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Cover photo: Orange jewelweed (*Impatiens capensis*). Photo: J.L.C.H. van Valkenburg.

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Content

Samenvatting

Het Team Invasieve Exoten Nederland van de Nederlandse Voedsel- en Warenautoriteit (NVWA), Ministerie van Economische Zaken heeft verzocht om een risicoanalyse van *Impatiens* (Springzaad) soorten ter preventie van ecologische, socio-economische en volksgezondheidseffecten.

De risicoanalyse van *Impatiens* soorten en hun hybriden is uitgevoerd in twee stappen.

(1) Eerst is uitgezocht welke uitheemse *Impatiens* soorten en hybriden zich al hebben gevestigd of in staat zouden zijn zich te vestigen in Nederland.

(2) Van de soorten die in staat zijn zich in Nederland te vestigen en de soorten die zich al in Nederland hebben gevestigd zijn vervolgens de (potentiële) ecologische risico's geëvalueerd door middel van het Belgische 'Invasive Species Environmental Impact Assessment (ISEIA)' protocol. Bovendien zijn kosteneffectieve beheermaatregelen geïdentificeerd.

Voor de selectie van *Impatiens* soorten die voldoen aan de voorwaarden voor stap 1 zijn twee criteria gebruikt, (i) de soort is al gevestigd in de Nederlandse natuur (wordt gekarakteriseerd door zichzelf vernieuwende populaties), of (ii) de soort is al gevestigd in omringende landen en/of is aanwezig in de Europese handel van uitheemse plantensoorten, en is volgens de internationale literatuur in staat om het Nederlandse klimaat te tolereren.

Een literatuurstudie leverde informatie over de verspreiding en invasiebiologie van de geselecteerde *Impatiens* soorten. Literatuur werd verzameld over fysiologische toleranties, kolonisatie vectoren, ecologische en socio-economische gevolgen en potentiële maatregelen voor het beheer van deze soorten. Informatie van de literatuurstudie werd gebruikt voor een risicoanalyse workshop met *Impatiens* en invasie deskundigen. Het ISEIA risicobeoordelingsprotocol werd gekozen om een raamwerk te verkrijgen voor discussies die uiteindelijk geleid hebben tot consensus over de potentiële ecologische risico's van elke soort voor Nederland.

De selectie van Impatiens soorten en hybriden
Nederland huisvest slechts één inheemse *Impatiens* soort, namelijk Groot springzaad (*I. noli-tangere*). Tegenwoordig zijn vier uitheemse *Impatiens* soorten in Nederland gevestigd: Tweekleurig springzaad (*I. balfourii*), Oranje springzaad (*I. capensis*), Reuzenbalsemien *(I. glandulifera*) en Klein springzaad (*I. parviflora*). Een vijfde soort Ruig springzaad (*I. scabrida*) is recent gemeld op enkele locaties in stedelijke gebieden. *I. edgeworthii* is recent voor het eerst waargenomen in Duitsland en blijkt zich daar steeds verder te verspreiden. Een mogelijke hybride tussen *I. parviflora* en *I. balfourii* is geïdentificeerd in Zwitserland. Achttien andere *Impatiens* soorten worden in Europa verhandeld en zouden kunnen verwilderen via plantenkwekerijen en tuinen, namelijk *I. arguta*, *I. auricoma*, *I. balsamina*, *I. flanaganae*, *I. gordonii*, *I. grandis*, *I. hawkeri*, *I. hochstetteri*, *I. marianae*, *I. niamniamensis*, *I. pallida, I. repens*, *I. sodenii*, *I. sulcata*, *I. tinctoria*, *I. usambarensis*, *I. verticillata* en *I. walleriana.* Dertien van de bovengenoemde 24 uitheemse taxa tolereren minimum temperatuurranges van 0 tot -5˚C tot < -20˚C. Deze soorten worden in staat geacht het Nederlandse klimaat te

tolereren en zijn beoordeeld op hun ecologische risico's. De verkorte lijst omvat de volgende dertien beoordeelde uitheemse soorten: *I. arguta*, *I. balfourii*, *I. balsamina*, *I. capensis*, *I. edgeworthii*, *I. flanaganae*, *I. glandulifera*, *I. pallida*, *I. parviflora*, *I. parviflora x I. balfourii*, *I. scabrida*, *I. sulcata* en *I. tinctoria*.

Dispersievermogen en invasiviteit

Een overzicht van de introductiemechanismen en manieren van verspreiding van de in dit rapport besproken *Impatiens* soorten wordt gepresenteerd in tabel S1.

Tabel S1: Overzicht van belangrijke introductie- en dispersiemechanismen van *Impatiens* soorten in Nederland.

Soort	Introductiemechanismen	Primaire dispersie mechanismen	Secondaire dispersie mechanismen
I. arguta	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend
I. balfourii	Internationale handel, mogelijk introductie vanuit naburige landen	Verwildering via tuinen, soortverrijking	Onbekend; relatief lage kans op verspreiding via waterstroming
I. balsamina	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend
I. capensis	Internationale handel, mogelijk introductie van naburige landen	Verwildering via tuinen, soortverrijking	Via waterstroming
I. edgeworthii	Internationale handel, mogelijk introductie vanuit naburige landen (bijvoorbeeld Duitsland)	Verwildering via tuinen, soortverrijking	Bosbouwmachines
I. flanaganae	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend
I. glandulifera	Internationale handel, mogelijk introductie vanuit naburige landen	Verwildering via tuinen, soortverrijking	Via waterstroming en vissen
I. pallida	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend, relatief lage kans op dispersie via waterstroming
I. parviflora	Mogelijk introductie vanuit naburige landen	Onbewuste introductie	Houttransport, bosbouwmachines of via dieren; relatief lage kans op verspreiding via waterstroming
I. parviflora x balfourii	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend
I. scabrida	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend
I. sulcata	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend
I. tinctoria	Internationale handel	Verwildering via tuinen, soortverrijking	Onbekend

De belangrijkste introductieroute voor *Impatiens* soorten naar Nederland is de internationale (online) handel in sierplanten. De belangrijkste routes voor de verspreiding van *Impatiens* soorten naar de natuurlijke omgeving in Nederland zijn verwildering vanuit tuinen en het bewust aanplanten of uitzaaien voor soortverrijking. *Impatiens* soorten worden dikwijls aanbevolen aan bijenhouders. De bloemen worden door honingbijen druk bezocht vanwege hun rijke nectar. *Impatiens* soorten zijn in verschillende mate populair bij tuinliefhebbers. Dit wordt weerspiegeld in de relatief beperkte verspreiding van *I. capensis* die voor een deel kan worden toegeschreven aan de beperkte beschikbaarheid in Europa vergeleken met *I. glandulifera* die in Europa massaal worden gekweekt. *I. edgeworthii*, een soort die nog niet in Nederland is waargenomen, wordt in toenemende mate gemeld als verwilderd uit tuinen in delen van Duitsland. Belangrijke natuurlijke verspreidingsmechanismen van *Impatiens* soorten zijn mechanische zaadverspreiding (ballochorie) en transport zaden of (delen van) planten via water (hydrochorie) of dieren (zoöchorie). Ballochorie is een mechanisme waarbij vruchten door aanraking zodanig openspringen dat de zaden worden weggeschoten. Dit mechanisme is kenmerkend voor alle *Impatiens* soorten. Hydrochorie blijkt een uitzonderlijk belangrijk verspreidingsmechanisme voor *I. glandulifera* en *I. capensis*. *I. pallida*, *I. balfourii* en *I. parviflora* zijn minder afhankelijk van vocht dan andere *Impatiens* soorten en hun zaden hebben een relatief kleine kans om door hydrochorie te worden verspreid. Dispersie via de vacht en poten van dieren (epizoöchorie) is een belangrijk mechanisme voor verspreiding over langere afstanden bij *I. parviflora*. Daarnaast kan transport door bosbouwmachines en houttransport een rol spelen bij de secondaire verspreiding van een aantal soorten. *I. parviflora* wordt bijvoorbeeld verspreid met hout, terwijl transport via bosbouwmachines een rol speelt bij zowel *I. parviflora* als *I. edgeworthii*. Het is echter waarschijnlijk dat de hoeveelheid zaad dat wordt verspreid door mensen minder zal zijn in dichte boshabitats, waarvoor *I. parviflora* een voorkeur heeft, dan op rivieroevers waarvoor *I. glandulifera* een voorkeur heeft.

De maximale verspreidingssnelheid van *I. glandulifera* is in Engeland bepaald op 38 km per jaar. Dit is hoger dan de maximale verspreidingssnelheid van *I. parviflora* (24 km per jaar) en *I. capensis* (13 km per jaar). Behalve de verscheidenheid aan verspreidingsmechanismen (zoals ballochorie, hydrochorie, zoöchorie en handel) dragen nog een aantal factoren bij aan de snelle verspreiding van *I. glandulifera* in Nederland en andere Europese landen. Een aantal eigenschappen maken deze soort duidelijk concurrentiekrachtiger dan andere *Impatiens* soorten: vorsttolerantie vroeg in de levenscyclus*,* een kortere tijd benodigd voor zaadstratificatie, een hoog kiemingspercentage en een snelle groei. Andere kenmerken die kunnen hebben bijgedragen aan de succesvolle vestiging van *I. glandulifera* zijn sterke hoogtegroei, synchrone kieming, een grote zaadproductie en andere reproductieve eigenschappen zoals het hoge zaadgewicht.

Gegevens uit landen met een met Nederland vergelijkbaar klimaat kunnen aanwijzingen geven voor de potentiële invasiviteit van andere *Impatiens* soorten. Bijvoorbeeld, *I. balfourii* is verwilderd in verstoorde habitats in Centraal en Zuidelijk Europa (bijvoorbeeld Zwitserland), maar wordt niet als invasief beschouwd. *I. balsamina* is ingedeeld als een subtropische soort. Verwilderde planten in het noordoosten van de VS, blijken vooral beperkt voor te komen in tuinen en andere beschutte locaties. *I. balsamina* wordt echter al vele jaren lang gekweekt in Europa en heeft zich al gevestigd in vele gebieden met een gematigd klimaat.

De verspreiding van *Impatiens* soorten op wereldschaal heeft invloed op hun dispersiekans en de potentiële invasiviteit binnen Nederland. *I. balfourii*, *I. capensis*, *I. edgeworthii*, *I. glandulifera* en *I. parviflora* zijn allemaal waargenomen in de buurlanden en kunnen buiten de internationale handel om in Nederland worden geïntroduceerd door waterstroming (hydrochorie) of met bosbouwmachines. Dit is vooral relevant voor *I. edgeworthii* omdat deze soort is waargenomen in Duitsland, maar nog niet in Nederland.

De *Impatiens* soorten komen voor in uiteenlopende habitattypen, die ook aanwezig zijn in Nederland. Over het algemeen prefereren *Impatiens* soorten schaduwrijke, vochtige locaties aan de oevers van rivieren en beken, in weilanden, half-natuurlijke en verstoorde locaties, struwelen, bos, moerassen en laagveengebieden (Tabel S2).

Tabel S2: Habitattypen geassocieerd met *Impatiens* soorten.

Habitattypen	***Impatiens* soorten**
Vochtige weilanden	*I. balfourii*
Vochtige kunstmatige, half-natuurlijke of verstoorde locaties bijvoorbeeld tuinen, sloten, wegbermen, spoorlijnen	*I. balfourii*, *I. glandulifera*, *I. parviflora*, *I. capensis*, *I. edgeworthii*
Vochtige bosjes en bos	*I. balfourii*, *I. capensis*, *I. edgeworthii*, *I. glandulifera*, *I. pallida*, *I. parviflora, I. scabrida*
Oevers van rivieren en beken	*I. capensis*, *I. pallida*, *I. glandulifera*, *I. parviflora*, *I. tinctoria*
Moerassen	*I. capensis*, *I. pallida*, *I. tinctoria*
Laagveengebieden	*I. capensis*, *I. glandulifera*

De voornaamste habitattypen van *I. glandulifera* en *I. capensis* in Europa zijn rivieroevers en uiterwaarden. *I. glandulifera* komt vooral voor langs langzaam stromende wateren in laaglandgebieden met fijn sediment en floreert waar inheemse vegetatie slecht is ontwikkeld en ruimte beschikbaar is voor kolonisatie. *I. parviflora* is tegenwoordig de belangrijkste exoot aan de randen van vochtige tot natte gematigde loofbossen en gemengde bossen, zelfs op klaarblijkelijk ongestoorde plaatsen. Het is de enige uitheemse *Impatiens* soort die zich in Europese bossen op grote schaal heeft verspreid. De tragere verspreiding van *I. parviflora* vergeleken met *I. glandulifera* in het Verenigd Koninkrijk is waarschijnlijk gerelateerd aan zijn relatieve grotere gevoeligheid voor vorst samen met zijn voorkeur voor boshabitats. In het Verenigd Koninkrijk zou *I. parviflora* in principe net zo wijd verspreid kunnen zijn als *I. glandulifera*, maar vanwege de beperkte habitattolerantie is zij minder algemeen. In tegenstelling tot andere *Impatiens* soorten die in Europa gevestigd zijn, koloniseert *I. balfourii* open habitats met een hoge lichtintensiteit en heeft zij een voorkeur voor droge tot vochtige bodems.

Verspreiding in Nederland en kolonisatie van habitats met een hoge natuurwaarde
Volgens de BFIS classificatie, zijn vier *Impatiens* soorten al wijdverspreid in Nederland. Dat zijn, in volgorde van het aantal waarnemingen, *I. glandulifera* > *I. parviflora* > *I. capensis* > *I. balfourii*. *I. scabrida* is sinds 1990 slechts waargenomen op twee locaties in totaal en is daarom geclassificeerd als geïsoleerde populaties. *I. arguta*, *I. balsamina*, *I. edgeworthii*, *I. flanaganae*, *I. pallida*, *I. parviflora x balfourii*, *I. sulcata* en *I. tinctoria* zijn nog niet in Nederland waargenomen. *I. glandulifera* is gemeld in 61 Natura 2000 gebieden, waarvan de meeste gesitueerd zijn langs de Rijn en haar zijrivieren en langs het Rijn-Maas estuarium. *I. parviflora* is gemeld in 53 Natura 2000 gebieden, voornamelijk gebieden die bestaan uit

bossen op de hoger gelegen zandgronden. *I. capensis* komt voor in 15 Natura 2000 gebieden, meestal gelegen binnen het zoetwatergetijdengebied. *I. balfourii* komt in Nederland vooral voor in urbane gebieden. Tot nu toe is deze soort slechts binnen één Nederlands Natura 2000 gebied waargenomen.

Negatieve invloed op inheemse soorten
I. glandulifera is de meest competitieve van alle *Impatiens* soorten. De soort vormt hoge, dichte, sterk vertakte bestanden, die met inheemse soorten concurreren om ruimte, licht, nutriënten en bestuivers. Alleen meerjarige inheemse soorten met een sterke vegetatieve vermeerdering zijn in staat om *I. glandulifera* te weerstaan. De vroege kieming in sommige jaren, de gelijktijdige ontkieming van zaailingen, de snelle toename in hoogte, de grotere dichtheid en de hoge biomassa, werken waarschijnlijk in het voordeel van *I. glandulifera* ten opzichte van naburige soorten.

In België is waargenomen dat bij aanwezigheid van *I. parviflora* het aantal inheemse plantensoorten afneemt en dat de abundantie van kruidachtige bosplanten waarschijnlijk afneemt. In een experiment waarbij de competitie tussen de inheemse *I. noli-tangere* en de uitheemse *I. glandulifera*, *I. parviflora*, en *I. capensis*, werd vergeleken, was *I. glandulifera* de sterkste concurrent en nam *I. parviflora,* vooral op weinig vochthoudende bodems, de middenpositie in. In Duitsland, Polen en Tsjechië echter werd geen invloed op de diversiteit van inheemse soorten gemeld. De invloed van *I. parviflora* op de biodiversiteit lijkt beperkt te zijn.

I. balfourii kan dichte bestanden vormen die andere soorten zouden kunnen onderdrukken. Het is echter onbekend of *I. balfourii* ook daadwerkelijk inheemse soorten onderdrukt. *I. balfourii* heeft waarschijnlijk een negatieve invloed op de natuurlijke vegetatie van ruderale of half-natuurlijke habitats.

In tegenstelling hiermee, vormt *I. capensis* geen monospecifieke bestanden en wordt daarom buiten zijn oorspronkelijke verspreidingsgebied in het algemeen niet als een problematische plant beschouwd. Hoewel *I. capensis* minder competitief is dan zowel *I. glandulifera* als *I. parviflora*, zou *I. capensis* mogelijk onder bepaalde omstandigheden de inheemse *I. noli-tangere* kunnen onderdrukken. *I. capensis* en *I. noli-tangere* komen echter in Europa zeldzaam of nooit in hetzelfde biotoop voor. Theoretisch zou *I. capensis* in staat moeten zijn om met *I. noli-tangere* te hybridiseren. Tot op heden is er echter geen bewijs van actuele hybridisatie tussen deze twee soorten.

Gedurende het literatuuronderzoek is geen informatie gevonden over de ecologische effecten van *I. arguta, I. balsamina, I. edgeworthii*, *I. pallida, I. parviflora x balfourii*, *I. scabrida* en *I. tinctoria*.

Verandering van ecosysteemfuncties
Er is geen informatie over de ecologische invloed van *I. arguta, I. balsamina, I. edgeworthii*, *I. pallida, I. parviflora x balfourii*, *I. scabrida* en *I. tinctoria*. Het ligt echter in de lijn der verwachting dat enige fysische habitatverandering zal plaatsvinden zoals erosie van kale grond na het afsterven in de winter en lichtonderschepping gedurende de groeiperioden van deze soorten.

De vestiging van *I. glandulifera* kan resulteren in veranderingen in vegetatiestructuur, veranderingen in trofische interacties, en toegenomen oevererosie of juist het invangen van sediment waardoor inheemse soorten kunnen worden benadeeld. In dichte bestanden is *I. parviflora* in staat om licht en ruimte te monopoliseren en daarmee andere plantensoorten uit te sluiten. Het ontstaan van een dichte kruidlaag in bossen, waar dergelijke vegetatie eerder afwezig was, zou de verjonging van bos kunnen beïnvloeden. *I. balfourii* kan dichte monospecifieke bestanden vormen die de lichtdoordringing negatief kunnen beïnvloeden.

Gevolgen voor volksgezondheid
Tijdens deze literatuurstudie is geen informatie over een mogelijke invloed van *Impatiens* soorten op de volksgezondheid gevonden.

Economische schade
Er is geen informatie gevonden over mogelijke economische schade veroorzaakt door *I. arguta*, *I. balfourii*, *I. balsamina*, *I. capensis*, *I. edgeworthii*, *I. flanaganae*, *I. pallida*, *I. parviflora x balfourii*, *I. scabrida* en *I. tinctoria*. Wel zijn er aanwijzingen voor potentiële invloed op de bosbouw door *I. glandulifera* en *I. parviflora*. *I. glandulifera* zou de bosbouw negatief kunnen beïnvloeden door natuurlijke bosregeneratie te verhinderen. Dit is echter niet bewezen. Dichte bestanden van *I. glandulifera* en dood plantenmateriaal kunnen gedurende zware regenval de waterstroming blokkeren en daardoor overstromingen veroorzaken. Het Engelse Milieuagentschap (Environment Agency) schat dat eliminatie van de soort in het Verenigd Koninkrijk circa € 420 miljoen zou kosten. *I. parviflora* koloniseert cultuurbossen en houtaanplant en zou de boomregeneratie kunnen aantasten. In Nepal is *I. sulcata* een onkruid in velden met tarwe (*Triticum* spp.).

Risicoclassificaties
I. glandulifera heeft de hoogste ecologische risicoscore van alle *Impatiens* soorten voor ecologische risico's (12 uit 12 punten). Vier soorten zijn geclassificeerd als middelmatig risico (*I. balfourii*, *I. capensis*, *I. edgeworthii* en *I. parviflora*). Acht soorten zijn geclassificeerd als laag risico (*I. arguta*, *I. balsamina*, *I. flanaganae*, *I. pallida*, *I. parviflora* x *balfourii*, *I. scabrida*, *I. sulcata* en *I. tinctoria*) (Tabel S3).

De hoogst scorende soorten voor de categorieën dispersie potentieel of invasiviteit en kolonisatie van natuurgebieden (totale scores van vijf of zes uit een maximum van zes) zijn *I. glandulifera*, *I. parviflora*, *I. capensis* en *I. balfourii*. De hoogst scorende soorten voor de categorieën (in)directe negatieve invloed op inheemse soorten en (in)directe verandering van ecosysteemfuncties zijn *I. glandulifera* en *I. edgeworthii.*

Vanwege gebrek aan data zijn veel risicoscores bepaald op basis van de best beschikbare deskundige kennis (Tabel S3; vermeld met *). Deze benadering resulteert over het algemeen in een hoge onzekerheid van de risicoscore van soorten en een onderschatting van hun risicoclassificatie.

Tabel S3: Verspreiding en ecologische risicoclassificatie van *Impatiens* soorten voor Nederland (*: vanwege gebrek aan data zijn de risicoscores voor meerdere criteria bepaald op basis van best beschikbare deskundige kennis).

Weten-schappelijke naam	Nederlandse naam	Risico score (ISEIA)	Verspreiding in Nederland	Risico classificatie (BFIS systeem)
I. arguta	Niet van toepassing	8*	Afwezig	C0*
I. balfourii	Tweekleurig springzaad	9*	Wijdverspreid	B3*
I. balsamina	Balsemien	5*	Afwezig	C0*
I. capensis	Oranje springzaad	9	Wijdverspreid	B3
I. edgeworthii	Niet van toepassing	9*	Afwezig	B0*
I. flanaganae	Niet van toepassing	5*	Afwezig	C0*
I. glandulifera	Reuzenbalsemien	12	Wijdverspreid	A3
I. pallida	Niet van toepassing	8*	Afwezig	C0*
I. parviflora	Klein springzaad	9	Wijdverspreid	B3
I. parviflora x balfourii	Niet van toepassing	6*	Afwezig	C0*
I. scabrida	Ruig springzaad	8*	Geïsoleerde populaties	C1*
I. sulcata	Niet van toepassing	5*	Afwezig	C0*
I. tinctoria	Niet van toepassing	5*	Afwezig	C0*

Ecologische risicoclassificatie: Hoog risico; Matig risico; Laag risico.

Kosteneffectieve beheeropties

Over het algemeen zullen de kosten van controle en uitroeiing van een eenmaal gevestigde invasieve soort ver uitstijgen boven de preventiekosten van introductie. Wanneer een invasieve soort zich eenmaal heeft gevestigd en al wijd is verspreid, is het meestal extreem moeilijk, of soms zelf onmogelijk, om deze soort nog volledig uit te roeien.

De plantenhandel is de belangrijkste vector voor de wereldwijde verspreiding van *Impatiens* soorten en ook voor de introductie in Nederland en omringende landen. Reductie van het introductie- en verspreidingsrisico van (potentieel) invasieve *Impatiens* soorten is mogelijk door (inter)nationale regelgeving of een vrijwillig convenant met de plantensector over welke soorten wel of niet mogen worden verhandeld en onder welke condities de handel is toegestaan (zoals verschaffen van informatie over de potentiële risico’s van verspreiden van soorten in het wild). Publieke bewustwording is altijd een belangrijke component van strategieën die zijn gericht op uitroeiing of beheer van plaagsoorten. Folders, persberichten, websites en informatieborden met waarschuwingen over de milieurisico’s of sociaaleconomische gevolgen van uitheemse soorten dragen bij aan publieke bewustwording. Imkers en plantenkwekers zaaien *Impatiens* soorten uit omdat deze planten veel nectar produceren voor bijen of andere insecten. Het verdient aanbeveling om dergelijke doelgroepen te voorzien van specifieke informatie over de milieugevolgen van invasieve nectarplanten (zoals de Reuzenbalsemien) en mogelijke alternatieven.

Vlakdekkende monitoring is van groot belang voor de vroegtijdige signalering van nieuwe vegetaties van uitheemse *Impatiens* soorten. Natuur- en terreinbeheerders kunnen de vroegtijdige signalering van uitheemse plaagsoorten in hun beheersgebieden faciliteren door a) identificatie van relevante plaagsoorten voor hun gebieden op basis van risicoanalyses, b) bevorderen van snelle herkenning van die plaagsoorten door gerichte training van veldmedewerkers en vrijwilligers, c) verzamelen en registreren van waarnemingen van die soorten door derden, d) vastleggen van waarnemingen in een centrale database (zoals de Nationale Database Flora & Fauna). Daarnaast is ook inzet en raadpleging mogelijk van vrij-toegankelijke databases met waarnemingen van amateurs en professionele waarnemers (zoals www.waarnemingen.nl).

Beheermaatregelen voor invasieve *Impatiens* soorten zijn alleen effectief als deze worden uitgevoerd voor de zaadzetting van planten. Daarom moeten de planten vroeg in het groeiseizoen worden verwijderd. Een beheerinspanning kan immers weer volledig teniet worden gedaan als één of meerdere planten al zaad hebben gezet. *I. glandulifera* vormt geen persistente zaadbank. Het zaad van deze soort is anderhalf tot twee jaar kiemkrachtig. Daarom wordt aanbevolen om gedurende minimaal twee groeiseizoenen na bestrijding te controleren of vestiging van nieuwe kiemplanten optreedt en in dergelijke gevallen de maatregelen te herhalen. Uitroeiingsmaatregelen moeten altijd van bovenstrooms naar benedenstrooms worden uitgevoerd omdat het zaad via stromend water wordt verspreid. Hierdoor wordt rekolonisatie vanuit bovenstroomse zaadbronnen voorkomen.

Maaien en handmatig verwijderen zijn de meest kosteneffectieve methoden voor het uitroeien of beheren van invasieve *Impatiens* soorten. Dergelijke maatregelen moeten voor de zaadzetting dus in juni of begin juli worden uitgevoerd. Mechanisch maaien is alleen effectief op locaties die toegankelijk zijn voor (zwaar) materieel. De positieve effecten van de eliminatie van de plaagsoort moeten dan wel opwegen tegen de eventuele schade, anders kunnen de planten beter handmatig worden uitgetrokken. Schade aan beschermde flora en fauna moet altijd worden voorkomen of afdoende verminderd. De planten moeten vlak boven de grond worden gemaaid om uitgroei en bloemvorming te voorkomen. Handmatige verwijdering is arbeidsintensiever dan mechanisch maaien maar kan accurater en ook op moeilijk toegankelijke plekken worden uitgevoerd. Na het uittrekken moet de stengel volledig worden gebroken om uitgroei en nieuwe wortelvorming te voorkomen (dit is vooral van belang in vochtige gebieden). Bij bestrijding van een groot oppervlak invasieve planten is na het initieel maaien nog handmatige nazorg en herhaalde controle nodig. Daarbij is vooral aandacht vereist voor het opsporen van platgereden of onvolledig gemaaide planten, omdat die zich weer kunnen herstellen en uitgroeien. Op droge gronden kan het maaisel bij droge weersomstandigheden op het terrein achterblijven. Onder vochtige omstandigheden zijn echter maatregelen nodig om herstel, wortelvorming en uitgroei van planten te voorkomen. Sommige *Impatiens* soorten kunnen gemakkelijk herstellen als de stengel niet volledig is gebroken. Ook kleine planten, die niet zijn gemaaid of worden gemist bij controles, kunnen uitgroeien. Zowel bij de opsporing, monitoring als de bestrijding is een stroomgebied-benadering nodig omdat het zaad van soorten zoals *I. glandulifera* zich gemakkelijk via stromend water verspreidt.

De inzet van vrijwilligers bij de bestrijding van invasieve *Impatiens* soorten zal over het algemeen kosten-effectiever zijn dan bestrijding door alleen professionele medewerkers. Daarbij is het wel van belang dat de vrijwilligers goed worden getraind en begeleid. Vrijwilligers kunnen ook bijdragen aan de nazorg, monitoring, vroegtijdige signalering, voorlichting en communicatie en maatschappelijk draagvlakvorming. Voor het maaien met zwaar materieel zijn altijd professionele veldmedewerkers nodig.

Begrazing is over het algemeen niet effectief omdat de meeste herbivoren geen voorkeur hebben voor *Impatiens* soorten en liever andere planten eten. Drukbegrazing is wellicht mogelijk bij grote oppervakken met een monotone vegetatie. Momenteel is onvoldoende informatie beschikbaar over de effectiviteit van andere biologische bestrijdingsmethoden. De eerste veldexperimenten naar de bestrijding van *I. glandulifera* met schimmels zijn onlangs gestart in het Verenigd Koninkrijk. Chemische bestrijding kan effectief zijn, maar moet altijd zeer zorgvuldig worden uitgevoerd om ongewenste neveneffecten te voorkomen. De bestrijding met herbiciden moet plaatsvinden voordat bloemen zijn gevormd omdat de zaden anders nog kunnen afrijpen. Chemische bestrijding wordt echter niet aanbevolen vanwege de beschikbaarheid van kosteneffectieve alternatieven en de potentiële milieueffecten van herbiciden (bijvoorbeeld bij toepassing nabij oppervlaktewater).

Belemmerende factoren voor effectieve beheersmaatregelen zijn: 1) onvolledige uitroeiing vanwege beperkte toegang tot particuliere terreinen, en 2) facilitering van de verspreiding van zaden of planten wanneer bij de uitvoering van andere projecten geen rekening wordt gehouden met de aanwezigheid van invasieve *Impatiens* soorten (bijvoorbeeld de aanleg van nieuwe invasie routes door rivierherstel).

Verder onderzoek

Tijdens de soortenselectie en risicoanalyse zijn een aantal onderwerpen geïdentificeerd die verder onderzoek vereisen. Ten eerste zouden vele *Impatiens* soorten die niet in de risicobeoordeling zijn meegenomen, in de toekomst, door klimaatverandering en veranderingen in de Europese handel van uitheemse planten, kunnen voldoen aan de criteria vermeld in sectie 2.1 voor opname. Daarom is regelmatige herbeoordeling van de vestigingskans van uitheemse *Impatiens* soorten in Nederland nodig. Ten tweede blijken traditionele opties voor het beheer van *Impatiens* soorten een probleem door de risico's van zaadverspreiding en de risico's die samenhangen met het gebruik van herbiciden nabij aquatische systemen. Aanbevelingen voor verder onderzoek betreffen de identificatie van eventuele plantenziekten, sediment en nutriënten karakteristieken, klimaatmatch en de rol van allopathie in inheemse gebieden als een eerste stap in de ontwikkeling van innovatieve beheerstechnieken. Ten derde is er sprake van een hoge onzekerheid in risicoclassificaties van soorten waarvoor de beschikbare kennis gering is (zoals *I. arguta*, *I. flanaganae* en *I. tinctoria*). Aanbevolen wordt om verder onderzoek te richten op habitateisen en de potentiële ecologische invloed van deze soorten in hun uitheemse verspreidingsgebied.

Summary

To support decision making with regard to the design of measures to prevent ecological, socio-economic and public health effects, the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority (Ministry of Economic Affairs) has asked for a risk analysis of *Impatiens* species*.*

The risk analysis of *Impatiens* species and hybrids was carried out in two steps:

(1) A survey was conducted to identify which *Impatiens* species and hybrids are able to establish in the Netherlands.

(2) Species able to establish in the Netherlands were then assessed for (potential) ecological risk using the Belgium Invasive Species Environmental Impact Assessment (ISEIA) protocol and cost-effective management measures of potential invasive *Impatiens* species were identified.

Two criteria were applied to identify *Impatiens* species fulfilling the requirements of stage 1, (i) the species is already established in Dutch nature (is characterised by self-sustaining populations), or (ii) the species is already established in surrounding countries of the Netherlands and / or features in the European trade of non-native plant species, and is able to withstand the Dutch climate according to international literature.

A literature study provided information on the distribution and invasion biology of the *Impatiens* species capable to establish in the Netherlands. Literature data were collected on the physiological tolerances, colonization vectors, ecological and socio-economic impact and potential measures for management of this species. Information obtained from the literature study was used as input for a risk assessment workshop involving experts in the fields of *Impatiens* species and invasion biology. The ISEIA risk assessment protocol was chosen to provide a framework for discussions that led to consensus on the potential ecological risk of each species for the Netherlands.

Survey of non-native Impatiens species and hybrids able to establish in the Netherlands
The Netherlands harbours only one native *Impatiens* species, namely the Touch-me-not balsam (*I. noli-tangere*). Currently, four non-native *Impatiens* species are established in the Netherlands: Balfour's touch-me-not (*I. balfourii*), Orange jewelweed (*I. capensis*), Himalayan balsam *(I. glandulifera*) and Small balsam (*I. parviflora*). A fifth species, Rugged yellow balsam (*I. scabrida*) has recently been recorded at a few locations in urban areas. *I. edgeworthii* has recently been recorded for the first time in Germany and appears to be spreading in this country. A possible hybrid of *I. parviflora* and Balfour's touch-me-not (*I. balfourii*) has been identified in Switzerland. In addition, 18 other *Impatiens* species traded in Europe may escape from cultivation. These are: *I. arguta*, *I. auricoma*, *I. balsamina*, *I. flanaganae*, *I. gordonii*, *I. grandis*, *I. hawkeri*, *I. hochstetteri*, *I. marianae*, *I. niamniamensis*, *I. pallida, I. repens*, *I. sodenii*, *I. sulcata*, *I. tinctoria*, *I. usambarensis*, *I. verticillata* and *I. walleriana.* A shortlist shows that 13 of the above 24 non-native taxa tolerate low temperature ranges of 0 to -5 ˚C to < -20 ˚C. These species are able or expected to tolerate the Dutch climate and were assessed for ecological risk. The shortlist for risk assessment

comprised the following 13 non-native species: *I. arguta*, *I. balfourii*, *I. balsamina*, *I. capensis*, *I. edgeworthii*, *I. flanaganae*, *I. glandulifera*, *I. pallida*, *I. parviflora*, *I. parviflora x I. balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*.

Dispersion potential and invasiveness

A summary of the mechanisms of introduction and dispersal pathways available to *Impatiens* species in the Netherlands is given in table S1.

Table S1: overview of important introduction and dispersal mechanisms of *Impatiens* species in the Netherlands.

Species	**Introduction mechanisms**	**Primary dispersal mechanisms**	**Secondary dispersal mechanisms**
I. arguta	International trade	Garden escapes, species enrichment	Unknown
I. balfourii	International trade, possible introduction from neighbouring countries	Garden escapes, species enrichment	Unknown, relatively low chance of dispersal by hydrochory
I. balsamina	International trade	Garden escapes, species enrichment	Unknown
I. capensis	International trade, possible introduction from neighbouring countries	Garden escapes, species enrichment	Hydrochory
I. edgeworthii	International trade, possible introduction from neighbouring countries (e.g., Germany)	Garden escapes, species enrichment	Forest machinery and vehicles
I. flanaganae	International trade	Garden escapes, species enrichment	Unknown
I. glandulifera	International trade, possible introduction from neighbouring countries	Garden escapes, species enrichment	Hydrochory, ichthyochory
I. pallida	International trade	Garden escapes, species enrichment	Unknown, relatively low chance of dispersal by hydrochory
I. parviflora	Possible introduction from neighbouring countries	Unintentional human introductions	Timber trade, forestry vehicles and machinery, zoochory, relatively low chance of dispersal by hydrochory
I. parviflora x balfourii	International trade	Garden escapes, species enrichment	Unknown
I. scabrida	International trade	Garden escapes, species enrichment	Unknown
I. sulcata	International trade	Garden escapes, species enrichment	Unknown
I. tinctoria	International trade	Garden escapes, species enrichment	Unknown

The main pathway of introduction of *Impatiens* species to the Netherlands is the international (online) trade in ornamental plants and garden escape. *Impatiens* species are recommended to beekeepers as their flowers are highly attractive to honeybees as nectar source. Dependent on the species *Impatiens* species are popular with gardeners. This is reflected in the relatively limited non-native range of *I. capensis* which could be in part attributed to its limited cultivation in Europe compared to *I. glandulifera* that has been extensively cultivated.

The most important primary dispersal mechanisms of *Impatiens* species to the natural environment in the Netherlands are garden escape or deliberate planting in the wild by members of the public (e.g., for species enrichment). *I. edgeworthii*, a species currently unrecorded in the Netherlands, is increasingly recorded as a garden escape in parts of Germany. Important natural dispersal mechanisms of *Impatiens* species are mechanical seed spread (ballochory) and the transport of seeds or plant fragments in water (hydrochory) or by animals (zoochory). Ballochory is a mechanism whereby fruit breaks open when touched, launching seeds into the air. This mechanism is a characteristic of all Impatiens species. Hydrochory appears to be a particularly important dispersal mechanism for *I. glandulifera* and *I. capensis*. *I. pallida*, *I. balfourii* and *I. parviflora* are less dependent on moisture than other *Impatiens* species and seeds have a relatively low chance of being dispersed by hydrochory. Moreover, the spread of seeds and plants by forest vehicles or machinery and transport with timber is relevant for some species. For instance, *I. parviflora* is spread with timber, whilst transport on vehicles and forest machinery has been implicated in the transport of both *I. parviflora* and *I. edgeworthii*. However, it is probable that the amount of seed dispersed by people will be less in the dense woodland habitats favoured by *I. parviflora* than on the areas of river banks that are preferred by *I. glandulifera*. Epizoochorous dispersal in animal fur and feet is an important mechanism of long-distance dispersal of *I. parviflora*.

The maximum instantaneous rate of spread of *I. glandulifera* in England has been determined to be 38 km/year, significantly faster than either *I. parviflora* (24 km/year) or *I. capensis* (13 km/year). A number of factors contribute to the rapid spread and wide distribution of *I. glandulifera* in the Netherlands and other European countries apart from the wide range of dispersal mechanisms available to it (e.g., ballochory, hydrochory, ichthyochory and trade). Frost tolerance early in the life cycle of *I. glandulifera,* a shorter time required for seed stratification, a high level of germination success and rapid growth gives it a significant advantage over other *Impatiens* species. Other characteristics that may have contributed to its establishment are its height, synchronous germination, high level of seed production, and other reproductive traits such as seed mass variation.

Evidence from countries with a similar climate to that of the Netherlands may give an indication of the potential for invasiveness of other *Impatiens* species. For example, *I. balfourii* is naturalised in disturbed habitats in central and southern Europe (e.g., Switzerland), but is not considered invasive. *I. balsamina* is classified as a subtropical species and in north-eastern USA escapes appear to be mostly restricted to gardens and other sheltered locations. However, *I. balsamina* has been in cultivation in Europe for many years and is already established in many temperate areas.

The global distribution of *Impatiens species* may also influence their dispersion potential and invasiveness. *I. balfourii*, *I. capensis*, *I. edgeworthii*, *I. glandulifera* and *I. parviflora* are all recorded in countries neighbouring the Netherlands and may be introduced by mechanisms other than international trade (e.g., hydrochory or transport by forest vehicles). This is particularly relevant to *I. edgeworthii* as this species has been recorded in Germany but has not yet been recorded in the Netherlands.

The *Impatiens* species tolerate a wide range of habitats many of which occur in the Netherlands. Generally, *Impatiens* species prefer shadowy, moist locations on the banks of rivers and streams, in meadows, semi-natural and disturbed locations, woodland or forest, swamps, marshes and fens (Table S2).

Table S2: Summary of habitat types associated with *Impatiens* species.

Habitat	***Impatiens* species**
Moist meadows	*I. balfourii*
Moist artificial, semi-natural or disturbed locations (e.g., gardens, roadside ditches, railway lines)	*I. balfourii*, *I. glandulifera*, *I. parviflora*, *I. capensis*, *I. edgeworthii*
Moist woodland or forest	*I. balfourii*, *I. capensis*, *I. edgeworthii*, *I. glandulifera*, *I. pallida*, *I. parviflora, I. scabrida*
Banks of rivers and streams	*I. capensis*, *I. pallida*, *I. glandulifera*, *I. parviflora*, *I. tinctoria*
Swamps, marshes	*I. capensis*, *I. pallida*, *I. tinctoria*
Fens	*I. capensis*, *I. glandulifera*

The major habitat types of *I. glandulifera* and *I. capensis* in Europe are riverbanks and floodplains. *I. glandulifera* prefers low powered streams at low altitudes and with fine sediment particles and flourishes where native vegetation is poorest and space is available for colonisation. *I. parviflora* is now the most serious invader at the margins of moist to wet temperate deciduous forests and mixed conifer forests, even in apparently undisturbed places. It is the only non-native plant being dispersed in European forests on a large scale. The slower spread of *I. parviflora* compared to *I. glandulifera* in the United Kingdom was probably due to its relative vulnerability to frost together with its preference for wood or forest habitats. In the United Kingdom, *I. parviflora* may eventually spread as widely as *I. glandulifera*, but remain less frequent due to narrower habitat requirements. In contrast to other *Impatiens* species established in Europe, *I. balfourii* colonises open habitats with high light intensities and prefers dry to humid soil conditions.

Distribution in the Netherlands and colonisation of habitats with high conservation values

According to the Belgian Forum Invasive Species (BFIS) classification, four *Impatiens* species are already widespread in the Netherlands. These are, in order of number of records, *I. glandulifera* > *I. parviflora* > *I. capensis* > *I. balfourii*. *I. scabrida* has only been recorded at two locations since 1990 in total, and is therefore classified under isolated populations. *I. arguta*, *I. balsamina*, *I. edgeworthii*, *I. flanaganae*, *I. pallida*, *I. parviflora x balfourii*, *I. sulcata* and *I. tinctoria* are all absent from the Netherlands. *I. glandulifera* has been recorded in 61 Natura 2000 areas, mostly situated along the Rhine and its tributaries and along the Rhine-Meuse estuary. *I. parviflora* have been confirmed in 53 mostly wooded N2000 areas. *I. capensis* occurs within 15 Natura 2000 areas, mostly lying within the tidal freshwater area. *I. balfourii* has mostly been recorded in cities and towns in the Netherlands. Confirmed records exist only for two wooded Natura 2000 areas in the Netherlands.

Adverse impacts on native species

No information on the ecological impacts of *I. arguta, I. balsamina, I. edgeworthii*, *I. pallida, I. parviflora x balfourii*, *I. scabrida* or *I. tinctoria* was found during the literature survey. *I. glandulifera* is the most competitive of all *Impatiens* species. It forms tall, dense, many branched stands, outcompeting native species for space, light, nutrients and pollinators. Only perennial native species with a strong vegetative propagation are able to withstand *I. glandulifera.* The competitive advantage of *I. glandulifera* may be facilitated by early germination in some years, synchronised seedling emergence, rapid growth, greater density and biomass, increase in stem height in the presence of neighbouring species. *I. parviflora* has been reported to reduce native plant species abundance and possibly reduce the abundance of herbaceous species in Belgium. In an experiment comparing native *I. noli-tangere* and non-native *I. glandulifera*, *I. parviflora*, and *I. capensis*, *I. parviflora* appeared to be the second strongest competitor, especially under conditions of low soil moisture. However, in Germany, Poland and the Czech Republic no impact on the diversity of native species has been recorded. Overall the biodiversity impact of *I. parviflora* seems to be limited. *I. balfourii* can form dense pure stands that could suppress other species. It is unknown whether a hazard to German native species from *I. balfourii* exists. *I. balfourii* is likely to have a negative impact on the natural vegetation of ruderal or semi-natural communities. In contrast, *I. capensis* does not form monocultures and is generally not classified as a problematic plant in its non-native range. While *I. capensis* is less competitive than either *I. glandulifera* or *I. parviflora*, it may competitively exclude native *I. noli-tangere* which has declined in abundance in recent years. To date, *I. capensis* and *I. noli-tangere* have rarely, if ever, co-occurred in Europe. Theoretically, *I. capensis* may be able to hybridise with *I. noli-tangere*. However, to date there is no evidence of actual hybridisation between these two species.

Alteration of ecosystem functions
No information on the ecological impacts of *I. arguta, I. balsamina, I. edgeworthii*, *I. pallida, I. parviflora x balfourii*, *I. scabrida* en *I. tinctoria*. However, some physical modification of habitats may be expected, such the erosion of bare soil after winter die back and light interception during growth periods of these species. *I. glandulifera* invasion may result in changes in vegetation structure, trophic interactions and increased bank erosion and sediment entrainment may negatively impact native species. In dense stands, *I. parviflora* is able to monopolise light and space, excluding other plant species. The addition of a herbaceous layer in forests where vegetation was formerly absent may affect tree regeneration and consequently ecological succession. *I. balfourii* can form dense pure stands that could affect light penetration.

Human health impacts
No information on the possible human health effects of *Impatiens* species was found during the literature study.

Economic impacts
No information on the possible economic impacts of *I. arguta*, *I. balfourii*, *I. balsamina*, *I. capensis*, *I. edgeworthii*, *I. flanaganae*, *I. pallida*, *I. parviflora x balfourii*, *I. scabrida* and *I. tinctoria*. However, some evidence of potential impacts to the forestry industry by *I. glandulifera* and *I. parviflora* were found during the literature study. *I. glandulifera* may impact forestry by impairing natural regeneration. However, this has not been proven. Dense stands of *I. glandulifera* and dead plant material may impede water-flow during heavy rainfall and promote flooding. In the United Kingdom the Environment Agency estimates that it would cost £300 million (circa €420 million) to eradicate *I. glandulifera*. *I. parviflora* colonises managed forests and timber plantations and may affect tree regeneration silvicultural systems where this is important. Lastly, *I. sulcata* is a weed of wheat (*Triticum* spp.) in Nepal.

Risk classifications

I. glandulifera received the highest ecological risk score of all the Impatiens species assessed receiving a maximum of 12 out of 12 points for ecological risk. This species was the only species to be classified as high risk under the BFIS system. Four other species were classified as medium risk (*I. balfourii*, *I. capensis*, *I. edgeworthii* and *I. parviflora*). Eight species were classified as low risk (*I. arguta*, *I. balsamina*, *I. flanaganae*, *I. pallida*, *I. parviflora* x *balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*) (Table S3). The highest scoring species for the categories dispersion potential or invasiveness and colonisation of high conservation value habitats (total scores of five or six out of a maximum of six) *I. glandulifera*, *I. parviflora*, *I. capensis* and *I. balfourii*. The highest scoring species for the categories direct or indirect adverse impact on native species and direct or indirect alteration of ecosystem functions were *I. glandulifera* and *I. edgeworthii.*

However, many scores for risk criteria were determined by best professional judgement, due to data limitations (Table S3; indicated with *). This approach is inherently associated with high uncertainty in total risk score of species and may have caused underestimation of their risk classification.

Table S3: Ecological risk scores and classification of *Impatiens* species for the Netherlands (*: Risk score and classification strongly determined by best professional judgement due to data limitations).

