bui L, Koehler P, Vail K, Gardner W, Drees BM, Fuchs TW (2005) Broadcast baits for fire ant control, B-6099. Texas Cooperative Extension, Texas A&M University System, College Station, TX.

Bextine BR, Thorvilson HG (2004) Novel *Beauveria bassiana* delivery system for biological control of the Red Imported Fire Ant. Southwestern Entomologist 29: 47-53.

CABI (2017) *Solenopsis invicta* [original text updated by D Gunawardana]. In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

Christian S (2009) Red imported fire ant eradicated from Napier. Biosecurity 92: 28-29.

Drees BM, Gold RE (2003) Development of integrated pest management programs for the red imported fire ant (Hymenoptera: Formicidae). Journal of Entomological Science 38: 170-180.

Drees B M, Calixto AA, Nester PR (2013) Integrated pest management concepts for red imported fire ants *Solenopsis invicta* (Hymenoptera: Formicidae). Insect Science 20: 429-438.

Folgarait PJ, Bruzzone OA, Patrock RJ, Gilbert LE (2002) Developmental rates and host specificity for *Pseudacteon* parasitoids (Diptera: Phoridae) of fire ants (Hymenoptera: Formicidae) in Argentina. Journal of Economic Entomology 95: 1151-1158.

Graham LC, Porter SD, Pereira RM, Dorough HD, Kelley AT (2003) Field releases of the decapitating fly *Pseudacteon curvatus* (Diptera: Phoridae) for control of imported fire ants (Hymenoptera: Formicidae) in Alabama, Florida and Tennessee. Florida Entomologist 86: 334-339.

Greenberg L, Kabashima JN (2013) Red Imported Fire Ant. Integrated Pest management in and around the home. Pest Notes. University of California Publication 7487. California, USA: University of California Agriculture and Natural Resources.

Kean JM, Suckling DM, Sullivan NJ, Tobin PC, Stringer LD, Smith GR, Kimber B, Lee DC, Flores Vargas R, Fletcher J, Macbeth F, McCullough DG, Herms DA et al. (2017) Global eradication and response database. http://b3.net.nz/gerda (accessed 5 July 2017).

Invasive species council (2015) Red Imported fire ant (*Solenopsis Invicta*). Factsheet available at: invasives.org.au/files/2015/01/fs-red-imported-fire-ants.pdf (accessed 5 July 2017)

Hwang J-S (2009) Eradication of *Solenopsis invicta* by pyriproxyfen at the Shihmen Reservoir in northern Taiwan. Insect Science 16: 493-501.

Lin HM, Chi WL, Lin CC, Tseng YC, Chen WT, Kung YL, Lien YY, Chen YY (2011) Fire ant detecting canines: a complementary method in detecting red imported fire ants. Journal of Economic Entomology 104: 225-231.

Morrison LW, Porter SD (2005) Phenology and parasitism rates in introduced populations of *Pseudacteon tricuspis*, a parasitoid of *Solenopsis invicta*. BioControl 50: 127-141.

Morrison LW (2012) Biological control of *Solenopsis* fire ants by *Pseudacteon* Parasitoids: theory and practice. Psyche. 424817. doi:10.1155/2012/424817

Ma J, Hu XN, Wu JJ, Zhao JP, Chen NZ (2010) An analysis for the interception dynamic of *Solenopsis invicta* Buren at ports in Guangdong. Journal of Environmental Entomology 32: 122-124.

Noordijk J (2010) A risk analysis for the fire ants in the Netherlands. Stichting European Invertebrate Survey, Leidem, the Netherlands.

Oi DH, Valles SM (2012). Host specificity testing of the *Solenopsis* fire ant (hymenoptera: formicidae) pathogen, *Kneallhazia* (= *Thelohania*) *solenopsae* (microsporidia: thelohaniidae), in Florida. Florida Entomologist 95: 509-512.

Oi DH, Williams DF, Pereira RM, Horton PM, Davis T, Hyder AH, Bolton HT, Zeichner BC, Porter SD, Hoch AL, Boswell ML, Williams G (2008) Combining biological and chemical controls for the management of red imported fire ants (Hymenoptera: Formicidae). American Entomologist: 54, 44–53.

Porter SD, Fowler HG, McKay WP (1992) Fire ant mound densities in the United States and Brazil (Hymenoptera: Formicidae). Journal of Economic Entomology 85: 1154–1161.

Tschinkel WR (2006) The fire ants. Harvard University Press, Cambridge.

USDA (2010) lmported fire ant program manual. USDA Animal and Plant Health Inspection Service Plant. Protection and Quarantine.

USDA (2015) Imported fire ant: quarantine treatments for nursery stock, grass sod, and related materials. Program Aid No. 1904, updated January 2015. USDA, Animal and Plant Health Inspection Service.

Wang L, Lu YY, Xu YJ, Zeng L (2013) The current status of research on *Solenopsis invicta* Buren (Hymenoptera: Formicidae) in Mainland China. Asian Myrmecology 5: 125-138.

Williams DF, Oi DH, Porter SD, Pereira RM, Briano JA (2003) Biological control of imported fire ants (Hymenoptera: Formicidae). American Entomologist 49: 150-163.