Species	Common name	Total risk score (ISEIA)	Distribution in the Netherlands	Risk classification (BFIS list system)
I. arguta	Not applicable	8*	Absent	C0*
I. balfourii	Balfour's touch-me-not	9*	Widespread	B3*
I. balsamina	Common garden balsam	5*	Absent	C0*
I. capensis	Orange jewelweed	9	Widespread	B3
I. edgeworthii	Not applicable	9*	Absent	B0*
I. flanaganae	Not applicable	5*	Absent	C0*
I. glandulifera	Himalayan balsam	12	Widespread	A3
I. pallida	Pale jewelweed	8*	Absent	C0*
I. parviflora	Small balsam	9	Widespread	B3
I. parviflora x balfourii	Not applicable	6*	Absent	C0*
I. scabrida	Rugged yellow balsam	8*	Isolated	C1*
I. sulcata	Gigantic Himalayan balsam	5*	Absent	C0*
I. tinctoria	Not applicable	5*	Absent	C0*

Ecological risk categorisation: High risk; Medium risk; Low risk

Effective management options

Generally, the cost of control and eradication of an invasive species once it has become established far outweighs the costs associated with prevention of introduction. Once an invasive species has become established it is extremely difficult, if not impossible, to eradicate. The main vector of dispersal over long distance for *Impatiens* species is the trade in garden plants. The introduction of a voluntary code of conduct or (inter)national legislation aimed at the professional sector that provides guidelines on which species should not be sold to the public or sold with information on their potential invasiveness may reduce the risk of non-native species introduction. Public awareness is an important component in a strategy aimed at controlling or removing an invasive species. Awareness leaflets, press releases, calendars, information boards and websites warning of the environmental, economic and social hazards posed by non-native plants will contribute to public awareness. *Impatiens* species are often planted by beekeepers and horticulturalist in an effort to encourage bees and other insects. Recommendations for alternative high nectar producing native plants and information on the potential ecological risks posed by non-native *Impatiens* species should be provided to these groups.

Monitoring should be introduced that facilitates the early identification of new *Impatiens* stands. Nature organisations may facilitate the early identification of non-native species establishing in their management area by a) identifying priority species through risk assessment, b) encouraging early recognition by training field staff, c) registering incoming notifications from third-parties, d) registering any new records in central registration databases (e.g., the 'Nationale Database Flora & Fauna'). Moreover, openly accessible databases may also be used and consulted (e.g., www.waarnemingen.nl, that feature species records made by the public and professionals).

Control measures will only be effective if seed setting is prevented. Therefore it is vital to remove all individuals in a timely manner as the seed formation of a single plant can be enough to completely nullify management efforts. *I. glandulifera* does not form a persistent seed bank. The seeds of this species are fertile for one and a half to two years. Therefore, it is recommended that checks for the establishment of new seedlings are made for a minimal of two growing seasons following management interventions, and that management measures are repeated as required. As *Impatiens* often spreads by hydrochory, management interventions should begin at locations highest up in the river catchment and then progress downstream to prevent the recolonization of areas previously cleared.

Mechanical (mowing) and manual removal are the most cost-effective methods for the management or elimination of *Impatiens* species. Mechanical and manual removal should be carried out in June or July in the Netherlands. Mechanical methods are only effective at locations where accessibility is guaranteed and damage to native fauna and flora does not outweigh the benefits of *Impatiens* removal, otherwise manual methods should be applied. Mowing should occur as close to the ground as possible to prevent further flowering and regrowth. Manual removal is more labour intensive than mowing but can be performed accurately, ensuring all plants are removed. Following manual removal, it is vital that the stem of each individual is completely broken in two before discarding them otherwise plants may re-root and recover, particularly if the soil is not completely dry. At locations of very large coverage initial mowing should be undertaken followed by the manual removal of plants. Particular attention should be focused on identifying plants that have been flattened or not entirely cut during mowing as these individuals will likely recover and form the basis for new stands. Cuttings may be left in the field in dry weather when the soil is also dry, however, plants should be removed in damp conditions to prevent re-rooting. It is vital that repeated checks are made following efforts to remove *Impatiens* species. *Impatiens* may re-establish if the plant stems are not properly destroyed and small plants are easily missed. A river catchment approach should be taken during monitoring as certain *Impatiens* species (e.g., *I. glandulifera* disperse highly effectively by hydrochory). For example, if an upstream stand of *I. glandulifera* is identified, downstream locations, particularly disturbed areas, should also be checked for the presence of the plant.

Volunteers are potentially more effective than professionals in the effective removal of *Impatiens* if properly trained and supervised. The only instance when a professional is more effective than a volunteer is when mowing is required. Moreover, volunteers will possibly continue their work independently in future, removing *Impatiens* during recreational activities and informing nature managers of potential new *Impatiens* stands. It is important that sufficient numbers of people are present to completely remove of all plants. Whether professionals or volunteers are used in the control of *Impatiens* species, clear, step by step instructions should be provided prior to any intervention to maximise management success.

Grazing is of limited benefit as most grazers will consume other plants before eating *I. glandilufera.* Therefore grazing will only be effective in locations where other plant species are rare or absent. Currently, no information was available concerning the effectiveness of biological measures. Therefore, no recommendation for biological control can be made. Chemical control is an effective control method, but must be carried out carefully in order to treat all plants. Chemical control should be carried out in spring, when the plants develop flower buds, but before seed formation to prevent the seed ripening after the plant is treated. However, chemical control is not recommended as mechanical and manual removal are effective and do not feature the potentially damaging side effects associated with herbicide use.

Other factors that may hinder the effective application of management measures are 1) not gaining access to private land resulting in the incomplete removal of plant stands; and 2) other projects (e.g., river rehabilitation), may not incorporate a non-native species assessment and can facilitate the spread of *Impatiens* by creating new invasion pathways.

Further research

A number of issues were identified during the species selection and risk assessment process that require further research. Firstly, many *Impatiens* species that were not identified for inclusion in the risk assessment process may fulfil the inclusion criteria listed in section 2.1 in future due to climate change and changes in the European trade of non-native plants. It is recommended that periodic re-assessment of the potential for establishment of non-native *Impatiens* species in the Netherlands is undertaken to account for these changes. Secondly, traditional options for the management of *Impatiens* species appear to be compromised due to the risk of increased seed dispersal as a result of disturbance and the risks associated with herbicide use near to aquatic systems. Further research could investigate pests, sediment and nutrient characteristics, climate match and other inhibitors such as the role of allelopathy in native ranges as a first step in developing innovative management techniques. Thirdly, there is a high level of uncertainty associated with risk classifications of species where knowledge is limited (particularly *I. arguta*, *I. flanaganae* and *I. tinctoria*). It is recommended that further research be conducted on the habitat requirements and potential ecological impacts of these species in their non-native ranges.

1. Introduction

1.1. Background and problem statement

Impatiens is a large genus of approximately 850 to 1000 species of herbaceous flowering plants (depending on the applied taxonomy). The species occur in all the continents of the Northern hemisphere and in the tropics. A number of non-native *Impatiens* species are sold in Europe via the plant trade and are planted in gardens because of their attractive flowers and copious nectar production that is favoured by honey bees. However, a number of *Impatiens* species have been released or escaped from cultivation and have become invasive in Europe leading to diverse ecological impacts. The most well-known example of this is the Himalayan balsam (*Impatiens glandulifera*) that, according to CABI (2015b), is invasive in the United Kingdom, Austria, the Czech Republic, Denmark, Germany, Hungary, Ireland, the Netherlands, Poland, Slovakia, Sweden and Switzerland. At the start of this project, there was a lack of knowledge regarding the pathways for introduction, vectors for spread, key factors for establishment and invasiveness, and (potential) effects of *Impatiens* in the Netherlands. To support decision making with regard to the design of measures to prevent ecological, socio-economical and public health effects, the Invasive Alien Species Team of the Netherlands Food and Consumer Product Safety Authority (Ministry of Economic Affairs) requested that a risk assessment of non-native *Impatiens* should be undertaken. The present report reviews available knowledge and data about the non-native *Impatiens* species with the highest establishment potential in the Netherlands, reports the results of a risk assessment of these species within the Dutch context and discusses possibilities for prevention of introduction and cost-effective management of the species once they have become established in Dutch nature.

1.2. Research goals

The major goals of this study are:

- To describe the global distribution and to analyse the current spread of *Impatiens* in the Netherlands.
- To identify the key factors for dispersal (pathways, vectors, invasiveness) and successful establishment of *Impatiens*.
- To describe the species and habitat characteristics of *Impatiens.*
- To analyse (potential) ecological, socio-economical and public health effects of *Impatiens* in the Netherlands, taking into account their impacts and risk classifications in other geographical areas.
- To assess (potential) ecological risks of *Impatiens* species in the Netherlands.
- To develop an interactive key for identification and information of *Impatiens* species in the invasive plants database Q-bank.
- To review management options for the control of spread, establishment and negative effects of *Impatiens*.

1.3. Outline and coherence of research

The coherence between various research activities and outcomes of the study are visualised in a flow chart (Figure 1.1). The present chapter describes the problem statement, goals and research questions in order to identify key factors for the dispersal, establishment, effects and management of *Impatiens* in the Netherlands. Chapter 2 gives the methodological framework of the project and describes the literature review, data acquisition and field surveys. Chapter 3 describes the results of the survey of *Impatiens* species and hybrids in the Netherlands and surrounding countries and concludes on species selection for risk analysis. Chapter 4 includes detailed descriptions of each *Impatiens* species and describes the identity, taxonomical status, reproductive biology, habitat characteristics, geographical distribution and trends in distribution in the Netherlands including relevant pathways and vectors for dispersal, ecological, economic and public health effects and available risk classifications from other countries. Moreover, this chapter includes the results of risk assessments of selected species that have been performed by an expert team, using available information and data. Chapter 5 ranks and evaluates risk classification of all *Impatiens* species involved. Chapter 6 reviews the scope of management options for these species. The development of an interactive key for species identification and information is described in chapter 7. Relevant uncertainties, knowledge gaps, risks and management implications are discussed in chapter 8. Finally, chapter 9 draws conclusions and gives recommendations for management and further research. Appendices with raw data and background information complete this report. The report will be used as background information for an expert meeting in order to assess the dispersion, invasiveness, (potential) risks and management options of these species in the Netherlands (Risk analysis).

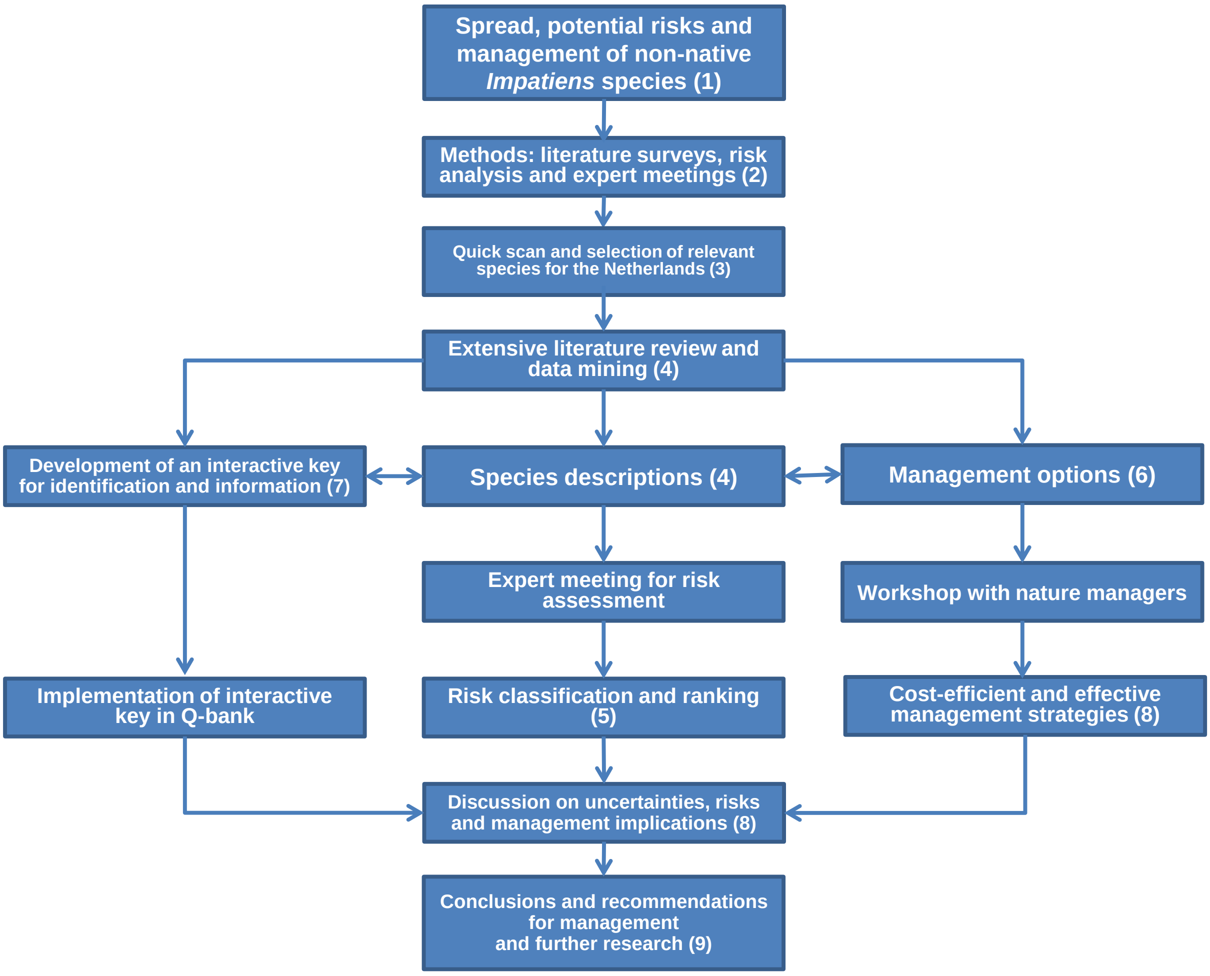

Figure 1.1: Flow chart visualising the coherence of various research activities in order to develop a knowledge document for risk analysis of *Impatiens* in the Netherlands. Chapter numbers are indicated in brackets.

2. Materials and methods

2.1 Quick scan of relevant *Impatiens* species and hybrids

The aim of the quick scan of non-native *Impatiens* species and hybrids in the Netherlands and surrounding countries was to identify *Impatiens* species that are already established or have the potential to establish in Dutch nature. Two criteria were applied to identify *Impatiens* species fulfilling these requirements:

- The species is already established in Dutch nature and is characterised by self-sustaining populations (Van Ooststroom, 1975; Van der Meijden, 2005), or

- The species is already established in countries surrounding the Netherlands and / or features in the European trade of non-native plant species, and is able to withstand the Dutch climate according to international literature.

It should be noted that there are many *Impatiens* species that currently do not, but in future may fulfil the above inclusion criteria due to climate change and changes in the European trade of non-native plants. Therefore, *Impatiens* species not assessed in this report may require risk assessment in the future. The taxonomy of *Impatiens* species is fairly well established and current insights are used in this report. From literature it was determined what species occur in neighbouring countries (Stace, 2010; Jäger, 2011, Lambinon & Verloove, 2012; Tison & de Foucault, 2014; Baade & Gutte, 2008; unpublished data) and the species in trade were also found in literature (Grey-Wilson, 2011).

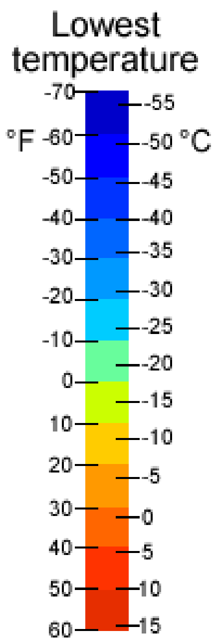

Figure 2.1: Minimum temperatures tolerated by plant species classified under the European Garden Flora (EGF) zones (Grey-Wilson, 2011).

The hardiness codes of the European Garden Flora zones (Grey-Wilson, 2011) were used to determine if the *Impatiens* species traded in Europe or established in neighbouring European countries will be able to withstand the Dutch climate (Figure 2.1). In general a plant species may be described as hardy if it is able to withstand year-round climatic conditions, including frost, without protection. The hardiness code gives a tentative indication of the lowest temperatures that a particular species can withstand (Cullan et al., 2011; Grey-Wilson, 2011). Species may have various adaptations to survive during cold periods (e.g., seeds or dormant vegetative plant parts). The system was developed by the Royal Horticultural Society (RHS) of the United Kingdom and it uses a list of hardiness 'H' numbers based on minimum temperature ranges. Later, two 'G' numbers were added to this list allowing the incorporation of plants which require indoor growing conditions even in Southern Europe. The tentative indications of the lowest temperatures that species can withstand in Europe are (EGF zones; Figure 2.1):

H1: Hardy everywhere, withstands -20˚C (-4˚F) and below;
H2: Hardy almost everywhere, withstands -15 to -20˚C (5 to -4˚F) minimum;
H3: Hardy in cool areas, withstands -10 to -15˚C (14 to 5˚F) minimum;
H4: Hardy in mild areas, withstands -5 to -10˚C (23 to 14˚F), minimum;
H5: Hardy in favourable areas, withstands 0 to -5˚C (32 to 40˚F) minimum;
G1: Needs a cool glasshouse protection even in south Europe;
G2: Needs a heated glasshouse protection even in south Europe.

Jäger et al. (2008) and Weiss (2013) were consulted to establish the winter hardiness of plant species not listed in the European Garden Flora.

2.2. Literature review

A literature study was carried out to collect all available data and information on the distribution and invasion biology of *Impatiens*. Literature data were collected on physiological tolerances, substrate preference, colonization vectors, ecological and socio-economic impacts and potential measures for the management of this species. Our search was largely internet based, supported by the use of a university library. Academic and non-academic search engines and websites were systematically searched using the Web of Knowledge, Google Scholar and Google.nl. Specific searches of invasive species databases were made to identify ecological effects relating to the potential invasive nature of *Impatiens*. Databases were queried from Q-bank (http://www.q-bank.eu/Plants/), the GB non-native species secretariat (http://www.nonnativespecies.org/home/index.cfm), Invasive alien species Belgium (http://ias.biodiversity.be/), DAISIE (http://www.europe-aliens.org/), NOBANIS (http://www.nobanis.org/), EPPO (http://www.eppo.int/) and the Global non-native species database (http://www.issg.org/database/welcome/). All search results from the Web of Knowledge and the invasive species databases were examined, while the first 50 results from Google Scholar and Google.nl were examined due to the decreasing relevance of search results returned using this search engine. Search terms used to carry out the literature study were: the species scientific name, e.g., *Impatiens glandulifera*, the official English common name and, if applicable, frequently used synonyms.

Due to time limitations, not all the results of the literature study could be included in the making of this report. Instead, the results of the literature study were scanned to pick out information that is most relevant to an ecological risk assessment of *Impatiens* species. Moreover, literature providing information on *Impatiens* species not fulfilling the criteria of this risk assessment was discovered. A bibliography was produced that includes all the references discovered during the literature study that may be useful for researchers wanting to discover more about *Impatiens*. This bibliography is available from the authors on request.

An analysis of search engine hits via Google.nl was performed in order to analyse the general public's access to *Impatiens* plants and seeds in the Netherlands from online retailers. The first 50 websites found were categorised according to their content. Separate searches of Google were carried out using the scientific and Dutch common names combined with the term 'te koop' (for sale). Websites that contained names not referring directly to a species were omitted (e.g., where only the genus *Impatiens* was mentioned). The retailer's country of origin was noted, as this was assumed to influence the buying behaviour of hobbyists. Also the type of product available was recorded (whole plants, seeds, cuttings). The total number of websites contained within each category was calculated. If the same website was found using two or more different search terms, it was included in the calculations of both or all of these search terms. This gives an impression of the accessibility of the websites using different search terms which reflects the ease with which the public have access to them, and the potential level of impact of the information contained. It should be noted that Google may provide personalised results according to previous search terms entered. The results may therefore not be reproducible from different IP addresses.

2.3. Data acquisition on current distribution

Distribution data originated from the Dutch 'Nationale Database Flora & Fauna' (NDFF), a web based biodiversity resource. The NDFF is the most complete and up to date biodiversity databank in the Netherlands and contains only validated information on the distribution of species (NDFF, 2015). Distribution maps and trend charts of the *Impatiens* species in the Netherlands were obtained from Verspreidingsatlas.nl. This website presents the data in the NDFF at the level of 5x5 kilometre squares. Data on international distributions was obtained from international non-native species databases and scientific literature (see references).

2.4. Risk assessment

2.4.1. Selection of risk assessment method

Initially, the aim of this project was to assess *Impatiens* species using two risk assessment methods: The ISEIA protocol and the Harmonia$^+$ protocol. However, during the initial assessment stage it was decided to apply the ISEIA protocol only. Harmonia$^+$ uses a web portal that allows risk assessors to enter information on the ecological, economic and sociological risks of a non-native species for a particular region. Following data input a score is automatically generated that reflects the global risk of the non-native species to the region. However, due to the wide range of information required and the lack of information available for many *Impatiens* species, it was often not possible to obtain a risk score that accurately reflected the information entered and allowed for comparison and ranking of all species. As one of the aims of this project is to provide insight into the relative ecological risks of *Impatiens* species to the Netherlands, valid risk scores were required on ecological risks for all species and it was decided to apply the ISEIA protocol only. The ISEIA protocol requires less detailed information on impacts to obtain a valid risk classification and focuses on ecological impacts only.

2.4.2. The ISEIA ecological risk assessment protocol

The ISEIA protocol assesses risks associated with dispersion potential, invasiveness and ecological impacts only (Branquart, 2007). Definitions for risk classifications relating to the four sections contained within the ISEIA protocol are given in Table 2.1.

Table 2.1: Definitions of criteria for risk classifications per section used in the ecological risk assessment protocol (Branquart, 2007).

1. Dispersion potential or invasiveness risk	
Low	The species does not spread in the environment because of poor dispersal capacities and a low reproduction potential.
Medium	Except when assisted by man, the species doesn't colonise remote places. Natural dispersal rarely exceeds more than 1 km per year. However, the species can become locally invasive because of a strong reproduction potential.
High	The species is highly fecund, can easily disperse through active or passive means over distances > 1km / year and initiate new populations. Are to be considered here plant species that take advantage of anemochory, hydrochory and zoochory, insects like *Harmonia axyridis* or *Cemeraria ohridella* and all bird species.
2. Colonisation of high conservation habitats risk	
Low	Population of the non-native species are restricted to man-made habitats (low conservation value).
Medium	Populations of the non-native species are usually confined to habitats with a low or a medium conservation value and may occasionally colonise high conservation habitats.
High	The non-native species often colonises high conservation value habitats (i.e., most of the sites of a given habitat are likely to be readily colonised by the species when source populations are present in the vicinity) and makes therefore a potential threat for red-listed species.
3. Adverse impacts on native species risk	
Low	Data from invasion histories suggest that the negative impact on native populations is negligible.
Medium	The non-native is known to cause local changes (<80%) in population abundance, growth or distribution of one or several native species, especially amongst common and ruderal species. The effect is usually considered as reversible.
High	The development of the non-native species often causes local severe (>80%) population declines and the reduction of local species richness. At a regional scale, it can be considered as a factor for precipitating (rare) species decline. Those non-native species form long standing populations and their impacts on native biodiversity are considered as hardly reversible. Examples: strong interspecific competition in plant communities mediated by allelopathic chemicals, intra-guild predation leading to local extinction of native species, transmission of new lethal diseases to native species.
4. Alteration of ecosystem functions risk	
Low	The impact on ecosystem processes and structures is considered negligible.
Medium	The impact on ecosystem processes and structures is moderate and considered as easily reversible.
High	The impact on ecosystem processes and structures is strong and difficult to reverse. Examples: alterations of physico-chemical properties of water, facilitation of river bank erosion, prevention of natural regeneration of trees, destruction of river banks, reed beds and / or fish nursery areas and food web disruption.

The ISEIA protocol contains twelve criteria that match the last steps of the invasion process (i.e., the potential for spread establishment, adverse impacts on native species and ecosystems). These criteria are divided over the following four risk sections: (1) dispersion potential or invasiveness, (2) colonisation of high conservation habitats, (3) adverse impacts on native species, and (4) alteration of ecosystem functions. Section 3 contains sub-sections referring to (i) predation / herbivory, (ii) interference and exploitation competition, (iii) transmission of diseases to native species (parasites, pest organisms or pathogens) and (iv) genetic effects such as hybridisation and introgression with native species. Section 4 contains sub-sections referring to (i) modifications in nutrient cycling or resource pools, (ii) physical modifications to habitats (changes to hydrological regimes, increase in water turbidity, light interception, alteration of river banks, destruction of fish nursery areas, etc.), (iii) modifications to natural successions and (iv) disruption to food-webs, i.e., a modification to lower trophic levels through herbivory or predation (top-down regulation) leading to ecosystem imbalance.

Each criterion of the ISEIA protocol was scored. The scores range from 1 (low risk) to 2 (medium risk) and 3 (high risk). Definitions for low, medium and high risk, according to the four sections of the ISEIA protocol are given in table 2.1. If knowledge obtained from the literature review was insufficient, then the assessment was based on expert judgement and field observation leading to a score of 1 (unlikely) or 2 (likely). If no answer could be given to a particular question (no information) then no score was given (DD - deficient data). In cases with data or knowledge limitations, periodical review of new literature and updates of risk scores will be recommended. Finally, the highest score within each section was used to calculate the total score for the species.

Consensus of an expert team on the risk score of each section was reached using a hierarchical method where evidence from within the Netherlands was given priority over evidence derived from impacts occurring outside the Netherlands (paragraph 2.3.3). Consideration was given to the future application or non-application of management measures that will affect the invasiveness and impacts of this invasive plant in the Netherlands.

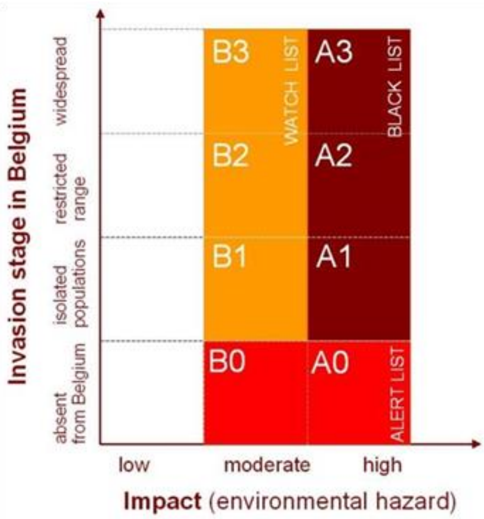

Figure 2.2: BFIS list system to identify species of most concern for preventive and mitigation action (Branquart, 2007).

Subsequently, the Belgian Forum Invasive Species (BFIS) list system for preventive and management actions was used to categorise the species of concern (Branquart, 2007). This list system was designed as a two dimensional ordination (Environmental impact * Invasion stage; Figure 2.2). It is based on guidelines proposed by the Convention on Biological Diversity (CBD decision VI/7) and the European Union strategy on invasive non-native species. Environmental impact of the species was classified based on the total risk score (global environmental risk) which is converted to a letter / list: score 4-8 (C), 9-10 (B - watch list) and 11-12 (A - black list). This letter is then combined with a number representing invasion stage: (0) absent, (1) isolated populations, (2) restricted range, and (3) widespread. A cross is used to indicate the risk classification of the assessed species within the BFIS system. A green cross indicates a low risk species that should not appear on any list within the BFIS system. A black cross indicates a species that should appear on either the watch, alert or black list of the BFIS system.

2.4.3. Expert meeting on risk classification using the ISEIA protocol

The *Impatiens* risk assessment was carried out by a team of eight experts. Two from the Netherlands Food and Consumer Product Safety Authority; one from Naturalis Biodiversity Center, two from the Dutch plant research and conservation organisation FLORON; and three from the Radboud University Nijmegen. An initial assessment of each species was carried out independently by a senior ecologist based on the information presented in Chapter 4. Following this preliminary individual assessment, the entire project team met. The risk classifications of the preliminary assessments of species were presented during this expert meeting and subsequently consensus was achieved on the risk classifications by elucidating and discussing differences in opinion and interpretation of key information.

2.5. Workshop on cost-effective management strategies

A workshop was undertaken to compare and contrast different management approaches for the cost-effective management of *Impatiens* species in the Netherlands. In total, fifteen nature and water managers were contacted with a request for information on their approach to the management of risks relating to *Impatiens* species in their management areas and to invite them to the workshop. The nature managers represented Dutch and Belgian water boards, and some nature management organisations in the Netherlands. Additional information was obtained from the websites of nature organisations in France and the United Kingdom. Information was obtained in relation to:

- Prevention of *Impatiens* introduction.
- The monitoring of areas sensitive to *Impatiens* introduction and colonisation.
- Methods and strategies for the prevention, elimination and management of *Impatiens* introduction and colonisation.
- Issues encountered with the practical application and organisation of prevention, elimination and management methods.
- The role of volunteers.
- Factors determining the success or failure of management interventions.
- Bottlenecks that may inhibit the effective application of measures.

The workshop on cost-effective management strategies was carried out by a group of ten experts in the field of invasive species (Appendix 1). Two nature managers contacted were able to attend the workshop and gave presentations describing their organisations approach to cost-effective management. An additional presentation described information obtained from nature and water managers in the Netherlands and abroad who were unable to attend and internet sources. Following the presentations, a group discussion led to consensus on the most cost-effective approach for managing *Impatiens* species in the Netherlands, the results of which provide a starting point for the formulation of an *Impatiens* management protocol that can be applied (inter)nationally.

3. Survey of *Impatiens* species and hybrids in the Netherlands and surrounding countries

The literature search revealed that there are a number of different descriptions of the *Impatiens* genus at national level. An overview of the species also exists in the book entitled ‘The European garden flora’ by Grey-Wilson (2011). However, there is no worldwide monograph available and new *Impatiens* species are continually being described.

The results of the literature search show that besides native touch-me-not balsam (*I. noli-tangere*), four non-native *Impatiens* species have been established in the Netherlands (Van Ooststroom, 1975; Van der Meijden, 2005): Balfour’s touch-me-not (*I. balfourii*), orange jewelweed (*I. capensis*), Himalayan balsam (*I. glandulifera*) and small balsam (*I. parviflora*). A fifth non-native species, rugged yellow balsam (*I. scabrida*), is recently recorded at a few locations in urban areas (Odé, 2013; recorded as *I. cristata*).

I. edgeworthii has recently been recorded for the first time in Germany and this species appears to be spreading there (Baade & Gutte, 2008; Weiss, 2013). A possible hybrid of *I. parviflora* and *I. balfourii* has been identified in Switzerland. The origin of this hybrid is currently being examined by the Netherlands Food and Consumer Product Safety Authority (NVWA), Hortus Botanicus at Leiden University, and Naturalis Biodiversity Center in Leiden (The Netherlands). Recent floras did not add other *Impatiens* species to our list of established species in neighbouring countries (Stace, 2010; Jäger, 2011, Lambinon & Verloove, 2012; Tison & de Foucault, 2014).

Besides the *Impatiens* species that are established in the Netherlands and Europe, there are 18 species traded in Europe that may escape from cultivation. These are *I. arguta*, *I. auricoma*, *I. balsamina*, *I. flanaganae*, *I. gordonii*, *I. grandis*, *I. hawkeri*, *I. hochstetteri*, *I. marianae*, *I. niamniamensis*, *I. pallida*, *I. repens*, *I. sodenii*, *I. sulcata*, *I. tinctoria*, *I. usambarensis*, *I. verticillata* and *I. walleriana* (Grey-Wilson, 2011; Jäger et al., 2008).

The frost sensitivity of all the above mentioned species is known (Grey-Wilson, 2011; Jäger et al. 2008; Weiss, 2013). Table 3.1 shows that 13 taxa, highlighted in red, tolerate low temperature ranges of 0 to -5˚C to < -20˚C (Hardiness H1 to H5; Grey-Wilson, 2011) or are regarded as winter hard (Jäger et al. 2008; Weiss 2013). These species are able or expected to tolerate the Dutch climate. Therefore, *I. arguta*, *I. balfourii*, *I. balsamina*, *I. capensis*, *I. edgeworthii*, *I. flanaganae*, *I. glandulifera*, *I. pallida*, *I. parviflora*, *I. parviflora x I. balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria* were chosen to be examined in further detail using the ISEIA risk assessment method in Chapter 4.

Table 3.1: *Impatiens* species climatically matched with the Netherlands, and their trade, spread and establishment in Europe.

Scientific name	Synonyms	Dutch name	European Garden Flora climate code[3]	Winter hard[4,5]	The Netherlands		Neighbouring countries	Other European countries	Present in European trade	References
					Established	Recorded	Recorded	Recorded		
I. arguta Hook.*f*. & Thomson	*Impatiens arguta* var. *bulleyana* Hook. f.; *Impatiens gagei* Hook. f.; *Impatiens namchabarwensis* R.J. Morgan, Y.M. Yuan & X.J. Ge; *Impatiens taliensis* Lingelsh. & Borza		H5						•	7
I. auricoma Baill.		Afrikaanse balsemien	G2						•	7
I. balfourii Hook. f.		Tweekleurig springzaad	H2		•	•	•	•		8, 12
I. balsamina L.	*Balsamina angustifolia* Blume; *Balsamina balsamina* (L.) Huth; *Balsamina coccinea* (Sims) DC.; *Balsamina cornuta* (L.) DC.; *Balsamina foeminea* Gaertn.; *Balsamina hortensis* Desp.; *Balsamina lacca* Medik.; *Balsamina minutiflora* Span.; *Balsamina mollis* G.Don; *Balsamina odorata* Buch.-Ham. ex D.Don; *Balsamina racemosa* Buch.-Ham. ex D.Don; *Balsamina salicifolia* Bojer ex Baker; *Impatiens balsamina* var. *corymbosa* Santapau; *Impatiens coccinea* Sims; *Impatiens cornuta* L.; *Impatiens eriocarpa* Launert; *Impatiens stapfiana* Gilg	Balsemien	H5					•	•	5, 6, 13
I. capensis Meerb.	*Balsamina capensis* (Meerb.) DC.; *Balsamina fulva* Ser.; *Chrysaea biflora* (Walter) Nieuwl. & Lunell; *Impatiens biflora* Walter; *Impatiens biflora* Willd.; *Impatiens capensis* f. *capensis*; *Impatiens fulva* Nutt.; *Impatiens nortonii* Rydb.	Oranje springzaad	n.a.	Yes	•	•	•	•		12
I. edgeworthii Hook.f.	*Impatiens chrysantha* Hook. f.		n.a.	Yes			•			4, 5, 6, 7

Table 3.1: Continued.

Scientific name	Synonyms	Dutch name	European Garden Flora climate code[3]	Winter hard[4,5]	The Netherlands		Neighbouring countries	Other European countries	Present in European trade	References
					Established	Recorded	Recorded	Recorded		
I. flanaganae Hemsl.			H5-G1						●	4, 7
I. glandulifera Royle	*Balsamina glandulifera* (Royle) Ser.; *Balsamina macrochila* (Lindl.) Ser.; *Balsamina roylei* (Walp.) Ser.; *Impatiens glanduligera* Lindl.; *Impatiens macrochila* Lindl.; Impatiens roylei Walp.	Reuzenbalsemien	H2		●	●	●	●		4, 7 , 12
I. gordonii Horne ex Baker			G1						●	4, 7
I. grandis B. Heijne			G2						●	4, 7
I. hawkeri W. Bull		Nieuw-Guinea-impatiens	G1						●	4, 7
I. hochstetteri Warb.		Afrikaanse balsemien, Kruidje-roer-me-niet	n.a.	No[2]					●	10
I. marianae Rchb. F. ex Hook. f.			Frost free overwintering						●	4, 7
I. niamniamensis Gilg		Congobalsemien	G2						●	4, 7
I. pallida Nuttal				Yes					●	11
I. parviflora DC.	*Balsamina parviflora* (DC.) Ser.; *Impatiens nevskii* Pobed.	Klein springzaad	H2		●	●	●	●		4, 7 , 12
I. parviflora x I. balfourii[1]			n.a.	Yes				●		4, 7
I. repens Moon		Kruipende vlijtig Liesje	G2						●	4, 7
I. scabrida DC.	*Balsamina cristata* (Wall.) Ser.; *Balsamina tricornis* Ser.; *Impatiens cristata* Wall.; *Impatiens praetermissa* Hook.f.; *Impatiens tricornis* Lindl.	Ruig springzaad	H1		●9a	●		●		4, 7, 9b, 13
I. sodenii Engl & Warb.			G1					●	●	4, 7
I. sulcata Wall.	*Impatiens gigantea* Edgew.		H2						●	4, 7
I. tinctoria A. Rich.	*Impatiens flagellifera* Hochst. *ex* A.Rich.		H5-G1						●	4, 7
I. usambarensis Grey-Wilson			G1						●	7
I. verticillata Wight			G2						●	4, 7
I. walleriana Hook. f.		Vlijtig liesje	G1					●	●	7, 13

High risk of establishment in the Netherlands if introduced to nature; Low risk of establishment in the Netherlands; [1] identity unconfirmed; [2] originated from South-East Africa; [3] Climate codes from European Garden Flora (Grey-Wilson, 2011): G1/2 needs cool/heated glasshouse even in south Europe and H1-5 hardy everywhere (<-20 ˚C) - withstands 0 to -5 ˚C; [4] according to Jäger et al. (2008); [5] according to Weiss (2013); [6] Baade & Gutte (2008); [7] Grey-Wilson (2011); [8] Ingberg (2014); [9b] Establishment has been recorded in an urban area by Odé (2013); [9b] Odé (2013); [10] Tuinadvies (2015); [11] USDA (2015); [12] Van der Meijden (2005); [13] Van Ooststroom (1975).

4. Descriptions of *Impatiens* species

It should be noted that if no information on ecological impacts was found as a result of the literature search it does not mean that a particular effect does not occur. It may not yet have been observed, published or occurred.

4.1. *Impatiens arguta*

4.1.1. Species description

Impatiens arguta is a perennial herb that grows to a maximum of 70 cm tall. The stem is erect, rigid and branched. The glabrous leaves often feature two stipitate basal glands with seven or eight pairs of lateral veins, are alternate, with petioles of 1-4 cm, ovate or ovate-lanceolate and 3-12 x 1.2-4.5 cm, the base is cuneate and the leaf margins are sharply serrate with an acute or acuminate apex. The inflorescences are axillary, featuring one or two flowers with very short peduncles (Figure 4.1). The pedicels are long and slender, often with two setose bracts at the base. The large or medium-sized flowers are pink or purple-red in colour. There are four lateral sepals, the outer two are subovate, apex long cuspidate, the inner two are narrowly lanceolate. The lower petal is saccate and narrowed into an incurved, short spur. The upper petal is orbicular with a mucronate apex, an abaxial midvein and is narrowly carinate. The two-lobed lateral united petals are not clawed, the basal lobes are broadly oblong and the large distal lobes are dolabriform. The auricle is conspicuous, the anthers obtuse. The capsule is fusiform. The seeds are globose and slightly shiny (www.efloras.org).

Figure 4.1: *Impatiens arguta* (© Photo: SuperFantastic, Wikimedia Commons).

Species taxonomy

Table 4.1: Nomenclature and taxonomical status of *Impatiens arguta*.

Scientific name: *Impatiens arguta* Hook.f. & Thomson (1860) **Synonyms:** *Impatiens arguta* var. *bulleyana* Hook. f., Hooker's Icon. Pl. 29, pl. 2875. 1908; *Impatiens gagei* Hook. f., Hooker's Icon. Pl. 30: t. 2951. 1911; *Impatiens namchabarwensis* R.J. Morgan, Y.M. Yuan & X.J. Ge, Curtis's Bot. Mag. 22(4): 206 (205-208; figs., plate 537). 2005; *Impatiens taliensis* Lingelsh. & Borza, Repert. Spec. Nov. Regni Veg. 13: 388. 1914. **Taxonomic tree (Naturalis, 2015):** Kingdom: Plantae Phylum: Tracheophyta Class: Spermatopsida Order: Ericales Family: Balsaminaceae Genus: *Impatiens* Species: *Impatiens arguta* **Preferred Dutch name:** Not applicable **Preferred English name:** Not applicable **Other Dutch names:** Not applicable **Other English names:** Not applicable

Life cycle

In its native range in Asia, *I. arguta* flowers from July to September (Encyclopedia of Life, 2015).

Reproductive capacity

According to anecdotal information from a UK gardener, *I. arguta* produces a prolific number of seeds and produces high levels of biomass that requires removal. However, according to the Encyclopedia of Life (2015), *I. arguta* produces few seeds.

4.1.2. Habitat summary

The physiological conditions found during the literature review tolerated by *I. arguta* are listed in table 4.2. According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), it is an H5 species meaning that it is hardy in favourable areas and withstands temperatures of 0 to -5˚C minimum. The plant is classified as very winter hard in both the Netherlands and England (De Werkplaats, 2015; Tuingoed Foltz, 2015; Keeping it Green Nursery, 2015).

Table 4.2: Physiological conditions tolerated by *Impatiens arguta*.

Parameter	Data origin	Occurrence	References
Hardiness (°C)	Unknown	0 to -5	Grey-Wilson (2011)

4.1.3. Recorded distribution

Native range

I. arguta is native to China (south west Sichuan, east Xizang, central and north west Yunnan), Bhutan, north east India, Myanmar and Nepal (Encyclopedia of Life, 2015).

Non-native range

No information on *I. arguta*'s non-native range could be found during the literature review.

Distribution in the Netherlands

According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. arguta* in the Netherlands. However, it should be noted that lag times between introduction and establishment of non-native species can be considerable, even for herbaceous species. For example, the lag time for *I. glandulifera* was 40 years in central Europe (Pysek & Prach, 1995).

Colonisation of high conservation value habitats.

According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. arguta* in the Netherlands.

4.1.4. Invasion process

Introduction

No information on the potential introduction pathways of *I. arguta* to the Netherlands could be found during the literature review. A quick scan of the first 50 results of google.nl using the search term '*Impatiens arguta* te koop' revealed one international websites offering *I. arguta* for sale to the public. According to Grey-Wilson (2011) and Jäger et al. (2008), this species is available via the European ornamental market.

Establishment

No information on the potential for establishment of *I. arguta* in the Netherlands or climatically similar countries could be found during the literature review.

Spread

No information on the potential for spread of *I. arguta* in the Netherlands or climatically similar countries could be found during the literature review.

4.1.5. Environmental impact summary

Effects on environmental targets or native species

No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.1.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. arguta* a 'medium' ecological risk classification to the categories dispersion potential or invasiveness and alteration of ecosystem functions, and a ‘likely’ risk classification to the categories colonization of high value conservation habitats and adverse impacts on native species (Table 4.3). The total ecological risk score for the species is 8 out of a maximum of 12. Therefore, *I. arguta* is classified in the C list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs. Note that two risk sections are based on expert judgement due to lack of data. The maximum for these sections is 2 and this approach may cause an underestimation.

Table 4.3: Consensus scores for potential risks of *Impatiens arguta* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Likely	2
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Medium	2
Environmental risk score		**8**

Dispersion potential or invasiveness
Classification: **Medium risk**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. arguta* in the Netherlands. Except when assisted by humans, *I. arguta* does not colonise remote areas and its natural dispersal is not expected to exceed 1 km/year. However, the species may become locally invasive because of strong biomass production and a high seed production. Moreover, seed dispersal occurs through

autochory which involves the mechanical launching seeds over some metres from the parent. Long distance dispersal by wind is not likely and it is not known if *I. arguta* seeds are dispersed by water.

Colonization of high value conservation habitats
Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. arguta* in the Netherlands. However, it is likely that the species can establish in high conservation value habitats and may cause a (potential) treat for red listed or protected species.

Adverse impacts on native species
Classification: **Likely**. There is no available evidence to suggest that *I. arguta* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. There is no available evidence to suggest that *I. arguta* could negatively impact Dutch native species through hybridisation. *I. arguta* is a perennial herb that grows to a maximum of 70 cm tall. The plant produces high levels of biomass. Moreover, *I. arguta* is very winter hard. Therefore, the occurrence of exploitation competition with native plant species is likely. Additional competition with for pollinators may be expected that will likely further impact native species. Local changes in population abundance (< 80%), growth or distribution of one or more native species can be expected, however the effect may be reversible.

Alteration of ecosystem functions
Classification: **Medium risk**. *I. arguta* is a perennial herb and is very winter hard. Climate will probably not form a barrier to the growth of *I. arguta* in the Netherlands and the plant produces a high level of biomass which may result in light interception. However, physical modification of habitats in the Netherlands is expected to be low in comparison with other *Impatiens* species (e.g., *I. glandulifera*). For example, erosion of bare soil during the winter period is not expected.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.3) in combination with the current recorded distribution in the Netherlands.

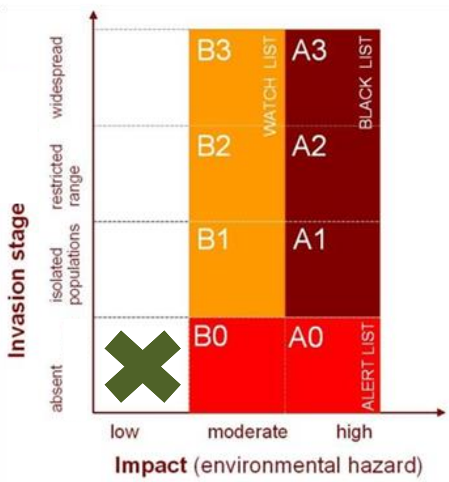

Figure 4.2: Risk classification of *Impatiens arguta* according to the BFIS list system.

The species classification for *I. arguta* is C0 (Figure 4.2). This characterises a non-native species that is absent from the area under assessment and is not eligible for placement on the watch, alert or blacklist. Note that scores for two risk categories are based on expert judgement due to lack of data (paragraph 4.1.6.). Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

4.1.7. Other risk assessments and classifications

No risk assessments or classifications of *I. arguta* for other regions or countries could be found in our literature search.

4.2. Balfour's touch-me-not (*Impatiens balfourii*)

4.2.1. Species description

Balfour's touch-me-not (*Impatiens balfourii*) is a glabrous, erect annual herb usually 40 to 80 cm tall. It may feature a single or branched stem which is translucent and pale green in colour. Roots are fibrous. The glabrous leaves are 2-3 cm x 2-13 cm, simple, without stipules, ovate-lanceolate or ovate-oblong, the base is cuniate, shortly decurrent on the petiole, the apex long and acuminate, glandular near the base with 20 to 40 teeth on each side, and mucronate with eight to 13 pairs of lateral nerves, the lamina is bright medium green on its upper surface and paler beneath with serrated margins. Three to eight flowers are arranged in axillary racemes which often become elongated in fruit. The flowers are 2.5-4 cm. Flowers feature three sepals, the lowest of which is sack like (0.8-0.9 x 0.6-0.8 cm) and gradually tapers into a spur. The spur is 1.2 to 1.8 cm and straight or slightly curved. The flowers feature five petals, the uppermost is free and hooded while each of the two lower ones are fused to each of the two lateral ones forming two compound flanges (Figure 4.3). The upper lateral petals are ovate, a third of the sise of the lower petals. The lower petals are asymmetric, two-lobed and elliptical. Flower colours range from white variable to pink variable, red variable and purple variable. Each flower features five stamens with connate anthers that lie alternately with the petals. Flowers feature a single style, ovary and stigma. The ovary is superior, five-celled and each featuring numerous ovules. The stigma is sessile and five lobbed. The fruit is linear to subclavate capsule, 2 to 4 cm long, glabrous, loculicidal, with the valves dehiscing elastically and coiling. The seeds are ovoid and 0.25 to 0.3 cm long (Q-Bank, 2015a). *I. balfourii* can be distinguished from the similar Himalayan balsam (*Impatiens glandulifera*) by its alternate leaves, small bi-coloured flowers and non-glandulous flower stalks.

Figure 4.3: Balfour's touch-me-not (*Impatiens balfourii*) (© Photo: J.L.C.H. van Valkenburg).

Species taxonomy

Table 4.4: Nomenclature and taxonomical status of Balfour's touch-me-not (*Impatiens balfourii*).

Scientific name: *Impatiens balfourii* Hook.f. (1903) **Synonyms:** *I. mathildae* Chiov., Nuov. Giorn. Bot. Ital., ser. 2, 34: 1053. 1928; *I. insubrica* Beauverd, 1928, nom. nud. **Taxonomic tree (Naturalis, 2015):** Kingdom: Plantae Phylum: Tracheophyta Class: Spermatopsida Order: Ericales Family: Balsaminaceae Genus: *Impatiens* Species: *Impatiens balfourii* **Preferred Dutch name:** Tweekleurig springzaad **Preferred English name:** Balfour's touch-me-not **Other Dutch names:** Not applicable **Other English names:** Kashmir balsam

Life cycle

I. balfourii is an annual that flowers at the end of July, through August and September in Europe (Perrins et al., 1993; Q-Bank, 2015a). It is killed by the first autumn frosts (Perrins et al., 1993). Similarly to small balsam (*Impatiens parviflora*), and other *Impatiens* species originating in the Himalayas, *I. balfourii* requires a period of cold and drought stratification to break its physiological dormancy (Jouret, 1976b; Tabak & Von Wettberg, 2008).

Reproductive capacity

In a garden experiment in the United Kingdom, *I. balfourii* produced a maximum of 50 to 80 seed capsules per plant and produced an estimated total of 500 seeds, significantly less than *I. glandulifera*. Each seed capsule contained three seeds on average. However, the highly favourable spaced conditions in the garden encouraged plants to produce more seed than would be expected outside cultivation (Perrins et al., 1993).

4.2.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. balfourii* are listed in table 4.5.

Table 4.5: Physiological conditions tolerated by Balfour's touch-me-not (*Impatiens balfourii*).

Parameter	Data origin	Occurrence	References
Hardiness (˚C)	Unknown	-15 to -20	Grey-Wilson (2011)
Temperature inducing 25% seedling mortality (˚C)	United Kingdom	-5	Perrins et al. (1993)
Temperature for optimal photosynthesis (˚C)	Laboratory	24 to 32	Schmitz & Dericks (2010)
Light intensity at max. photosynthesis (µmol photons m^{-2} s^{-1})	Laboratory	725	Schmitz & Dericks (2010)
Light compensation point (µmol photons m^{-2} s^{-1})	Laboratory	27.2	Schmitz & Dericks (2010)

Habitat

In contrast to other *Impatiens* species established in Europe, *I. balfourii* colonises open habitats with high light intensities (Schmitz & Dericks, 2010). It invades waste sites and abandoned gardens (Wittenberg, 2005). In Germany, *I. balfourii* was recorded at a moist meadow situated on the land side of a dike where it persisted in the company of perennial meadow plants. The species remained at this location for three years after which the habitat was destroyed by construction works. A second stand was located in a German mesic deciduous forest with mostly non-indigenous tree species (e.g., Balsam poplar *Populus balsamifera*) and a herb layer that was dominated by Ground ivy (*Glechoma hederacea*) (Schmitz & Dericks, 2010).

Climate

Photosynthesises of *I. balfourii* is optimal at 24 to 32˚C and is therefore adapted to warm temperate climates. Its temperature requirement is similar to that of *I. parviflora* (Dericks, 2006; Kremer, 2003; Schmitz & Dericks, 2010). According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), *I. balfourii* is an H2 species that is hardy almost everywhere and withstands temperatures of -15 to -20˚C minimum. During a garden experiment in the United Kingdom, a frost of about -5˚C caused less severe mortality in *I. balfourii* (25%) than in *I. parviflora* (67%) seedlings (Perrins et al., 1993).

Light

I. balfourii prefers high light intensities which allow the species to grow in open habitats as well as forests. In experiments *I. balfourii* tolerates a light saturation of more than 700 µmol m^{-2} s^{-1} PPFD without any signs of photo-inhibition (Schmitz & Dericks, 2010).

Moisture

Similarly to *I. parviflora*, *I. balfourii* prefers lower soil moisture content than other native and non-native *Impatiens* species present in Europe (Dericks, 2006; Schmitz & Dericks, 2010). Experiments conducted by Schmitz & Dericks (2010) revealed that *I. balfourii* prefers dry to humid soil conditions, growing to 100 cm tall under these conditions. In the same experiments plants sowed on waterlogged substrate died after 20 to 30 days. In waterlogged to moist substrate *I. balfourii* plants reached heights of just 15 to 30 cm (Schmitz & Dericks, 2010).

4.2.3. Recorded distribution

Native range

I. balfourii is native to Himalaya (India, Nepal and Pakistan), particularly Kashmir and surrounding areas, where it grows in mountains of 1500 to 1800 metres (Figure 4.4) (Q-bank, 2015; ISSG, 2009).

Non-native range

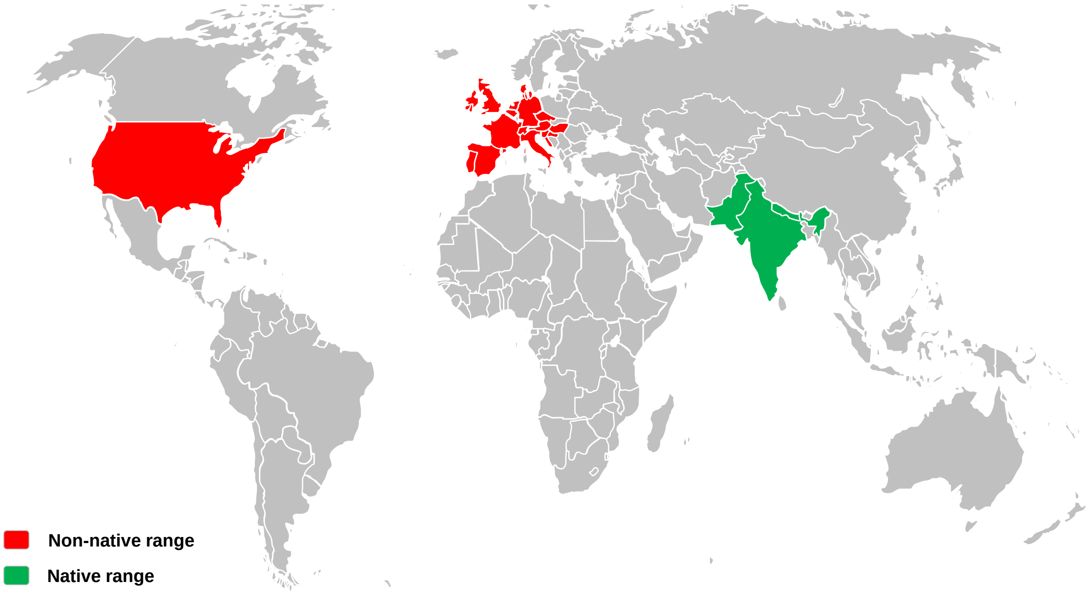

Figure 4.4: Current global recorded distribution of Balfour's touch-me-not (*Impatiens balfourii*) (Sources: Q-bank, 2015; DAISIE, 2015a).

I. balfourii was first introduced to Europe in the south of France around 1890 (Beerling & Perrins, 1993; Adamowski, 2009; Ugolleti et al., 2013). The species has been reported as a casual garden escape in the British Isles, running wild in the southeast of Belgium and very rare in Germany (Schmitz & Dericks, 2010). *I. balfourii* has been recorded in Austria, Belgium, Denmark, France, Germany, Hungary, Italy, Corsica, the Netherlands, Switzerland, United Kingdom, Croatia, the Czech Republic, Portugal, Spain and Slovenia (Figure 4.4). The species has also been recorded in the USA (Q-bank, 2015a).

Distribution in the Netherlands

I. balfourii was recorded in Leiden, the Netherlands in a garden in 1973 (Van Ooststroom et al., 1977). This was the only recording of the species till 1994 when it was discovered in a garden at Maassluis. Since the year 2000, the species has been recorded every year in one or more new kilometre squares. Most of the current records lie within urban and suburban areas, particularly in large cities in the west of the country such as Den Haag (the Hague), Haarlem, Amsterdam and Utrecht. At present, the species has been recorded in 99 5x5 km squares and 163 1x1 km squares in total (Figure 4.5).

Colonisation of high conservation value habitats

To date, *I. balfourii* has mostly been recorded in cities and towns in the Netherlands. Confirmed records of the species in Natura 2000 areas exist only for the centre of Hoek van Holland that borders the Solleveld & Kapittelduinen N2000 area (Table 4.6). Here, the plants grows in small woods in dry and damp locations and is accompanied by *Salix cinerea*, *Crataegus monogyna*, *Acer pseudoplatanus*, *Circaea lutetiana*, *Geranium robertianum* and *Geum urbanum*, among others (Inberg, 2014).

Table 4.6: Number of kilometre squares in Natura 2000 areas where Balfour's touch-me-not (*Impatiens balfourii*) has been recorded in the Netherlands.

Natura 2000 area	Definite	Possible	Range
Solleveld & Kapittelduinen	2	2	2-4
Loonse en Drunense Duinen & Leemkuilen	0	1	0-1

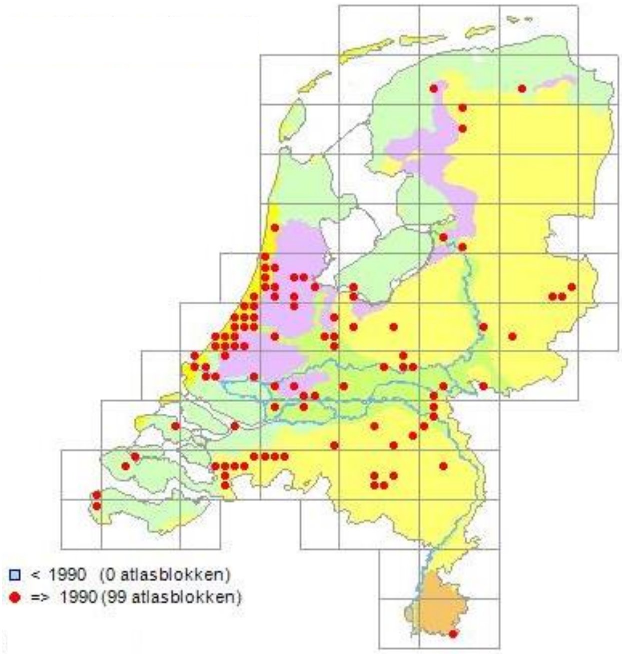

Figure 4.5: Current recorded distribution* of Balfour's touch-me-not (*Impatiens balfourii*) in the Netherlands (Source: Nationale Databank Flora en Fauna, 2015; *July 1, 2015: 100 5 x 5 km).

4.2.4. Invasion process

Introduction

Introductions of *I. balfourii* to the Netherlands, Germany and Belgium have occurred as a result of garden escapes (Lambinon et al., 2004; Schmitz & Dericks, 2010; Q-bank, 2015a; Schmitz & Dericks, 2010). The supply of plants and seeds to consumers is, therefore, an important route of introduction for this species. There are occasional opportunities to obtain *I. balfourii* from commercial traders and seeds are available via the internet (Lambinon et al. 2004; Stace, 1997; Schmitz & Dericks, 2010). A quick scan of the first 50 results of google.nl using the search terms 'Tweekleurig springzaad te koop' and '*Impatiens balfourii* te koop' revealed two foreign and one Dutch web-shops where *I. balfourii* seeds are sold and offered delivery to addresses in the Netherlands. All the websites were available in the Dutch language. It should be noted that, similar to Himalayan balsam (*Impatiens glandulifera*), the seeds of *I. balfourii* are tolerant of long periods of drying and require a period of desiccation in their native range to break their physiological dormancy (Tabak & Von Wettberg, 2008). This characteristic makes these plants more suitable for storage and use in gardens.

Establishment
In general, *I. balfourii*'s northerly spread is probably limited by its relatively limited tolerance to frost (Tabak & Von Wettberg, 2008). However, it appears to be more frost tolerant than *I. parviflora* (Perrins et al., 1993). In the United Kingdom, *I. balfourii* is able to persist from year to year and in a walled garden experiment *I. balfourii's* level of establishment was slightly greater than *I. parviflora's* (17.5% to 10.5% respectively) but less than the 40% recorded for *I. glandulifera* (Tutin et al., 1968; Stace, 1991; Perrins et al., 1993). Experiments conducted in Ireland demonstrated that *I. balfourii* is able to grow, flower and produce seeds under the local climate (Ugolleti et al., 2013). In Germany large *I. balfourii* stands have not yet been observed (Nehring et al., 2013). Tabak & Von Wettberg (2008) concluded that, although not widely recorded in the Northeast of North America, *I. balfourii* had been able to naturalise in multiple new regions and deserved careful observation. Records demonstrate that the plant is able to grow and reproduce in a number of different locations in the Netherlands (Figure 4.5).

Spread
There is no evidence to suggest that *I. balfourii*'s natural local dispersal differs from other *Impatiens* species, all are able to explosively spread seeds by up to about 2 m (Perrins et al., 1993). *I. glandulifera* is currently much more invasive than *I. balfourii* in Europe. However, it is possible that *I. balfourii* may become more widespread in the future (Adamowski, 2009; Schmitz & Dericks, 2010; Ugolleti et al., 2013). In a Swiss study examining potential reproductive success, *I. balfourii* attracted more pollinator individuals, species and taxonomic groups than *I. glandulifera.* However, only *I. glandulifera* is considered invasive in this country (Chrobock et al., 2013). *I. balfourii* is naturalised in disturbed habitats in central and southern Europe, but is not considered invasive (Moore, 1968; Tabak & Von Wettberg, 2008).

4.2.5. Environmental impact summary

Effects on environmental targets or native species

Parasitism
No recorded impacts were discovered during the literature review.

Competition
I. balfourii can form dense pure stands that could suppress other species by shading (Nehring et al., 2013). Nehring et al. (2013) concluded that it is unknown whether a hazard to German native species exists. *I. balfourii* is likely to have a negative impact on the natural vegetation of ruderal or semi-natural communities (Wittenberg, 2005).

Interbreeding
No evidence of potential interbreeding with Dutch native species was found during the literature review. Nehring et al. (2013) concluded that it is unknown whether the potential for interbreeding exists between *I. balfourii* and German native species.

The habitat and flowering period of *I. balfourii* overlap with that of *I. glandulifera* and the two species feature a similar flower morphology and reproductive system. In an experiment examining the potential for hybridisation between these two species seeds were produced but germination was negligible (Ugolleti et al., 2013).

Hosting pathogens or parasites
Nehring et al. (2013) concluded that there are no known dangers to German native species.

Effects on ecosystem function targets

Abiotic properties (e.g., nutrient cycling and structural modification)
I. balfourii can form dense pure stands that lead to a monopolisation of space and light (Nehring et al., 2013).

Effecting ecosystem integrity by biotic properties
Nehring et al. (2013) concluded that there are no known impacts on German ecosystem function targets.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.2.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. balfourii* a 'medium' ecological risk classification to the category dispersion potential and invasiveness, a ‘likely’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions and a ‘high’ risk classification to the category colonization of high value conservation habitats (Table 4.7). The total ecological risk score for the species is 9 out of a maximum of 12. Therefore, *I. balfourii* is classified in the B list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs. However, note that the risk scores for adverse effects on biodiversity and ecosystem functions are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.7: Consensus scores for potential risks of Balfour's touch-me-not (*Impatiens balfourii*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	High*	3
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Environmental risk score		**9**

*: Quantitative analysis was focused on Natura 2000 areas may indicate a lower score, however, this species occurs also in other areas with high conservation value.

Dispersion potential or invasiveness

Classification: **Medium risk**. Except when assisted by humans *I. balfourii* does not colonise remote areas and natural dispersal rarely exceeds 1 km/y. However, the species may become locally invasive because of strong reproduction. Similarly to other Impatiens species, *I. balfourii* is able to disperse seeds by autochory. Seeds are launched seed pods and may travel up to 2 m from the plant. *I. balfourii* is less dependent on moisture than other *Impatiens* species and seeds have a relatively low chance of being dispersed by hydrochory. *I. balfourii* produces 50 to 80 seed capsules per plant and an estimated total of 500 seeds which is significantly less than *I. glandulifera*. However, this figure may be higher under optimal garden conditions. *I. balfourii* seeds are tolerant to long periods of drying and require a period of cold and drought stratification in their native range to break their physiological dormancy.

Optimal temperatures for photosynthesis occur in the region of 24 to 32˚C, *I. balfourii* is therefore adapted to warm temperate climates. Moreover, *I. balfourii* is an H2 species meaning that it is hardy almost everywhere and withstands temperatures of -15 to -20˚C minimum. During a UK garden experiment, a -5 °C frost caused less severe mortality in *I. balfourii* (25%) than *I. parviflora* (67%). *I. balfourii* is a Himalayan species which may explain why it is more resistant to frost than *I. parviflora* which is native to Central Asia and Siberia. Climate change will probably increase the invasiveness of *I. balfourii*.

There has been a rapid increase in the number of records of *I. balfourii* in the Netherlands which have mainly occurred in urban areas. This indicates multiple introductions facilitated by humans.

Colonization of high value conservation habitats

Classification: **High* risk**. To date, *I. balfourii* has mostly been recorded in cities and towns in the Netherlands. Confirmed records of the species in high value conservation habitats exist only for the centre of Hoek van Holland that borders the Solleveld & Kapittelduinen N2000 area. Here, the plants grow in dry and damp locations in woodland and are accompanied by *Salix cinerea, Crataegus monogyna, Acer pseudoplatanus, Circaea lutetiana, Geranium robertianum* and *Geum urbanum*, among others. In general, *I. balfourii* colonises open habitats as well as forests with high light intensities, moist meadow alongside perennial meadow plants, mesic deciduous forest with mostly non-indigenous tree species (e.g., Balsam poplar *Populus balsamifera*) and a herb layer dominated by Ground ivy (*Glechoma hederacea*). The species will probably be able to establish in high conservation value habitats and pose a (potential) threat to red listed or protected species. Our analysis of the colonisation of high value conservation habitats in the Netherlands by *I. balfourii* examined Natura 2000 regions only. It is possible that other undisturbed habitats, not classified under Natura 2000, may also be affected by this species.

Adverse impacts on native species

Classification: **Likely**. There is no available evidence to suggest that *I. balfourii* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. *I. balfourii* can form dense pure stands that could suppress other species by shading (Nehring et al., 2013). Nehring et al. (2013) concluded that it is unknown whether a hazard to German native species exists. However, according to Wittenberg (2005) *I. balfourii* is likely to have a negative impact on the natural vegetation of ruderal or semi-natural communities. Moreover, *I. balfourii* attracts more pollinator individuals, species and taxonomic groups than *I. glandulifera*. Therefore, competition with native plant species is likely. Also competition for pollinators may be expected. Local changes in population abundance (< 80%), growth or distribution of one or more native species can be expected, but the effect should be reversible.

Alteration of ecosystem functions

Classification: **Likely**. *I. balfourii* can form dense pure stands that lead to a monopolisation of space and light (Nehring et al., 2013). Moreover, *I. balfourii* is an annual species that dies off in winter leaving bare ground that is vulnerable to erosion. Light interception during the growing season occurs due to the tall, dense vegetation produced. Therefore, the physical modification of habitats in the Netherlands is likely.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.7) in combination with the current recorded distribution in the Netherlands. The species classification for *I. balfourii* is B3 (Figure 4.6). This characterises a non-native species that is widespread in the area under assessment, poses a moderate ecological risk and should be placed on the watch list of the BFIS list system.

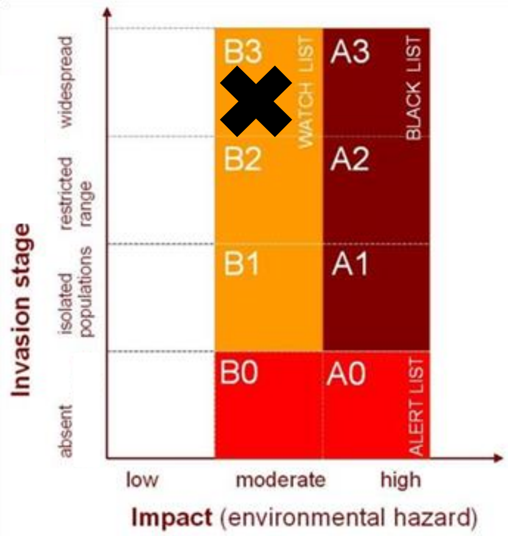

Figure 4.6: Risk classification of Balfour's touch-me-not (*Impatiens balfourii*) according to the BFIS list system.

4.2.7. Other risk assessments and classifications

Two risk classifications were found for *I. balfourii* in Europe. The species has been placed on a watch list according to the German-Austrian Black List Information System (GABLIS) (Table 4.8). *I. balfourii* is on the watch List of invasive species in France (Espèces végétales exotiques envahissantes en France Méditerranéenne Continentale, 2015). Both these classifications correspond to the watch list classification assigned to this species as part of our risk analysis of *Impatiens* species.

Table 4.8: Overview of risk classifications previously performed for Balfour's touch-me-not (*Impatiens balfourii*).

	Germany	**France**
Scope	Risk prioritisation method	Risk assessment method
Method	German-Austrian Black List Information System GABLIS	rating system to assess the invasion potential of exotic plant species in central Europe (Weber & Gut, 2004)
Year	2013	2009
Risk classification	**Grey list (watch list)**	**Medium risk (watch list)**
Source	Nehring et al. (2013)	Espèces végétales exotiques envahissantes en France Méditerranéenne Continentale (2015)

4.3. Common garden balsam (*Impatiens balsamina*)

4.3.1. Species description

Common garden balsam (*Impatiens balsamina*) is an annual herb that grows to between 60 and 100 cm tall. The stem is erect and robust, approximately 0.8 cm in diameter at the base, glabrous or laxly pubescent when young, succulent, simple or branched, with many fibrous roots. The leaves are usually alternate, the petiole is 1 to 3 cm long, both sides feature a few pairs of stipitate glands and is adaxially shallowly sulcate. The leaf blade is 3-15 × 1.5-3 cm, lanceolate, narrowly elliptical or oblanceolate, glabrous or sparsely pubescent, featuring four to seven pairs of lateral veins, the base is cuneate, the margins are deeply serrate and the apex is acuminate. The inflorescences are single flowered or with two to three flowers fascicled in the leaf axils and are without peduncles (Figure 4.7). The pedicels are 2 to 2.5 cm long, densely pubescent and with a linear bract at the base. The flowers are white, pink, or purple, and simple or double petalous. There are two lateral sepals which are ovate or ovate-lanceolate and 0.2 to 0.3 cm. The lower sepal is deeply navicular, 1.3-1.9 × 0.4-0.8 cm, pubescent and abruptly narrowed into an incurved, 1 to 2.5 cm long and slender spur. The upper petal is orbicular, the apex retuse, mucronate, with an abaxial midvein which is narrowly carinate. The lateral petals are united and shortly clawed, 2.3 to 2.5 cm long and double lobed. The basal lobes are obovate to oblong and small. The distal lobes are suborbicular and apically retuse. The auricule is narrow. There are five stamens, filaments are linear. The anthers are ovoid and the apex obtuse. The ovary is fusiform and densely pubescent. The capsule is broadly fusiform, 1 to 2 cm long, densely tomentose and narrowed at both ends. The multiple seeds are black to brown, globose, tuberculate and 0.15 to 0.3 cm in diameter (www.efloras.org).

Figure 4.7: Common garden balsam (*Impatiens balsamina*). (© Photo: M. Bloem, Wikimedia commons).

Species taxonomy

Table 4.9: Nomenclature and taxonomical status of Common garden balsam (*Impatiens balsamina*).

Scientific name:
Impatiens balsamina L. (1753)

Synonyms:
Balsamina angustifolia Blume Bijdr. 239. 1825; *Balsamina balsamina* (L.) Huth; *Balsamina coccinea* (Sims) DC., Prodr. 1: 685. 1824; *Balsamina cornuta* (L.) DC., Prodr. 1: 686. 1824; *Balsamina foeminea* Gaertn., Fruct. Sem. Pl. 2: 151, t. 113, Figure 4. 1790, nom. illeg; *Balsamina hortensis* Desp., Dict. Sc. Nat. 3: 485. 1816, *nom. illeg.* non St.Hil. (1808); *Balsamina lacca Medik*., Malvenfam. 71. 1787; *Balsamina minutiflora* Span., Linnaea 15: 185. 1841; *Balsamina mollis* (Wall.) G.Don, Gen. Hist. 1: 749. 1831; *Balsamina odorata* Buch.-Ham. ex D.Don, Prodr. Fl. Nepal. 203. 1825; *Balsamina racemosa* Buch.-Ham. ex D.Don; *Balsamina salicifolia* Turcz., Bull. Soc. Imp. Naturalistes Moscou 32: 271. 1859; *Impatiens balsamina* var. *corymbosa* Santapau; *Impatiens coccinea* Sims; *Impatiens cornuta* L., Sp. Pl. 937. 1753; *Impatiens eriocarpa* Launert; *Impatiens stapfiana* Gilg.

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens balsamina*

Preferred Dutch name:
Balsemien

Preferred English name:
Common garden balsam

Other Dutch names:
Tuinbalsemien

Other English names:
Rose balsam, spotted snapweed

Life cycle
Flowering in its native range occurs from July to October. Desiccation is required to break the dormancy of *I. balsamina* seeds (Jouret, 1976a; Tabak & Von Wettberg, 2008).

Reproductive capacity
No information on the reproductive capacity of *I. balsamina* could be found during the literature review.

4.3.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. balsamina* are listed in table 4.10. *I. balsamina* is classified as a subtropical species (Tabak & Von Wettberg, 2008). However, according to the climate codes of the European Garden Flora (Grey-Wilson, 2011), it is an H5 species meaning that it is hardy in favourable areas, withstanding temperatures of 0 to -5 ˚C minimum. Moreover, *I. balsamina* is already established in many temperate areas and increased winter temperatures and fewer frosts due to climate change may facilitate its further spread (Tabak & Von Wettberg, 2008).

I. balsamina is a highly drought susceptible species (Todd et al., 1974; Tabak & Von Wettberg, 2008).

Table 4.10: Physiological conditions tolerated by of Common garden balsam (*Impatiens balsamina*).

Parameter	Data origin	Occurrence	References
Hardiness (°C)	Unknown	0 to -5	Grey-Wilson (2011)

4.3.3. Recorded distribution

Native range
I. balsamina is thought to be native to India. However, because it has been in cultivation in Europe for many years, its exact native range is difficult to establish. However, *I. balsamina* is considered a subtropical plant (Tabak & Von Wettberg, 2008) (Figure 4.8).

Non-native range
I. balsamina occurs as non-native in Spain, the Azores, Madeira, France, Italy, Croatia, the Czech Republic, Austria, Hungary, Romania, Norway, European parts of Russia, The United States, Cuba and Saint Lucia. Unconfirmed records exist for Australia and Brazil (Figure 4.8) (CABI, 2015a; DAISIE, 2015b; USDA, 2015).

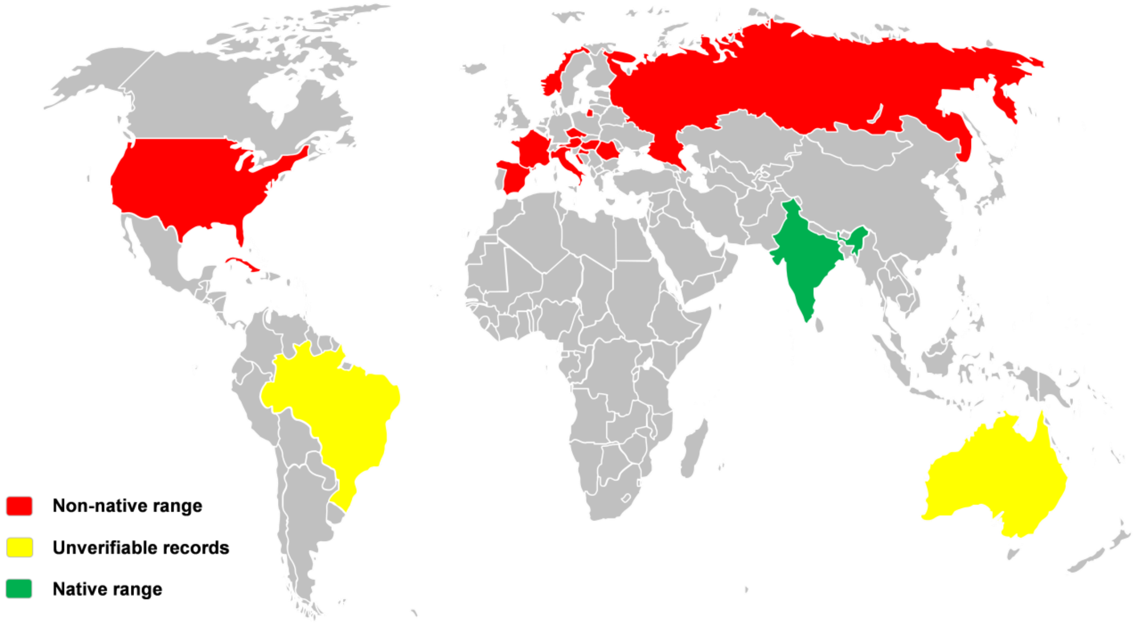

Figure 4.8: Current global recorded distribution of Common garden balsam (*Impatiens balsamina*) (Sources: CABI, 2015a; DAISIE, 2015b; USDA, 2015).

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. balsamina* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. balsamina* in the Netherlands.

4.3.4. Invasion process

Introduction
I. balsamina has been in cultivation in Europe for many years and occasionally escapes from cultivation in north east USA (Fernald, 1950; Tabak & Von Wettberg, 2008). According to Grey-Wilson (2011) and Jäger et al. (2008), this species is available via the European ornamental market. Therefore, any introductions of *I. balsamina* to the Netherlands will likely be as a result of garden escapes. A quick scan of the first 50 results of google.nl using the search terms 'tuinbalsemien te koop' and '*Impatiens balsamina* te koop' revealed four Dutch and three international websites offering *I. balsamina* for sale.

Establishment
I. balsamina is classified as a subtropical species. However, it is already established in many temperate areas. In the north eastern USA, escapes appear to be mostly restricted to gardens and other sheltered locations (Tabak & Von Wettberg, 2008). According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. balsamina* in the Netherlands.

Spread
In the north eastern USA, escapes appear to be mostly restricted to gardens and other sheltered locations (Tabak & Von Wettberg, 2008).

4.3.5. Environmental impact summary

Effects on environmental targets or native species
No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.3.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. balsamina* a 'medium' ecological risk classification to the category dispersion potential or invasiveness, an ‘unlikely’ risk classification to the category colonization of high value conservation habitats and a ‘low’ risk classification to the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.11). The total ecological risk score for the species is 5 out of a maximum of 12. Therefore, *I. balsamina* is classified in the C list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs.

Table 4.11: Consensus scores for potential risks of Common garden balsam (*Impatiens balsamina*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Unlikely	1
Adverse impacts on native species	Low	1
Alteration of ecosystem functions	Low	1
Environmental risk score		**5**

Dispersion potential or invasiveness
Classification: **Medium risk**. Except when assisted by humans *I. balfourii* does not colonise remote areas and natural dispersal rarely exceeds 1 km/y. However, the species may become locally invasive because of strong reproduction. Similarly to other Impatiens species, *I. balfourii* is able to disperse seeds by autochory. Seeds are launched seed pods and may travel up to 2 m from the plant. *I. balfourii* is less dependent on moisture than other *Impatiens* species and seeds have a relatively low chance of being dispersed by hydrochory. *I. balsamina* seeds require desiccation to break their dormancy (Jouret 1976a; Tabak & Von Wettberg, 2008). *I. balsamina* is an H5 species (Grey-Wilson, 2011) meaning that it is hardy in favourable areas and withstands temperatures of 0 to -5˚C. It is already established in many temperate areas. However, *I. balsamina* is classified as a subtropical species suggesting that its ecological impact in the Netherlands will be limited. Increased winter temperatures and fewer frosts as a result of climate change may facilitate *I. balsamina*’s further spread (Tabak & Von Wettberg, 2008). However, this spread may be tempered by the plants high drought susceptibility (Todd et al., 1974; Tabak & Von Wettberg, 2008).

I. balsamina poses a high risk of introduction via the horticultural pathway. The plant occurs as non-native in Spain, the Azores, Madeira, France, Italy, Croatia, the Czech Republic, Austria, Hungary, Romania, Norway, European parts of Russia, The United States, Cuba and Saint Lucia. Unconfirmed records exist for Australia and Brazil.

Colonization of high value conservation habitats
Classification: **Unlikely**. According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. balsamina* in the Netherlands. Moreover, escapes In the north eastern USA, a region climatically similar to the Netherlands, appear to be mostly restricted to gardens and other sheltered locations (Tabak & Von Wettberg, 2008). Therefore, it is ullikely that the species will be able to establish in high conservation value habitats and cause a (potential) treat for red listed or protected species.

Adverse impacts on native species
Classification: **Low risk**. There is no available evidence to suggest that *I. balsamina* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. *I. balsamina* is an annual herb that grows to between 60 and 100 cm tall. Therefore, minimal competition between *I. balsamina* and Dutch native plant species is expected due to a low invasion and establishment risk in nature areas. If established, some competition for pollinators may be expected. Negative impact and local changes in population abundance, growth or distribution of one or more native species as a result of *I. balsamina* establishment can be expected to be negligible and reversible.

Alteration of ecosystem functions
Classification: **Low risk**. *I. balsamina* is a tall, annual species. Based on available information it is not expected that *I. balsamina* will form dense single species stands and monopolises space and light in the Netherlands. Physical modification of habitat by *I. balsamina* is unlikely. However, during the winter period, some erosion of bare soil and during the growing season, some light interception may occur due to the height of plants. The impact of *I. balsamina* establishment on ecosystem processes and structure in the Netherlands is expected to be negligible.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.9) in combination with the current recorded distribution in the Netherlands.

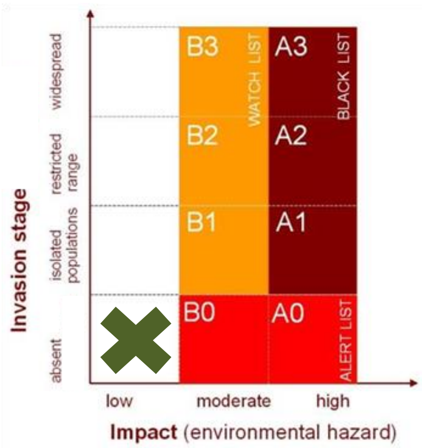

Figure 4.9: Risk classification of Common garden balsam (*Impatiens balsamina*) according to the BFIS list system.

The species classification for *I. balsamina* is C0. This characterises a non-native species that is absent from the area under assessment and is not eligible for placement on the watch, alert or blacklist. However, note that the risk score for colonisation of high value habitat is based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

4.3.7. Other risk assessments and classifications

The only risk assessment examining *I. balsamina*, carried out in Hawaii concluded that the plant required further evaluation (Table 4.12). *I. balsamina* may be at a higher risk of spread in Hawaii due to climatic differences in comparison to the Netherlands which may have led to a requirement for further evaluation in this USA state.

Table 4.12: Overview of risk classifications previously performed for Common garden balsam (*Impatiens balsamina*).

	Hawaii (USA)
Scope	Risk assessment
Method	Australian/New Zealand Weed Risk Assessment adapted for Hawai'i
Year	2005
Risk classification	**Plant requires further evaluation (5)**
Source	http://www.hear.org/pier/wra/pacific/impatiens_balsamina_htmlwra.htm

4.4. Orange jewelweed (*Impatiens capensis*)

4.4.1. Species description

Orange jewelweed (*Impatiens capensis*) is an annual herbaceous plant that grows to 150 cm or more in height. The branching taproot system is shallow. The somewhat translucent round stems are glabrous, succulent and pale green to pale reddish green (www.illinoiswildflowers.info). It features glaucous or pale leaves that are ovate or elliptical and crenate. The slender petioles are up to 5 cm long and usually shorter than the leaf blades (www.illinoiswildflowers.info). The flowers of *I. capensis* (including spur) are mostly 2-3.5 cm and drooping (Figure 4.10). Sepals 3, free, 2 lateral sepals are small and membranous, light green to light yellow and are located behind the upper lip, the third sepal forms a conical posterior of the flower, including the small, abruptly contracted nectar spur, light orange and shiny, the nectar spur (5-9 mm) bend forward to a position underneath the rest of the flower. Petals 5, forming the front of the flower and are dark orange-yellow with reddish streaks or brown dots; one petal forms the upper lip, which is curved upward, while 2 fused petals form the lower lip; the lower lip is divided into 2 lobes and functions as a landing pad for visiting insects. There are also 2 smaller lateral petals between the upper and lower lips of the flower (Q-bank, 2015b).

Figure 4.10: Orange jewelweed (*Impatiens capensis*) (© Photo: J.L.C.H. van Valkenburg).

Species taxonomy

Table 4.13: Nomenclature and taxonomical status of Orange jewelweed (*Impatiens capensis*).

Scientific name:
Impatiens capensis Meerb. (1775)

Synonyms:
Balsamina capensis (Meerb.) DC.; *Balsamina fulva* Ser.; *Chrysaea biflora* (Walter) Nieuwl. & Lunell; *Impatiens biflora* Walter; *Impatiens biflora* Willd.; *Impatiens capensis* f. *capensis*; *Impatiens fulva* Nutt.; *Impatiens nortonii* Rydb.

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens capensis*

Preferred Dutch name:
Oranje springzaad

Preferred English name:
Orange jewelweed

Other Dutch names:
Not applicable

Other English names:
Common jewelweed, spotted jewelweed, orange balsam

Life cycle

Similarly to the Himalayan balsam (*Impatiens glandulifera*) and Pale jewelweed (*Impatiens pallida*), the seeds of *I. capensis* germinate almost synchronously in early spring, after cold winter temperatures interrupt their physiological dormancy (Grime, 1979; Jouret, 1976a; Mumford, 1988; Nozzolillo & Thie, 1983; Winsor, 1983; Tabak & Von Wettberg, 2008). *I. capensis* is a recalcitrant species (has seeds that do not survive drying and freezing during ex-situ storage) and are therefore dependent on being fully imbibed during cold stratification in order to germinate (Jouret, 1976a; Nozzolillo & Thie, 1983; Tabak, 2005; Tabak & Von Wettberg, 2008). Therefore, *I. capensis* seeds cannot be stored for long periods like orthodox seeds because they may lose their viability.

Reproductive capacity

I. capensis possesses a mixed mating system. A single individual may feature flowers that are cleistogamous (self-crossing and closed) and chasmogamous (outcrossing). In small, marginal populations or under stressful conditions, self-pollination may secure successful reproduction (Schemske, 1978; Waller, 1979; Tabak & Von Wettberg, 2008). Similarly to the native touch-me-not Balsam (*Impatiens noli-tangere*), *I. capensis* forms short term persistent seed banks with seeds remaining viable for up to three years in the soil (Perglova et al., 2009).

4.4.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. capensis* are listed in table 4.14. According to Jäger et al. (2008) and Weiss (2013) *I. capensis* is a winter-hard species.

Table 4.14: Physiological conditions tolerated by Orange jewelweed (*Impatiens capensis*).

Parameter	Data origin	Occurrence	References
Temperature suitable for germination	Laboratory experiments	5-15˚C	Jouret (1976a); Leck (1979); Perglova et al. (2009)

Habitat
I. capensis may be found in moist woodland clearings, floodplains and rivers at partially shaded locations, at the edges of woodland paths, swamps, fens, and roadside ditches (Tabak & Von Wettberg, 2008; Encyclopedia of Life, 2015).

Climate
Observations from the Czech Republic suggest that the frost resistance of *I. capensis* was within the range of *I. noli-tangere*, *I. glandulifera* and small balsam (*Impatiens parviflora*) despite its originating from locations with milder climates than that found there (Muller, 1982; Skalova et al., 2011). Of these four species, *I. noli-tangere* was found to be the most frost resistant, followed by *I. capensis*, *I. glandulifera* and *I. parviflora.* However, the authors concluded that lower frost resistance of *I. capensis* in comparison with *I. noli-tangere* would not form a barrier to *I. capensis* establishing in the Czech Republic (Skalova et al., 2011). In laboratory experiments in the Czech Republic, the maximum germination of *I. capensis* was achieved at 5˚C (Perglova et al., 2009), however, Leck (1979) stated that 15˚C resulted in a high germination percentage.

Moisture
Comparisons between *I. capensis* and *I. glandulifera* from New England (USA) demonstrate that the two species have a similar habitat requirement. However, *I. glandulifera* is more tolerant of drier soils and is capable of higher rates of germination across a broader range of soil moisture than *I. capensis* (Tabak, 2005; Tabak & Von Wettberg, 2008). Moreover, *I. capensis* is a weaker competitor than both *I. glandulifera* and *I. parviflora* under different moisture conditions (Skalova et al., 2013). However, similarly to *I. parviflora*, a combination of drought and flooding does not reduce the survival rate of *I. capensis*, whereas the survival rate of both *I. glandulifera* and *I. noli-tangere* are negatively affected (Skalova et al., 2012).

Light
I. capensis has a lower relative growth rate across a broad range of light conditions than *I. glandulifera* (Tabak, 2005; Tabak & Von Wettberg, 2008). For cultivation *I. capensis* requires 75% shade (Encyclopedia of life, 2015). However, *I. capensis* does not occupy areas with high canopy cover as frequently in its English non-native range than in its native range of south-eastern New England, USA (Tabak & Von Wettberg, 2008).

Nutrients
In growth experiments, *I. capensis* produced less biomass than both *I. glandulifera* and *I. parviflora* under a range of nutrient conditions. *I. capensis* produced a similar level of

biomass as native *I. noli-tangere* in all but the highest nutrient conditions. High nutrient conditions decreased survival in *I. capensis* as well as relative biomass production (Skalova et al., 2012).

4.4.3. Recorded distribution

Native range

I. capensis is native to the North American continent. It is widely distributed in the north-eastern United States including all eastern states, many mid-western states, the Pacific Northwest and is native to most Canadian provinces (Figure 4.11) (Tabak & Von Wettberg, 2008). However, some of its Pacific Northwest range may have resulted from recent range extension (Ornduff, 1967; Tabak & Von Wettberg, 2008).

Non-native range

Figure 4.11 shows that *I. capensis'* non-native range extends to France, Germany, the Netherlands, Belgium, the United Kingdom and Ireland, Poland, Denmark and Finland (Alien Plants Belgium, 2015; DAISIE, 2015c; Q-bank, 2015b; Steeman, 2011).

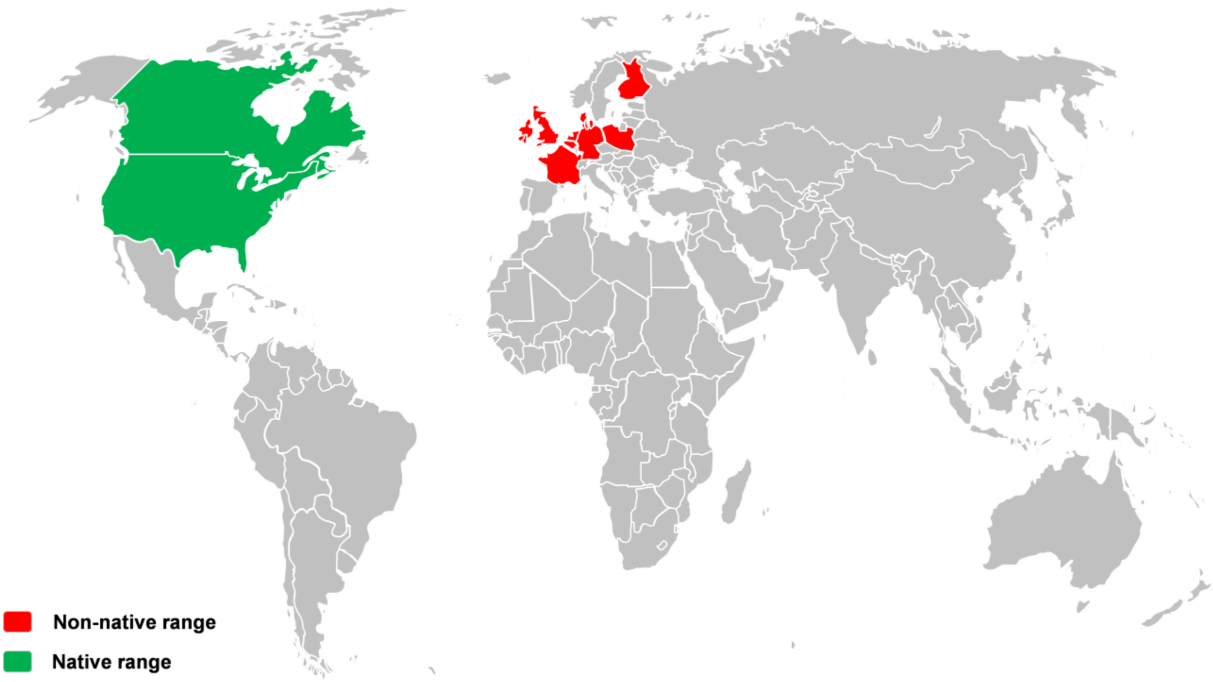

Figure 4.11: Current global recorded distribution of Orange jewelweed (*Impatiens capensis*) (Tabak & Von Wettberg, 2008; Steeman, 2011; Alien Plants Belgium, 2015; DAISIE, 2015c; Q-bank, 2015b).

Distribution in the Netherlands

The first documented recording of *I. capensis* dating from 1992 describes a large stand of around 100 plants growing in the Stormpolder along the river Nieuwe Maas near Krimpen aan de IJssel (Van der Meijden et al., 1996). Further stands were discovered along the Nieuwe Merwede in the Hollandse Biesbosch and along the river IJssel, east of Arnhem. Initially, new stands were recorded only along large rivers and in the Biesbosch. However, after the year 2000 new stands were discovered along still waters such as the Haarlemmermeer ring canal, on the banks of various lakes in the Province of Friesland and in the Zuidlaardermeer area (Vreeken, 2008; Anonymus, 2008) (Figure 4.12 and 4.13).

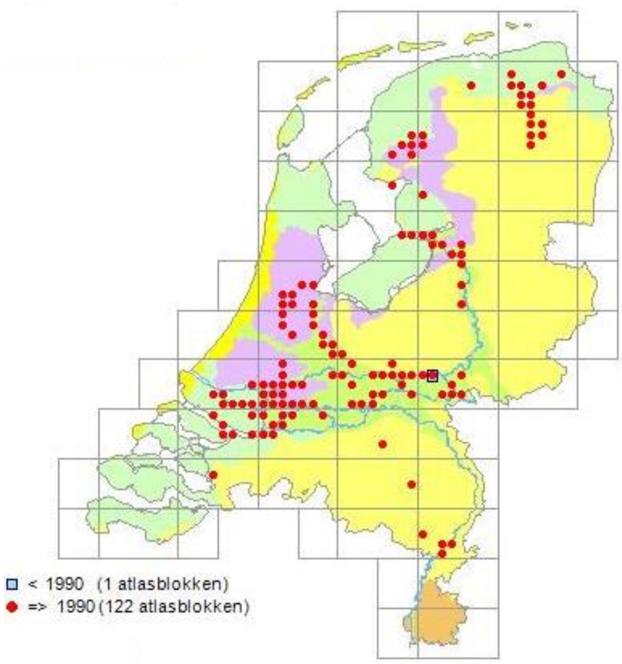

Figure 4.12: Current recorded distribution of Orange jewelweed (*Impatiens capensis*) in the Netherlands (Source: Nationale Databank Flora en Fauna, 2015).

Recently, the species has begun to spread along a few small rivers in the west and in the centre of the country along the river Amstel, river Kromme Rijn and the Utrechtse Vecht, and in the north of the country along the lower reaches of the Drentsche Aa and along the river Reitdiep. A few stands have been recorded in the Maasplassen in the Roermond area since the beginning of 2014. More recently, new records have been made in the eastern part of the Nieuwkoopse plassen (Figure 4.12).

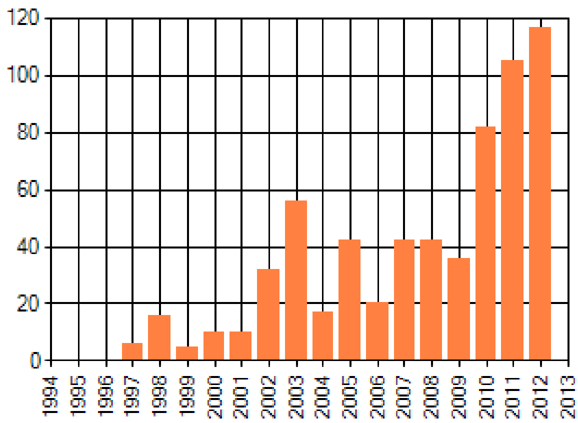

Figure 4.13: Estimated number of 5x5 kilometre-squares occupied by Orange jewelweed (*Impatiens capensis*) per year in the Netherlands (Source: Verspreidingsatlas.nl, © CBS & FLORON 2014).

Colonisation of high conservation value habitats

I. capensis has been confirmed to occur within 15 Natura 2000 areas in the Netherlands (Table 4.15). Most locations lie within the tidal freshwater area (the Biesbosch, the Oude Maas, Haringvliet, Loevestein, Pompveld & Kornsche Boezem). At these locations *I. capensis* grows in (abandoned) willow coppices, within reed fringes and in hydrophilous tall herb vegetation along watercourses and woodland borders. Along rivers, *I. capensis* grows in the Natura 2000 areas Gelderse Poort, the banks and floodplain of the river IJssel, the banks and floodplain of the river Nederrijn and the banks and floodplain of the river Waal. In these river systems, the plant grows along low dynamic banks with limited currents and water depth changes such as regulated and downstream river sections. *I. capensis* grows in relatively still places along highly dynamic rivers (e.g., along banks of river floodplain lakes). Stands that develop at more dynamic locations are often not sustained. Outside the river system, *I. capensis* grows in Natura 2000 areas situated in fenland (Nieuwkoopse Plassen and De Haeck, Sneekermeer area, Witte and Zwarte Brekken). In the North of the Netherlands, *I. capensis* is present in the Zuidlaardermeer area and the neighbouring Drentsche Aa area.

Table 4.15: Number of kilometre squares in Natura 2000 areas where Orange jewelweed (*Impatiens capensis*) has been recorded in the Netherlands.

Natura 2000 area	Definite	Possible	Range
The banks and floodplain of the river Nederrijn	11	4	11-15
Biesbosch	12	2	12-14
Gelderse Poort	10	3	10-13
Oude Maas	7	6	7-13
The banks and floodplain of the river IJssel	6	7	6-13
Drentsche Aa-gebied	10	2	10-12
Nieuwkoopse Plassen & De Haeck	4	1	4-5
The banks and floodplain of the river Waal	5	0	5-5
Haringvliet	1	3	1-4
Sneekermeergebied	1	3	1-4
Hollandsch Diep	0	2	0-2
Ketelmeer & Vossemeer	1	1	1-2
Zuidlaardermeergebied	2	0	2-2
Loevestein, Pompveld & Kornsche Boezem	1	0	1-1
Witte en Zwarte Brekken	1	0	1-1

4.4.4. Invasion process

Introduction

I. capensis was originally introduced to Europe as an ornamental plant (Tabak & Von Wettberg, 2008). Tabak & Von Wettberg (2008) stated that they were not aware of any records of current cultivation or the commercial sale of its seeds in Europe. This may be due to difficulties in cultivating the plant. Its requirement for shade, growth from seed, poorly developed root system, difficulty in collecting seeds and the possible need for cold treatment to stimulate germination have all been given as reasons why the plant has not been popular for cultivation in recent times (Encyclopedia of Life, 2015). The relatively limited non-native range of *I. capensis* could be in part attributed to its limited cultivation in Europe compared to *I. glandulifera* and *I. parviflora* (Perrins et al., 1993; Adamowski, 2009; Perglova et al., 2009). A quick scan of the first 50 results of google.nl using the search terms ‘Oranje springzaad te koop’ and ‘*Impatiens capensis* te koop’ revealed no websites offering *I. capensis* for sale to the public.

Establishment

Despite its relatively limited cultivation in Europe, *I. capensis* has been recorded in 122 atlas blocks in the Netherlands since 1990 (Figure 4.9).

Spread
Hydrochory appears to be an important dispersal mechanism for this species. *I. capensis* seeds float for a minimum of 200 days under laboratory conditions and dispersal may be facilitated if seeds fall into fast moving river systems (Tabak & Von Wettberg, 2008). In the Netherlands, *I. capensis* records appear to concentrate along major waterways suggesting that hydrochory may play a role in the dispersal of this species here (Figure 4.9).

While *I. capensis* has been attributed the status of invasive species in the south and east of England, it is less successful than both *I. glandulifera* and Balfour's touch-me-not (*Impatiens balfourii*) (Perrins et al., 1993). Moreover, in the United Kingdom, the maximum instantaneous rate of spread of *I. capensis* has been determined to be 13 km/year, significantly slower than either *I. glandulifera* (38 km/year) or *I. parviflora* (24 km/year) (Perrins et al., 1993). In the presence of *I. glandulifera* and *I. parviflora*, *I. capensis* suffers from decreased shoot biomass and branching. Moreover, *I. capensis* has small seedlings which may reduce its success in the early stages of population development suggesting that its potential to invade is lower than *I. glandulifera's* (Skalova et al., 2013). It seems unlikely that *I. capensis* will directly out-compete the latter species (Perglova et al., 2009). It should be noted that inter-species competition may be affected by local habitat conditions and differing habitat preferences between species.

4.4.5. Environmental impact summary

Effects on environmental targets or native species

Parasitism
No recorded impacts were discovered during the literature review.

Competition
I. capensis spreads relatively slowly and does not form monocultures (Beerling & Perrins, 1993; Preston et al., 2002; Tabak & Von Wettberg, 2008). Therefore, it is generally not classified as a problematic plant in its non-native range (Tabak & Von Wettberg, 2008). *I. capensis* is likely to have a lesser impact on native species than *I. edgeworthii* as it grows less densely than this species. Hatcher (2003) suggested that a low relative growth rate and seedling biomass indicate that *I. capensis* has a similar competitive ability to that of *I. noli-tangere* which is often outcompeted by surrounding vegetation (Perglova et al., 2009). However, Skalova et al. (2013) stated that while *I. capensis* is less competitive than either *I. glandulifera* or *I. parviflora*, it may competitively exclude native *I. noli-tangere* as the niches of the native and invasive *Impatiens* species overlap to a great degree. To date, *I. capensis* and *I. noli-tangere* have rarely, if ever, co-occurred in Europe (Preston et al., 2002; Tabak & Von Wettberg, 2008). However, further spread of *I. capensis* may lead to greater co-occurrence of these two species in the future.

Interbreeding
Theoretically, *I. capensis* may be able to hybridise with its close phylogenetic relative *I. noli-tangere* which has declined in abundance in recent years (Preston et al., 2002; Tabak & Von Wettberg, 2008). However, to date there is no evidence of actual hybridisation between these two species and they rarely co-occur even though they colonise similar habitats (Preston et al., 2002; Tabak & Von Wettberg, 2008).

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.4.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. capensis* a 'high' ecological risk classification for sections of the ISEIA protocol relating to dispersion potential or invasiveness and colonization of high value conservation habitats, ‘medium’ for the section relating to adverse impacts on native species and ‘low’ for the section relating to alteration of ecosystem functions (Table 4.16). The total ecological risk score for the species is 9 out of a maximum of 12. Therefore, *I. capensis* is classified in the B list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs.

Table 4.16: Consensus scores for potential risks of Orange jewelweed (*Impatiens capensis*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	High	3
Adverse impacts on native species	Medium	2
Alteration of ecosystem functions	Low	1
Environmental risk score		**9**

Dispersion potential or invasiveness
Classification: **High risk**. *I. capensis* is an attractive plant. Its probable main route of introduction is via the ornamental plant trade. *I. capensis* is resistant to frost (Muller, 1982; Skalova et al., 2011) that is able to tolerate the climate in the Netherlands. It is not expected that climate change will affect future *I. capensis* invasiveness. Similarly to other *Impatiens* species, *I. capensis* disperses it´s seeds by ejecting them from seed pods. Wind dispersal rates are low. The plant grows along water bodies and seeds are capable of floating for

more than 200 days. The chance of seed dispersal via hydrochory is therefore high. The maximum instantaneous rate of spread of *I. capensis* has been determined to be 13 km/year (Perrins et al., 1993). *I. capensis* has rapidly expanded its range in the Netherlands since its first documented recording in 1992. Besides the Netherlands, *I. capensis*'s non-native range extends to Belgium, Denmark, Finland, France, Germany, Ireland, Poland and the United Kingdom.

A single *I. capensis* individual may feature flowers that are cleistogamous (self-crossing and closed) and chasmogamous (outcrossing). In small, marginal populations or under stressful conditions, self-pollination may secure successful reproduction (Schemske, 1978; Waller, 1979; Tabak & Von Wettberg, 2008). *I. capensis* seeds germinate almost synchronously in early spring, after cold winter temperatures interrupt their physiological dormancy (Barton, 1939; Baskin & Baskin, 1998; Grime, 1979; Jouret, 1976a; Leck, 1979; Mumford, 1988; Nozzolillo & Thie, 1983; Winsor, 1983; Tabak & Von Wettberg, 2008). The seeds form a short term, persistent seed bank and remain viable for up to three years in the soil (Perglova et al., 2009).

I. capensis is a recalcitrant species (has seeds that do not survive drying and freezing during ex-situ storage) and are therefore dependent on being fully imbibed during cold stratification in order to germinate (Jouret, 1976a; Leck, 1979; Nozzolillo & Thie, 1983; Tabak, 2005; Tabak & Von Wettberg, 2008). Therefore, *I. capensis* seeds cannot be stored for long periods like orthodox seeds because they may lose their viability.

In conclusion, *I. capensis* is highly fecund and can easily disperse both actively or passively over 1 km/y. Therefore it poses a high risk of dispersal and invasiveness in the Netherlands.

Colonization of high value conservation habitats
Classification: **High risk**. In general, *I. capensis* occurs in moist woodland clearings, floodplains and rivers at partially shaded locations, at the edges of woodland paths, swamps, fens, and roadside ditches (Tabak & Von Wettberg, 2008; Encyclopedia of Life, 2015). In the Netherlands, *I. capensis* occurs within 15 Natura 2000 areas. Most locations lie within the tidal freshwater area (Biesbosch, Oude Maas, Haringvliet, Loevestein, Pompveld & Kornsche Boezem). At these locations *I. capensis* grows in (abandoned) willow coppices, within reed fringes and in hydrophilous tall herb vegetation along watercourses and woodland borders. It also grows in the Gelderse Poort, Uiterwaarden IJssel, Uiterwaarden Nederrijn and Uiterwaarden Waal Natura 2000 areas. Outside the river system, *I. capensis* grows in Natura 2000 areas situated in fenland (Nieuwkoopse Plassen and De Haeck, Sneekermeer area, Witte and Zwarte Brekken). In the North of the Netherlands, *I. capensis* is present in the Zuidlaardermeer area and the neighbouring Drentsche Aa area.

In conclusion, the species has established in many high conservation value habitats in the Netherlands resulting in a (potential) threat for red listed or protected species in these areas.

Adverse impacts on native species
Classification: **Medium risk**. There is no available evidence to suggest that *I. capensis* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. *I. capensis* may hybridise with its close phylogenetic relative *I. noli-tangere* which has declined in abundance

in recent years in some countries (Preston et al., 2002; Tabak & Von Wettberg, 2008). However, there is no evidence of hybridisation between these two species to date (Preston et al., 2002; Tabak & Von Wettberg, 2008). *I. capensis* is an annual herbaceous plant that grows to 150 cm or more in height. It has a poorly developed root system and does not form monocultures (Beerling & Perrins, 1993; Preston et al., 2002; Tabak & Von Wettberg, 2008). Therefore, it is generally not classified as a problematic plant in its non-native range (Tabak & Von Wettberg, 2008). Hatcher (2003) suggested that a low relative growth rate and seedling biomass indicate that *I. capensis* has a similar competitive ability to that of *I. noli-tangere* which is often outcompeted by surrounding vegetation (Perglova et al., 2009). However, Skalova et al. (2013) stated that while *I. capensis* is less competitive than either *I. glandulifera* or *I. parviflora*, it may competitively exclude native *I. noli-tangere* as the niches of the native and invasive *Impatiens* species overlap to a great degree. However, *I. capensis* and *I. noli-tangere* rarely, if ever, co-occur in Europe (Preston et al., 2002; Tabak & Von Wettberg, 2008). Some competition for pollinators may be expected.

In conclusion, there is a medium risk that local changes in population abundance, growth or distribution of one or more native species may occur as a result of *I. capensis* competition.

Alteration of ecosystem functions

Classification: **Low risk**. Based on available information it is not expected that *I. capensis* forms dense single species stands (monocultures) in the Netherlands and monopolises space and light. *I. capensis* is an annual species, dying off during the colder autumn and winter months. However, the species occurs in relatively low dynamic areas of floodplains. Therefore, physical modification of habitat due to the erosion of bare soil and light interception is not expected. In conclusion, the impact of *I. capensis* on ecosystem processes and structure is expected to be negligible.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.11) in combination with the current recorded distribution in the Netherlands. The species classification for *I. capensis* is B3 (Figure 4.14). This characterises a non-native species that is widespread in the area under assessment, poses a moderate ecological risk and should be placed on the watch list of the BFIS list system.

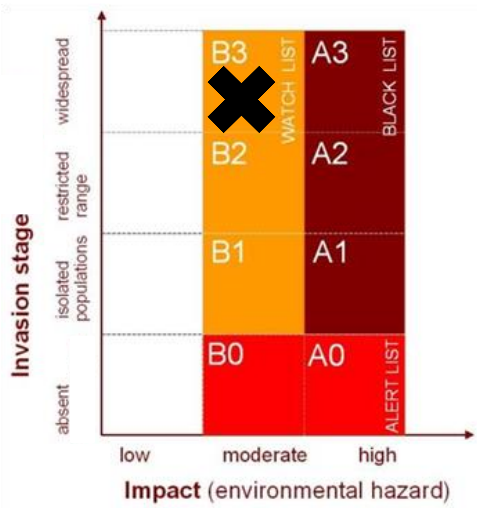

Figure 4.14: Risk classification of Orange jewelweed (*Impatiens capensis*) according to the BFIS list system.

4.4.7. Other risk assessments and classifications

Available risk assessments and classifications
No risk assessments or classifications for *I. capensis* were discovered during this literature review.

4.5. *Impatiens edgeworthii*

4.5.1. Species description

Impatiens edgeworthii is an annual herb that grows to 25 to 60 cm tall. The stem is erect and branched. The leaves are 4-18 x 1.5-7.5 cm, elliptic-ovate, acuminate, crenate to crenate-dentate and glandular towards the base. The petiole is 1.5 to 5 cm long. The racemes are subterminal with peduncle slender and 2.5 to 10.5 cm long. The flowers are commonly yellow, streaked red in the throat and 2.5 to 3.6 cm long, however, this can vary between individuals and in Germany colours may range from violet to yellow and white and anything in between or intermixed (Figure 4.15; Weiss, 2015). The pedicel is 1 to 1.3 cm long. The bracts are broad and ovate, 0.15 to 0.3 cm long, apiculate and keeled. The lateral sepals are green, subcordate to broadly ovate, 0.2 to 0.45 cm long and apiculate. The lower sepal is funnel shaped, gradually narrowed into a recurved spur and 0.8 to 1 cm long. The anterior petal is broad and orbicular, 0.7-0.8 x 1.2-1.5 cm, crested and apex bibbed. The lateral united petals are 1.8 to 2.0 cm long, the upper ones prolonged obliquely upwards and yellow-white in colour. The capsule is 2.5 to 2.9 cm long, broadly linear and erect. The seeds are oblong, circa 0.3 cm long and longitudinally rugose (www.efloras.org).

Figure 4.15: *Impatiens edgeworthii* (© Photo: K. de Niort).

Species taxonomy

Table 4.17: Nomenclature and taxonomical status of *Impatiens edgeworthii*.

Scientific name:
Impatiens edgeworthii Hook. f. (1874)

Synonyms:
Impatiens chrysantha Hook. f.

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens edgeworthii*

Preferred Dutch name:
Not applicable

Preferred English name:
Not applicable

Other Dutch names:
Not applicable

Other English names:
Not applicable

Life cycle
In Germany, *I. edgeworthii* flowers from July until October and seeds ripen in September and October. The plants die off after the first frosts (Weiss, 2013). After mild winters the first seedlings appear in late February or early March. *I. edgeworthii* can produce seeds by means off cross-pollination as well as by self-pollination.

Reproductive capacity
A single *I. edgeworthii* individual may produce several hundred seeds (Weiss, 2013).

4.5.2. Habitat summary

I. edgeworthii is gregarious in shady and open places in Pakistan (Encyclopedia of Life, 2015). In Germany it grows in moist, nutrient rich forest fringes and open deciduous woodland (canopy cover <40%) and along roadside ditches (Baade & Gutte, 2008). According to Jäger et al. (2008) and Weiss (2013) *I. edgeworthii* is a winter-hard species. Moreover, to break seed dormancy a prolonged period of low temperatures is required. However, frost is not necessary. The seeds germinate even after severe winters with temperatures below -20^{0}C (Weiss, 2013).

4.5.3. Recorded distribution

Native range

I. edgeworthii is native to the Indian sub-continent (Nehring et al., 2013), North-western Himalaya (Pakistan, Kashmir, Nepal). It grows at altitudes of 1800-3000 m in Pakistan.

Non-native range

I. edgeworthii was first recorded in 2001 at Leinaforst at Altenburg, Germany and subsequently in Leipzig floodplain forest. It was recorded in Berlin in 2006 (Baade & Gutte, 2008; Nehring et al., 2013). It has most recently been recorded in Essen-Borbec, Nordrhein-Westfalen (Baade & Gutte 2008; John et al., 2008; Weiss, 2013; Kalveram, 2014; Nehring et al., 2013).

Distribution in the Netherlands

According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. edgeworthii* in the Netherlands. However, it should be noted that lag times between introduction and establishment of non-native species can be considerable, even for herbaceous species. For example, the lag time for *I. glandulifera* was 40 years in central Europe (Pysek & Prach, 1995).

Colonisation of high conservation value habitats

According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. edgeworthii* in the Netherlands.

4.5.4. Invasion process

Introduction

I. edgeworthii was first introduced in Europe in 1900 when it was grown at the Botanical Gardens at Kew in the United Kingdom (Nehring et al., 2013). A quick scan of the first 50 results of google.nl using the search term '*Impatiens edgeworthii* te koop' revealed no websites offering *I. edgeworthii* for sale to the public.

Establishment

Information on the potential for establishment of *I. edgeworthii* in the Netherlands is not available. However, the species has been increasingly recorded in parts of Germany (Nehring et al., 2013).

Spread

I. edgeworthii is increasingly recorded as a garden escape in parts of Germany (Nehring et al., 2013). The historical spread of *I. edgeworthii* by seed in Germany was probably facilitated by construction of forest roads (Baade & Gutte, 2008; Nehring et al., 2013).

4.5.5. Environmental impact summary

Effects on environmental targets or native species

Parasitism

No recorded impacts were discovered during the literature review.

Competition
I. edgeworthii competes for space and is a strong vertical grower. According to Nehring et al. (2013) it is unknown whether *I. edgeworthii* poses a risk to German native species. However, *I. edgeworthii* has been observed to grow more densely than *I. capensis* in Germany and is likely to outcompete native species (J. van Valkenburg, personal observation). It is able to completely outcompete Stinging nettle (*Urtica dioica*) within several years of establishment in forest fringes. *Impatiens parviflora* is displaced by *I. edgeworthii* at shady, moist locations. The species composition of nitrophilous fringe communities (*Aegopodion podagrariae* and *Galio-Alliarion*) is considerably altered by the presence of *I. edgeworthii* (Weiss, 2013). Similarly to other *Impatiens* species, it is an important source of nectar for bumblebees and honeybees in late summer when other nectar sources are becoming scarce (Weiss, 2013).

Interbreeding
It is unknown whether there is a risk to German native species (Nehring et al., 2013).

Hosting pathogens or parasites
No known risk to German native species (Nehring et al., 2013).

Effects on ecosystem function targets
There are no known risks to biotic or abiotic properties of German ecosystem functions (Nehring et al., 2013).

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (such as damage to infrastructure, bank or dike stability).

4.5.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. edgeworthii* a 'likely' ecological risk classification to the categories dispersion potential or invasiveness and colonization of high value conservation habitats, a ‘medium’ ecological risk classification to the category alteration of ecosystem functions and a ‘high’ risk classification to the category adverse impacts on native species (Table 4.18). The total ecological risk score for the species is 9 out of a maximum of 12. Therefore, *I. edgeworthii* is classified in the B list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs. Note that the scores ‘likely’ for dispersion potential and colonization of high value conservation habitats are based on expert judgement due to lack of data. Recent information on spread in Germany (Baade & Gutte, 2008; Nehring et al., 2013) indicates that the risk score for dispersion potential may be underestimated based on the expert judgement approach. Based on German information the risk score may also be classified as medium to high. However, this approach will not affect the BFIS classification.

Table 4.18: Consensus scores for potential risks of *Impatiens edgeworthii* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Likely	2
Adverse impacts on native species	High	3
Alteration of ecosystem functions	Medium	2
Environmental risk score		**9**

Dispersion potential or invasiveness
Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. edgeworthii* in the Netherlands. However, Jäger et al. (2008) and Weiss (2013), state that *I. edgeworthii* is winter hard. Therefore, *I. edgeworthii* would likely tolerate the Dutch climate. Moreover, since 2001 *I. edgeworthii* has been increasingly recorded as an escape in parts of Germany, also in areas close to Dutch border. German *I. edgeworthii* seed spread was probably facilitated by forest road construction (Baade & Gutte, 2008; Nehring et al., 2013). *I. edgeworthii* can produce seeds by means off cross-pollination as well as by self-pollination. A single plant can produce several hundred seeds per year (Weiss, 2013).

In conclusion, *I. edgeworthii* is likely to display a high dispersal and invasiveness potential in the Netherlands.

Colonization of high value conservation habitats
Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. edgeworthii* in the Netherlands. In Germany *I. edgeworthii* grows in moist, nutrient rich forest fringes and open deciduous woodland where canopy cover is less than 40%, and along roadside ditches (Baade & Gutte, 2008).

In conclusion, it is likely that *I. edgeworthii* will be able to establish in high conservation value habitats and cause a (potential) treat for red listed or protected species in the Netherlands.

Adverse impacts on native species
Classification: **High risk**. There is no available evidence to suggest that *I. edgeworthii* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. No information on either potential adverse impacts of *I. edgeworthii* as a result of genetic effects or competition on Dutch native species was found during the literature review. Whether a hazard exists to German native species is unknown (Nehring et al., 2013). However, *I. edgeworthii* competes

for space and is a strong vertical grower and is able to completely outcompete Stinging nettle (*Urtica dioica*) within several years of establishment in forest fringes. *Impatiens parviflora* is displaced by *I. edgeworthii* at shady, moist locations. The species composition of nitrophilous fringe communities (*Aegopodion podagrariae* and *Galio-Alliarion*) is considerably altered by the presence of *I. edgeworthii* (Weiss, 2013). Similarly to other *Impatiens* species, it is an important source of nectar for bumblebees and honeybees in late summer when other nectar sources are becoming scarce (Weiss, 2013).

In conclusion, there is a high risk that *I. edgeworthii* may cause local changes (>80%) in population abundance, growth and distribution of one or more native species if it establishes in the Netherlands.

Alteration of ecosystem functions

Classification: **Medium risk**. No information on potential adverse impacts of *I. edgeworthii* on Dutch ecosystem functioning was found during the literature review. Nehring et al. (2013) stated that there are no known risks to German ecosystem functions associated with *I. edgeworthii*. However, *I. edgeworthii* is an annual herb that grows to 25 to 60 cm tall. It competes for space and is a strong vertical grower. Therefore, some physical modification of habitat such as the erosion of bare soil and light interception may occur.

In conclusion, there is a medium risk of alterations to ecosystem processes and functioning occurring in the Netherlands.

Risk classification according to the BFIS list system

The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.18) in combination with the current recorded distribution in the Netherlands. The species classification for *I. edgeworthii* is B0 (Figure 4.16). This characterises a non-native species that is absent from the area under assessment, poses a moderate ecological risk and should be placed on the alert list of the BFIS list system.

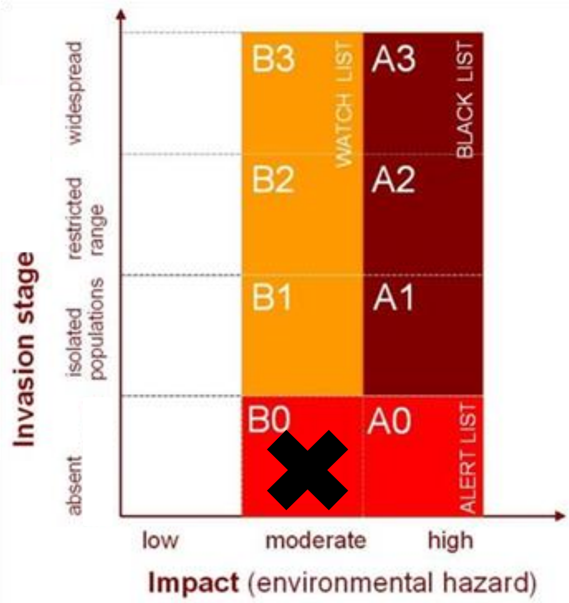

Figure 4.16: Risk classification of *Impatiens edgeworthii* according to the BFIS list system.

4.5.7. Other risk assessments and classifications

No risk assessments or classifications of *I. edgeworthii* could be found during the literature review.

4.6. *Impatiens flanaganae*

4.6.1. Species description

Impatiens flanaganae is a tuberous rooted perennial that grows up to 100 to 200 cm tall. The upright stem is fleshy and moderately branched. The leaves are glabrous and spirally arranged. The petiole is 1-4.5(-8) cm long. The leaf blade is oblong to oblong-elliptical and 7 to 24 cm long and 4.5-11 cm wide and has 9-11 pairs of lateral veins. The leaf apex is acute or subobtuse; the base ± cuneate or subobtuse. The leaf margins are serrate. The inflorescence is a stout, more or less erect, 6-12(-15) flowered raceme with pink, unspotted flowers, and is supported by a 17 to 39 cm long peduncle (Figure 4.17). Pedicel 2-3.4 cm long, slender, with at the base 0.5 to 0.8 cm long, linear-lanceolate, acute bracts. The upper pair of lateral sepals is ± 0.7 cm long and linear-lanceolate, acute; the lower pair of lateral sepals is ± 0.6 cm long and ovate-lanceolate, acute. The lower sepal is 1.5 to 1.7 cm long, bucciniform, gradually tapering into a curved, 3.2 to 4 cm long spur with distal third of the spur filiform and the tip slightly swollen. The dorsal petal ± 0.8 x 0.6 cm, cucullate, apically produced into a short, rather blunt, point. The lateral united petals are 2.7 to 2.8 cm long; the upper petal of each pair measures 0.7 x 0.6 cm; the lower petal measures 1.7 x 1.3 cm, distally with a slight emargination along the inner margin. The ovary is glabrous (Grey-Wilson, 1980b).

Figure 4.17: *Impatiens flanaganae*. (© Photo: Wikimedia, D. Keats).

Species taxonomy

Table 4.19: Nomenclature and taxonomical status of *Impatiens flanaganae*.

Scientific name: *Impatiens flanaganae* Hemsl. (1899) **Synonyms:** Not applicable **Taxonomic tree (Naturalis, 2015):** Kingdom: Plantae Phylum: Tracheophyta Class: Spermatopsida Order: Ericales Family: Balsaminaceae Genus: *Impatiens* Species: *Impatiens flanaganae* **Preferred Dutch name:** Not applicable **Preferred English name:** Not applicable **Other Dutch names:** Not applicable **Other English names:** Not applicable

Life cycle
Impatiens flanaganae is a perennial herb. In its native range on the southern hemisphere it flowers from January till March (Grey-Wilson, 1980b).

Reproductive capacity
No information on the reproductive capacity of *I. flanaganae* could be found during the literature review.

4.6.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. flanaganae* are listed in table 4.20. According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), *I. flanaganae* is classified as an H5 or G1 species meaning that it is hardy in favourable areas and withstands temperatures of 0 to -5˚C minimum (H5) or needs a cool glasshouse even in south Europe (G1). The precautionary principle was applied in this case and it was assumed that the seeds of *I. flanaganae* are able to tolerate Dutch winters.

Table 4.20: Physiological conditions tolerated by *Impatiens flanaganae*.

Parameter	Data origin	Occurrence	References
Hardiness (˚C)	Unknown	0 to -5	Grey-Wilson (2011)

I. flanaganae grows in lowland wooded areas in partial shade, along river banks and gullies; altitudinal range 20-200 m (Grey-Wilson, 1980b). It prefers well filtered sun or morning sunlight and prefers moist, well-drained soil (Strange wonderful things, 2015).

4.6.3. Recorded distribution

Native range
I. flanaganae is a South African endemic species and has a very limited distribution. It is only known from a few locations near Port St. Johns (Pondoland, Eastern Cape province) and a single location in the province Kwazulu-Natal (http://pacificbulbsociety.org/; Grey-Wilson, 1980b).

Non-native range
No information on the non-native range of *I. flanaganae* could be found during the literature review.

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. flanaganae* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. flanaganae* in the Netherlands.

4.6.4. Invasion process

Introduction
No information on the potential for introduction of *I. flanaganae* to the Netherlands could be found during the literature review. A quick scan of the first 50 results of google.nl using the search term '*Impatiens flanaganae* te koop' revealed no websites offering *I. flanaganae* for sale to the public. However, according to Grey-Wilson (2011) and Jäger et al. (2008), this species is available via the European ornamental market and our observations confirm the plant has been offered for sale on a German gardener's forum (gartenforum.de, 2015).

Establishment
No information on the potential for establishment of *I. flanaganae* in the Netherlands or climatically similar countries could be found during the literature review.

Spread
No information on the potential for spread of *I. flanaganae* in the Netherlands or climatically similar countries could be found during the literature review.

4.6.5. Environmental impact summary

Available risk assessments and classifications
No risk assessments or classifications of *I. flanaganae* could be found during the literature review.

Effects on environmental targets or native species
No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.6.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. flanaganae* an 'unlikely' ecological risk classification for category of the ISEIA protocol apart from dispersion potential or invasiveness where the species was allocated a ‘likely’ risk classification (Table 4.21). The total ecological risk score for the species is 5 out of a maximum of 12. Therefore, *I. flanaganae* is classified in the C list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs.

Table 4.21: Consensus scores for potential risks of *Impatiens flanaganae* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Unlikely	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Environmental risk score		**5**

Note that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Dispersion potential or invasiveness
Classification: **Likely**. No information on the potential for spread of *I. flanaganae* in the Netherlands or climatically similar countries could be found during the literature review. The plant is available via the European ornamental market and plants, however, only a partial climate match exists between the temperature requirements of *I. flanaganae* and current climatic conditions in the Netherlands. The risk establishment in the Netherlands may increase by climate change.

In conclusion, it is likely that *I. flanaganae* has the potential to disperse and become invasive in the Netherlands.

Colonization of high value conservation habitats
Classification: **Unlikely**. No information on the potential for spread of *I. flanaganae* in the Netherlands or climatically similar countries could be found during the literature review. In general, *I. flanaganae* grows in lowland wooded areas in partial shade, along river banks and gullies in an altitudinal range 20-200 m (Grey-Wilson, 1980b). It prefers well filtered sun or morning sunlight and prefers moist, well-drained soil.

In conclusion, it is unlikely that *I. flanaganae* will be able to establish in high conservation value habitats leading to a (potential) threat to red listed or protected species in the Netherlands.

Adverse impacts on native species
Classification: **Unlikely**. There is no available evidence to suggest that *I. flanaganae* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. No information on either potential adverse impact of *I. flanaganae* as a result of genetic effects or competition on Dutch native species was found during the literature review. No information on the potential for (potential) impacts of *I. flanaganae* on native species in the Netherlands or climatically similar countries could be found during the literature review. *I. flanaganae* may be an important source of nectar for bumblebees and honeybees.

In conclusion, it is unlikely that *I. flanaganae* may potentially causes local changes in population abundance, growth and distribution of one or more native species if established in the Netherlands.

Alteration of ecosystem functions
Classification: **Unlikely**. It is a perennial herb that grows up to 100 to 200 cm tall. These species traits may be associated with alterations of ecosystem functioning in cases of dense vegetation stands. However, no information on physical modification of habitat (e.g., light interception) by vegetation dominance (e.g., dense stands) or other effects of *I. flanaganae* on ecosystem functioning could be found during the literature review. The expert panel estimated the risk of ecosystem functions alteration as unlikely.

In conclusion, it is unlikely that *I. flanaganae* poses a risk to ecosystem processes and functioning in the Netherlands.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.21) in combination with the current recorded distribution in the Netherlands. The species classification for *I. flanaganae* is C0 (Figure 4.18). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and should not be placed on either the alert, watch or black list of the BFIS list system. However, note that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

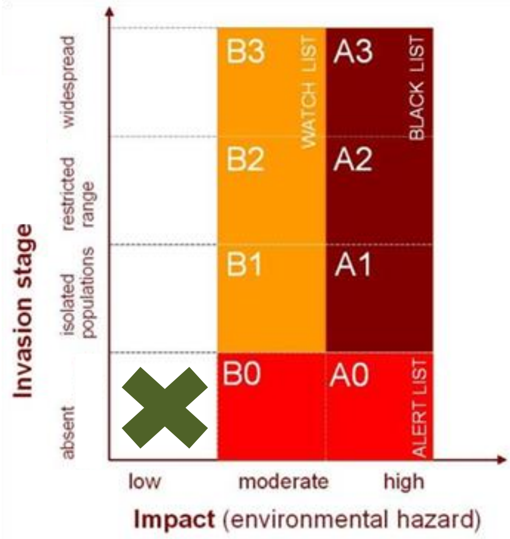

Figure 4.18: Risk classification of *Impatiens flanaganae* according to the BFIS list system.

4.6.7. Other risk assessments and classifications

Available risk assessments and classifications
No risk assessments or classifications of *I. flanaganae* could be found during the literature review.

4.7. Himalayan balsam (*Impatiens glandulifera*)

4.7.1. Species description

Himalayan balsam (*Impatiens glandulifera*) is a glabrous annual and is Europe's tallest annual plant usually reaching 50 to 250 cm tall (EPPO, 2015a) and can even reach 300 cm at maturity in deciduous woodland (CABI, 2015b). The hollow green stems have a reddish tinge and reach 0.5 to 5 cm in diameter. The stems are erect and sometimes branched. The roots can extend to 15 cm. The plant often forms many adventitious roots from lower nodes. Leaves are opposite, the uppermost ones sometimes arranged in whorls of three where branching occurs, always longer than they are wide growing to a maximum of 25 x 7 cm, are lanceolate to obovate shaped, petiolate and feature sharply serrated edges. The inflorescences are racemes 2.5 to 4 cm long and feature 2 to 14 flowers. Their posterior sepal forms a sac that ends in a straight spur. Flowers are produced from June through to October, are variable in colour from purple to pink and sometimes almost white (Figure 4.19) (CABI, 2015b). The seed capsule is 3 to 5 cm long and up to 1.5 cm wide, containing up to 6 (Grime et al., 1988; EPPO, 2015a) or 4 to 16 seeds (Beerling & Perrins, 1993; EPPO, 2015a) that are black at maturity (CABI, 2015b). Seeds reach 0.4 to 0.7 cm in length and are 0.2 to 0.4 cm wide, with a mean weight of 7.32 mg (EPPO, 2015a).

Figure 4.19: Himalayan balsam (*Impatiens glandulifera*) growing on floodplains along the river Waal near Ewijk, the Netherlands (© Photo: P.F. Klok, 9th October 2013).

Species taxonomy

Table 4.22: Nomenclature and taxonomical status of Himalayan balsam (*Impatiens glandulifera*).

Scientific name: *Impatiens glandulifera* Royle (1850). **Synonyms:** *Impatiens glanduligera* Lindl., Edwards's Bot. Reg. 26: t. 22. 1840, *Impatiens roylei* Walp., Repert. Bot. Syst. 1: 475. 1842. **Taxonomic tree (Naturalis, 2015):** Kingdom: Plantae Phylum: Tracheophyta Class: Spermatopsida Order: Ericales Family: Balsaminaceae Genus: *Impatiens* Species: *Impatiens glandulifera* **Preferred Dutch name:** Reuzenbalsemien **Preferred English name:** Himalayan balsam **Other Dutch names:** Not applicable **Other English names:** Indian balsam, policeman's helmet, ornamental jewelweed, touch-me-not, jumping Jack

Life cycle

The plant is pollinated by numerous insects especially honey bees (*Apis mellifera*), bumble-bees (*Bombus* spp.) and syrphids (EPPO, 2015a). *I. glandulifera* is exclusively propagated by seeds (EPPO, 2015a). Seeds are launched from the capsules via ballochory. This seed dispersal mechanism is typical for the whole family Balsaminaceae (CABI, 2015b; DAISIE, 2015d). Seeds are not able to float for long but do not lose their ability to germinate when submerged so may be transported under water to new locations where they can establish new plants (DAISIE, 2015d). Moreover, fish-mediated seed dispersal (ichthyochory) may contribute to spread of *I. glandulifera* (Boedeltje et al., 2015). The seeds of *I. glandulifera*, similarly to orange jewelweed (*Impatiens capensis*) and pale jewelweed (*Impatiens pallida*), germinate in early spring. Germination is triggered by winter's cold temperatures that break the seeds physiological dormancy (Barton, 1939; Baskin & Baskin, 1998; Grime, 1979; Jouret, 1976a; Leck, 1979; Mumford, 1988; Nozzolillo & Thie, 1983; Winsor, 1983; Tabak & Von Wettberg, 2008). Germination occurs somewhat later than other vegetation, so that sensitive seedlings are protected from frosts by the milder microclimate created by other plants (DAISIE, 2015d). In the United Kingdom, the cotyledon phase lasts until April after which shoots grow rapidly and adventitious roots develop (Beerling & Perrins, 1993; EPPO, 2015a). Flowering occurs at the end of June and continues until either the first severe frost, or until October by which time the plants are senescing (Perrins et al., 1993). In Germany, the duration from germination to flowering is 13 weeks and flowering continues for a subsequent 12 weeks (Sebald et al., 1998; EPPO, 2015a).

Reproductive capacity

Since seeds are the only persistent elements of *I. glandulifera*, their production and transport is vital for plant spread (DAISIE, 2015d). In a garden experiment in the United Kingdom, *I. glandulifera* produced a maximum of 50-80 of pods per plant (Perrins et al., 1993). In the same experiment *I. glandulifera* produced 600 seeds at peak seed production. In a growing season *I. glandulifera* may produce up to 4000 seeds per plant and 5.7 to 6.4 seeds per capsule (Salisbury, 1942; Perrins et al., 1993; Beerling & Perrins, 1993; Sebald et al., 1998; EPPO, 2015a). A maximum of 32,000 seeds per square metre were produced in a monoculture in Germany (Koenis & Glavac, 1979; EPPO, 2015a). Compared to other *Impatiens* species, *I. glandulifera* produces considerably more seeds than either *I. balfourii* or *I. parviflora* (Perrins et al., 1993). In a study comparing *I. glandulifera* with *I. balfourii*, two of the three bee species studied visited *I. glandulifera* flowers significantly more frequently, possibly because of a larger nectar reservoir and/or other flower characteristics (e.g., larger flower size, brighter colour and possibly stronger odour) (Nienhuis et al., 2009; Ugolleti et al., 2013). It should be noted that species may produce more seeds in a highly favourable garden environment than would be expected under natural conditions (Perrins et al., 1993). The species has been reported as not featuring a persistent seed bank (Grime et al., 1988; EPPO, 2015a). However, some seeds can persist for 18 to 24 months (Beerling & Perrins, 1993; Wittenberg, 2005; EPPO, 2015a).

4.7.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. glandulifera* are listed in table 4.23.

Table 4.23: Physiological conditions tolerated by Himalayan balsam (*Impatiens glandulifera*).

Parameter	Data origin	Occurrence	References
Temperature (˚C)	Not specified	5 (maximum germination success), plant and seedlings do not survive frost	Q-bank (2015c); Sebald et al. (1998); EPPO (2015a); Skalova et al. (2011); Grey-Wilson (2011)
Hardiness (˚C)	Not specified	-15 to -20	Q-bank (2015c); Grey-Wilson (2011)
Light	Not specified	≤30% daylight causes sharp decline in growth rate	Perrins et al. (1993); EPPO (2015a)
pH	Not specified	4.5-8.0	Grime et al. (1988); ISSG (2009);
Substrate	Not specified	Alluvial soils, mineral soils, peat	Q-bank (2015c); Kowarik (2003); EPPO (2015a); Branquart et al. (2010)
Nutrients	Not specified	Tolerant of poor nutrients, prefers nutrient rich substrates	Q-bank (2015c); Kowarik (2003); EPPO (2015a)
Elevation (m)	Native range	1600-4300	DAISIE (2015d); Q-bank (2015c)
	Non-native range	<210-1200	Q-bank (2015c); Drescher & Prots (2000); EPPO (2015a)

Habitat type

In its native range *I. glandulifera* prefers wet, open places in forests, shrubs and hedges at an elevation of 1600 to 4300 m, riverine and fen scrubs, hedgerows, lines of trees, small managed woodlands, recently felled woodland, early-stage woodland and coppice. *I. glandulifera* has a surprisingly small native range of approximately 800 km long and 50 km wide when the extent of its non-native range is considered (Williamson, 1996). In its non-native range, *I glandulifera* can be found in riparian vegetation, riverine and fen scrubs, wet disturbed places, forest edges, highly artificial man-made waters and associated structures e.g., waste lands, urban areas, roadsides and railways (DAISIE, 2015d; Q-bank, 2015c). However, it is not a weed of agricultural fields (Q-bank, 2015c). The plant depends on open sites for germination and consequently favours disturbed locations (Q-bank, 2015c). In Europe *I. glandulifera* is found at elevations of up to 1200 m in the eastern Alps in Austria and not found above 210 m in the United Kingdom (Q-bank, 2015c; Drescher & Prots, 2000; EPPO, 2015a). Its principal habitat in Europe including the Netherlands where it is introduced and invasive is on riverbanks (Q-bank, 2015c; Kowarik, 2003; EPPO, 2015a). *I. glandulifera* has a preference for low powered streams at low altitudes and with finer sediment particle size (Dawson & Holland, 1999). It has been observed along riverbanks in the London area (United Kingdom) that *I. glandulifera* flourishes where native vegetation is poorest and space is available for colonisation. However, some authors state that it is rarely found along streams and rivers (Beerling & Perrins, 1993; Drescher & Prots, 2000; EPPO, 2015a). In the Czech Republic, *I. glandulifera* is most commonly recorded in semi-natural habitats where it may become locally abundant and rarely in artificial habitats

Climate

Being drought-intolerant and quickly wilting in dry periods, *I. glandulifera* has a preference for temperature climates with relatively high humidity, warm to hot wet summers and cool to cold winters (wet or dry) (Beerling & Perrins, 1993; EPPO, 2015a; Q-bank, 2015c). Plants at all stages are vulnerable to frost with seedlings killed by late frosts in spring and adults killed by the first autumn frost. However, according to Grey-Wilson (2011) it is hardy almost everywhere can withstand temperatures of -15 to -20˚C (see also Sebald et al., 1998; EPPO, 2015a; Q-bank, 2015c). In the Czech Republic considerable frost sensitivity of early-emerging *I. glandulifera* seedlings may impose considerable risk of death due to late frosts (Skalova et al., 2011). However, local topography and individual plant size play a major role in determining the severity of frost damage to plants (Wittenberg, 2005). Mortality of seedlings and young plants can also be high due to physical damage from rainfall (Prowse, 1998; EPPO, 2015a; Q-bank, 2015c). In garden experiments in the Czech republic comparing *I. glandulifera*, *I. parviflora*, *I. capensis* and the native touch-me-not balsam (*Impatiens noli-tangere*) for their cold stratification requirements, the maximum germination of all species was achieved at a constant 5˚C (Perglova et al., 2009). When a 15/5˚C diurnal temperature cycle was applied, only the stratification requirements *I. glandulifera* were (partly) met as almost a third of the seed completed their low temperature stratification requirements. However, germination started later and the percentage germination was much lower than at 5˚C. (Perglova et al., 2009). Beerling (1993) predicted that a future temperature increase of 2.5˚C due to climate change would not increase the possibility of *I. glandulifera* establishment in the Netherlands.

Experiments show that *I. glandulifera* may be hardier to late frosts than other *Impatiens* species. During a UK garden experiment, a heavy frost of approximately -5˚C occurred just as seedlings were emerging. 3% (n = 77) of *I. glandulifera*, 25% (n = 52) of *I. balfourii* and 67% (n = 66) of *I. parviflora* seedlings died (Perrins et al., 1993). The largest *I. glandulifera* individuals may have been tall enough to avoid the worst of the frost (Perrins et al., 1993). However, in laboratory experiments *I. capensis* seedlings were more frost resistant than *I. glandulifera* and *I. parviflora* (60%, 57% and 40% survival respectively). Survival, of native *I. noli-tangere* was 72% (Skalova et al., 2011). Within species differences in germination and frost resistance of *I. parviflora* were explained by differences between populations (Skalova et al., 2011).

Light

Strong response to shade provides an experimental explanation for the fact that the occurrence of *I. glandulifera* in the field is driven mostly by canopy cover. (Skalova et al., 2013) The growth rate of *I. glandulifera* declines sharply below about 30% daylight, however, it does grow in half-shaded conditions (Perrins et al., 1993; EPPO, 2015a). In high light conditions *I. glandulifera* produces more biomass than other *Impatiens* species (*I. capensis*, *I. parviflora* and *I. noli-tangere*). In shaded conditions *I. glandulifera* biomass was comparable with that of *I. parviflora* (Skalova et al., 2012). However, seedling stems of *I. glandulifera* are the tallest compared with *I. capensis*, *I. parviflora* and *I. noli-tangere* when grown in shade. In a laboratory experiment, simulated shading stimulated rapid stem elongation, with *I. glandulifera* recording the highest plasticity (Skalova et al., 2012).

pH

I. glandulifera is tolerant to a pH range of about 4.5-7.7 (ISSG, 2009).

Soil type

I. glandulifera is tolerant of a wide range of soil types. It occurs on maritime shingle, fine and coarse alluvium, colliery spoil, free-draining mineral soils, and peats, but prefers alluvial soils (Beerling & Perrins, 1993; Branquart et al., 2010; EPPO, 2015a; Kowarik, 2003; Q-bank, 2015c). The plant has a high tolerance to heavily compacted soils.

Nutrients

I. glandulifera occurs on nutrient-poor to nutrient-rich soils (Beerlings & Perrins, 1993; EPPO, 2015a; Kowarik, 2003; Q-bank, 2015c). For example, in a study carried out in the UK, soil taken from five sites with *I. glandulifera* stands had average ammonium levels ranging from 1.19 ± 0.13 to 6.02 ± 3.03 µg/g; nitrate levels ranging from 0.53 ± 0.26 to 5.54 ±1.3 µg/g; and phosphate levels ranging from 3.7 ± 0.83 to 59.7 ± 4.7 µg/g (Beerling & Perrins, 1993). It is stated that *I. glandulifera* performs best on nutrient rich soils (Branquart et al., 2010). However, high nutrient levels in laboratory experiments decreased survival in *I. capensis* and *I. glandulifera*, but not in *I. noli-tangere* and *I. parviflora* (Skalova et al., 2012), In the same experiment, low levels of nutrients resulted in decreased total biomass and stem height and an increased root/shoot ratio, with plasticity being the highest in all three traits in *I. glandulifera*.

Soil moisture

I. glandulifera seeds are able to germinate even after periods of drying in contrast to *I. capensis* whose seeds need to be fully imbibed during cold stratification for germination to occur (Jouret, 1976a; Kollmann & Banuelos, 2004; Mumford, 1988; Tabak, 2005; Tickner et al., 2001). The primary dormancy-breaking mechanisms for *I. glandulifera* in its native range are seed desiccation in combination with cold stratification (Jouret, 1976a; Tabak & Von Wettberg, 2008). Both seedlings and fully grown *I. glandulifera* individuals performed well under low water availability (Skalova et al., 2012). Moreover, *I. glandulifera* plants have higher relative growth rates than *I. capensis* across a range of soil moisture conditions (Tabak, 2005; Tabak & Von Wettberg, 2008). Drought tolerance associated with a high light demand may explain why *I. glandulifera* is able to colonise habitats far from rivers and streams, such as woodland gaps and grasslands (Skalova et al., 2013). However, both drought and flooding reduce the survival of *I. glandulifera* and *I. noli-tangere*, but not that of *I. parviflora* and *I. capensis* (Skalova et al., 2013).

4.7.3. Recorded distribution

Native range
I. glandulifera is native to the Western Himalayas limited to parts of northern Pakistan, northern India and Nepal (Figure 4.20; Q-bank, 2015c).

Non-native range
I. glandulifera's non-native range extends to Asia: Japan, Russia (Eastern Siberia, Russian Far East); Europe: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, Former Yugoslavia, France, Germany, Hungary, Ireland, Netherlands, Norway, Poland, Romania, Russia (Central Russia, Eastern Russia, Russian Far East), Slovakia, Spain, Sweden, Switzerland, Ukraine, United Kingdom; North America: Canada (British Columbia, Manitoba, Ontario, Saskatchewan), USA (California, Idaho, Maine, Massachusetts, Michigan, Montana, New York, Oregon, Rhode Island, Vermont, Washington) and Oceania: New Zealand (Figure 4.20) (Q-bank, 2015c; EPPO, 2015a).

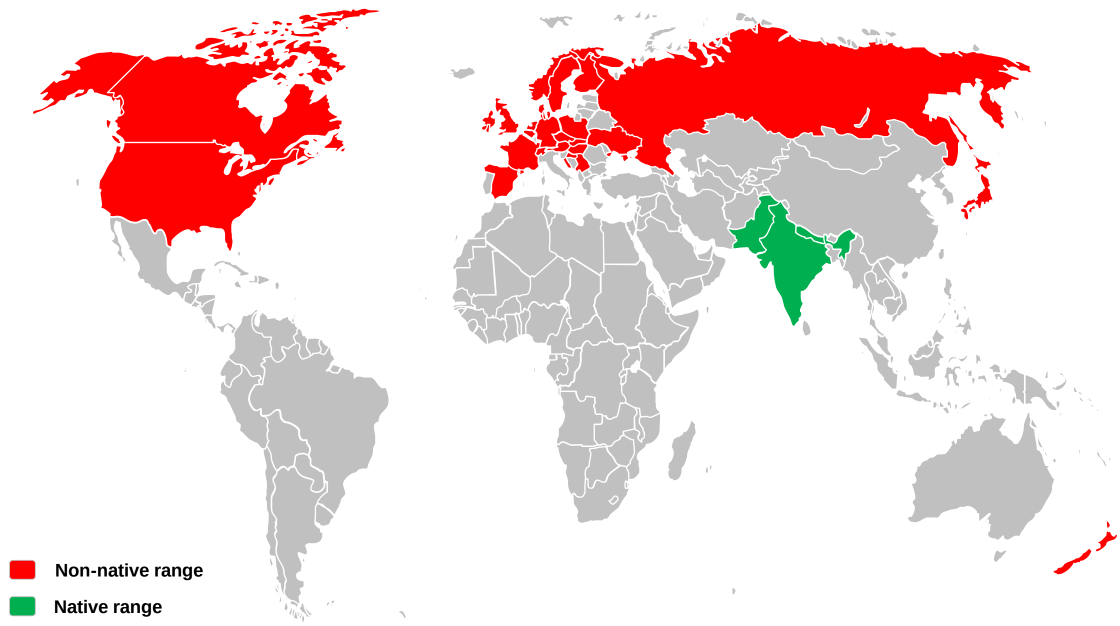

Figure 4.20: Current global recorded distribution of Himalayan balsam (*Impatiens glandulifera*) (Sources: Q-bank, 2015c; EPPO, 2015a).

Distribution in the Netherlands
The current distribution of *I. glandulifera* in the Netherlands is shown in figure 4.21. *I. glandulifera* was first identified in the Netherlands in 1903 at Denekamp (Heukels, 1985). *I.*

glandulifera has strongly widened its distribution since the 1930s, and in more recent times continues to do so (Figure 4.22). In the 1950s, the species was sown at separate locations in the Biesbosch. However, these initial efforts to introduce the plant were not immediately successful. The plants were damaged at high water at a number of locations (Van Ooststroom et al., 1957; Verhey, 1958). It is plausible that the plants spread strongly following the disappearance of the tide at these locations. Arable areas on clay and livestock areas on peat are the only locations where *I. glandulifera* is generally absent. The plant is mainly found in wet brushwood litter amongst hydrophilous tall herb vegetation along the banks of low-dynamic waters and in willow forests. In the Biesbosch and river systems, *I. glandulifera* is a very common local occurrence in the undergrowth of interleaved osier willows and softwood forests. On drier soils the plant only grows in shady spots. In urban areas it grows mainly in unmanaged gardens, vacant lots and places where garden waste is landfilled.

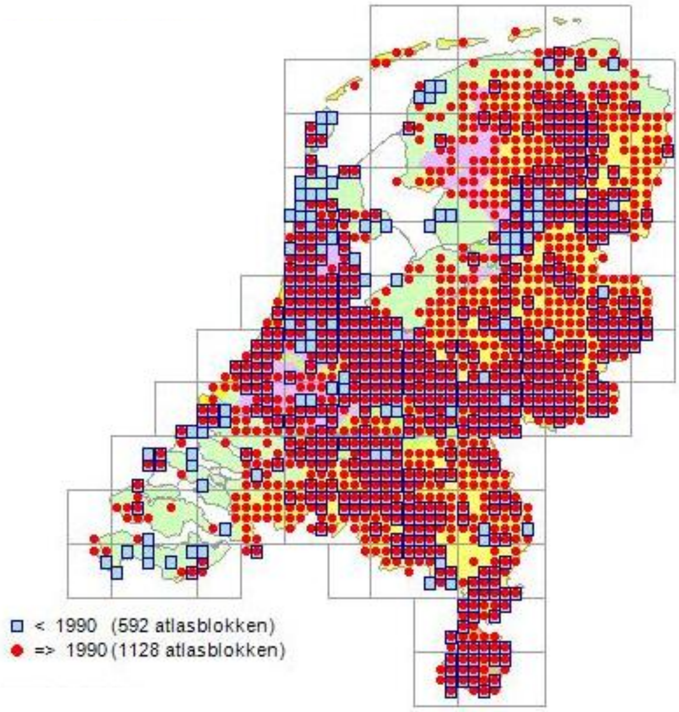

Figure 4.21: Current recorded distribution of Himalayan balsam (*Impatiens glandulifera*) in the Netherlands (Source: Nationale Databank Flora en Fauna, 2015).

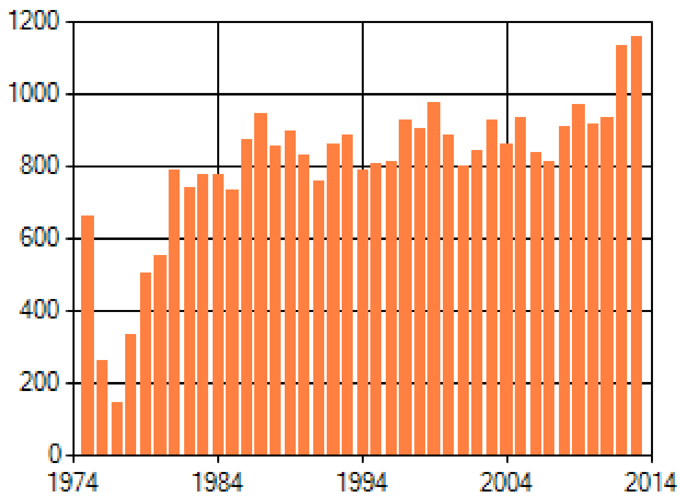

Figure 4.22: Estimated number of 5x5 kilometre-squares occupied by Himalayan balsam (*Impatiens glandulifera*) per year in the Netherlands (Source: Verspreidingsatlas.nl; © CBS & FLORON, 2014).

Colonisation of high conservation value habitats

In view of its wide distribution in the Netherlands, it is not surprising that *I. glandulifera* has been recorded in a great number of high conservation value habitats. The species has been recorded in 61 Natura 2000 areas, the most important of which are listed in Table 4.24. Most of these locations are situated along the Rhine and its tributaries and along the Rhine/Meuse estuary: Biesbosch, Hollandsch Diep, Haringvliet, Gelderse Poort, the banks and floodplain of the river Waal, the banks and floodplain of the river Neder-Rijn and the banks and floodplain of the river IJssel. Along smaller rivers, *I. glandulifera* has been recorded along the following Natura 2000 areas: Geuldal, Drentsche Aa area, Roerdal, Vecht and lower Regge area, Dinkelland and Swalmdal. In low lying fenland areas *I. glandulifera* has been recorded in the Oostelijke Vechtplassen, Alde Feanen, Weerribben and Leekstermeer Natura 2000 areas. *I. glandulifera* has also been recorded in Natura 2000 areas which are predominantly located on poor dry soils, for example, in the Veluwe, Brabantse Wal, Dwingelderveld, Maasduinen, Leenderbos, Groote Heide and De Plateaux, Drents-Friese Wold and Leggelderveld, Loonse and Drunense Dunes & Leemkuilen, Kennemerland south and the North Holland dune reserve. Within these predominantly dry and nutrient-poor areas, the species is often found on relatively nutrient rich, moist or shaded, scattered locations.

Table 4.24: Number of kilometre squares in Natura 2000 sites where Himalayan balsam (*Impatiens glandulifera*) has been recorded in the Netherlands.

Natura 2000 area	Definite	Possible	Range
Veluwe	84	52	84-136
Biesbosch	45	23	45-68
Gelderse Poort	35	19	35-54
The banks and floodplain of the river Waal	22	16	22-38
The banks and floodplain of the river Nederrijn	13	14	13-27
Hollandsch Diep	15	11	15-26
Geuldal	13	12	13-25
Oostelijke Vechtplassen	5	12	5-17
Brabantse Wal	3	11	3-14
The banks and floodplain of the river IJssel	2	11	2-13
Drentsche Aa-gebied	6	6	6-12
Dwingelderveld	8	4	8-12
Haringvliet	7	5	7-12
Maasduinen	7	5	7-12
Leenderbos, Groote Heide & De Plateaux	2	9	2-11
Roerdal	6	5	6-11
Vecht- en Beneden-Reggegebied	5	6	5-11
Alde Feanen	5	5	5-10
Drents-Friese Wold & Leggelderveld	1	9	1-10
Kennemerland-Zuid	8	2	8-10
Loonse en Drunense Duinen & Leemkuilen	4	6	4-10
Noordhollands Duinreservaat	1	8	1-9
Weerribben	3	6	3-9
Leekstermeergebied	1	7	1-8
Dinkelland	2	5	2-7
Swalmdal	5	2	5-7

4.7.4. Invasion process

Introduction

I. glandulifera was imported to many European countries as an ornamental species and has been sold by seed companies and used as a garden plant (Beerling & Perrins, 1993; EPPO, 2015a). It seems likely that *I. glandulifera* escaped from gardens or had been otherwise introduced on several separate occasions (Perrins et al., 1993). The tolerance of *I. glandulifera* seeds to dry conditions provides the species with added opportunities for dispersal. Seeds can be collected and distributed without being maintained in moist conditions (Tabak & Von Wettberg, 2008).

Transport of *I. glandulifera* with topsoil or as a seed contaminant is probable (Beerling & Perrins, 1993; EPPO, 2015a). Also seeds have been carried with river gravel in trains in Germany and as a contaminant of building rubbish transported to waste disposal sites (Hartmann et al., 1995; EPPO, 2015a). Bee-keepers have been known to disperse seeds in order to enhance forage for honey bees (Hartmann et al., 1995; EPPO, 2015a). However, these pathways are less likely to cause new introductions than garden escapes (EPPO, 2015a).

A quick scan of the first 50 results of google.nl using the search terms 'reuzenbalsemien te koop' and '*Impatiens glandulifera* te koop' revealed a single source of *I. glandulifera* seeds originating from a retailer in Germany, two Dutch bee hobbyist forums discussing the use of *I. glandulifera* for beekeeping and one site containing a blog where a gardener had obtained seeds from the national plant garden (Nationale Plantentuin) in Meise, Belgium and brought them back to Voorschoten, the Netherlands to plant in the garden.

Establishment
I. glandulifera is already widely established in the Netherlands (Figure 2). In the United Kingdom, a country climatically similar to the Netherlands, frost tolerance early in the life cycle of *I. glandulifera* gives it a significant advantage over other *Impatiens* species (Perrins et al., 1993). A shorter time required for seed stratification and high level of germination success may have increased *I. glandulifera's* invasion potential compared to other *Impatiens* species occurring in the Czech Republic (Perglova et al., 2009). Through early emergence followed by rapid growth, successful individuals may be able to partially suppress the existing vegetation, creating more bare ground where new *I. glandulifera* plants can establish the following year (Perrins et al., 1993). Other characteristics that may have contributed to its establishment are its height, synchronous germination, high level of seed production, and other reproductive traits such as seed mass variation (Beerling & Perrins, 1993; Grime, 1979; Koenis & Glavac, 1979; Willis & Hulme, 2004; Tabak & Von Wettberg, 2008).

Spread
I. glandulifera is the most invasive species of the *Impatiens* genus in the United Kingdom. Within 16 years of being introduced to the country it had escaped from gardens to nature (Perrins et al., 1993). Since its introduction to nature, *I. glandulifera* has rapidly become one of the UK's most widespread invasive weed species (CABI, 2015b)

Explosive seed pods may throw seeds up to 7 m from the plant (EPPO, 2015a). However, according to Perrins et al. (1993), ballistic spread is limited to 2 m per year in the United Kingdom. Observations of seeds dispersed up to 10 m may indicate the possibility of transport by small rodents (Beerling & Perrins, 1993; EPPO, 2015a). More long distance seed dispersal occurs when seeds are ejected into moving water, particularly at high tide (Pyšek & Prach, 1995). Dry *I. glandulifera* seeds float in still water for up to forty days in the laboratory (Tabak & Von Wettberg, 2008; Branquart et al., 2010). Fresh seeds sink and are transported with sediment on the river bottom (Branquart et al., 2010; Beerling & Perrins, 1993; EPPO, 2015a). The importance of this dispersal pathway to the secondary spread of *I.*

glandulifera is emphasised by a number of authors. The results of a study assessing the spatial distribution of *I. glandulifera* suggested that water current played a more important role in the distribution of propagules than the preference of the species for moist riparian habitats (Skalova et al., 2013). Tabak & Von Wettberg (2008) state that hydrochory is probably a common dispersal mechanism within the genus given that they occur often in wet habitats. European dispersal has been attributed to seed transport by flowing water. In 1904, escaped plants were recorded in Switzerland. From here the species migrated via the river Rhine to Germany (EPPO, 2015a). The EPPO concluded that further spread of *I. glandulifera* within the EPPO region will probably occur as a result of seed transport with flowing water (EPPO, 2015a). Other secondary dispersal pathways include the enrichment of nature, vehicles, garden waste and with soil depositions (Kowarik, 2003).

Compared to other species within the genus, *I. glandulifera* invasions feature much higher local densities and more of a uniform front than *I. capensis* independent of river flow velocity (Tabak & Von Wettberg, 2008). In the Czech Republic, *I. glandulifera* has spread faster than *I. parviflora,* however, both have become widespread (Williamson et al., 2005; Perglova et al., 2009). In the United Kingdom, the rate of *I. glandulifera* spread has been estimated to be up to 38 km per year, compared to up to 24 km per year for *I. parviflora* (Perrins et al., 1993). Perrins et al., 1993 concluded that the faster rate of spread of *I. glandulifera* appeared to be due to more rapid growth, greater frost resistance and higher seed production.

In Europe, *I. glandulifera* is expected to expand its northerly range and colonise higher altitudes in response to climate change (Beerling, 1993; Beerling & Woodward, 1994; Tabak & Von Wettberg, 2008).

4.7.5. Environmental impact summary

Effects on environmental targets or native species

Parasitism
No negative effects were discovered during a quick-scan of available literature.

Competition
Where invasive, *I. glandulifera* forms dense infestations that support few native species (Wittenberg, 2005). Evidence from literature suggests in general that *I. glandulifera* is highly competitive. For example, biodiversity was reduced by 25% in the UK (Hulme & Bremner, 2006; Cockel, 2010; Nehring et al., 2013). Trautmen & Lohmeyer (1975) reported that *I. glandulifera* locally suppresses native species in Europe. Sykora (1990) reported that only perennial native species with a strong vegetative propagation are able to withstand *I. glandulifera* and Lhotska & Kopecky (1966) state that *I. glandulifera* obstructs the natural rejuvenation of woody species. It is European tallest herb, quickly growing taller than native species such as Stinging nettle (*Urtica dioica*) and extensively branches from the stem monopolising the aerial environment (Chittka & Schürkens, 2001; Cockel & Tanner, 2011). However, no effects have been recorded on native species in the Czech Republic (Hejda & Pyšek, 2006; Hejda et al., 2009; Nehring et al., 2013). The plant is an annual, germinating in spring and reaching dominance in the summer. Therefore, plants completing their lifecycle in spring or early summer are hardly affected (Q-bank, 2015c; EPPO, 2015a). Moreover, impacts related to *I. glandulifera* may vary between years depending on weather conditions

during germination (EPPO, 2015a). However, a wide range of sources refer to the competitive strength of *I. glandulifera*. For example, CABI (2015b) and Q-bank (2015c) state that *I. glandulifera* grows and spreads rapidly, outcompeting annual and even perennial native species for space, light, nutrients and pollinators.

I. glandulifera attracts many more pollinators than native plants affecting the fitness of native flora (Chittka & Schürkens, 2001; Q-bank, 2015c; EPPO, 2015a). In an experiment simulating the invasion of native Marsh woundwort (*Stachys palustris*) stands by *I. glandulifera*, competition for pollinators reduced visitations by pollinators to *S. palustris* by 50% and seed set by 25% (Chittka & Schürkens, 2001). Bees select flowers over a large foraging range, therefore native species may be effected far beyond the limits of *I. glandulifera* stands (Chittka & Schürkens, 2001).

The competitive advantage of *I. glandulifera* may be facilitated by early germination in some years, synchronised seedling emergence, rapid growth, greater density and biomass, increase in stem height in the presence of neighbouring species (Beerling & Perrins, 1993; Skalova et al., 2012; Skalova et al., 2013; Hartmann et al., 1995; Nehring et al., 2013). Monitoring of riparian vegetation following the removal of *I. glandulifera* from a riparian habitat in the North East of England demonstrated a rapid increase in seedling recruitment and species abundance. In this example light demanding species were most highly affected. Monitoring suggested that extensive *I. glandulifera* stands may reduce species richness by as much as 25% (Hulme & Bremner, 2006). Further evidence from the United Kingdom suggests that *I. glandulifera* may decrease the abundance of soil invertebrates (Tanner, 2011; Cockel & Tanner, 2011; Nehring et al., 2013). In a Czech study, it was suggested that the indirect impact of *I. glandulifera* on native snails may have been related to the decrease in tall nitrophilous native plant species abundance that act as a food source for snails in riparian habitats (Horackova et al., 2014). Additionally, decaying *I. glandulifera* plants matter may restrict the germination of all plants in the following year (Hartmann et al., 1995; Nehring et al., 2013).

Compared to other *Impatiens* species, *I. glandulifera* is the most competitive (Daumann, 1967; Perglova et al., 2009). *I. glandulifera* grows more rapidly than other *Impatiens* species allowing it to germinate earlier in the year (Perrins et al., 1993). In experiments measuring competition under different light and moisture conditions, *I. glandulifera* was found to be as competitive as *I. parviflora* and significantly more competitive than both *I. capensis* and native *I. noli-tangere. I. glandulifera* was the tallest and produced the greatest biomass of all the species (Skalova et al., 2013). Skalova et al. (2013) concluded that local competitive exclusion of *I. noli-tangere* by *I. glandulifera* seems likely because the niches of the native and invasive *Impatiens* species overlap.

Other authors suggest situations where *I. glandulifera* may be less competitive than other species. Skalova et al. (2012) observed that deep shade may limit the success of *I. glandulifera* as it produces very elongated fragile stems associated and seed production may be limited. According to Branquart et al. (2010), reduction in species richness concerns mostly widespread weed and non–native species, and is often temporary. Other European studies indicate that the impacts of *I. glandulifera* on native plants may not be as extreme as those of other invasive riparian weeds (Hejda & Pysek, 2006; Hulme & Bremner, 2006;

Tabak & Von Wettberg, 2008). Nehring et al. (2013) stated that it is unknown whether a hazard exists to German native species.

I. glandulifera may potentially impact re-colonisation of native species indirectly by altering the soil microbe community. *I. glandulifera* has virtually no associated mycorrhizae resulting in their depletion under invasive stands. Mycorrhizae are essential for the establishment of native plant species and their absence inhibits the recolonization of native species (Cockel & Tanner, 2011).

Interbreeding
According to Nehring et al. (2013), there is no evidence that *I. glandulifera* will interbreed with German native flora. There is no available evidence of interbreeding of *I. glandulifera* with native species in the Netherlands.

Hosting pathogens or parasites
According to Nehring et al. (2013), there is no evidence that *I. glandulifera* hosts parasites that will affect German native species. However, *I. glandulifera* is a known host of the bean aphid (*Aphis fabae*) (Stary et al., 2014). *A. fabae* is a carrier of the cucumber mosaic virus (Nehring et al., 2013).

Effects on ecosystem function targets
Abiotic properties e.g., nutrient cycling, structural modification
Changes in vegetation structure as a result of *I. glandulifera* invasion may possibly negatively affect insects that need open water, e.g., damselflies (Calopterygidae) (Schmitz personal communication in Nehring et al., 2013). Changes in trophic interactions may possibly negatively impact pollination of native species (Chittka & Schürkens, 2001). Increased bank erosion and sediment entrainment resulting from the displacement of native plant species by *I. glandulifera* on river banks may impact fish spawning grounds and invertebrate niches (Cockel & Tanner, 2011).

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
I. glandulifera may promote bank erosion due to its modest root system compared to native riparian vegetation and because it dies back in winter and leaves bare unprotected ground (DAISIE, 2015d; EPPO, 2015a; Branquart et al., 2010). *I. glandulifera* can also completely change the appearance of riverbanks, especially when in bloom (DAISIE, 2015d). Dense stands and dead plant material may impede water flow during heavy rainfall and promote

flooding (CABI, 2015b). *I. glandulifera* may impact forestry by impairing natural regeneration. However, this is not proven (Nehring et al., 2013). The Environment Agency estimates that it would cost £300 million (circa 420 million €) to eradicate *I. glandulifera* from the United Kingdom (CABI, 2015b).

4.7.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. glandulifera* a 'high' ecological risk classification for each section of the ISEIA protocol (Table 4.25). The total ecological risk score for the species is 12 out of a maximum of 12. Therefore, *I. glandulifera* is classified in the A list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs.

Table 4.25: Consensus scores for potential risks of Himalayan balsam (*Impatiens glandulifera*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonization of high value conservation habitats	High	3
Adverse impacts on native species	High	3
Alteration of ecosystem functions	High	3
Environmental risk score		**12**

Dispersion potential or invasiveness
Classification: **High risk**. There is an increasing trend in the distribution of *I. glandulifera* in the Netherlands, the species is already widespread. *I. glandulifera* is introduced via the ornamental plant trade which leads to garden escapes in European countries (EPPO, 2015a). Moreover, bee-keepers have been known to disperse *I. glandulifera* seeds in order to enhance forage for honey bees (Hegi, 1912; Hartmann et al., 1995; EPPO, 2015a). *I. glandulifera* is a frost resistant species and the Dutch climate does not appear to form a barrier to establishment. It is not expected that climate change will affect invasiveness.

I. glandulifera is exclusively propagated by seeds (EPPO, 2015a). The plant has a high reproductive potential and produces considerably more seed than other *Impatiens* species. In one growing season *I. glandulifera* may produce up to 4000 seeds per plant and 5.7 to 6.4 seeds per capsule (Salisbury, 1942; Perrins et al., 1993; Beerling & Perrins, 1993; Sebald et al., 1998; EPPO, 2015a). A maximum of 32,000 seeds per square metre were produced in a monoculture in Germany (Koenis & Glavac, 1979; EPPO, 2015a). Seeds are dispersed by autochory, hydrochory and zoochory. Initially, seeds are launched from the seed pods via ballochory and can travel several meters (CABI, 2015b; DAISIE, 2015d). Seeds are not able to float for long but do not lose their ability to germinate when submerged so may be transported under water to new locations where they can establish new plants (DAISIE, 2015d). Seeds are also able to survive and be transported in the intestines of fish. In England, *I. glandulifera*'s dispersal rate has been estimated to be up to 38 km/year. Some authors report that the species does not feature a persistent seed bank (Grime et al., 1988; EPPO, 2015a). However, some seeds can persist for 18 to 24 months (Beerling & Perrins, 1993; Wittenberg, 2005; EPPO, 2015a).

In conclusion, *I. glandulifera* has already demonstrated a high risk for dispersal and invasiveness in the Netherlands, this may be explained by its use as an ornamental plant in Europe that has led to multiple garden escapes, a high reproductive potential and the multiple seed dispersal mechanisms available to this species.

Colonization of high value conservation habitats
Classification: **High risk**. *I. glandulifera* has been recorded in 61 Natura 2000 areas in the Netherlands. Most of these locations are situated along the Rhine and its tributaries and along the Rhine/Meuse estuary (i.e., the Biesbosch, Hollandsch Diep, Haringvliet, Gelderse Poort, Uiterwaarden Waal, Uiterwaarden Nederrijn and Uiterwaarden IJssel). *I. glandulifera* has been recorded in the following Natura 2000 areas along smaller rivers: the Geuldal, Drentsche Aa area, Roerdal, Dinkelland, Swalmdal, and the Vecht and lower Regge area. *I. glandulifera* has been recorded in the Oostelijke Vechtplassen, Alde Feanen, Weerribben and Leekstermeer Natura 2000 areas, all of which are low lying fenland areas. *I. glandulifera* has also been recorded in Natura 2000 areas which predominantly feature poor dry soils. For example, the species is present in the Veluwe, Brabantse Wal, Dwingelderveld, Maasduinen, Leenderbos, Groote Heide and De Plateaux, Drents-Friese Wold and Leggelderveld, Loonse and Drunense Dunes & Leemkuilen, Kennemerland south and the North Holland dune reserve. Within these predominantly dry and nutrient poor areas, the species is often found in relatively nutrient rich, moist or shaded, scattered locations.

In conclusion, *I. glandulifera* has already demonstrated that it poses a high risk of establishment in a wide variety of high conservation value habitats. The species (potentially) threatens red listed and protected species in the Netherlands.

Adverse impacts on native species
Classification: **High risk**. There is no available evidence to suggest that *I. glandulifera* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. There is no available evidence of interbreeding of *I. glandulifera* with native species in the Netherlands. Moreover, according to Nehring et al. (2013), there is no evidence that *I. glandulifera* will interbreed with German native flora. *I. glandulifera* is Europe's tallest annual plant usually reaching 50 to 250 cm tall (EPPO, 2015a); it can even reach 300 cm tall at maturity in deciduous woodland (CABI, 2015b). A wide range of sources refer to the competitive strength of *I. glandulifera*. CABI (2015b) and Q-Bank (2015c) state that *I. glandulifera* grows and spreads rapidly, outcompeting annual and even perennial native species for space, light and nutrients. *I. glandulifera* attracts many more pollinators than native plants affecting the fitness of native flora (Chittka & Schürkens, 2001; Q-Bank, 2015c; EPPO, 2015a).

In conclusion, risks of local changes in population abundance (>80%), growth or distribution of one or more native species as a result of *I. glandulifera* establishment are high.

Alteration of ecosystem functions
Classification: **High risk**. *I. glandulifera* is an annual, tall growing species. The plant may promote bank erosion due to its modest root system compared to native riparian vegetation and as a result of die back in winter that leaves bare unprotected ground (DAISIE, 2015d; EPPO, 2015a; Branquart et al., 2010). Dense *I. glandulifera* stands and dead plant material may impede water-flow during heavy rainfall and promote flooding (CABI, 2015b; NNSS,

2015). Changes in vegetation structure as a result of *I. glandulifera* invasion may negatively affect insects that need open water, e.g., damselflies (Calopterygidae) (Schmitz personal communication cited in Nehring et al., 2013). Moreover, changes in trophic interactions may possibly negatively impact pollination of native species (Chittka & Schürkens, 2001).

In conclusion, *I. glandulifera* forms dense single species stands (monocultures) in the Netherlands that may monopolise space and light. Physical modifications to habitat may be expected. The impact on ecosystem processes and structure is expected to be high.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.25) in combination with the current recorded distribution in the Netherlands. The species classification for *I. glandulifera* is A3 (Figure 4.23). This characterises a non-native species that is widespread from the area under assessment, poses a high ecological risk and should be placed on the black list of the BFIS list system.

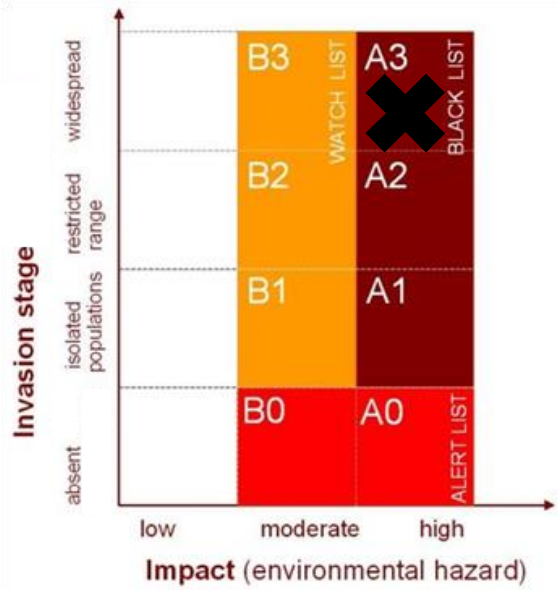

Figure 4.23: Risk classification of Himalayan balsam (*Impatiens glandulifera*) according to the BFIS list system.

4.7.7. Other risk assessments and classifications

No full risk assessments for *I. glandulifera* were discovered during a quick scan of available literature concerning the European Union (Table 4.26). In Belgium and Luxembourg, *I. glandulifera* poses a high ecological risk according to the ISEIA risk prioritisation method. In Ireland, *I. glandulifera* poses a major risk to native biodiversity, native ecosystems and conservation goals in principally riparian habitats (Millane & Caffrey, 2014). In a review of invasive species present in other European countries apart from Spain, *I. glandulifera* was considered to be a potential threat to Spanish ecosystems (Elorza et al., 2001). These risk classifications are in agreement with the high risk classification assigned to this species as part of our risk analysis of *Impatiens* species.

In northern America, *I. glandulifera* received a moderate invasiveness ranking using the New York non-native invasiveness ranking procedure for natural to minimally managed areas (Glenn & Moore, 2013). The species scored 13 out of 40 for ecological impact, 20 out of 25 for dispersal ability, 21 out of 25 for ecological amplitude and distribution, and 6 out of 10 for difficulty of control.

Table 4.26: Overview of risk classifications previously performed for Himalayan balsam (*Impatiens glandulifera*) in other European countries.

	Belgium	Ireland	Luxembourg	Spain
Scope	Risk prioritisation method	Risk assessment	Risk prioritisation method	Risk prioritisation method
Method	ISEIA	Non-native species Application based Risk Analysis (NAPRA)	ISEIA	Literature review
Year	2010	2014	2010	2001
Risk classification	**A3 (High risk, widespread species)**	**Major risk to native biodiversity**	**A3 (High risk, widespread species)**	**Potential threat to Spanish ecosystems**
Source	http://ias.biodiversity.be/species/show/65	Millane & Caffrey (2014)	Ries et al. (2013)	Elorza et al. (2001)

The Belgian Code of conduct on invasive plants, introduced in 2013, lists *I. glandulifera* as plant species that should not be traded in Belgium (Halford et al., 2011).

4.8. Pale jewelweed (*Impatiens pallida*)

4.8.1. Species description

Pale jewelweed (*Impatiens pallida*) is an annual herb that grows to about 100 to 120 cm tall and is frequently branched. The stems are somewhat succulent, glabrous, glaucous and light green in colour. The leaves are alternate, ovate, hairless, and serrated along the margins, growing to a maximum of 10 cm long and 5 cm across and feature slender petioles that extend to up to 5 cm. Short racemes of one to three flowers are produced from the axils of the middle to upper leaves. Each 2.5 to 4 cm flower consists of five petals, three sepals, and reproductive organs within the tubular corolla (Figure 4.24). This corolla is usually yellow, less frequently cream, and consisting of the fused (or near fused) five petals and lower sepal. The lower sepal is petaloid and defines the conical posterior section of the corolla, which terminates in a tiny nectar spur that curls and tapers downward. The upper petal forms the upper lip the corolla while the two lower petals form a pair of well-rounded, rather irregular and wrinkled lobes. Two small lateral petals form the sides of the corolla opening. Reddish brown spots are usually found inside the corolla, although they are occasionally absent. The upper two sepals are light green and ovate, and located at the top of the corolla. Each flower is suspended form a slender 2 cm long pedicel. The seedpod is broad in the middle and tapers toward its tips with a number of dark green lines along its length. The roots consist of a shallow branching taproot (illinoiswildflowers.org).

I. pallida is similar to orange jewelweed (*Impatiens capensis),* however, *I. capensis* flowers are usually orange-yellow with reddish brown markings and feature a slender more elongated spur that curves gently forward as opposed to the more aggressively curved spur of *I. pallida* (Schemske, 1978; Gleason & Cronquist, 1991; Tabak & Von Wettberg, 2008; illinoiswildflowers.org). Flowers of *I. pallida* have short spurs (± 5 mm) and are almost exclusively pollinated by bees. Flowers of *I. capensis* have longer spurs (up to 12 mm) and are pollinated by both hummingbirds and bees (Travers et al., 2003).

Figure 4.24: Pale jewelweed (*Impatiens pallida*). (© Photo: A.O. Doyle, 2008).

Species taxonomy

Table 4.27: Nomenclature and taxonomical status of Pale jewelweed (*Impatiens pallida*).

Scientific name:
Impatiens pallida Nuttall (1818)

Synonyms:
Not applicable

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceaeae
Genus: *Impatiens*
Species: *Impatiens pallida*

Preferred Dutch name:
Not applicable

Preferred English name:
Pale jewelweed

Other Dutch names:
Not applicable

Other English names:
Yellow jewelweed

Life cycle

I. pallida features an unusual mixed mating system with both cleistogamous (self-fertilizing, closed) flowers and chasmogamous (open, accessible to pollinators) flowers on the same plant (Tabak & Von Wettberg, 2008). The male parts, the anthers, of the chasmogamous flowers mature first and are therefore protandrous. When the anthers dry, they fall off, exposing the female stigma. This division in time of male and female characteristics prevents self-fertilisation and promotes out-crossing. The effective sex ratio of flowers on a plant is heavily male biased as flowers remain in the male phase for about five times longer than in the female phase (Schemske, 1978). In cleistogamous flowers, nectaries are absent and the sepals, anthers, and the number of pollen grains produced are all reduced. Once a flower is fertilised it is replaced by an ellipsoidal fruit formed from a five-valved capsule of up to 5 cm long. The fruit dehisces elastically, launching seeds by up to 2 meters from the parent plant (Schemske, 1978). The ovaries of chasmogamous flowers contain three to five ovules, cleistogamous flowers from one to five (more usually two to three). In early autumn, the production of chasmogamous flowers ceases, however, cleistogamous flowers are produced until the plant dies off as a result of frost (Schemske, 1978). The total time for development from the bud stage to seed pod dehiscence varies, averaging from 28 to 38 days for cleistogamous flowers and 37 to 48 days for chasmogamous flowers (Schemske, 1978; The Encyclopedia of Life, 2015).

Reproductive capacity
Under experimental conditions, seeds of *I. pallida* required five months of cold stratification at 5 °C before germination occurred (Nozzolillo & Thiel, 1983).

4.8.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. pallida* are listed in table 4.28. Suitable habitats in *I. pallida's* native Illinois (USA) include openings in moist deciduous woodlands, muddy borders along ponds and streams especially in wooded areas, swamps, and soggy thickets. The species is sometimes cultivated in Illinois gardens (Encyclopedia of Life, 2015). In its native range, *I. pallida* prefers shadier sites than *I. capensis* and appears more tolerant of dry sites than the latter species (Schemske, 1978; Gleason & Cronquist, 1991; Encylopedia of Life, 2015) and does not appear to tolerate higher levels of soil water content well (Lechowicz et al., 1988). Field observations in its native range of Quebec, Canada showed that *I. pallida* predominantly grows in a narrower range of habitats that are both significantly drier and richer in nitrate and phosphorus than those of *I. capensis*. Sites dominated by *I. pallida* tended to be richer in potassium, relatively poor in calcium and magnesium, and had significantly lower soil pH than those of *I. capensis* (Lechowicz et al., 1988). In fact, *I. capensis* growth was highest on insolated sites rich in calcium and magnesium (Lechowicz et al., 1988). *I. pallida* appears to be able to utilise even full sunlight effectively. Increased growth and fecundity of *I. pallida* have been observed under increased solar radiation (Lechowicz et al., 1988; Schemske, 1978; Cid-Benevento & Schaal, 1986) and increased population densities have been observed following the opening of the canopy by a storm (Riemenschneider & Blodgett, 1983; Lechowicz et al., 1988).

Table 4.28: Physiological conditions tolerated by Pale jewelweed (*Impatiens pallida*).

Parameter	Data origin	Variable	Range	References
Temperature	Unknown	°C	15[1]	Nozzolillo & Thie (1993)
Soil moisture	Canada	g(H_20) g^{-1} (dry soil)	0.39-2.95	Lechowicz et al. (1988)
Light	Canada	% full sunlight	51-100	Lechowicz et al. (1988)
Nitrate	Canada	µg($N0^{3-}$)g^{-1} (dry soil)	4.9-42.0	Lechowicz et al. (1988)
Ammonium	Canada	µg (NH^{4+}) g^{-1} (dry soil)	13.5-90.5	Lechowicz et al. (1988)
Phosphorus	Canada	µg (P) g^{-1} (dry soil)	34.0-450.0	Lechowicz et al. (1988)
Potassium	Canada	µg (K) g^{-1} (dry soil)	63-1050	Lechowicz et al. (1988)
Calcium	Canada	µg (Ca) g^{-1} (dry soil)	620-8382	Lechowicz et al. (1988)
Magnesium	Canada	µg (Mg) g^{-1} (dry soil)	75-666	Lechowicz et al. (1988)
pH	Canada	Soil pH	4.56-7.00	Lechowicz et al. (1988)
Organic matter	Canada	% organic matter	14.4-58.2	Lechowicz et al. (1988)

[1]Optimal temperature for germination

4.8.3. Recorded distribution

Native range
I. pallida is a species native to eastern USA (south to Georgia, west to Oklahoma, and north to North Dakota), and Canada (Ontario east to Nova Scotia), (Figure 4.25), and shares its native range with *I. capensis* (USDA, 2015).

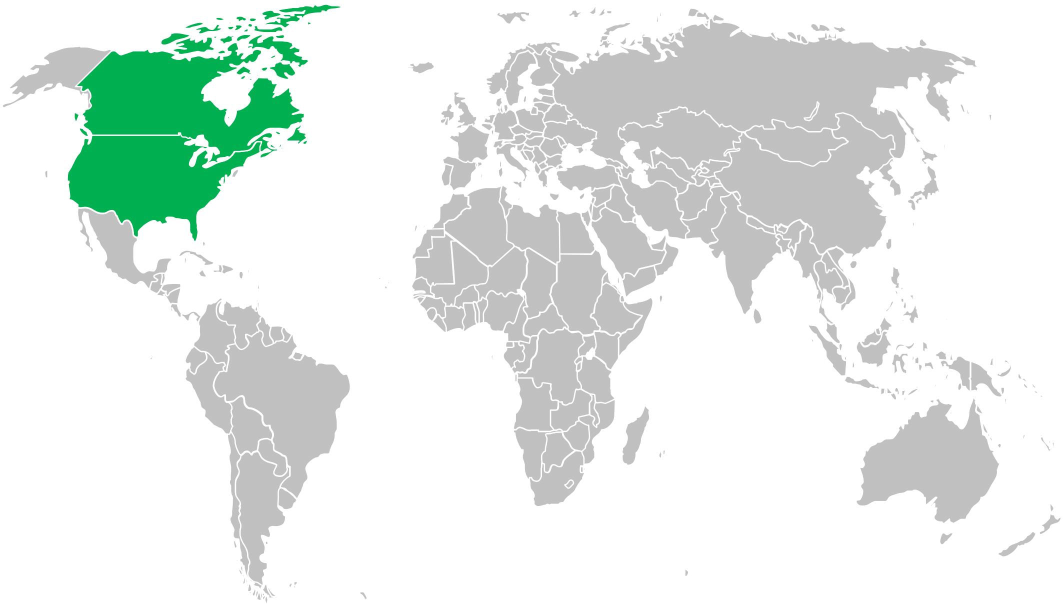

Figure 4.25: Native range of Pale jewelweed (*Impatiens pallida*) (Source: USDA, 2015).

Non-native range
No information on *I. pallida*'s non-native range could be found during the literature review.

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. pallida* in the Netherlands. However, it should be noted that lag times between introduction and establishment of non-native species can be considerable, even for herbaceous species. For example, the lag time for *I. glandulifera* was 40 years in central Europe (Pysek & Prach, 1995).

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. pallida* in the Netherlands.

4.8.4. Invasion process

Introduction
No information on the potential introduction pathways of *I. pallida* to the Netherlands could be found during the literature review. A quick scan of the first 50 results of google.nl using the search term '*Impatiens pallida* te koop' revealed one website in the United Kingdom offering *I. pallida* seeds for sale internationally.

Establishment
No information on the potential for establishment of *I. pallida* in the Netherlands or climatically similar countries could be found during the literature review.

Spread
No information on the potential for spread of *I. pallida* in the Netherlands or climatically similar countries could be found during the literature review.

4.8.5. Environmental impact summary

Effects on environmental targets or native species
No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.8.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. pallida* a 'medium' ecological risk classification to the category dispersion potential or invasiveness and a ‘likely’ classification to the categories colonization of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions (Table 4.29). The total ecological risk score for the species is 8 out of a maximum of 12. Therefore, *I. pallida* is classified in the C list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs. Note that three risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.29: Consensus scores for potential risks of Pale jewelweed (*Impatiens pallida*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Likely	2
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Environmental risk score		**8**

Dispersion potential or invasiveness

Classification: **Medium risk**. According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. pallida* in the Netherlands. Except when assisted by humans, *I. pallida* does not colonise remote areas and natural dispersal rarely exceeds 1 km/y. However, the species may become locally invasive because of strong reproduction. Similarly to other *Impatiens* species, the seeds of *I. pallida* are spread by autochory. Seeds are launched from seed pods travelling by up to 2 m from the plant. *I. pallida* favours relatively dry habitat conditions which reduce the chance that seeds will be spread by hydrochory.

In conclusion, the expert panel classified the dispersal potential (invasiveness) of *I. pallida* as medium risk.

Colonization of high value conservation habitats

Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. pallida* in the Netherlands. However, habitat characteristics indicate that it is likely that the species will able to establish in high conservation value habitats in cases of human introductions and it causes a (potential) threat for red listed or protected species.

In conclusion, the experts judged that colonization risk of high value conservation habitats is likely.

Adverse impacts on native species

Classification: **Likely**. There is no available evidence to suggest that *I. pallida* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. No information on either potential adverse impacts of *I. pallida* as a result of genetic effects or competition on Dutch native species was found during the literature review. No information on the potential for (potential) impacts of *I. pallida* on native species in the Netherlands or climatically similar countries could be found during the literature review. However, *I. pallida* is a fast growing species that produces tall, dense vegetation. Moreover, *I. pallida* may be an important source of nectar for bumblebees and honeybees. Therefore, competition with native species for pollinators may be expected. In conclusion, competition between *I. pallida* and native plant species is likely. Local changes in population abundance (< 80%), growth or distribution of one or more native species can be expected, but the effects are likely to be reversible.

In conclusion, the expert panel judged that adverse impacts on native species are likely.

Alteration of ecosystem functions

Classification: **Likely**. No information on physical modification of habitat (e.g., light interception) or other effects of *I. pallida* on ecosystem functioning could be found during the literature review. However, *I. pallida* is an annual species and erosion of bare soil may occur during the winter period when plants have died back. Moreover, light interception due to high and dense vegetation may occur during the growing season. Therefore, physical modification of habitat in the event of *I. pallida* establishment in the Netherlands is likely.

In conclusion, the experts judged that alteration of ecosystem functions is likely.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.29) in combination with the current recorded distribution in the Netherlands. The species classification for *I. pallida* is C0 (Figure 4.26). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and should not be placed on either the alert, watch or black list of the BFIS list system. However, note that several risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

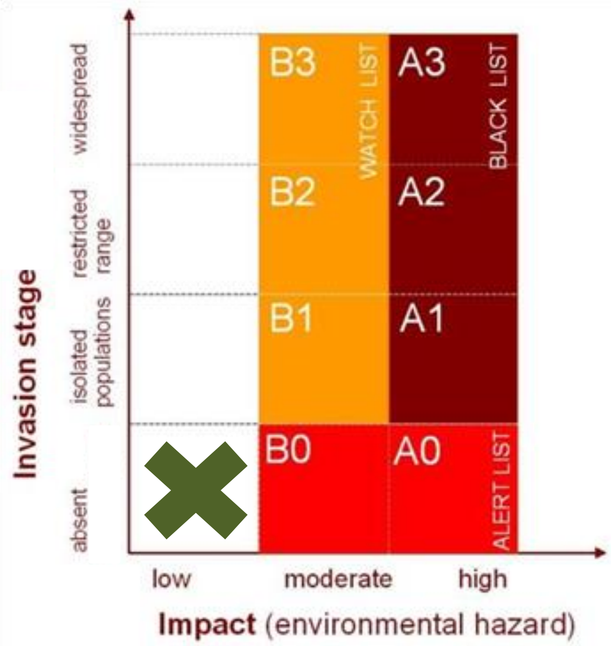

Figure 4.26: Risk classification of Pale jewelweed (*Impatiens pallida*) according to the BFIS list system.

4.8.7. Other risk assessments and classifications

No risk assessments or classifications of *I. pallida* could be found during the literature review.

4.9. Small balsam (*Impatiens parviflora*)

4.9.1. Species description

Small balsam (*Impatiens parviflora*) is a glabrous, erect annual herb usually 20-60 cm tall, rarely reaching 150 cm. It may feature a single stem or branching from the lower nodes (Tabak & Von Wettberg, 2008). In well-developed plants, third order branches may develop. Roots are shallow and the primary root has a short life and is replaced by laterals and adventitious roots emanating from the lower node. Leaves are 5-12 cm long x 2.5-5 cm wide, alternate, ovate and serrated with 20 to 35 teeth on each side (Figure 4.27A). The petioles carry stalked glands that may provide nectar. The flowers are arranged in axillary racemes of (1-) 4-10 (-15) (Figure 4.27B). Flowers are 1 to 1.5 cm long including their spur and upright which distinguishes them from the hanging flowers of other *Impatiens* species, usually yellow with red spots on the inside and straight spurs, though white flowers with yellow spots may also occur, flowers feature five petals, the anterior of which is large and singular, the other four occurring in two pairs. Young flowers are often cleistogamous (Moore, 1968; Tabak & Von Wettberg, 2008). The capsule contains one to five seeds, which are straight to club shaped, 1.5 to 2 cm long, glabrous and green. The seeds are oblong, 0.4 to 0.5 cm long featuring fine longitudinal striations (Coombe, 1956; Sebald et al., 1998; EPPO, 2015b).

Species taxonomy

Table 4.30: Nomenclature and taxonomical status of Small balsam (*Impatiens parviflora*).

Scientific name:
Impatiens parviflora DC. (1824)

Synonyms:
Balsamina parviflora (DC.) Ser.; *Impatiens nevskii* Pobed. in Kom., Fl. URSS 14: 746. 1949.

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens parviflora*

Preferred Dutch name:
Klein springzaad

Preferred English name:
Small balsam

Other Dutch names:
Not applicable

Other English names:
Small-flowered touch-me-not

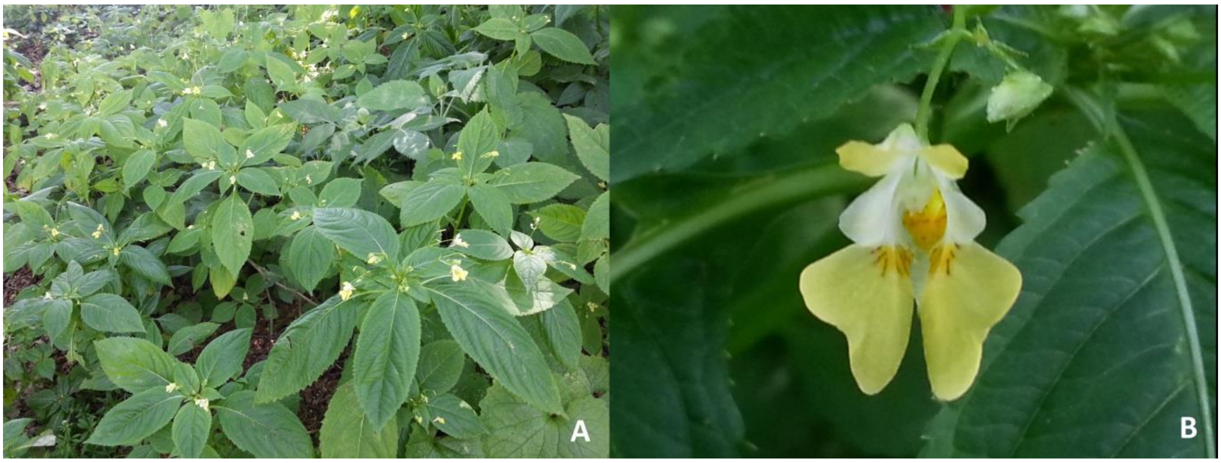

Figure 4.27A: Dense stand of Small balsam (*Impatiens parviflora*) along a cycling path in a forest, located west of the Municipality Huizen, The Netherlands; **B:** Flower of the yellow and white variety (Photos: R.S.E.W Leuven, 5 June 2015).

Life cycle

Reproduction occurs solely through the propagation of seed. Similarly to Balfour's touch-me-not (*Impatiens balfourii*), *I. parviflora* seeds require cold stratification, but not frost, to break their dormancy (Jouret, 1976a; Tabak & Von Wettberg, 2008; EPPO, 2015b). The shortest period required for effective cold stratification results in a germination period of 13 days. Longer stratification periods result in shortened germination periods. In the U.K., *I. parviflora* flowers earlier than the other *Impatiens* species (Perrins et al., 1993), and plants germinate between March and April. Following germination, plants in Europe usually flower eight to nine weeks starting in May or June and continuing until September or October. Seeds ripen three to four weeks later (Coombe, 1956; EPPO, 2015b). Flowers are protandrous, featuring an initial male phase of two to four hours followed by a female phase of one to two days. All flowers usually produce seed, even in periods of low visitation by pollinators. The plant is self-compatible, allogamous and geitonogamous. Cleistogamy occurs occasionally, but the majority of the flowers are chasmogamous (EPPO, 2015b).

Reproductive capacity

I. parviflora is an annual species with a relatively high seed production (Trepl, 1984; Nehring et al., 2013). However, the number of seeds produced varies with soil quality and plant density (Coombe, 1956; EPPO, 2015b). In the favourable spaced conditions of a UK garden experiment, *I. parviflora* produced a maximum of 50 to 80 pods per plant (Perrins et al., 1993). Seed production is estimated to peak at 10,000 seeds per plant (Coombe, 1956; EPPO, 2015b) although 1000-2000 is more common (Trepl, 1984; EPPO, 2015b). However, this is significantly more than *I. balfourii* that had an estimated total production of 675 seeds in a garden experiment in the United Kingdom (Perrins et al., 1993). Moreover, allocation to peduncle biomass is the highest compared to *I. capensis*, *I. glandulifera* and native *I. noli-tangere* (Skalova et al., 2013), suggesting a higher reproductive capacity. Seeds are expelled by an explosive mechanism to a maximum recorded distance of 3.4 m (Trepl, 1984; CABI, 2015b). Dry stored seeds kept at room temperature remain viable for less than three years. Stored wet, seeds can germinate after four years (Coombe, 1956; EPPO, 2015b).

4.9.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. parviflora* are listed in table 4.30.

Table 4.30: Physiological conditions tolerated by Small balsam (*Impatiens parviflora*).

Parameter	Data origin	Occurrence	References
Mean minimum temperature (˚C)	Not specified	-5 to 5	CABI (2015b)
Mean maximum temperature (˚C)	Not specified	10 to 25	CABI (2015b)
Hardiness (˚C)	Not specified	-23 to -18	Grey-Wilson (2011); EPPO (2015b)
Temperature for optimal germination (˚C)	Not specified	5-25	Coombe (1956); Perglova et al. (2009)
Light	Not specified	5 to 40 % relative daylight	Hughes (1965); Jouret (1977); Perrins et al. (1993); Tabak & Von Wettberg (2008)
Substrate	Not specified	wide range of mineral but not necessarily calcareous soils	Coombe (1956); EPPO (2015b)
pH	Not specified	4.5 to 7.6	Coombe (1956); EPPO (2015b)
Moisture	Not specified	seedlings cannot survive waterlogged conditions	EPPO (2015b)

Habitat type

When it first naturalised in Europe, *I. parviflora* firstly colonised towns, gardens, parks and cemeteries and then disturbed locations. Subsequently, it invaded undisturbed deciduous forests, suggesting that it is in the secondary phase of invasion (Kornas, 1990; Tabak & Von Wettberg, 2008; Skalova et al., 2011). It is the only non-native plant being dispersed in European forests on a large scale (Branquart et al., 2010). At the present time, *I. parviflora* grows in shady places at the margins of temperate deciduous forests and mixed conifer forests (EPPO, 2015b; Clapham et al., 1987; Perrins et al., 1993). It is now the most serious invader of this habitat type, even in apparently undisturbed places (Kornas, 1990). It is more often found in moist to wet forests from floodplains to beech forests (EPPO, 2015b). In addition, the species occurs in ruderal vegetation in settlements, at roadsides, on waste ground, in hedgerows, gardens, parks, on riverbanks and along railways (Wittenberg, 2005; EPPO, 2015b; CABI, 2015b).

Climate

I. parviflora colonises areas with warm to hot wet summers and cool to cold wet winters (EPPO, 2015b). According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), *I. parviflora* is an H2 species meaning that it is hardy almost everywhere and withstands temperatures of -15 to -20˚C minimum. EPPO (2015b) reports that hardiness is probably limited between -23 and -18˚C. However, other authors describe that its regional distribution may be limited by a low frost tolerance (Hughes, 1965; Perrins et al., 1993; Tabak & Von Wettberg, 2008). Moreover, *I. parviflora* appears to be more vulnerable to frost than other *Impatiens* species. During a UK garden experiment, a frost (about -5˚C) during seedling emergence, caused 3% mortality (n = 77) in *I. glandulifera*, 25% mortality (n = 52) in *I. balfourii* and 67% mortality (n = 66) in *I. parviflora* (Perrins et al., 1993). Experiments support these observations. Seedlings of *I. noli-tangere, I. capensis, I. glandulifera* and *I. parviflora* exhibited 72%, 60%, 57% and 40% survival respectively under frost conditions recreated in the laboratory (Skalova et al., 2011). However, frost resistance may vary between populations (Skalova et al., 2011), and the risk of frost damage may be at least partly negated by later seedling emergence, e.g., in the Czech Republic (Skalova et al., 2011). The optimal temperature of germination for *I. parviflora* seeds ranges from 5 to 25˚C (Coombe, 1956; Perglova et al., 2009). Mean minimum temperatures where the species occurs range from -5 to 5˚C and mean maximum temperatures where the species occurs at a range of 10 to 25˚C (CABI, 2015c).

Light
I. parviflora is more tolerant of shade than Himalayan balsam (*Impatiens glandulifera*), orange jewelweed (*Impatiens capensis*) and *I. balfourii* and is mostly found at 5 to 40 % relative daylight (Hughes, 1965; Jouret, 1977; Perrins et al., 1993; Tabak & Von Wettberg, 2008). In England, *I. parviflora*, survives a minimum of 7% daylight and achieves reasonable seed production even when shaded (Perrins et al., 1993). Moreover, in shaded conditions *I. parviflora* seed production is equivalent to that of *I. glandulifera* and is the second most productive *Impatiens* species compared to *I. glandulifera*, *I. capensis* and native touch-me-not balsam (*Impatiens noli-tangere*) regardless of the environment (Skalova et al., 2012).

Substrate and nutrients
I. parviflora colonises a wide range of mineral but not necessarily calcareous soils that are moderately to highly mineral rich (Coombe, 1956; EPPO, 2015b). In laboratory experiments, low nutrients resulted in increased survival in *I. parviflora* (Skalova et al., 2012).

pH
I. parviflora colonises soils with pH ranging from 4.5 to 7.6 (Coombe, 1956; EPPO, 2015b).

Moisture
I. parviflora is less tolerant of high soil moisture than the *I. glandulifera*, *I. capensis* and native *I. noli-tangere* that can tolerate even waterlogged soils (Dericks, 2006; Schmitz & Dericks, 2010). *I. parviflora* seedlings cannot survive waterlogged conditions (EPPO, 2015b). However, a combination of drought and flooding, while reducing survival in *I. glandulifera* and *I. noli-tangere*, has no effect on *I. parviflora* and *I. capensis* (Skalova et al., 2012).

4.9.3. Recorded distribution

Native range
I. parviflora is native to the mountains of Central Asia and Siberia (Figure 4.28) (Hulten & Fries, 1986; Perrins et al., 1993). According to Trepl (1984), descriptions of *I. parviflora*'s native range in the older floristic literature are imprecise or wrong leading to doubts over its occurrence in some areas. The native range *of I. parviflora* includes parts of Turkmenistan, Afghanistan, Kazakhstan and Mongolia (Trepl, 1984). Moreover, the US Agricultural Research Service (USDA-ARS) includes other Central Asian countries and parts of Russia in its native range (EPPO, 2015b).

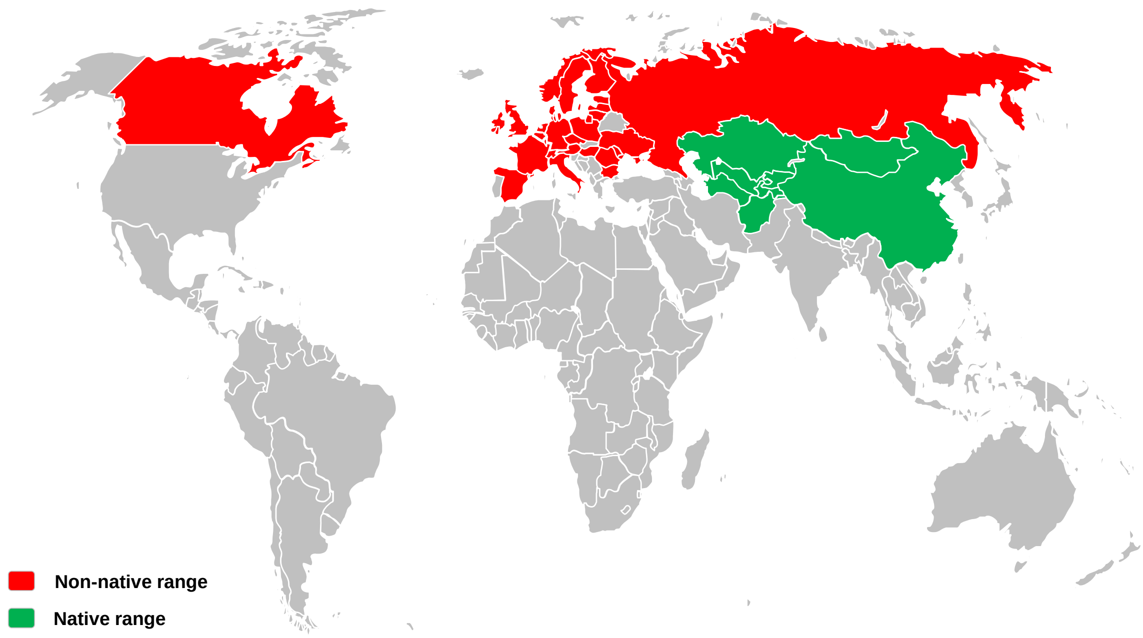

Figure 4.28: Current global recorded distribution of Small balsam (*Impatiens parviflora*) (Source: Q-bank, 2015; CABI, 2015c; USDA, 2015). Note that the species is regarded as native in some parts of Russia (i.e., Siberia).

Non-native range.

The non-native range of *I. parviflora* extends to most of central Europe, France and the United Kingdom, and North America, with scattered occurrences in Scandinavia and Baltic states (Gleason, 1952; Hulten & Fries, 1986) (Figure 4.28). The introduction spread of *I. parviflora* in central Europe is described in Trepl (1984). *I. parviflora* was initially introduced to a botanical garden in Genf, Sweden in or before 1830. In 1831, the plant was first discovered in the wild close to this botanical garden. The species was recorded in the wild in Dresden, Germany in 1838, the UK in 1848 and in Prague, the Czech Republic in 1871, mostly in close proximity to botanical gardens. The plant initially colonised artificial habitats such as parks, gardens and populated areas. The species was first recorded initially in managed forests and forest edges in the late 1800s, subsequently colonising less disturbed locations in the 1900s which coincided with an increase in the rate of spread (EPPO, 2015b).

Distribution in the Netherlands

The current recorded distribution *of I. parviflora* is shown in figure 4.29. *I. parviflora* was first collected in Culemborg. The plant had grown here since 1880 where it grew under bushes along a canal (Suringar, 1897). According to the Prodromus (Anonymus, 1901), Valkenburg is also a location where *I. parviflora* has been recorded. Here, *I. parviflora* was identified by E. Heimans. However, in "de verslagen en mededeelingen der Nederlandsche Botanische Vereeniging" from 1917, E. Heimans is said to have sown *I. parviflora* in the vicinity of Haarlem and Apeldoorn, resulting in relatively high abundances (Heukels, 1917). By 1917 *I. parviflora* had been recorded in Hilversum, Overveen and between Gulpen and Margraten. In 1950, *I. parviflora* was already recorded in 61 5x5 kilometre squares in the centre of the country, mainly as a result of seed sowing by members of the public. By 1980 the plant had been recorded in nearly 400 5x5 kilometre squares (Van der Meijden et al., 1989) and currently there are records from around 1000 kilometre squares (Figure 4.30). The species occurs in mostly wooded areas, on sandy ground, in the middle and south of the country. Here, the plant grows on disturbed, relatively nutrient rich patches or in naturally nutrient rich riverine alluvial forests along stream habitat (*Pruno-Fraxinetum*).

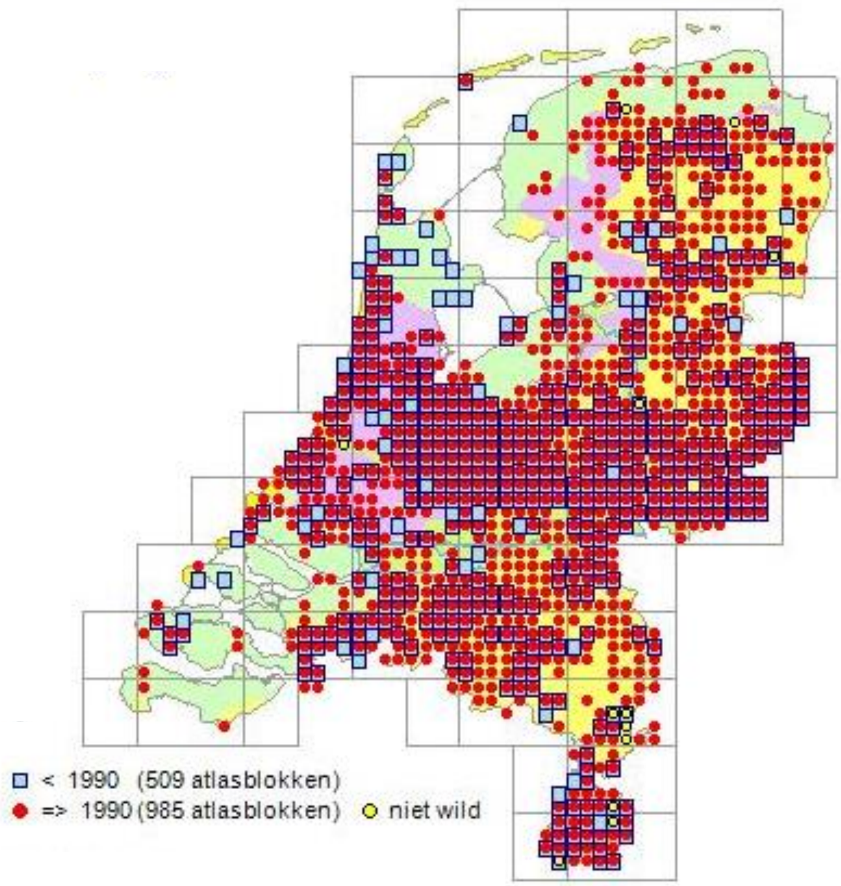

Figure 4.29: Current recorded distribution of Small balsam (*Impatiens parviflora*) in the Netherlands (Source: Nationale Databank Flora en Fauna, 2015).

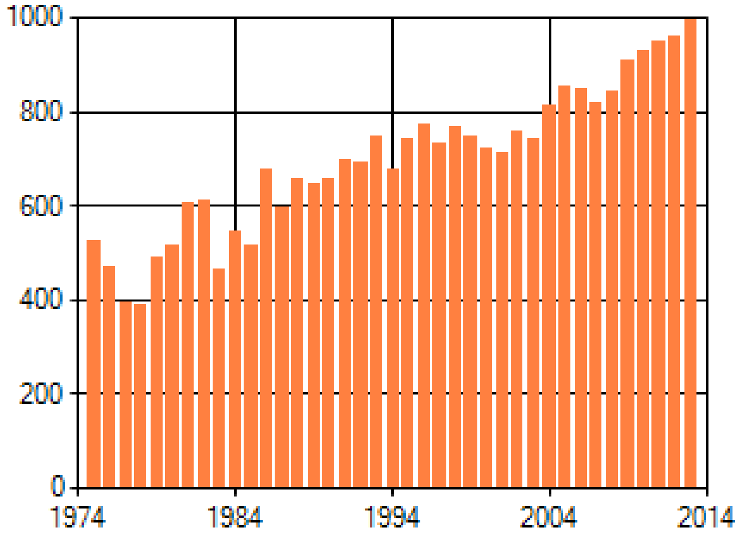

Figure 4.30: Estimated number of 5x5 kilometre-squares occupied by Small balsam (*Impatiens parviflora*) per year in the Netherlands (Source: Verspreidingsatlas.nl, ©CBS & FLORON, 2014).

Colonisation of high conservation value habitats

Records of *I. parviflora* have been confirmed in 53 N2000 areas. The most important of these are shown in table 4.31.

Table 4.31: T Number of kilometre squares in Natura 2000 sites where Small balsam (*Impatiens parviflora*) has been recorded in the Netherlands. Only the most important Natura 2000 sites are displayed.

Natura 2000 area	Definite	Possible	Range
Veluwe	279	160	279-439
Kennemerland-Zuid	29	11	29-40
Geuldal	12	5	12-17
Springendal & Dal Mosbeek	9	2	9-11
Drentsche Aa area	8	5	8-13
Brabantse Wal	7	10	7-17
Loonse en Drunense Duinen & Leemkuilen	7	9	7-16
Dinkelland	7	5	7-12
Meijendel & Berkheide	6	6	6-12
Maasduinen	5	4	5-9
Leudal	5	2	5-7
Noordhollands Duinreservaat	4	8	4-12
Drents-Friese Wold & Leggelderveld	4	6	4-10
Gelderse Poort	4	6	4-10
Naardermeer	4	5	4-9
Brunssummerheide	4	4	4-8
Landgoederen Oldenzaal	4	4	4-8
Banks and floodplains of the river Nederrijn	4	4	4-8
Buurserzand & Haaksbergerveen	4	3	4-7
Landgoederen Brummen	4	3	4-7
Voornes Duin	4	1	4-5

4.9.4. Invasion process

Introduction

I. parviflora was intentionally introduced to Europe and North America through planting in and subsequent escape from botanical gardens (Tabak & Von Wettberg, 2008; Nehring et al., 2013). Plants were also sown in semi-natural environments with the aim of enriching floral diversity (Trepl, 1984; EPPO, 2015b). In the United Kingdom, *I. parviflora* may have been dispersed as a seed contaminant in buckwheat for feeding pheasants or flower seeds, and as a soil contaminant attached to the roots of garden plants (Coombe, 1956; Trepl, 1984; EPPO, 2015b). Timber carried by train has been identified as a possible vector for the transport of seeds that have led to frequent occurrences along railway tracks (Trepl, 1984; EPPO, 2015b).

A quick scan of the first 50 results of google.nl using the search terms ‘klein springzaad te koop’ and ‘*Impatiens parviflora* te koop’ revealed a single Dutch website that recommended *I. parviflora* as a nectar plant to attract bees and butterflies. A single web-shop was found that offers delivery of *I. parviflora* to buyers across international borders.

Establishment

I. parviflora has a wide recorded distribution in the Netherlands, is widespread in climatically similar countries such as Germany and the United Kingdom, and is present in Belgium (Figure 4.20 & 4.21; CABI, 2015c). However, it appears to be more frost sensitive than *I.*

glandulifera and *I. balfourii* (Perrins et al., 1993). *I. parviflora* produces relatively low biomass compared to other *Impatiens* species suggesting that successful invasion is not dependent on prolific growth. *I. parviflora* seedlings are larger than those of other *Impatiens* species (Skalova et al., 2013). Under conditions of low soil moisture, *I. parviflora* seems to be a strong competitor, decreasing the biomass of *I. glandulifera* in competition experiments (Skalova et al., 2013). This and its tolerance of low light levels explain its establishment in shady places at the edges of temperate deciduous forests and mixed conifer forests (EPPO, 2015b). *I. parviflora* has a poor or non-existent seed bank, however, this does not seem to limit its establishment potential (Skalova et al., 2013).

Spread
Seeds are launched up to 3.4 m from the plant capsules by an explosive mechanism (Trepl, 1984; EPPO, 2015b). However, its estimated rate of spread of 24 km/year in the United Kingdom suggests that other mechanisms exist that augment seed dispersal (Perrins et al., 1993; EPPO, 2015b). Seed transport in river sediments with fast moving winter flood water may facilitate long distance dispersal and floating seeds and water-aided dispersal are probably common within the *Impatiens* genus (Tabak & Von Wettberg, 2008; CABI, 2015c). However, in the case of *I. parviflora*, seed dispersal by hydrochory is probably of limited importance (CABI, 2015c). Moreover, it is probable that the amount of seed dispersed by people will be less in the dense woodland habitats favoured by *I. parviflora* than on the areas of river banks that are preferred by *I. glandulifera* (Perrins et al., 1993). Perrins et al., 1993 suggested that it was this reason, combined with a relative vulnerability to frost, that led to the slower spread of *I. parviflora* compared to *I. glandulifera* in the United Kingdom. However, there are examples of vectors that could facilitate the spread of *I. parviflora* in forested regions. In one study, 22 *I. parviflora* seeds per litre of soil were obtained from the tyres and other parts of a forest vehicle, seeds may also be spread by forestry machinery (Trepl, 1984; EPPO, 2015b). Moreover, timber transport has been implicated in the long distance dispersal of seeds (Trepl, 1984; Nehring et al., 2013). There are no reports of endozoochorous dispersal, but epizoochorous dispersal in animal fur and feet is an important mechanism of long-distance dispersal (Trepl, 1984; EPPO, 2015b). Additionally, isolated observations of *I. parviflora* growing on trees indicate that birds transport seeds (EPPO, 2015b). Perrins et al., 1993 argued that *I. parviflora* may eventually spread as widely as *I. glandulifera* in the United Kingdom, but remain less frequent due to narrower habitat requirements.

4.9.5. Environmental impact summary

Effects on environmental targets or native species

Parasitism
No recorded impacts were discovered during the literature review.

Competition
I. parviflora is able to take advantage of gaps in the forest floor due to its tolerance of low light availability (EPPO, 2015b). Evidence, reporting impacts on native species is mixed. In dense stands, *I. parviflora* is able to monopolise light and space, excluding other plant species (Starfinger & Kowarik, 2003; Nehring et al., 2013). Competition with other plants may lead to a shift in dominance but no competitive exclusion has been reported (Schmitz,

1997; Kowarik, 2003; EPPO, 2015b; CABI, 2015c). Reduction of plant species abundance and possible competition with several native forest herbaceous species (e.g., *Asarum europaeum*, *Galeobdolon luteum*, *Galium odoratum* and *Mercurialis perennis*) has been reported (Branquart et al., 2010). However, in Germany, Poland and the Czech Republic no impact or significant effect on the diversity of native species has been recorded (Chmura & Sierka, 2006; Hejda, 2012; Nehring et al., 2013). Overall the biodiversity impact of *I. parviflora* seems to be limited (Trepl, 1984; EPPO, 2015b).

In an experiment comparing native *I. noli-tangere* and non-native *I. glandulifera*, *I. parviflora*, and *I. capensis*, *I. parviflora* appeared to be the second strongest competitor, especially under conditions of low soil moisture (Skalova et al., 2013). This suggests that *I. parviflora* may be able to competitively exclude *I. noli-tangere*, however, this is only true in conditions that are suboptimal for native species (EPPO, 2015b).

Interbreeding
Nehring et al. (2013) stated that it is unknown if a hazard from interbreeding between native species and *I. parviflora* exists in Germany.

Hosting pathogens or parasites
I. parviflora supports a number of aphidophagous insect species. It hosts the Asian aphid (*Impatientinum asiaticum*) (Schmitz, 1997; CABI, 2015c), the bean aphid (*Aphis fabae*) and is a carrier of the cucumber mosaic virus (Nehring et al., 2013). However, Nehring et al. (2013) stated that the risk to German native species is probably insignificant.

Effects on ecosystem function targets
Abiotic properties e.g., nutrient cycling, structural modification
The addition of a herbaceous layer in forests where vegetation was formerly absent may affect tree regeneration and consequently ecological succession. However, this possibility has not been studied in detail (CABI, 2015c).

Effecting ecosystem integrity by biotic properties
Nehring et al. (2013) stated that there is no known threat to German ecosystem functions.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition and interbreeding were discovered during the literature review.

Cultivation systems
I. parviflora colonises managed forests and timber plantations and may affect tree regeneration silvicultural systems where this is important (CABI, 2015c; EPPO, 2015b). *I. parviflora* is not an agricultural weed (EPPO, 2015b).

Pathogens or parasites
I. parviflora acts as an alternative host for crop pests such as cucumber mosaic virus and the aphid *Aphis fabae* (Schmitz, 1998; Brcak, 1979; EPPO, 2015b). Estimates regarding the economic consequences are not available (EPPO, 2015b).

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.9.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. parviflora* a 'high' ecological risk classification to the categories dispersion potential or invasiveness and colonisation of high value conservation habitats, 'medium' for the category adverse impacts on native species and 'unlikely' for the category alteration of ecosystem functions (Table 4.32). The total ecological risk score for the species is 9 out of a maximum of 12. Therefore, *I. parviflora* is classified in the B list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs.

Table 4.32: Consensus scores for potential risks of Small balsam (*Impatiens parviflora*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	High	3
Colonisation of high value conservation habitats	High	3
Adverse impacts on native species	Medium	2
Alteration of ecosystem functions	Low	1
Environmental risk score		**9**

Dispersion potential or invasiveness
Classification: **High risk**. *I. parviflora* is wide spread in the Netherlands and its distribution is increasing. The climate in the Netherlands is, therefore, suitable for the establishment of *I. parviflora*. However, the species appears to be more frost sensitive than *I. glandulifera* and *I. balfourii* (Perrins et al., 1993). Therefore, increasing winter temperatures as a result of climate change may increase the invasiveness of this species.

The plant was intentionally introduced to Europe and North America through planting and subsequent escape from botanical gardens (Tabak & Von Wettberg, 2008; Nehring et al., 2013). Plants were also sown in semi-natural environments with the aim of enriching floral diversity (Trepl, 1984; EPPO, 2015b).

Similarly to other *Impatiens* species, seeds are ejected explosively from seed pods (ballochory), travelling up to 3.4 m from the plant (Trepl, 1984; EPPO, 2015b). However, its estimated rate of spread of 24 km/year in the United Kingdom suggests that other mechanisms exist that augment seed dispersal (Perrins et al., 1993; EPPO, 2015b). There are no reports of endozoochorous dispersal, but epizoochorous dispersal in animal fur and on feet is an important mechanism of long-distance dispersal (Trepl, 1984; EPPO, 2015b). Additionally, isolated observations of *I. parviflora* growing in trees indicate that birds transport seeds (EPPO, 2015b). However, seed dispersal by hydrochory is probably of limited importance (CABI, 2015c). Human mediated dispersal mechanisms involve the transport of seeds on tyres and other parts of forest vehicles and machinery (Trepl, 1984; EPPO, 2015b) and the transport of timber which facilitates long distance dispersal (Trepl, 1984; Nehring et al., 2013). Moreover, timber carried by train has been identified as a possible vector for the transport of seeds that have led to frequent records along railway tracks (Trepl, 1984; EPPO, 2015b). In the United Kingdom, *I. parviflora* may have been dispersed as a seed contaminant in buckwheat for feeding pheasants or flower seeds, and as a soil contaminant attached to the roots of garden plants (Coombe, 1956; Trepl, 1984; EPPO, 2015b).

In conclusion, *I. parviflora* is highly fecund and easily disperses actively or passively over distances greater than 1 km per year and therefore poses a high risk of dispersal and invasiveness in the Netherlands.

Colonization of high value conservation habitats

Classification: **High risk**. *I. parviflora* records of have been confirmed in 53 N2000 areas in the Netherlands. In conclusion, *I. parviflora* has already demonstrated that it poses a high risk of establishment in a large number of high conservation value habitats. The species (potentially) threatens red listed and protected species in the Netherlands.

Adverse impacts on native species

Classification: **Medium risk**. There is no available evidence to suggest that *I. parviflora* is a parasitic plant. *I. parviflora* is a known host of the bean aphid (*Aphis fabae*) and a carrier of the cucumber mosaic virus (Nehring et al., 2013). *I. parviflora* may support aphidophagous insects as it hosts the Asian aphid (*Impatientinum asiaticum*) (Schmitz, 1997; CABI, 2015c). However, these parasite species and diseases do not impact Dutch native species. Moreover, Nehring et al. (2013) stated that the risk to German native species is probably insignificant. No *I. parviflora* hybrids are known to exist in Europe (Coombe, 1956; EPPO, 2015b). Nehring et al. (2013) stated that it is unknown if a hazard from interbreeding between native species and *I. parviflora* exists in Germany. Evidence for impacts on European native species as a result of *I. parviflora* competition is mixed. In dense stands, the plant is able to monopolise light and space, excluding other plant species (Starfinger & Kowarik, 2003; Nehring et al., 2013). Competition with other plants may lead to a shift in species dominance favouring *I. parviflora* but no competitive exclusion has been reported (Schmitz, 1997; Kowarik, 2003; EPPO, 2015b; CABI, 2015c). Reduction of plant species abundance and possible competition with several native forest herbaceous species (e.g., *Asarum europaeum*, *Galeobdolon luteum*, *Galium odoratum* and *Mercurialis perennis*) has been reported in Belgium (Branquart et al., 2010). However, in Germany, Poland and the Czech Republic no impact or significant effects on the diversity of native species has been recorded (Chmura & Sierka, 2006; Hejda, 2012; Nehring et al., 2013). Overall the biodiversity impact of *I. parviflora* seems to be limited (Trepl, 1984; EPPO, 2015b).

In conclusion, there is a medium risk that *I. parviflora* causes local changes (<80%) in population abundance, growth and distribution of one or more native species in the Netherlands. These impacts are probably reversible.

Alteration of ecosystem functions
Classification: **Low risk**. *I. parviflora* is an erect annual herb that usually grows to between 20 and 60 cm tall, rarely reaching 150 cm. In dense stands, *I. parviflora* is able to monopolise light and space (Starfinger & Kowarik, 2003; Nehring et al., 2013). In general, the addition of a herbaceous layer in forests where vegetation was formerly absent may affect tree regeneration and consequently ecological succession. However, this possibility has not been studied in detail (CABI, 2015c). Nehring et al. (2013) stated that there is no known threat to German ecosystem functions.

In conclusion, some physical modification of habitat such as the erosion of bare soil following die back and light interception during growth periods may occur. However, in general, the risk of *I. parviflora* negatively impacting ecosystem processes and structure in the Netherlands is expected to be low.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.32) in combination with the current recorded distribution in the Netherlands. The species classification for *I. parviflora* is B3 (Figure 4.31). This characterises a non-native species that is widespread from the area under assessment, poses a moderate ecological risk and should be placed on the watch list of the BFIS list system. However, note that data on genetic effects (e.g., hybridization) are lacking.

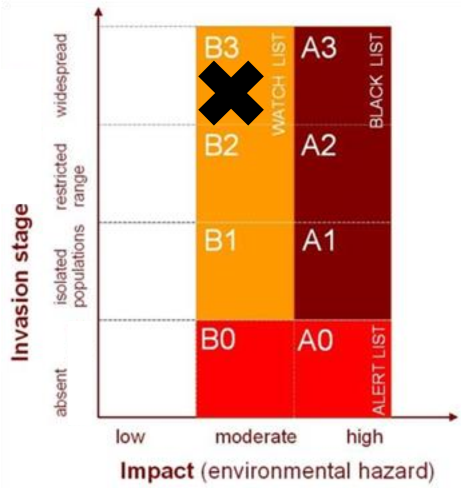

Figure 4.31: Risk classification of Small balsam (*Impatiens parviflora*) according to the BFIS list system.

4.9.7. Other risk assessments and classifications

One full risk assessments for *I. parviflora* has been carried out in the United States where the plant was given a high risk rating (Table 4.33). In Belgium and Luxembourg *I. parviflora* poses a moderate and low ecological risk score respectively according to the ISEIA risk prioritisation method. In a review of invasive species present in other European countries apart from Spain, *I. parviflora* was considered to be a potential threat to Spanish ecosystems. It is on the list of potentially invasive species that require assessment (grey list) in France (Espèces végétales exotiques envahissantes en France Méditerranéenne Continentale, 2015). Our assessment of *I. parviflora* that assigns a moderate risk to this species is in agreement with the assessments carried out in Belgium and Spain.

Table 4.33: Overview of risk classifications previously performed for Small balsam (*Impatiens parviflora*).

	Belgium	France	Luxembourg	Spain	USA
Scope	Risk prioritisation method	Risk assessment method	Risk prioritisation method	Risk prioritisation method	Risk assessment method
Method	ISEIA	rating system to assess the invasion potential of exotic plant species in central Europe (Weber & Gut, 2005)	ISEIA	Literature review	PPQ WRA model
Year	2010	2009	2013	2001	2013
Risk classification	**B3 (moderate risk, widespread species)**	**Grey list (requires assessment)**	**C3 (low risk, widespread species)**	**Potential threat to Spanish ecosystems**	**High Risk**
Source	http://ias.biodiversity.be/species/show/66	Espèces végétales exotiques envahissantes en France Méditerranéenne Continentale (2015)	Ries et al. (2013)	Elorza et al. (2001)	United States Department of Agriculture (2013)

The Belgian Code of conduct on invasive plants, introduced in 2013, lists *I. parviflora* as plant species that should not be traded in Belgium (Halford et al., 2011).

4.10. *Impatiens parviflora x balfourii*

4.10.1. Species description

The hybrid *Impatiens parviflora* x *balfourii* is an annual herb up to 60 cm tall (Figure 4.32). The stem of this hybrid is erect or ascending, glabrous, green and round in cross section. The leaves are alternate. The petiole is less than 1-3(-5) cm long. The leaf blades are ovate to elliptic, the margins serrate or crenate, 4 - 8 cm x (5-)8-15 cm. The base is acute to cuneate, shortly decurrent, and the apex acute to acuminate. The inflorescence is axillary, consisting of multiple erect flowers that may be grouped in a raceme or panicle. Flowers are up to 3 cm long including the spur and upright, white with pink spots on the inside and yellow or pink blotches on the anterior lobe. The calyx comprises three lobes with the lower one ending in a straight to slightly curved spur, shorter to equal to the lower lobe. The corolla comprises of five lobes, with the anterior one conspicuous with pink blotches. The fruits are linear to clavate up to 2.5 cm long and glabrous.

Species taxonomy

Table 4.34: Nomenclature and taxonomical status of *Impatiens parviflora x balfourii*.

Scientific name:
Impatiens parviflora x *balfourii*

Synonyms:
Not applicable

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens parviflora* x *balfourii*

Preferred Dutch name:
Not applicable

Preferred English name:
Not applicable

Other Dutch names:
Not applicable

Other English names:
Not applicable

Life cycle
No information on the life cycle of *I. parviflora x balfourii* could be found during the literature review.

Figure 4.32: *Impatiens parviflora x balfourii* (Photo: N. Schoenberger).

Reproductive capacity
No information on the reproductive capacity of *I. parviflora x balfourii* could be found during the literature review.

4.10.2. Habitat summary

The hybrid was observed in riparian forest along the Ticino River in Switzerland, on moist soil bordering a swampy site, amidst *I. glandulifera* and *I. parviflora* plants.

4.10.3. Recorded distribution

Native range
Not applicable, because it is a hybrid with parents from originally disjunctive native ranges.

Non-native range
The hybrid *I. parviflora x balfourii* was first observed in 2011 in Switzerland. Information on spread in other European countries could not be found during the literature review.

Distribution in the Netherlands
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. parviflora x balfourii* in the Netherlands.

Colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. parviflora x balfourii* in the Netherlands.

4.10.4. Invasion process

Introduction

No information on the potential introduction pathways of *I. parviflora x balfourii* to the Netherlands could be found during the literature review. A quick scan of the first 50 results of google.nl using the search term '*Impatiens parviflora x balfourii* te koop' revealed no websites offering *I. parviflora x balfourii* for sale to the public.

Establishment

No information on the potential for establishment of *I. parviflora x balfourii* in the Netherlands or climatically similar countries could be found during the literature review.

Spread

No information on the potential for spread of *I. parviflora x balfourii* in the Netherlands. According to Duistermaat (unpublished), potential records of the hybrid *I. parviflora x balfourii* exist for Switzerland. Currently, research by the Netherlands Food and Consumer Product Safety Authority, the Hortus Botanicus of Leiden University and Naturalis in Leiden is underway to determine if the plant recorded in Switzerland is in fact a hybrid of *I. parviflora* and *I. balfourii* (H. Duistermaat, unpublished).

4.10.5. Environmental impact summary

Effects on environmental targets or native species

No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets

No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems

No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets

No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets

No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets

No recorded impacts on other targets (such as damage to infrastructure or bank and dike stability) were discovered during the literature review.

4.10.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. parviflora x balfourii* a 'likely' risk classification to the categories dispersion potential or invasiveness and colonisation of high value conservation habitats and ‘unlikely’ for the categories adverse impacts on native species and alteration of ecosystem functions (Table 4.35). The total ecological risk score for the species is 6 out of a maximum of 12. Therefore, *I. parviflora x balfourii* is classified in the C list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs. Note that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

Table 4.35: Consensus scores for potential risks of *Impatiens parviflora* x *balfourii* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Likely	2
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Environmental risk score		**6**

Dispersion potential or invasiveness
Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. parviflora* x *balfourii* in the Netherlands. However *I. parviflora x balfourii* is a winter-hardy hybrid suggesting that the climate in the Netherlands will not form a barrier to establishment. Both parent species, *I. parviflora* and *I. balfourii*, have been able to establish and are currently widespread in the Netherlands.

In conclusion, based on the characteristics of its parent species, it is likely that *I. parviflora* x *balfourii* could disperse and become invasive in the Netherlands.

Colonization of high value conservation habitats
Classification: **Likely**. Records of *I. parviflora* have been confirmed in 53 Natura 2000 areas. *I. balfourii* records are mainly limited to urban locations. Confirmed records of the species in high value conservation habitats exist only for the centre of Hoek van Holland that borders the Solleveld & Kapittelduinen Natura 2000 area. However, *I. balfourii* has been assessed as posing a high risk of establishment in high value conservation habitats in the Netherlands (Section 4.2.6.).

In conclusion, based on the characteristics of its parent species, it is likely that the hybrid *I. parviflora* x *balfourii* will be able to establish in high conservation value habitats and cause a (potential) treat for red listed or protected species.

Adverse impacts on native species
Classification: **Unlikely**. There was no available evidence to suggest that *I. parviflora* x *balfourii* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. There is

no available evidence to suggest that *I. parviflora* x *balfourii* could negatively impact Dutch native species through hybridisation or competition. However, the risk of impacts of this hybrid on Dutch native species is expected to lie between the minimum and maximum scores allocated to the parent species *I. parviflora* and *I. balfourii*. In general, the performance of hybrids is lower than that of the parent species.

In conclusion, it is unlikely that the hybrid *I. parviflora* x *balfourii* will cause local changes (<80%) in population abundance, growth and distribution of one or more Dutch native species.

Alteration of ecosystem functions
Classification: **Unlikely**. No evidence for the potential of *I. parviflora* x *balfourii* to alter ecosystem functions in the Netherlands was found during the literature review. However, the risk of alteration of ecosystem processes and functioning will lie between the minimum and maximum scores for the parent species *I. parviflora* and *I. balfourii*. In general, the performance of hybrids is lower than that of the parent species. Some physical modification of habitat such the erosion of bare soil after winter die back and light interception during growth periods may occur. However, in general, it is unlikely that impacts on ecosystem processes and structure will occur as a result of *I. parviflora* x *balfourii* establishment in the Netherlands.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.35) in combination with the current recorded distribution in the Netherlands. The species classification for *I. parviflora x balfourii* is C0 (Figure 4.33). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and should be not be placed on either the alert, watch or black list of the BFIS list system. However, note that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

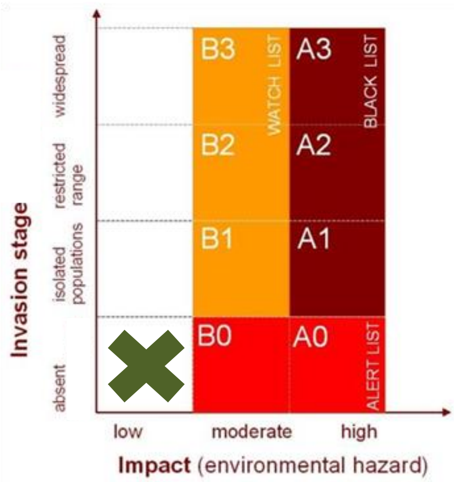

Figure 4.33: Risk classification of *Impatiens parviflora x balfourii* according to the BFIS list system.

4.10.7. Other risk assessments and classifications

No risk assessments or classifications of *I. parviflora x balfourii* could be found during the literature review.

4.11. Rugged yellow balsam (*Impatiens scabrida*)

4.11.1. Species description

Rugged yellow balsam (*Impatiens scabrida*) is an annual herb that normally grows to 30 to 50 cm tall. The stem is erect and basally green or purple-tinged, many branched and basally pubescent or sub-glabrous. The leaves are alternate, sessile or sub-sessile. The petiole features two globose basal glands. The leaf blades are ovate or ovate-lanceolate, 5-15 × 1.5-2 cm, abaxially pubescent, adaxially sparsely strigose, apices of teeth with marginal glands and 7-9 pairs lateral veins. The leaf bases are somewhat rounded, with sharply serrated margins, the apex is acuminate. Inflorescences in leaf axils, 1-3-flowered and shortly pedunculate. The pedicels are bracteate in the middle, the peduncles, pedicels, and bracts are brown and pubescent. The bracts are persistent, setose, lanceolate, their apex is long and mucronate. The flowers are golden-yellow or purple spotted and 2.5 to 3 cm long (Figure 4.34). There are two lateral sepals which are ovate, sparsely pubescent, with a mucronate apex. The lower sepal is broadly funnel-form, abruptly narrowed into a curved spur and approximately 1 cm long. The upper petal is broadly orbicular, with a green abaxial midvein, cornute-cristate, the crista is conspicuous in flowering buds. The two lobed lateral united petals are not clawed. The basal lobes are orbicular and short. The distal lobes are oblong-dolabriform. The auricle is inflexed and narrow. The anthers are obtuse. The linear capsule is 2.5 to 3 cm long, glabrous or sparsely hairy (www.efloras.org).

Figure 4.34: Rugged yellow balsam (*Impatiens scabrida*) (© Photo: K. Stüber, Wikimedia commons).

Species taxonomy

Table 4.36: Nomenclature and taxonomical status of Rugged yellow balsam (*Impatiens scabrida*).

Scientific name:
Impatiens scabrida DC. (1824)

Synonyms:
Balsamina cristata (Wall.) Ser., Index Seminum (Lyon). 1853; *Balsamina tricornis* Ser., Fl. Jard. 3: 452. 1849; *Impatiens cristata* Wall., Fl. Ind. 2: 456. 1824; *Impatiens praetermissa* Hook.f., J. Linn. Soc., Bot. 37: 29. 1904; *Impatiens tricornis* Lindl., dwards's Bot. Reg. 26: t. 9. 1840.

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens scabrida*

Preferred Dutch name:
Ruig springzaad

Preferred English name:
Rugged yellow balsam

Other Dutch names:
Not applicable

Other English names:
Scabby balsam, Himalayan jewel orchid

Life cycle
In its native range, *I. scabrida* flowers from July to September (www.efloras.org).

Reproductive capacity
No information on the reproductive capacity of *I. scabrida* could be found during the literature review.

4.11.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. scabrida* are listed in table 4.37. According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), it is an H1 species that is hardy everywhere and withstands -20˚C and below.

Table 4.37: Physiological conditions tolerated by Rugged yellow balsam (*Impatiens scabrida*).

Parameter	Data origin	Occurrence	References
Hardiness (˚C)	Unknown	< -20	Grey-Wilson (2011)

In its native range, *I. scabrida* is usually found in forest understories and along waterways at an altitude of 2000 to 3100 m (www.efloras.org).

4.11.3. Recorded distribution

Native range

I. scabrida is native to the Himalayas from Kashmir to Bhutan (Figure 4.35) (www.efloras.org).

Non-native range

I. scabrida occurs as non-native in the Netherlands, Sweden, Norway (one record) and the Czech Republic (one record) (Figure 4.35) (DAISIE, 2015e; Encyclopedia of Life, 2015; AOPK ČR, 2015; Norwegian species map service, 2015).

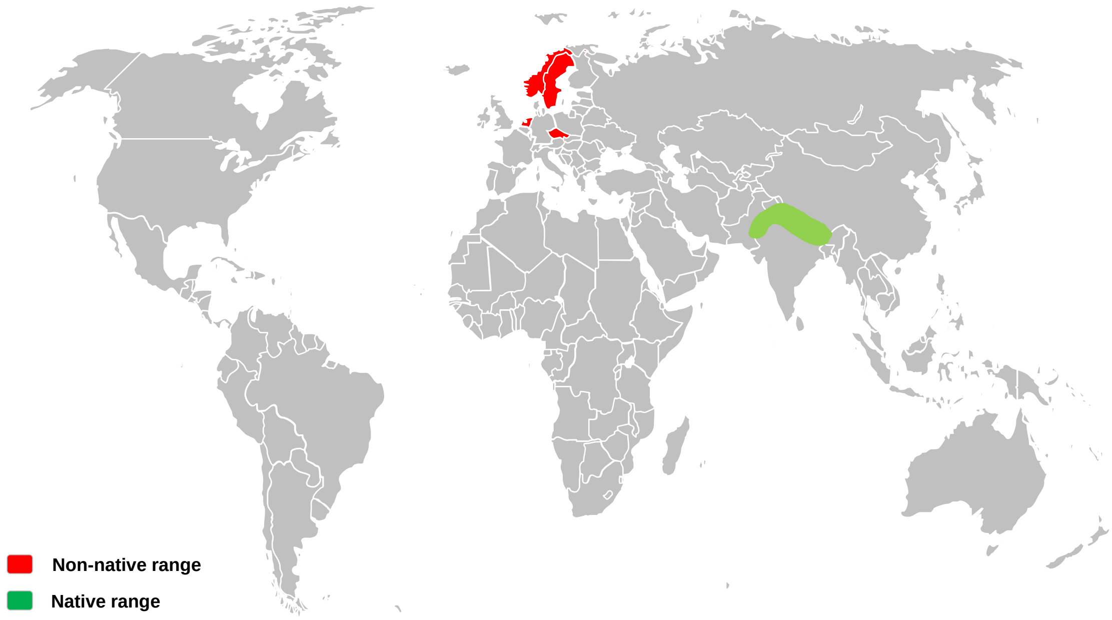

Figure 4.35: Current global recorded distribution of Rugged yellow balsam (*Impatiens scabrida*) (Sources: DAISIE, 2015e; Encyclopedia of Life, 2015; Norwegian species map service, 2015).

Distribution in the Netherlands

The current distribution of *I. scabrida* in the Netherlands in the field is shown in figure 4.36. *I. scabrida* was recorded around 1966 at Clingendaal near Den Haag (Van Ooststroom, 1970). A few plants were found here between large numbers of Himalayan balsam (*Impatiens glandulifera*). A further record of *I. scabrida* exists from 1969 in IJmuiden where it was recorded at a dump between Strandweg en Haringhaven (Van Ooststroom & Mennema, 1970). The next record of the species was much later in Amsterdam in 2010. The species has remained at this location for four years and has set seed. The plant had spread over a distance of approximately 150 metres by July 2014. In the autumn of 2014, almost the entire population was removed (waarneming.nl). The plants grew at a shadowed, more or less damp location, with a northerly exposure, along the bottom of a small wall. A second record for *I. scabrida*, made in 2013, exists for Gorinchem.

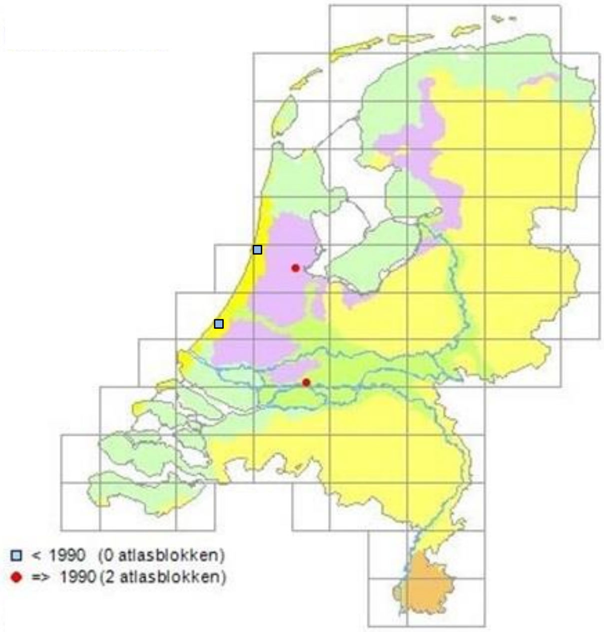

Figure 4.36: Current recorded distribution of Rugged yellow balsam (*Impatiens scabrida*) in the Netherlands (Source: Nationale Databank Flora en Fauna, 2015).

Colonisation of high conservation value habitats
All current recordings of *I. scabrida* in the Netherlands lie within urban areas. In the Czech Republic *I. scabrida* occupies traditional agricultural landscapes that are classified as semi-natural habitats (Pysek et al., 2002).

4.11.4. Invasion process

Introduction
No information on the potential introduction pathways of *I. scabrida* to the Netherlands could be found during the literature review. However, garden escapes may be a possible introduction pathway as a quick scan of the first 50 results of google.nl using the search terms '*Impatiens scabrida* te koop' and 'ruig springzaad te koop' revealed two international and one Dutch website offering *I. scabrida* for sale to the public. One result included a Dutch blog that recommended *I. scabrida* for attracting bees and insects.

Establishment
No information on the potential for establishment of *I. scabrida* in the Netherlands or climatically similar countries could be found during the literature review.

Spread
No information on the potential for spread of *I. scabrida* in the Netherlands or climatically similar countries could be found during the literature review.

4.11.5. Environmental impact summary

Effects on environmental targets or native species
No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.11.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. scabrida* a 'medium' ecological risk classification to the category dispersion potential or invasiveness. A ‘likely’ risk classification was allocated to the categories colonization of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions (Table 4.38). The total ecological risk score for the species is 8 out of a maximum of 12. Therefore, *I. scabrida* is classified in the C list of the BFIS list system. The rationale for the allocated scores is given in the following paragraphs. Note that risk scores for three ISEIA-sections are based on expert judgement due to lack of data.

Table 4.38: Consensus scores for potential risks of Rugged yellow balsam (*I. scabrida*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Medium	2
Colonization of high value conservation habitats	Likely	2
Adverse impacts on native species	Likely	2
Alteration of ecosystem functions	Likely	2
Environmental risk score		**8**

Dispersion potential or invasiveness
Classification: **Medium risk**. *I. scabrida* has been recorded in four atlas squares in the Netherlands. It is an H1 species meaning that it is hardy everywhere (to under -20˚C), suggesting that the Dutch climate will not form a barrier to establishment. The plant is

available via the European ornamental market and plants and at least two international retailers and one Dutch online retailer were found to offer *I. scabrida* for sale to the public. *I. scabrida* occurs as a non-native species in the Netherlands, Sweden and the Czech Republic (DAISIE, 2015e; Encyclopedia of Life, 2015). Except when assisted by humans *I. scabrida* does not colonise remote areas and natural dispersal rarely exceeds 1 km per year. *I. scabrida* may become locally invasive because of strong reproduction.

In conclusion, the risk of *I. scabrida* dispersal and invasiveness in the Netherlands is medium.

Colonization of high value conservation habitats
Classification: **Likely**. It is likely that Dutch floodplains provide suitable habitats for *I. scabrida*. In conclusion, it is likely that this species will be able to establish in high conservation value habitats and cause a (potential) threat for red listed or protected species.

Adverse impacts on native species
Classification: **Likely**. An example of *I. scabrida* has been monitored while growing in a private garden in the Netherlands. In this environment the plant grew to 180 cm and produced many seeds (H. Duistermaat, personal observation). Due to its height, it is likely that this species will shade out native species and compete for space. This combined with the likelihood that Dutch floodplains will provide suitable habitat for this species suggests that *I. scabrida* will have a likely adverse impact on native species in the Netherlands.

In conclusion, it is likely that *I. scabrida* will cause local changes in population abundance, growth and distribution of one or more native species if established in the Netherlands.

Alteration of ecosystem functions
Classification: **Likely**. An example of *I. scabrida* has been monitored while growing in a private garden in the Netherlands. In this environment the plant grew to 180 cm and produced many seeds (H. Duistermaat, personal observation). Due to its height, it is likely that this species will limit light availability. In conclusion, it is likely that this species will alter ecosystem processes and functioning in the Netherlands.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.38) in combination with the current recorded distribution in the Netherlands. The species classification for *I. scabrida* is C1 (Figure 4.37). This characterises a non-native species that has isolated populations in the area under assessment, poses a low ecological risk and should be not be placed on either the alert, watch or black list of the BFIS list system. However, several risk scores are based on best professional judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

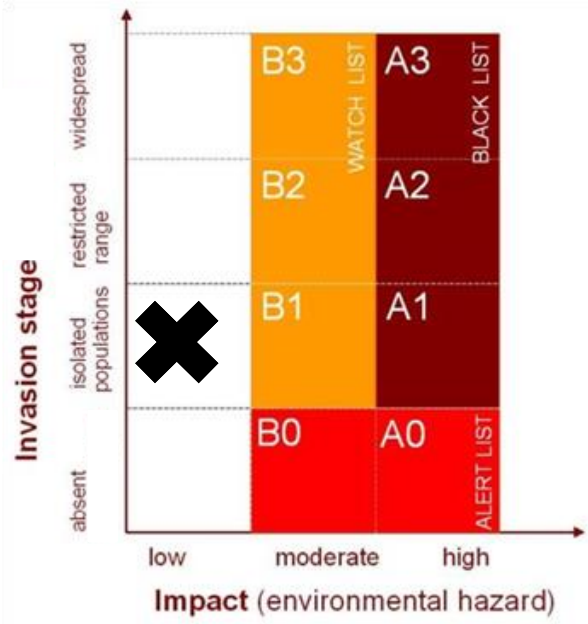

Figure 4.37: Risk classification of Rugged yellow balsam (*I. scabrida*) according to the BFIS list system.

4.11.7. Other risk assessments and classifications

No risk assessments or classifications of *I. scabrida* could be found during the literature review.

4.12. Gigantic Himalayan balsam (*Impatiens sulcata*)

4.12.1. Species description

The gigantic Himalayan balsam (*Impatiens sulcata*) is an annual herb that grows to between 60 and 120 cm tall. The stem is erect, terete, robust, conspicuously grooved, simple or branched in the upper part and sparsely glandular at the nodes. The leaves are alternate or opposite. The petiole is 1.5 to 3.5 cm long and sparsely glandular or without glands. The leaf blades are elliptic-ovate or ovate-lanceolate, 6-20 × 2-5.5 cm, with red or purple stipitate basal glands. The leaf base is cuneate or sub-rounded, slightly inequilateral, the margins crenate-serrate, the apex acuminate or long acuminate with 8 to 12 pairs lateral veins. The inflorescences are sub-corymbose-racemose, featuring multiple flowers (Figure 4.38). The peduncles are 3.5 to 9 cm long. The pedicels are swollen at the apex and bracteate at the base. The bracts are pink or purple-red in colour and lanceolate or ovate-lanceolate. The large flowers are purplish pink, 3 x 3.5 cm long and 3 x 3.5 cm deep. The two lateral sepals are obliquely ovate-cordate, approximately 0.7 to 0.4 cm and the apex is mucronate. The lower sepal is saccate, 1.5 to 1.8 cm deep and abruptly narrowed into an incurved spur of 0.4 to 0.8 cm. The upper petal is cucullate, suborbicular, has a curved-rostellate apex and abaxially not carinate. The broad, lateral united petals are not clawed and between 2.8 to 3.2 cm long. The basal lobes are subdolabriform to oblong-ovate, approximately 1.4 × 0.6 cm, with an acute cuspidate apex. The distal lobes are broadly dolabriform to broadly elliptic or ovate, approximately 2 × 1 cm with an acute apex. The anthers are obtuse. The capsule is pendulous, clavate and 2 to 2.5 cm long. The seeds are obovoid and rugose (www.efloras.org).

Figure 4.38: Gigantic Himalayan balsam (*Impatiens sulcata*) (© Photo: www.topicstock.pantip.com).

Species taxonomy

Table 4.39: Nomenclature and taxonomical status of Gigantic Himalayan balsam (*Impatiens sulcata*).

Scientific name:
Impatiens sulcata Wall. (1824)

Synonyms:
Impatiens gigantea Edgew.

Taxonomic tree (Naturalis, 2015):
Kingdom: Plantae
Phylum: Tracheophyta
Class: Spermatopsida
Order: Ericales
Family: Balsaminaceae
Genus: *Impatiens*
Species: *Impatiens sulcata*

Preferred Dutch name:
Not applicable

Preferred English name:
Gigantic Himalayan balsam

Other Dutch names:
Not applicable

Other English names:
Not applicable

Life cycle
In its native range *I. sulcata* flowers from August to September (www.efloras.org).

Reproductive capacity
No information on the reproductive capacity of *I. sulcata* could be found during the literature review.

4.12.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. sulcata* are listed in table 4.40. According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), *I. sulcata* is an H2 species meaning that it is hardy almost everywhere and withstands -15 to -20˚C minimum.

Table 4.40: Physiological conditions tolerated by Gigantic Himalayan balsam (*Impatiens sulcata*).

Parameter	Data origin	Occurrence	References
Hardiness (˚C)	Unknown	-15 to -20	Grey-Wilson (2011)

I. sulcata colonises the understorey of *Picea* forests, along waterways and shaded moist places (www.efloras.org).

4.12.3. Recorded distribution

Native range
I. sulcata's native range spans the temperate Himalayas from 2000 to 4000 m (www.efloras.org). The plant is native to China (South Xizang and South Tibet), Kashmir (India and Pakistan), Nepal and Bhutan.

Non-native range
No information on the non-native range of *I. sulcata* could be found during the literature review.

Distribution in the Netherlands and colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. sulcata* in the Netherlands.

4.12.4. Invasion process

Introduction
No information on the potential introduction pathways of *I. sulcata* to the Netherlands could be found during the literature review. A quick scan of the first 50 results of google.nl using the search term '*Impatiens sulcata* te koop' revealed no websites offering *I. sulcata* for sale to the public. However, according to Grey-Wilson (2011) and Jäger et al. (2008), this species is available via the European ornamental market.

Establishment and spread
No information on the potential for establishment and spread of *I. sulcata* in the Netherlands or climatically similar countries could be found during the literature review.

4.12.5. Environmental impact summary

Effects on environmental targets or native species
No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on biotic and abiotic properties were discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, pathogens and parasites were discovered during the literature review. *I. sulcata* is a weed of wheat (*Triticum* spp.) in Nepal (Sharma et al., 2010; Dangol, 2013).

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (such as damage to infrastructure, bank or dike stability).

4.12.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. sulcata* a 'likely' ecological risk classification the category dispersion potential or invasiveness, the species was allocated a 'unlikely' classification for the categories colonisation of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions (Table 4.41). The total ecological risk score for the species is 5 out of a maximum of 12. Therefore, *I. sulcata* is classified in the C list of the BFIS list system. However, it should be noted that this classification is associated with high uncertainty because of the lack of evidence concerning this species. The rationale for the allocated scores is given in the following paragraphs.

Table 4.41: Consensus scores for potential risks of Gigantic Himalayan balsam (*Impatiens sulcata*) in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Unlikely	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Environmental risk score		**5**

Dispersion potential or invasiveness
Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. sulcata* in the Netherlands. No information on the reproductive capacity, dispersal and potential introduction pathways of *I. sulcata* to the Netherlands could be found during the literature review. However, according to Grey-Wilson (2011) and Jäger et al. (2008), the species is available via the European ornamental market and plants. Moreover, *I. sulcata* is an H2 species meaning that it is hardy everywhere and withstands temperatures of -15 to -20˚C minimum. Therefore, the Dutch climate is unlikely to provide a barrier for the establishment of this species in the Netherlands.

In conclusion, the dispersal ability and reproduction capacity are unknown. However, it is likely that *I. sulcata* can naturally dispersal over more than 1 km per year and that the species will become locally invasive if established in the Netherlands because of strong reproduction.

Colonization of high value conservation habitats
Classification: **Unlikely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. sulcata* in the Netherlands. *I. sulcata* colonises the understorey of

Picea forests, canal banks and shaded moist places. It is normally found at altitudes between 3000 and 4000 m in its native range (Encyclopedia of Life, 2015).

In conclusion, it is unlikely that *I. sulcata* will be able to establish in high conservation value habitats in the Netherlands and cause a (potential) treat for red listed or protected species.

Adverse impacts on native species
Classification: **Unlikely**. There was no available evidence to suggest that *I. sulcata* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. There is no available evidence to suggest that *I. sulcata* could negatively impact Dutch native species through hybridisation or competition. Similarly to other *Impatiens* species, *I. sulcata* may be an important source of nectar for bumblebees and honeybees.

In conclusion, it is unlikely that *I. sulcata* will cause local changes in population abundance, growth and distribution of one or more native species if established in the Netherlands.

Alteration of ecosystem functions
Classification: **Unlikely**. *I. sulcata* is an annual species that grows to between 60 and 120 cm tall. There was no available evidence to suggest that *I. sulcata* will cause physical modification of habitats (e.g., light interception) or other effects on ecosystem functioning if it were to establish in the Netherlands.

In conclusion, it is unlikely that *I. sulcata* poses a risk for alteration of ecosystem processes and functioning in the Netherlands.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.41) in combination with the current recorded distribution in the Netherlands.

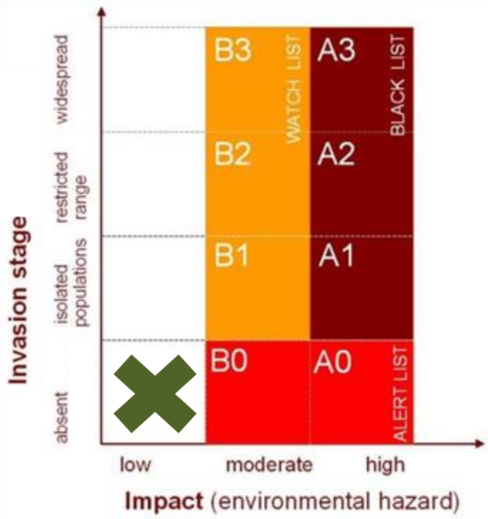

Figure 4.39: Risk classification of Gigantic Himalayan balsam (*Impatiens sulcata*) according to the BFIS list system.

The species classification for *I. sulcata* is C0 (Figure 4.39). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and should be not be placed on either the alert, watch or black list of the BFIS list system. However, note that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

4.12.7. Other risk assessments and classifications

No risk assessments or classifications of *I. sulcata* could be found during the literature review.

4.13. *Impatiens tinctoria*

4.13.1. Species description

Impatiens tinctoria is an upright perennial herb that grows to approximately 2 m tall. It develops a large tuberous rootstock that lies at or just below the soil surface. The leaves are spirally arranged, petiolate or subsessile. The petiole is 1-8(-9) cm long, rather slender, sometimes with a few short stipitate or almost sessile glands in the upper half or close to the lamina. The laminae are oblong to oblong-lanceolate to broadly ovate and 7.5-23 cm long and 2.6-9.8 cm wide and have (7-)8-12(-14) pairs of lateral veins. The leaf apex is sub-obtuse to acute; the base shortly attenuate or cuneate. The leaf margins are coarsely or finely crenate or ± serrate. The inflorescence is a 3-7(-9) flowered raceme, rarely subumbellate with white flowers. The lower lateral petals are veined or spotted pink or purple towards the base. The inflorescence is supported by an 8.5-30 cm long upright peduncle. Flowers are 1.5 to 3.6(-4.0) cm long with rather slender pedicels, with at the base 0.6-1.1 cm long, oblong to ovate bracts (Figure 4.40). The lateral sepals are 0.6-1 cm long and 0.4-0.7 cm wide, ovate or oblong, shortly acuminate. The lower sepal is 12-25 mm long at the mouth, 2-18 mm deep, shallowly and obliquely navicular or funnel-shaped, abruptly or more or less gradually constricted into a 3-13 cm long, curved filiform spur, slightly swollen at the tip. The dorsal petal is 1.7 to 2.2 cm long and 1 to1.4 cm wide, cucullate, shallowly crested dorsally, the crest terminating into a short acute point. The lateral united petals are 2.2 to 5.5 cm long; the upper petal of each pair very reduced, measuring 0.6-1.5 x 0.2-0.5 cm; the lower petal measures 1.8-5 x 1.6-4.6 cm, ± orbicular or transversely oblong, with an emargination along the inner margin towards the top. The ovary is glabrous. The fruit is 3.2-4 cm long, narrowly clavate, short beaked (Grey-Wilson, 1980b; African Plant Database, 2015).

Figure 4.40: *Impatiens tinctoria*. (© Photo: Wikimedia, peganum).

According to Grey-Wilson (1980b), *I. tinctoria* is a variable species distributed from central Africa to east and north east Africa. Five more or less clearly defined subspecies can be distinguished on the basis of leave shape, spur length and the length of the lateral united petal. The five subspecies are geographically isolated.

Impatiens tinctoria subsp. *tinctoria*: Ethiopia, Sudan, Uganda, Zaire
Impatiens tinctoria subsp. *elegantissima*: Kenya, Uganda
Impatiens tinctoria subsp. *abyssinica*: Ethiopia
Impatiens tinctoria subsp. *latifolia*: Tanzania, Malawi, Zambia
Impatiens tinctoria subsp. *songeana*: Tanzania

The subspecies *elegantissima* is probably the only subspecies in cultivation. These cultivated plants probably originate from Kenya (Mount Elgon).

Species taxonomy

Table 4.42: Nomenclature and taxonomical status of *Impatiens tinctoria*.

Scientific name: *Impatiens tinctoria* A. Rich. (1847) **Synonyms:** *Impatiens flagellifera* Hochst. ex A.Rich.; *Impatiens brachycentra* Kar. & Kir.; *Impatiens flemingii* Hook. f. **Taxonomic tree (Naturalis, 2015):** Kingdom: Plantae Phylum: Tracheophyta Class: Spermatopsida Order: Ericales Family: Balsaminaceae Genus: *Impatiens* Species: *Impatiens tinctoria* **Preferred Dutch name:** Not applicable **Preferred English name:** Not applicable **Other Dutch names:** Not applicable **Other English names:** Not applicable

Life cycle
All *I. tinctoria* growth above ground is killed by frost, but it reappears vigorously in spring. Flowers appear in about June, followed by a lull in flower production in the heat of summer, then a vibrant show through September and October. Unlike most *Impatiens* species, *I. tinctoria* does not spread by seeds in England.

Reproductive capacity
No information on the reproductive capacity of *I. tinctoria* could be found during the literature review.

4.13.2. Habitat summary

The physiological conditions found during the literature review and tolerated by *I. tinctoria* are listed in table 4.43. According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), *I. tinctoria* is classified as an H5 or G1 species meaning that it withstands temperatures of 0 to -5˚C (H5) or needs a cool glasshouse even in south Europe (G1). The precautionary principle was applied in this case and it was assumed that the seeds of *I. tinctoria* are able to tolerate Dutch winters.

Table 4.43: Physiological conditions tolerated by *Impatiens tinctoria*.

Parameter	Data origin	Occurrence	References
Hardiness (˚C)	Unknown	0 to -5	Grey-Wilson (2011)

In its native range, *I. tinctoria* grows in damp, generally shaded places. It is found in rain forests, at forest edges, in shrub filled gullies, at stream margins, on shady banks, hill slopes, swampy or marshy sites and grassy scrub. The plant grows at an altitude of 750 to 3630 metres in its native range (African Plant Database, 2015).

4.13.3. Recorded distribution

Native range
I. tinctoria is native to East Africa (African Plant Database, 2015).

Non-native range
I. tinctoria has been recorded in Ireland where it had been able to survive a few winters. The above ground portions of the plant died in freezing conditions. However, the root tuber, which can grow to the size of a football, survived (Van de Kaa, 2012).

Distribution in the Netherlands and colonisation of high conservation value habitats
According to the Nationale Databank Flora en Fauna (2015), there are no current records of *I. tinctoria* in the Netherlands.

4.13.4. Invasion process

Introduction
No information on the potential introduction pathways of *I. tinctoria* to the Netherlands could be found during the literature review. A quick scan of the first 50 results of google.nl using the search term ‘*Impatiens tinctoria* te koop’ revealed no websites offering *I. tinctoria* for sale to the public. However, according to Grey-Wilson (2011) and Jäger et al. (2008), this species is available via the European ornamental market.

Establishment and spread
No information on the potential for establishment or spread of *I. tinctoria* in the Netherlands or climatically similar countries could be found during the literature review.

4.13.5. Environmental impact summary

Effects on environmental targets or native species
No recorded impacts resulting from parasitism, competition, interbreeding and hosting pathogens and parasites were discovered during the literature review.

Effects on ecosystem function targets
No recorded impacts on were biotic and abiotic properties discovered during the literature review.

Effects on plant targets in cultivation systems
No recorded impacts resulting from parasitism, competition, interbreeding, cultivation systems, pathogens and parasites were discovered during the literature review.

Effects on animal health and production targets
No recorded impacts resulting from parasitism, toxicity or pathogens and parasites were discovered during the literature review.

Human targets
No recorded impacts resulting from toxicity or pathogens and parasites were discovered during the literature review.

Effects on other targets
No recorded impacts on other targets were discovered during the literature review (e.g., damage to infrastructure, bank and dike stability).

4.13.6. Ecological risk assessment with the ISEIA protocol

The expert team allocated *I. tinctoria* a 'likely' ecological risk classification in the section of the ISEIA protocol focussing on dispersion potential or invasiveness, the species was allocated an ‘unlikely’ risk classification in the sections colonisation of high value conservation habitats, adverse impacts on native species and alteration of ecosystem functions (Table 4.44).

Table 4.44: Consensus scores for potential risks of *Impatiens tinctoria* in the current situation in the Netherlands, using the ISEIA-protocol.

ISEIA section	Risk	Consensus score
Dispersion potential or invasiveness	Likely	2
Colonization of high value conservation habitats	Unlikely	1
Adverse impacts on native species	Unlikely	1
Alteration of ecosystem functions	Unlikely	1
Environmental risk score		**5**

The total ecological risk score for the species is 5 out of a maximum of 12. Therefore, *I. tinctoria* is classified in the C list of the BFIS list system. However, it should be noted that this classification is associated with high uncertainty because of the lack of evidence concerning this species. The rationale for the allocated scores is given in the following paragraphs.

Dispersion potential or invasiveness
Classification: **Likely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. tinctoria* in the Netherlands. However, Grey-Wilson (2011) and Jäger et al. (2008) state that the species is available via the European ornamental market suggesting that future introductions to the Netherlands cannot be rules out.

According to the climate codes of the European Garden Flora (Grey-Wilson, 2011), *I. tinctoria* is an H5 to G1 species meaning that it is hardy in favourable areas and withstands temperatures of 0 to -5˚C, or needs a cool glasshouse even in southern Europe. In England, *I. tinctoria* appears to survive the winter months. In this country all growth above ground dies back as a result of frost, but the plant reappears and grows vigorously in spring. Moreover, in Ireland *I. tinctoria* has been able to survive a few winters. Here, the above ground portions of the plant also dies back in freezing conditions, however, the root tuber, that can grow to the size of a football, survives (Van de Kaa, 2012). Therefore, the Dutch climate may well be suitable for the establishment of this species.

No information on the reproductive capacity or dispersal potential of *I. tinctoria* to the Netherlands could be found during the literature review. However, it has been reported that *I. tinctoria* does not spread itself by seeds in England.

In conclusion, the dispersal ability and reproduction capacity of *I. tinctoria* are unknown. However, it is likely that the species can naturally disperse more than 1 km per year and the species may become locally invasive if established in the Netherlands because of strong reproduction.

Colonization of high value conservation habitats
Classification: **Unlikely**. According to the Nationale Databank Flora en Fauna (2015) there are no current records of *I. tinctoria* in the Netherlands. *I. tinctoria* generally prefers shaded places. It is found in rain forests, at forest edges, in shrub filled gullies, at stream margins, on shady banks, hill slopes, swampy or marshy sites and grassy scrub. The plant grows at an altitude of 750 to 3630 meters in its native range (African Plant Database, 2015).

In conclusion, it is unlikely that *I. tinctoria* will be able to establish in high conservation value habitats in the Netherlands and cause a (potential) treat for red listed or protected species.

Adverse impacts on native species
Classification: **Unlikely**. There was no available evidence to suggest that *I. tinctoria* is a parasitic plant and there were no records found that suggested that the plant carries parasites and diseases that may impact native species in the Netherlands. There is no available evidence to suggest that *I. tinctoria* could negatively impact Dutch native species through hybridisation or competition. Similarly to other *Impatiens* species, *I. tinctoria* may be an important source of nectar for bumblebees and honeybees.

In conclusion, it is unlikely that *I. tinctoria* will cause local changes in population abundance, growth and distribution of one or more native species if established in the Netherlands.

Alteration of ecosystem functions
Classification: **Unlikely**. *I. tinctoria* is an upright perennial herb that grows to a height of approximately 200 cm. There was no available evidence to suggest that *I. tinctoria* will cause physical modification of habitats (e.g., light interception) or other effects on ecosystem functioning if it were to establish in the Netherlands.

In conclusion, it is unlikely that *I. tinctoria* poses a risk for alteration of ecosystem processes and functioning in the Netherlands.

Risk classification according to the BFIS list system
The risk classification according to the BFIS list system is determined by combining the risk score in accordance with the ISEIA protocol (Table 4.44) in combination with the current recorded distribution in the Netherlands. The species classification for *I. tinctoria* is C0 (Figure 4.41). This characterises a non-native species that is absent from the area under assessment, poses a low ecological risk and should be not be placed on either the alert, watch or black list of the BFIS list system.

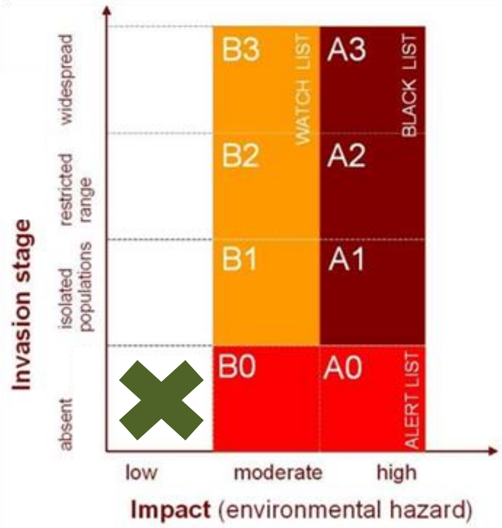

Figure 4.41: Risk classification of *Impatiens tinctoria* according to the BFIS list system.

Note that all risk scores are based on expert judgement due to lack of data. Therefore, periodical reviews of new literature and updates of the risk scores for this species are recommended.

4.13.7. Other risk assessments and classifications

No risk assessments or classifications of *I. tinctoria* could be found during the literature review.

5. Risk classifications for the Netherlands

Table 5.1 gives an overview of all risk scores and risk classifications for the assessed *Impatiens* species. These risk assessments have been performed for the current situation.

Table 5.1. Overview of risk classifications of *Impatiens* species for the current situation in the Netherlands.

	Impatiens arguta	*Impatiens balfourii*	*Impatiens balsamina*	*Impatiens capensis*	*Impatiens edgeworthii*	*Impatiens flanaganae*	*Impatiens glandulifera*	*Impatiens pallida*	*Impatiens parviflora*	*Impatiens parviflora x balfourii*	*Impatiens scabrida*	*Impatiens sulcata*	*Impatiens tinctoria*
1.Dispersion potential or invasiveness	**2**	**2**	**2**	**3**	**2***	**2***	**3**	**2**	**3**	**2***	**2**	**2***	**2***
2. Colonisation of high conservation value habitats	**2***	**3[a]**	**1***	**3**	**2***	**1***	**3**	**2***	**3**	**2***	**2***	**1***	**1***
3.Direct or indirect adverse impacts on native species	**2***	**2***	**1**	**2**	**3**	**1***	**3**	**2***	**2**	**1***	**2***	**1***	**1***
3.1. Predation/herbivory	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3.2. Interference or exploitation competition	2	2	1	2	3	1	3	2	2	1	2	1	1
3.3. Transmission of parasites and diseases	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	NR	NR	NR
3.4. Genetic effects (hybridisation / introgression with natives)	NR	NR	NR	2	NR	NR	NR	NR	NR	NR	NR	NR	NR
4. Direct or indirect alteration of ecosystem functions	**2**	**2***	**1**	**1**	**2**	**1***	**3**	**2***	**1**	**1***	**2***	**1***	**1***
4.1. Modification of nutrient cycling or resource pools	1	1	1	1	1	1	2	1	1	1	1	1	1
4.2. Physical modifications of habitat	2	2	1	1	2	1	3	2	1	1	2	1	1
4.3. Modification to natural succession	1	1	1	1	2	1	2	1	1	1	1	1	1
4.4. Disruption to food webs	1	1	1	1	1	1	1	1	1	1	1	1	1
												1	1
Total score	**8***	**9***	**5***	**9**	**9***	**5***	**12**	**8***	**9**	**6***	**8***	**5***	**5***
Range of spread	**Absent**	**Wide spread**	**Absent**	**Wide spread**	**Absent**	**Absent**	**Wide spread**	**Absent**	**Wide spread**	**Absent**	**Isolated**	**Absent**	**Absent**
Risk Classification	**C0**	**B3**	**C0**	**B3**	**B0**	**C0**	**A3**	**C0**	**B3**	**C0**	**C1**	**C0**	**C0**

NA: not applicable; NR: no records; *: risk score based on best professional judgement, due to lack of data; [a]: quantitative analysis was focused on Natura 2000 area and indicated a lower score, however, this species occurs also in other areas with high conservation value.

Ecological risk categorisation: High risk; Medium risk; Low risk

I. glandulifera received the highest risk score of all the *Impatiens* species assessed receiving a maximum of 12 out of 12 points for (potential) ecological risk in the Netherlands. This species was the only species to be classified as high risk under the BFIS system. Four other species were classified as medium risk (*I. balfourii*, *I. capensis*, *I. edgeworthii* and *I. parviflora*). Eight species were classified as low risk (*I. arguta*, *I. balsamina*, *I. flanaganae*, *I. pallida*, *I. parviflora* x *balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*). However, it should be mentioned that many scores of these species for risk criteria were determined by best professional judgement, due to data limitations (Table 5.1; indicated with *). This approach is inherently associated with high uncertainty in the total risk score of species and may have caused an underestimation of their risk classification (see section 8.4).

It is interesting to note that all but one of the species classified as low risk are currently not recorded in the Netherlands. Four out of five medium and high risk species are recorded as widespread in the Netherlands. Only *I. edgeworthii* is classified as a medium risk species whilst being anything other than widespread in the Netherlands.

The highest scoring species for the categories ‘dispersion potential or invasiveness’ and ‘colonisation of high conservation value habitats’ were *I. glandulifera*, *I. parviflora*, *I. capensis* and *I. balfourii* (total scores of five or six out of a maximum of six for both categories combined).

The highest scoring species for the categories direct or indirect adverse impact on native species and direct or indirect alteration of ecosystem functions were *I. glandulifera* and *I. edgeworthii.*

6. Management options

Combating the introduction of invasive plant species involves a number of stages that should be applied in order. The first stage involves the prevention of spread of the species across international borders. The second stage involves the prevention of the release of plants to the natural environment from isolated locations such as gardens and parks, by accident or deliberately. The third stage involves the prevention of dispersal via mechanisms such as hydrochory or human vectors such as the machinery or vehicles used in nature management. If prevention measures fail then a number of options found during the literature study are available to eradicate or control *Impatiens* species (Table 6.1). A description of the available methods relevant to the management of *Impatiens* species found given in the following paragraphs.

Table 6.1. Summary of potentially effective management options for *Impatiens* species.

Approach	**Management type**	**Examples**	**References**
Prevention	Prevention of trade	(International) voluntary codes of conduct or blanket sales ban.	Verbrugge et al. (2014)
	Land management	Maintaining traditional forms of land use	EPPO (2015a,b)
	Public awareness campaigns	Leaflets, press releases, notice boards and information websites	Caffrey & O'Callaghan (2007)
Eradication / control	Biocontrol agents	Rust fungus (*Puccinia komarovii* var. *glanduliferae*)	Tanner et al. (2015)
	Herbicides	2,4-D and triclopyr; non-selective herbicides (e.g.. glyphosate)	EPPO (2015a,b)
	Mechanical	Cutting, mowing	Coombe (1956); Beerling & Perrins (1993); Dawson & Holland (1999); Cockel & Tanner (2011); EPPO (2015a,b)

6.1. Prevention of introduction and spread

Initial introductions of *Impatiens* species to Europe has been attributed to the international plant trade. For example, KPR gardeners shop (http://www.kpr-eshop.eu/en/) represents an international network of seed and plant collectors who will collect and send seeds and plants to order from a variety of countries. The website is available in multiple languages including Dutch. The organization was set up in 1998, has its head office in Slovakia, and has six main branches (Slovakia, the Czech Republic, Australia, India, Thailand, South Africa and Tanzania) and over 400 co-operators and seeds collectors all over the world. They are able to collect 10,000 plant species and are able to deliver plants and seeds of *I. parviflora, I. balfourii*, *Impatiens balsamina*, *I. glandulifera*, *I. noli-tangere* and *Impatiens scabrida* to the Netherlands. International co-operation with regard to the prevention of the cross-border trade in non-native species is vital in the prevention of further introductions of non-native species. Voluntary codes guiding stakeholders in the sale of potentially invasive plants may be effective in the prevention of introduction. An attempt to introduce a voluntary code of conduct in an effort to prevent the trade of invasive aquatic plants was introduced in the Netherlands in 2010. Potentially invasive plants are allocated to one of two lists. List one species should not be sold in the Netherlands. List two species should only be sold when accompanied with a warning about their invasiveness (Verbrugge et al., 2014). Awareness leaflets, press releases, information boards and websites, warning of the environmental, economic and social hazards posed by non-native plants will contribute to public awareness (Caffrey & O'Callaghan, 2007). The ability of some *Impatiens* species e.g., *I. glandulifera*, to disperse widely by hydrochory, across international borders, further emphasises this need. In addition, the maintenance of traditional forms of land-use in grasslands may prevent *Impatiens* establishing (EPPO, 2015a).

6.2. Eradication and control measures

6.2.1. Management approaches

Once established, eradication of *I. glandulifera* from large areas is not considered feasible. However, control is advisable in certain situations, e.g., nature reserves (EPPO, 2015a). Caution should be exercised as non-native species may increase their abundance more strongly than native species when *I. glandulifera* is removed leading to an increased relative abundance of non-native species at managed sites (Hulme & Bremner, 2006; EPPO, 2015a). Moreover, the effectiveness of removal has been questioned due to the ability of *I. glandulifera* seeds to disperse downstream in rivers resulting in re-invasion (Hejda, 2009). Removal should be continued for at least two seasons due to the ability of *I. glandulifera* seeds to remain viable for up to 18 months (Beerling & Perrins, 1993). An integrated approach on a river catchment scale should be implemented to maximise control while minimising environmental side-effects. Management of species that spread primarily by hydrochory should occur from an upstream to downstream direction to prevent re-invasion (Cockel & Tanner, 2011). Effective control necessitates several years of monitoring and adaptive management (Cockel & Tanner, 2011; Q-bank, 2015c).

6.2.2. Manual and mechanical measures

Mowing and grazing may be successful in eliminating *I. glandulifera*. Moreover, there is no evidence to suggest that *I. parviflora* would withstand cutting or mowing. Control may be maximised by preventing the plants from flowering and fruiting (Dawson & Holland, 1999). Seed production can be minimised by applying mechanical control when plants are in flower or beginning to flower before seed-set. However, simple cutting early in the season will result in plant re-growth and the plants will still produce flowers (Cockel & Tanner, 2011; EPPO, 2015a). Repeated clearance every two weeks will ensure that plants do not set seed and late germinating plants will not mature (Beerling & Perrins, 1993). In smaller stands, hand-held cutters may be used in place of mowers (Coombe, 1956; EPPO, 2015a). However, regular cutting is extremely labour intensive and expensive and other authors have suggested that complete uprooting of plants in April or May followed by local composting will yield greater benefits, allowing other species to recolonise the area (Cockel & Tanner, 2011).

6.2.3. Biological measures

The rust fungus *Puccinia komarovii* var. *glanduliferae* may be effective in controlling *I. balsamina* in its non-native range (Tanner et al., 2015). The rust fungus was first observed infecting *I. glandulifera* in its native range in 2006 and 2010. Following evaluation as a classical biocontrol agent, only *I. balsamina* was found to be fully susceptible to urediniospore inoculum. A number of other species were tested for their vulnerability to rust fungus to assess its suitability as a biocontrol agent in Europe. The initial selection test plants involved closely related *Impatiens* species which was then expanded to include more distantly related species from other families of the same order as *I. glandulifera* (Ericales). Species with a similar morphology, and biochemical composition to that of *I. glandulifera* were added to the test selection. Finally, a number of 'safeguard' species, which by definition occur in similar ecological habitats to *I. glandulifera* were included in the testing process. The full test plant list comprised 75 species. A number of *Impatiens* species that are economically important to the horticultural market were represented by more than one cultivar. Native *I. noli-tangere* was represented by two distinct populations originating from different locations in the United Kingdom. Of the 74 non-target plant species tested, only *I. balsamina* was consistently and fully susceptible to the rust. One replicate of *I. scabrida* was weakly susceptible, whilst the other replicates showed necrotic spotting only. Five other *Impatiens* species were resistant in that, following spore germination and penetration, internal hyphal development was halted. The remaining 68 plant species were immune to the rust. The authors concluded that the rust fungus poses no threat to native biodiversity within EU Member States according to a pest risk assessment (Tanner et al., 2015). However, it would be impossible to consider the entire native European flora in any test of a new biocontrol agent. Therefore, unexpected susceptibility of other species to rust fungus not considered in this study cannot be ruled out.

No examples of the biological control of *I. parviflora* are available, however in Europe, slugs, snails and 13 insect taxa feed on *I. parviflora*. Included on this list are nine polyphagous and 4 oligophagous species, both formerly restricted to native *I. noli-tangere*, and the oligophagous *Impatientinum asiaticum*, an aphid imported from the native range of *I. parviflora* and, according to Schmitz (1997), limited to *Impatiens* species only.

Slugs and *I. asiaticum* are thought to limit *I. parviflora* to the greatest extent. A number of phytopathogenic fungi are associated with *I. parviflora* in central Europe; among these are two Uredinales species (*Puccinia argentata* and *P. komarovii*), two Sphaeropsidales species (*Ascochyta impatientis* and *Phyllosticta impatientis*) and one Erysiphales species (*Sphaerotheca balsaminae*). These species are also associated with *I. noli-tangere*, only *P. komarovii* is specific to *I. parviflora* (Schmitz, 1997). *P. komarovii* has spread from *I. parviflora's* native range to Europe where it was first recorded in Ukraine in 1921, then in Germany in 1935, in Switzerland in 1938, Slovakia in 1942 and the Netherlands 1986, travelling consistently westward. *Puccinia komarova* is commonly found on *I. parviflora* in the Netherlands (http://www.natuurbericht.nl/?id=8913). In general *P. komarova* has little apparent impact but has been repeatedly observed to eliminate entire *I. parviflora* populations (Eliás, 1995; Bacigálová et al., 1998; EPPO, 2015a; Weeda et al., 1987).

Larger animals such as cows, sheep and horses are known to feed on *I. glandulifera*, however, grazing on the banks of watercourses may lead to further disturbance and, during periods of seed dispersal, stimulate the release of seeds that may then be transported in water to new locations (Cockel & Tanner, 2011).

6.2.4. Chemical measures

Selective herbicides (e.g., 2,4-D and triclopyr) and non-selective herbicides (e.g., glyphosate) are suitable for controlling *I. glandulifera* (EPPO, 2015a). However caution is advised when applying herbicides around aquatic habitats (Cockel & Tanner, 2011). It has been reported that the application of herbicide while *Impatiens* spp. is flowering does not prevent the production of seeds (Hejda, 2009).

6.2.5. Management case study: South Limburg, Belgium

A pilot project carried out by the Watering De Dommelvallei (water board Dommelvallei) near Peel, Limburg (Belgium) in 2010 assessed the effectiveness of the mowing and manual weeding of *I. glandulifera* in controlling the species (Kesters & Gorissen, 2010). Firstly a survey including representatives from nature organisations and reports from local people was carried out to identify locations of *I. glandulifera* growth. The survey area was divided into three categories according to the distribution and density of *I. glandulifera*: (1) Absent - no management intervention necessary; (2) Few individuals of *I. glandulifera* present - manual removal indicated; (3) *I. glandulifera* widespread - mowing indicated.

The results of the survey recorded *I. glandulifera* on disturbed ground or areas lacking vegetation where *I. glandulifera* was dominant in the previous year. The species also occurred on ground where vegetation had been killed as a result of herbicide use. The plants were most easily identified when they germinated in early April because of their large thick cotyledons. However, it should be noted that in the Czech Republic in the mild winter of 2007, seedlings of *I. glandulifera* appeared in mid-January (H. Skálová, unpublished data; Perglova et al., 2009). Plants were more difficult to identify during the growth period of April to June because they could not be distinguished from other plants. Once the plants flowered *I. glandulifera* became far easier to identify. It was concluded that surveys should be conducted very early in the season, immediately following germination, to maximise the chances of management success. Mowing was carried out between the 22nd and 29th of June, before *I. glandulifera* flowered and was carried out using a mowing basket in areas where 50% or more of the area was colonised. Cut plants were removed from the area using large trailers. *I. glandulifera* was manually removed from inaccessible areas. In places where little or no *I. glandulifera* occurred, manual removal by cutting or pulling was judged sufficient. However, in areas where manual removal was indicated *I. glandulifera* was difficult to distinguish from other plants and these areas were also mowed. It was concluded that manual removal should occur at a much earlier stage when *I. glandulifera* can still be distinguished from other plants. It was concluded that the mowing period was well chosen, however, mowing must be carried out accurately and the vegetation cut low to the ground and removed completely. Plants that are not cut short enough or are simply crushed may recover later and produce four or more side branches. Plants that were snapped and appeared to be destroyed recovered later. Plants may also survive mowing because they are young and too small to be cut, were forgotten or missed because they were hidden between shrubs and brambles. It was recommended that the area should be checked a week after mowing to identify any plants that were not completely destroyed or were missed during the initial mowing intervention. In this case further mowing or manual intervention may be required.

A problem not predicted by nature managers was that *I. glandulifera* rapidly formed flowers from July to August meaning that rapid and regular intervention was required. The area was visually surveyed initially every fortnight and from August to September weekly because of rapid seed production during this period. A period of very intense biomass production was observed late in August. Plants observed during visual surveys were removed meaning that seed production in the managed area was rare. In total nine checks were carried out. It was concluded that these checks are vital to the level of management success.

6.3. Cost-effective management measures

In general, it is accepted that the cost of control and eradication of an invasive species once it has become established far outweighs the costs associated with prevention of introduction (e.g., Wittenburg & Cock, 2005). Once an invasive species has become established it is extremely difficult, if not impossible, to eradicate. For example, the Environment Agency estimates that it would cost £300 million (circa €420 million) to eradicate *I. glandulifera* from the United Kingdom (CABI, 2015b). Therefore, from a cost benefit point of view, prevention should always be the primary management approach in combating potentially invasive species.

The results of the workshop on cost-effective management strategies are described in the following paragraphs. Nature and water managers in the Netherlands revealed that the focus remains strongly on the management of *I. glandulifera* and that the problem of invasion by this *Impatiens* species is increasing. It was agreed that it is vital that management policy should be applied on a river catchment scale and that the different organisations and individuals responsible for the management of different land use types within the river catchment e.g., waterways, roads, railways and farming, should communicate effectively allowing a co-ordinated approach that includes all aspects of prevention and management. Moreover, effective top-down and bottom-up communication between nature managers and policy makers is vital in facilitating a rapid and cost-effective response to non-native plant invasions.

Prevention
The main vector of dispersal over long distance for *Impatiens* species is the trade in garden plants. The prevention of the selling of seeds and plants will help reduce the risk of introductions of the plant in the Netherlands. The introduction of a voluntary code of conduct that provides guidelines on which species should not be sold to the public or sold with information on their potential invasiveness is one method that may reduce the risk of non-native species introduction. Codes of conduct are aimed at the professional sector and plant growers, horticulturalists and garden centres, garden and landscape architects, garden contractors, landscapers, botanical gardens and arboreta should all be encouraged to sign. For example, the Belgian Code of conduct on invasive plants, introduced in 2013, lists both *I. glandulifera* and *I. parviflora* as plant species that should not be traded in Belgium (Halford et al., 2011). Moreover, the Belgian code requires that participants inform the regulatory body of potentially invasive plant species arriving in culture, gardens and public areas and provides guidelines on the early detection of potentially invasive plants.

Public awareness is an important component in a strategy aimed at controlling or removing an invasive species. This is especially true of ornamental species such as *Impatiens* where human mediated dispersal may occur accidentally as a result soil contamination, transport in garden waste or attached to the roots of garden plants, or purposefully in an attempt to enrich nature. Moreover, *Impatiens* species maybe purposefully planted by beekeepers or gardeners to encourage bees and other insects that are attracted by the plants prolific nectar production. Awareness leaflets, press releases, calendars, information boards and websites warning of the environmental, economic and social hazards posed by non-native plants will contribute to public awareness. Information should be provided to beekeeping or horticulturalist interest groups recommending alternative high nectar producing native plants and informing them of the potential ecological risks posed by non-native *Impatiens* species.

Further spread *Impatiens* species that use hydrochory as a dispersal mechanism, e.g., *I. glandulifera*, may be limited by focussing management interventions on the removal of plants growing within a riparian zone of circa 15 m of flowing water.

Monitoring

Nature organisations may facilitate the early identification of non-native species establishing in their management area by a) identifying priority species through risk assessment, b) encouraging early recognition by training field staff, c) registering incoming notifications from third-parties, d) registering any new records in a central registration database. Moreover, new *Impatiens* stands may be identified in the Netherlands by consulting www.waarnemingen.nl, a website that is openly accessible, allowing both members of the public and professionals to record the locations of any species sighted in the Netherlands. The record may then be verified by posting a picture of the species identified. Volunteers may also provide information to nature managers on new locations after being trained in the identification of *Impatiens* species. It is good practice to document the impact that *Impatiens* has on the surrounding native vegetation as limited information is available on the effect of *Impatiens* on (Dutch) native species.

Management and elimination

Control measures will only be effective if seed setting is prevented. Seeds remain fertile for up to 18 months and the plant itself is an annual, which means that elimination within two growing seasons is theoretically possible. When removing species spread via hydrochory e.g., *I. glandulifera*, management interventions should begin at locations highest up in the river catchment and then progress downstream to prevent the recolonization of areas previously cleared of *Impatiens*. It is vital to remove all individuals as the seed formation of a single plant can be enough to completely nullify management efforts.

Mechanical (mowing) and manual removal are the most cost-effective methods for the management or elimination of *Impatiens* species and this is reflected in the widespread application of this type of management practice in the Netherlands, Belgium, France and the United Kingdom. Mechanical and manual removal should be carried out in June or July in the Netherlands prior to the development of flowers to prevent seed spread. Mowing is an effective method for eliminating *Impatiens* but should occur as close to the ground as possible to prevent further flowering and regrowth. Particular attention should be focussed on identifying plants that have been flattened or not entirely cut during mowing as these individuals will likely recover and form the basis for new stands. However, mechanical methods are only effective at locations where accessibility is guaranteed and damage to native fauna and flora does not outweigh the benefits of *Impatiens* removal. Often, mowing machinery may be to large or heavy to access locations between trees and on the banks of river and streams. Only manual methods are effective at these locations. Manual removal is more labour intensive than mowing but can be performed accurately, ensuring all plants are removed. Plant removal is relatively easy as the root system of *Impatiens* is shallow and not extensive, and it is only necessary to remove the large roots directly attached to the stem to prevent regrowth. However, it is vital that stems are completely broken in two before disposal (Figure 6.1). If this is not done, the plant may still re-root and recover, particularly if the soil is not completely dry. Moreover, it is important to ensure that enough people are present to thoroughly complete the removal of all plants. At locations of large coverage (> approximately 50 m^2) initial mowing has to be undertaken followed by the manual removal of plants to ensure effective removal. Cuttings may be left in the field in dry weather when the soil is also dry, however, plants should be removed in damp conditions to prevent re-rooting. In this case, entire plants may be hung over tree branches to avoid contact with the soil and facilitate drying. Plant cuttings left on the ground may inhibit germination of *Impatiens* seeds by blocking sunlight and forming a mechanical barrier.

Figure 6.1: Correct manual removal of Himalayan balsam (*I. glandulifera*) including complete breaking of the stem (Photo: E. Boer, NVWA, www.q-bank.eu).

Volunteers are potentially more effective than professionals in the effective removal of *Impatiens* if properly trained and supervised. The only instance when a professional is more effective than a volunteer is when mowing is required. Moreover, volunteers will possibly continue their work independently in future, removing *Impatiens* during recreational activities and informing nature managers of potential new *Impatiens* stands. Whether professionals or volunteers are used in the control of *Impatiens* species, clear, step by step instructions should be provided prior to any intervention to maximise management success.

Grazing is of limited benefit as most grazers will consume other plants before eating *I. glandulifera.* Therefore grazing will only be effective in locations where other plant species are rare or absent. However, sheep may be effective at controlling *I. glandulifera* as they crop vegetation very closely to the ground and may not be as selective as other grazers.

Currently, research is being carried out in the United Kingdom on potential biological measures for managing *Impatiens* species. However, no information was available concerning the results of these trials. Therefore, no recommendation for biological control can be made.

Chemical control is an effective control method, but must be carried out carefully in order to treat all plants. Chemical control should be carried out in spring, when the plants develop flower buds, but before seed formation to prevent the seed ripening after the plant is treated. However, chemical control is not recommended as mechanical and manual removal are effective and do not feature the potentially damaging side effects associated with herbicide use.

It is vital that repeated checks are made following efforts to remove *Impatiens* species, particularly during the growing season. *Impatiens* may re-establish if the plant stems are not properly destroyed. Moreover, small plants are easily missed, particularly if they are hidden by other plant species. Certain *Impatiens* species, e.g., *I. glandulifera*, disperse highly effectively by hydrochory. Therefore it is important to apply a river catchment wide approach during monitoring, focusing on areas where *Impatiens* is likely to establish such as river banks and floodplains. For example, if an upstream stand of *I. glandulifera* is identified, downstream locations, particularly disturbed areas, should also be checked for the presence of the plant.

Other potential barriers to the effective control of Impatiens species are 1) Lack of access to private land resulting in incomplete removal of plant stands from the managed area; 2) Nature or river rehabilitation projects that do not incorporate a non-native species assessment at the planning stage resulting in new invasion pathways that facilitate the spread of *Impatiens* species.

7. Interactive key in Q-bank

The 13 *Impatiens* species assessed in this report have been integrated into an electronic identification key on invasive terrestrial plants. Currently, the electronic identification key is published on Q-bank, a web database for phytosanitary organisations for non-native species identification and information (see Q-bank). Moreover, Q-bank holds electronic identification keys on invasive aquatic plants, on weeds imported with pot-plants, on the seeds of invasive plants and on the seedlings of invasive plants.

The invasive terrestrial plants key is based on an information matrix which is queried by the user for the presence of (numerical) species characteristics. The key is a so called "multiple-entry key" meaning that observed characteristics can be marked and the key immediately displays results relating to those characteristics. This allows users to obtain results with a minimum of inputs reducing search time. The key is image-driven, meaning that all characteristics are illustrated to assist users who are unfamiliar with some or all technical (botanical) terms.

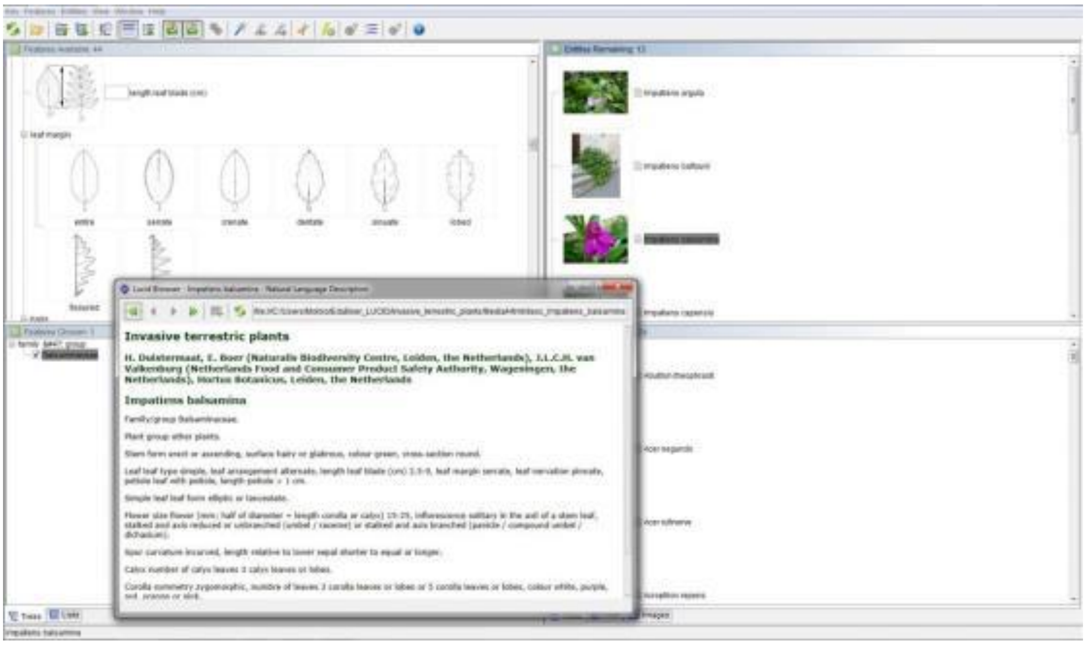

Figure 7.1: Invasive terrestrial plants key interface illustrating detailed species descriptions of Common garden balsam (*Impatiens balsamina*) (Q-bank, 2015).

The keys are developed using the software package LucidBuilder (see: http://www.lucidcentral.org/). This software allows the developers 1) to add pictures or drawings to descriptions of characteristics and species, 2) to add particular characteristics for specific groups of plants, and 3) to produce a text version of species characteristics for consultation by users (Figure 7.1). Users are provided with an easy-to-use interface, accessible via an internet browser. The key provides recommendations to the user that suggest which characteristics discriminate best between species displayed as a result of a search query. Additional information on the characteristics illustrated can be obtained by clicking on the line drawing (Figure 7.2). Species are all illustrated using multiple photographs showing the most important and/or discriminative characteristics of that species (Figure 7.3 & 7.4).

In summary, the electronic identification key provides the user with the ability to:

- Mark characteristics as soon as they are observed;
- Identify characteristics by name or by illustration;
- Obtain suggestions on the best, second best, etc. characteristic to identify next;
- Remove redundant characteristics;
- See all photographs for a particular species;
- Check the description of characteristics.

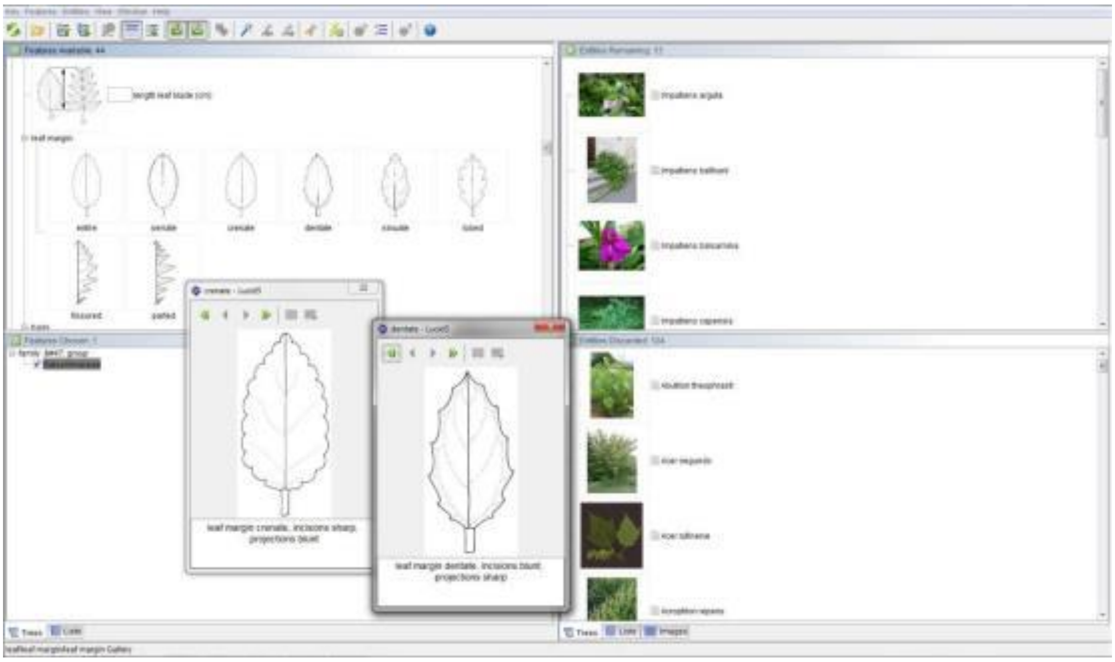

Figure 7.2: Invasive terrestrial plants key interface illustrating leaf characteristics with detailed descriptions, species exhibiting the marked characteristics and discarded species (Q-bank, 2015a).

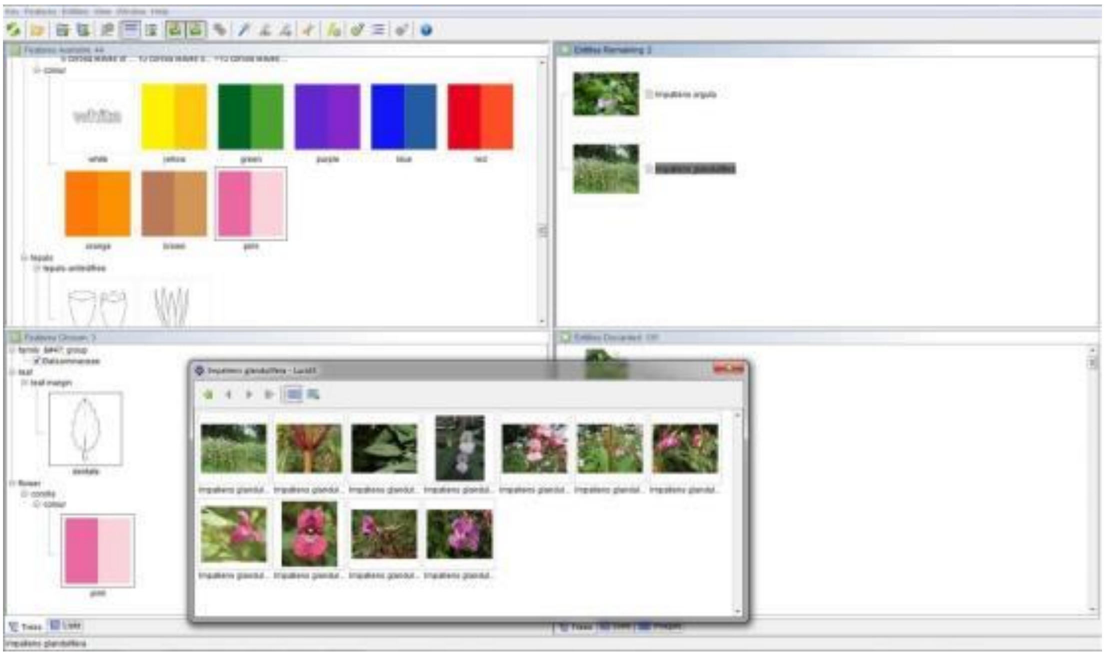

Figure 7.3: Invasive terrestrial plants key interface displaying photos of the key characteristics of Himalayan balsam (*Impatiens glandulifera*) (Q-bank, 2015c).

Figure 7.4: Invasive terrestrial plants key interface displaying a high quality photo of Balfour's touch-me-not (*Impatiens balfourii*) in flower (Q-bank, 2015a).

8. Discussion

8.1 Introduction and spread

It should be noted that lag times between introduction and establishment of non-native species can be considerable, even for herbaceous species. For example, the lag time for *I. glandulifera* was 40 years in central Europe (Pysek & Prach, 1995).

8.2 Potential risks

The results of the ranking of the ISEIA risk classifications for a number of the *Impatiens* species examined in this project are generally confirmed in literature by competition studies. However, this can only be concluded for the most widely studied species. For example, Skalova et al. (2013) state that *I. glandulifera* and *I. parviflora* are the strongest competitors, the native species *I. noli-tangere* is the weakest, and the potentially invasive species *I. capensis* is intermediate between the invasive and the native species. For example, *I. glandulifera* competiveness and affinity for shading appeared to result in a shift of the realised niche of both *I. noli-tangere* and *I. parviflora* into more-shaded areas in the Czech Republic. *I. glandulifera* appears to exhibit traits that result in a higher competitive ability than other *Impatiens* species. For example, *I. glandulifera* germinates early in some years allowing it to efficiently colonise space during population development, and has a greater tolerance to frost than *I. parviflora* (Perglova et al., 2009; Skalova et al., 2013). Moreover, *I. glandulifera* appears to have a greater reproductive capacity than other *Impatiens* species. In a garden experiment comparing *Impatiens* species carried out by Perglova et al. (2009), *I. capensis* was the only species that recorded a similarly high germination to *I. glandulifera*.

However, the risk classifications do not reflect that when in competition with each other, *I. parviflora* may be a stronger competitor than *I. capensis* and native *I. noli-tangere* under all conditions; and *I. glandulifera* under conditions of low soil moisture (Skalova et al., 2013). Moreover, while *I. capensis* may have a relatively high reproductive capacity, it appears to be a weaker competitor than both *I. glandulifera* and *I. parviflora* when in direct competition with these species (Skalova et al., 2013).

It should be noted that our risk categorisations reflect the potential ecological threat of *Impatiens* species to the native species and ecosystems of the Netherlands which may explain the differences seen between our risk classifications and the results of competition experiments carried out between *Impatiens* species reported in literature. Moreover, best professional judgement of species with data limitations may have caused an underestimation of risk scores and risk classifications of species (see section 8.4).

8.3 Cost-effective management strategies

In general, it is accepted that the cost of control and eradication of an invasive species once it has become established far outweighs the costs associated with prevention of introduction (e.g., Wittenburg & Cock, 2005). Once an invasive species has become established it is extremely difficult, if not impossible, to eradicate. For example, the Environment Agency estimates that it would cost £300 million (circa €420 million) to eradicate *I. glandulifera* from the United Kingdom (CABI, 2015B). Therefore, from a cost benefit point of view, prevention should always be the primary management approach in combating potentially invasive species.

The main introduction pathway of *Impatiens* species is the trade in garden plants. International co-operation with regard to the prevention of the cross-border trade in non-native species is vital in the prevention of further introductions of non-native species and legislation or voluntary national and international covenants may be effective in discouraging the sale of potentially invasive plant species within countries and across national borders. The ability of some *Impatiens* species, e.g., *I. glandulifera*, to disperse widely by hydrochory, across international borders, further emphasises the need for an international approach.

According to nature managers, poor communication and the prioritisation of tasks during budget allocation form bottlenecks that could influence the success of management interventions in the Netherlands. Barriers to cost effective management intervention include both communication between organisations responsible for different land-use types and top down, bottom up communication between nature managers working at grass roots level and management levels within water-boards. Effective communication is required to promote a coordinated and timely management response that results in the effective removal of plants from the managed area. Public and organisational attitudes to invasive plants may also form a barrier to management of potentially invasive non-native plants. In a study of attitudes towards *I. glandulifera* around Arnhem in the Netherlands it was concluded that even though management of *I. glandulifera* can be effective, no management interventions had been put in place by local government or nature organisations. The authors stated that this was because *I. glandulifera* was not seen as a damaging species and does not pose a threat to human health. *I. glandulifera* was seen as a positive addition to the local flora because the explosive seeds offer an extra nature experience for local children and the plants late blooming flowers offer nectar to insects after the flowers of other plants have died off (Brouwer & Gooijer, 2012). Moreover, *Impatiens* species may be purposefully planted by beekeepers or gardeners to encourage bees and other insects that are attracted by the plants prolific nectar production. Improved communication with the general public may, therefore, help change local attitudes towards potentially invasive species. Increased public access to information outlining the ecological, economic and social hazards posed by non-native plants will contribute to public awareness.

Lack of financial provision was highlighted as an important barrier to effective management provision by nature managers. In general, the Dutch water boards role comprises, in order of priority: safety provision (e.g., dike maintenance); water quality; and maintenance of biodiversity. Therefore, if non-native species such as *I. glandulifera* do not pose a risk to either safety or water quality (e.g., by posing a flood risk or increasing the risk of algal blooms), then their removal may not be prioritised during budget allocation. Smaller nature management organisations are often limited in their effectiveness due to budget limitation. Innovative methods of providing finance to smaller organisations are required to facilitate a coordinated and effective response to the threat of non-native species (e.g., an effective approach may be the re-allocation of funds from larger organisations responsible for land management to smaller organisations specialising in non-native species management).

8.4 Relevant gaps in knowledge and uncertainties

A lack of information in the literature on the (potential) impacts of a number of *Impatiens* species in the Netherlands has resulted in a reliance on expert knowledge and field observations to judge the level of certain impacts (best professional judgement). According to the ISEIA-protocol, the risks of such species were classified as likely or unlikely, resulting in risk scores 1 and 2, respectively, for one or more risk sections. The BFIS list-A or list-B classification of species is theoretically impossible if best professional judgement is applied for two or four risk sections, respectively (maximum total risk score is then 10 or 8 out of 12, with risk levels of 11-12 and 9-10 for black list and watch list, respectively). Therefore, best professional judgement may have caused an underestimation of risk scores and risk classifications of species. Limited data availability has inherently led to a high level of uncertainty in the risk scores for the assessment criteria 'dispersion potential or invasiveness' of *I. edgeworthii, I. flanaganae*, *I. parviflora x balfourii*, *I. sulcata* and *I. tinctoria* and for ecological effect criteria of *I. arguta, I. balfourii, I. flanaganae*, *I. pallida, I. parviflora x balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*. Data on genetic effects and transmission of diseases and parasites are lacking or scarce for nearly all species. Therefore, periodical reviews of new literature data of these species and updates of their risk scores are recommended.

Moreover, species can only be compared for characteristics such as habitat requirements and intensity of impact if sufficient information was available. Risk criteria in the ISEIA protocol were sometimes restrictive, as there was an absence of quantitative data that allowed the criteria to be assessed (e.g., for assessing the 1 km per year dispersal criterion for the 'dispersion or invasiveness' section). The broadness of the categories used in the ISEIA protocol to define the current recorded distribution of non-native species may in some instances be misleading. For example, *I. balfourii* and *I. glandulifera* can only be defined as widespread. However, *I. glandulifera* is much more widespread than *I. balfourii* in the Netherlands (Section 4.7.3., Figure 4.15; Section 4.2.3., Figure 4.4).

It should be emphasised that the search engine hits obtained via Google.nl in order to estimate the general public's access to *Impatiens* were user specific because of the way Google tailors search results to suit individuals. Moreover, search results will vary over time due to the dynamic nature of the internet. Therefore, the results of the Google.nl search should be treated only as a rough guide of online availability and is best used to compare differences between the species studied.

9. Conclusions and recommendations

9.1. Conclusions

- The risk analysis of *Impatiens* species was carried out in two stages, (1) *Impatiens* species were identified that have been recorded in Dutch nature or in the European ornamental plant trade. These species were then assessed to determine if the climate in the Netherlands is suitable for their establishment; (2) Species able to establish in the Netherlands were then assessed for (potential) ecological risk using the Belgium ISEIA protocol following a literature study. The literature study focussed on habitat requirements; the distribution, dispersal and invasion process, ecological impacts and socio-economic impacts. The results provide a ranking of ecological risk for *Impatiens* species for the Netherlands.

Survey of Impatiens species and hybrids in the Netherlands and surrounding countries

- Five non-native *Impatiens* species are recorded in the Netherlands: Balfour's touch-me-not (*I. balfourii*), orange jewelweed (*I. capensis*), Himalayan balsam *(I. glandulifera*), small balsam (*I. parviflora*) and rugged yellow balsam (*I. scabrida*). *I. edgeworthii* has recently been recorded for the first time in Germany and appears to be spreading there. A possible hybrid of *I. parviflora* and Balfour's touch-me-not (*I. balfourii*) has been identified in Switzerland. In total 18 other *Impatiens* species traded in Europe and may escape from cultivation. These are *I. arguta*, *I. auricoma*, *I. balsamina*, *I. flanaganae*, *I. gordonii*, *I. grandis*, *I. hawkeri*, *I. hochstetteri*, *I. marianae*, *I. niamniamensis*, *I. pallida*, *I. repens*, *I. sodenii*, *I. sulcata*, *I. tinctoria*, *I. usambarensis*, *I. verticillata* and *I. walleriana.*

- A shortlist of 13 of the above 24 taxa tolerate low temperature ranges from 0 to -5 ˚C up to < -20 ˚C. These species are able or expected to tolerate the Dutch climate and were assessed for ecological risk. The short list comprised the following species: *I. arguta*, *I. balfourii*, *I. balsamina*, *I. capensis*, *I. edgeworthii*, *I. flanaganae*, *I. glandulifera*, *I. pallida*, *I. parviflora*, *I. parviflora x I. balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*.

Habitat summary

- Generally, *Impatiens* species prefer shadowy, moist locations on the banks of rivers and streams, in meadows, semi-natural and disturbed locations, woodland or forest, swamps, marshes and fens.

- The principle habitat of *I. glandulifera* and *I. capensis* in Europe are riverbanks and floodplains. These species particularly have a preference for low powered streams at low altitudes with finer sediment. These species flourish where native vegetation is poorest and space is available for colonisation.

- *I. parviflora* is now the most serious invader at the margins of moist to wet temperate deciduous forests and mixed conifer forests, even in apparently undisturbed places. It is the only non-native plant being dispersed in European forests on a large scale.

- In contrast to other *Impatiens* species established in Europe, *I. balfourii* colonises open habitats with high light intensities and prefers dry to humid soil conditions.

Distribution, dispersal and invasion process

- Only limited information on the dispersion potential or invasiveness of *I. edgeworthii, I. flanaganae*, *I. parviflora x balfourii*, *I. sulcata* and *I. tinctoria* is available in literature.

- The main pathway of introduction of *Impatiens* species to the Netherlands is the International (online) trade in ornamental plants and garden escape. *Impatiens* species are popular with gardeners and often recommended to beekeepers as they are highly attractive to honeybees.

- The maximum instantaneous rate of spread of *I. glandulifera* in England has been determined to be 38 km/year, significantly faster than either *I. parviflora* (24 km/year) or *I. capensis* (13 km/year).

- All *Impatiens* species use an explosive mechanism (ballochory) to naturally disperse seeds some meters from the parent plant.

- Seeds of *I. glandulifera* are dispersed over long distances by hydrochory. Fish mediated dispersal may also contribute to the spread of this species. *I. capensis* records appear to concentrate along major waterways suggesting that hydrochory may play a role in the dispersal of this species. *I. pallida*, *I. balfourii* and *I. parviflora* are less dependent on moisture than other *Impatiens* species and seeds have a relatively low chance of being dispersed by hydrochory.

- *I. parviflora* seeds are transported on forest vehicles, machinery and in the transport of timber. Epizoochorous dispersal in animal fur and feet is an important mechanism of long-distance dispersal. Additionally, isolated observations of *I. parviflora* growing on trees indicate that birds transport seeds.

- A number of factors contribute to the wide distribution of *I. glandulifera* in the Netherlands. Frost tolerance early in the life cycle of *I. glandulifera,* a shorter time required for seed stratification, a high level of germination success and rapid growth gives it a significant advantage over other *Impatiens* species. Other characteristics that may have contributed to its establishment are its height, synchronous germination, high level of seed production, and other reproductive traits such as seed mass variation. *I. glandulifera* tolerates a wide range of nutrient levels. *I. glandulifera* biomass greatly exceeded that of *I. capensis*, *I. parviflora* and *I. noli-tangere* in both low and high nutrient conditions. Moreover, *I. glandulifera* exhibited the highest level of plasticity under low nutrient conditions (decrease in total biomass and stem height and an increased root/shoot ratio). However, high nutrient conditions led to reduced survival in *I. glandulifera*.

- It is probable that the amount of seed dispersed by people will be less in the dense woodland habitats favoured by *I. parviflora* than on the areas of river banks that are preferred by *I. glandulifera*. This may be the reason, combined with a relative vulnerability to frost, that led to the slower spread of *I. parviflora* compared to *I.*

glandulifera in the United Kingdom. In the UK, *I. parviflora* may eventually spread as widely as *I. glandulifera*, but remain less frequent due to narrower habitat requirements.

- The relatively limited non-native range of *I. capensis* could be in part attributed to its comparatively limited cultivation in Europe. Moreover, while *I. capensis* has been attributed the status of invasive species in the south and east of England, it is less successful than both *I. glandulifera* and *I. balfourii*.

- *I. balfourii* is naturalised in disturbed habitats in central and southern Europe (e.g., Switzerland), but is not considered invasive.

- In the north-eastern USA, *I. balsamina* escapes appear to be mostly restricted to gardens and other sheltered locations.

- *I. edgeworthii* is increasingly recorded as a garden escape in parts of Germany. The historical spread of *I. edgeworthii* by seed in Germany was probably facilitated by construction of forest roads.

- *I. balsamina* is classified as a subtropical species and has been in cultivation in Europe for many years. In the north-eastern USA, escapes appear to be mostly restricted to gardens and other sheltered locations. However, it is already established in many temperate areas.

Ecological impacts

- No or scarce information on the ecological impacts of *I. arguta, I. balfourii, I. flanaganae*, *I. pallida, I. parviflora x balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria* was found during the literature survey.

- *I. glandulifera* is the most competitive of all *Impatiens* species. It forms tall, dense, many branched stands, outcompeting native species for space, light, nutrients and pollinators. Changes in vegetation structure, trophic interactions and increased bank erosion and sediment entrainment may negatively impact native species. Only perennial native species with a strong vegetative propagation are able to withstand *I. glandulifera.* The competitive advantage of *I. glandulifera* may be facilitated by early germination in some years, synchronised seedling emergence, rapid growth, greater density and biomass, increase in stem height in the presence of neighbouring species.

- In dense stands, *I. parviflora* is able to monopolise light and space, excluding other plant species. The addition of a herbaceous layer in forests where vegetation was formerly absent may affect tree regeneration and consequently ecological succession. Reduction of plant species abundance and possible competition with several native forest herbaceous species has been reported in Belgium. In an experiment comparing native *I. noli-tangere* and non-native *I. glandulifera*, *I. parviflora*, and *I. capensis*, *I. parviflora* appeared to be the second strongest competitor, especially under conditions of low soil moisture. However, in Germany, Poland and the Czech Republic no impact on the diversity of native species has been recorded. Overall the biodiversity impact of *I. parviflora* seems to be limited.

- *I. balfourii* can form dense pure stands that could suppress other species by shading concluded that it is unknown whether a hazard to German native species exists. *I. balfourii* is likely to have a negative impact on the natural vegetation of ruderal or semi-natural communities.

- *I. capensis* does not form monocultures. Therefore, it is generally not classified as a problematic plant in its non-native range. While *I. capensis* is less competitive than either *I. glandulifera* or *I. parviflora*, it may competitively exclude native *I. noli-tangere* which has declined in abundance in recent years, as the niches of the native and invasive *Impatiens* species overlap to a great degree. To date, *I. capensis* and *I. noli-tangere* have rarely, if ever, co-occurred in Europe. Theoretically, *I. capensis* may be able to hybridise with *I. noli-tangere*. However, to date there is no evidence of actual hybridisation between these two species.

Socio-economic impacts

- Dense stands of *I. glandulifera* and dead plant material may impede water-flow during heavy rainfall and promote flooding. *I. glandulifera* may impact forestry by impairing natural regeneration; however, this is not proven. In the United Kingdom the Environment Agency estimates that it would cost £300 million (circa €420 million) to eradicate *I. glandulifera*.

- *I. parviflora* colonises managed forests and timber plantations and may affect tree regeneration silvicultural systems where this is important.

- *I. sulcata* is a weed of wheat (*Triticum* spp.) in Nepal.

Table: 9.1 Ecological risk scores and classification of *Impatiens* species for the Netherlands (*: Risk score and classification strongly determined by best professional judgement due to data limitations).

Species	Common name	Total risk score (ISEIA)	Distribution in the Netherlands	Risk classification (BFIS list system)
I. arguta	Not applicable	8*	Absent	C0*
I. balfourii	Balfour's touch-me-not	9*	Widespread	B3*
I. balsamina	Common garden balsam	5*	Absent	C0*
I. capensis	Orange jewelweed	9	Widespread	B3
I. edgeworthii	Not applicable	9*	Absent	B0*
I. flanaganae	Not applicable	5*	Absent	C0*
I. glandulifera	Himalayan balsam	12	Widespread	A3
I. pallida	Pale jewelweed	8*	Absent	C0*
I. parviflora	Small balsam	9	Widespread	B3
I. parviflora x balfourii	Not applicable	6*	Absent	C0*
I. scabrida	Rugged yellow balsam	8*	Isolated	C1*
I. sulcata	Gigantic Himalayan balsam	5*	Absent	C0*
I. tinctoria	Not applicable	5*	Absent	C0*

Ecological risk categorisation: High risk; Medium risk; Low risk

Risk classifications

- *I. glandulifera* received the highest ecological risk score of all the *Impatiens* species assessed receiving a maximum of 12 out of 12 points for ecological risk (Table 9.1). This species was the only species to be classified as high risk under the BFIS system. Four other species were classified as medium risk (*I. balfourii*, *I. capensis*, *I. edgeworthii* and *I. parviflora*). Eight species were classified as low risk (*I. arguta*, *I. balsamina*, *I. flanaganae*, *I. pallida*, *I. parviflora* x *balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*). The highest scoring species for the categories dispersion potential or invasiveness and colonisation of high conservation value habitats (total scores of five or six out of a maximum of six) are *I. glandulifera*, *I. parviflora*, *I. capensis* and *I. balfourii*. The highest scoring species for the categories direct or indirect adverse impact on native species and direct or indirect alteration of ecosystem functions were *I. glandulifera* and *I. edgeworthii.*

- Due to data limitation, risk scores of *Impatiens* species were often determined by best professional judgement. This approach is inherently associated with high uncertainty in total risk scores and may cause an underestimation of risk classifications.

9.2. Cost-effective management

Prevention

- Generally, the cost of control and eradication of an invasive species once it has become established far outweighs the costs associated with prevention of introduction. Once an invasive species has become established it is extremely difficult, if not impossible, to eradicate.

- The main vector of dispersal over long distance for *Impatiens* species is the trade in garden plants. The introduction of a voluntary code of conduct aimed at the professional sector that provides guidelines on which species should not be sold to the public or sold with information on their potential invasiveness may reduce the risk of non-native species introduction.

- Awareness leaflets, press releases, calendars, information boards and websites warning of the environmental, economic and social hazards posed by non-native plants will contribute to public awareness.

- *Impatiens* species are often planted by beekeepers and horticulturalist. Recommendations for alternative high nectar producing native plants and information on the potential ecological risks posed by non-native *Impatiens* species should be provided to these groups.

Monitoring

- Nature organisations may facilitate the early identification of non-native species establishing in their management area by a) identifying priority species through risk assessment, b) encouraging early recognition by training field staff, c) registering incoming notifications from third-parties, d) registering any new records in a central registration database.

Management and elimination

- Control measures will only be effective if seed setting is prevented. Seed form a single plant can be enough to completely nullify management efforts.

- As *Impatiens* often spreads by hydrochory, management interventions should begin at locations highest up in the river catchment and then progress downstream to prevent the recolonization of areas previously cleared.

- Mechanical (mowing) and manual removal are the most cost-effective methods for the management or elimination of *Impatiens* species and should be carried out in June or July in the Netherlands.

- Mowing should occur as close to the ground as possible to prevent further flowering and regrowth.

- Manual removal is more labour intensive than mowing but can be performed accurately, ensuring all plants are removed. Following manual removal, it is vital that the stem of each individual is completely broken in two before discarding them otherwise plants may re-root and recover, particularly if the soil is not completely dry.

- At locations of very large coverage (> approximately 50 m^2) initial mowing should be undertaken followed by the manual removal of plants. Particular attention should be focussed on identifying plants that have been flattened or not entirely cut during mowing as these individuals will likely recover and form the basis for new stands.

- Cuttings may be left in the field in dry weather when the soil is also dry, however, plants should be removed in damp conditions to prevent re-rooting.

- It is vital that repeated checks are made following efforts to remove *Impatiens* species. *Impatiens* may re-establish if the plant stems are not properly destroyed and small plants are easily missed. A river catchment approach should be taken during monitoring as certain *Impatiens* species, e.g., *I. glandulifera*, disperse highly effectively by hydrochory. For example, if an upstream stand of *I. glandulifera* is identified, downstream locations, particularly disturbed areas, should also be checked for the presence of the plant.

- Volunteers are potentially more effective than professionals in the effective removal of *Impatiens* if properly trained and supervised. The only instance when a professional is more effective than a volunteer is when mowing is required. Moreover, volunteers will possibly continue their work independently in future, removing *Impatiens* during recreational activities and informing nature managers of potential new *Impatiens* stands.

- Whether professionals or volunteers are used in the control of *Impatiens* species, clear, step by step instructions should be provided prior to any intervention to maximise management success.

- Grazing is of limited benefit as a management technique because most grazers will consume other plants before eating *I. glandulifera.*

- Currently, no information was available concerning the effectiveness of biological measures; therefore, no recommendation for biological control can be made.

- Chemical control is an effective control method, but must be carried out carefully in order to treat all plants. However, chemical control is not recommended as mechanical and manual removal are effective and do not feature the potentially damaging side effects associated with herbicide use.

- Other factors that may hinder the effective application of management measures are 1) not gaining access to private land resulting in the incomplete removal of plant stands; 2) other nature and river rehabilitation projects may not incorporate a non-native species assessment and facilitate the spread of *Impatiens* by creating new invasion pathways.

9.3. Recommendations for further research

- Many *Impatiens* species that were not identified for inclusion in the risk assessment process may fulfil the inclusion criteria listed in section 2.1 in future due to climate change and changes in the European trade of non-native plants. It is recommended that periodic re-assessment of the potential for establishment of non-native plant species in the Netherlands is undertaken to account for these changes.

- Traditional options for the management of *Impatiens* species appear to be compromised due to the risk of increased seed dispersal and seedling establishment as a result of disturbance and the risks associated with herbicide use near to aquatic systems. Further research could investigate pests, sediment and nutrient characteristics, native climate and other inhibitors such as the role of allelopathy in native ranges as a first step in developing innovative management techniques (Sheppard et al., 2006; Cockel & Tanner, 2011).

- Scientific knowledge on one or several assessment criteria was limited (i.e., *I. arguta, I. balfourii*, *I. balsamina, I. edgeworthii*, *I. flanaganae*, *I. pallida, I. parviflora x balfourii*, *I. scabrida*, *I. sulcata* and *I. tinctoria*). It is recommended that further research be conducted on the habitat requirements and ecological effects of these species in their native and introduced ranges.

- Periodical reviews of new literature on spread and impact of *Impatiens* species and updates of their risk assessments are recommended.

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Glossary

Term	Description
Abaxial	Situated out or directed away from the axis; the abaxial or lower surface of leaf
Acuminate	Tip of the leaf gradually tapering to a sharp point
Adaxial	Facing towards the axis, as the surface of a leaf that faces the stem
Adventitious	Plant part developing in an abnormal position, as a root that grows from a stem
Allelopathic	Secreting chemicals which suppress competitors
Allogamous	Cross fertilization
Alluvial	Holocene deposits
Anemochory	Seed dispersal by wind
Annual	Completing its life-cycle within twelve months from germination
Anther	Part of the stamen containing the pollen grains
Aphidophagous	Feeding on aphids
Attenuate	Gradually tapering
Auricles	Small ear-like projections at the base of a leaf
Autochory	Active seed dispersal by the plant itself
Axillary	Arising in the axil of a leaf or bract
Axil	(of a leaf) angle between its upperside and the stem on which it is borne; normal for lateral buds
Ballochory	Seed dispersal by shooting their seeds around
Bracteate	Having or bearing bracts
Bract	Small leaf with relatively undeveloped blade, in axil of which arises a flower or a
Carinate	Keeled (having a keel or ridge; shaped like a keel)
Chasmogamous	Outcrossing
Cleistogamous	Self-crossing and closed flowers
Clavate	Club-shaped
Cordate	Heart-shaped
Cornute-cristate	Horn-shaped, forming a crest
Corolla	The petals as a whole
Crista	Crest
Crenate	Having a scalloped margin (leaves)
Cucullate	Shaped like a hood or having a hoodlike part
Cuneate	Wedge-shaped. Used especially to describe a leaf or petal base that is narrowly
Cuspidate	A cuspidate leaf apex means in or tipped with a short firm point
Dehiscent	Opening to shed its seeds
Diurnal	Flowers open during the day and closed at night
Dolabriform	Shaped like a hatchet or axe head
Emarginate	Shallowly notched at the apex
Endozoochorous	Seed dispersal by animals via the digestive system
Epizoochorous	Seed dispersal by attaching on animals
Fecundity	The innate potential reproductive capacity of the individual organism
Filiform	Thread-like
Geitonogamy	Pollination and fertilization of one flower by another on the same plant
Glabrous	Without hairs
Glandular	Furnished with glands
Glaucous	Bluish
Globose	Spherical; globular
Hybridisation	A cross between parents, that are genetically unlike
Hydrochory	Dispersal by water
Ichthyochory	Fish-mediated seed dispersal
Introgression	Infiltration of genes of one species into genotype of another
Invasive species	Non-native species which spread quickly and are dominating in newly colonized areas
Lamina	The blade of a leaf or petal
Lanceolate	Shaped like the head of a lance, tapering from a rounded base towards the apex
Mucronate	Ending abruptly in a short point or mucro
Mycorrhizae	‘Fungus root’; an association of a fungus with the roots of a higher plant
Navicular	Shaped like a boat
Non-native	Species not native, originating from elsewhere
Oblong-dolabriform	Elongated with approximately, parallel sides, see dolabriform

Obovate	An egg-shaped leaf with narrow end at the base
Obovoid	See obovate
Obtuse	Blunt
Orbicular	Rounded, with length and breadth about the same
Ovate	Egg-shaped
Ovule	A structure containing the egg and developing into the seed after fertalization
Pedicel	Stalk of a single flower
Peduncle	Stalk of a inflorescence or partial inflorescence
Pedunculate	Having or supported on a peduncle
Pendulous	Hanging downwards
Perennial	Living for more than two years and usually flowering each year
Petaloid	Brightly coloured and resembling petals
Petiolate	With stalks, stalked
Petiole	Stalk of a leaf
Protandrous	Anthers maturing before carpels
Pubescent	Shortly and softy hairy
Raceme	Unbranched racemose inflorescence in which the flowers are borne on pedicels
Rostellum	Sterile modified stigmatic lobe
Ruderal	Plant living in waste places near habitations
Rugose	Wrinkled
Saccate	Pouched
Sepals	A number of outer series of perianth leaves, especially when green and leaf-like
Sessile	Without a stalk
Setose	With bristle-like hairs
Serrate	Toothed like a saw
Stipitate	Having a stalk or stalk-like base
Stratification	Cold exposure to seeds necessary to break dormancy for germination
Strigose	With stiffed appressed hairs
Sub-corymbose-racemose	A usually flat-topped flower cluster in which individual flower stalks grow upward from various points of the main stem to approximately the same height resembling a raceme
Subdolabriform	Near dolabriform
Suborbicular	Almost orbiculate or orbicular
Subsessile	Nearly sessile
Subumbellate	Nearly resembling an umbel
Succulent	Having a fleshy appearance (to store water within in the tissues)
Terete	Not ridged, grooved or angled
Zoochory	Seed dispersal by animals

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Appendix 1

Table A1: Workshop on the cost-effective management of *Impatiens* species - List of participants

Organisation	Name	Job title
Landscape management Flevoland	Lodewijk van Kemenade	Project leader
Naturalis and Netherlands Food and Consumer Product Safety Authority (NVWA), Plant Protection Service	Edu Boer	Project researcher
Netherlands Food and Consumer Product Safety Authority (NVWA), BuRO	Jenneke Leferink	Invasive exotic species advisor
Netherlands Food and Consumer Product Safety Authority (NVWA), Plant Protection Service	Johan van Valkenburg	Lead researcher
Radboud University Nijmegen	Rob Leuven	Senior researcher and Project manager
Radboud University Nijmegen	Lisette de Hoop	Junior researcher
Radboud University Nijmegen	Jonathan Matthews	Junior researcher
Radboud University Nijmegen and Naturalis	Gerard van der Velde	Senior researcher
Stichting Floron	Ruud Beringen	Project researcher
Water board 'De Dommel'	Bart Simons	Area manager