Publizierbarer Endbericht

gilt für Studien aus der Programmlinie Forschung

A) Projektdaten

Allgemeines zum Projekt	
Kurztitel:	Aliens_Health
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Projekt- und KooperationspartnerIn (inkl. Bundesland):	Medical University Vienna, Institute for Environmental Health (Wien) Centre for Evidence-Based Conservation Bangor-UK
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B) Projektübersicht

1 Kurzfassung

Neobiota, gebietsfremde Tier- und Pflanzenarten, werden häufig als ernsthafte Umweltbedrohung angesehen, sind aber auch wegen negative Auswirkungen auf die menschliche Gesundheit durch Verletzungen, Allergien oder als Krankheitsvektoren von Relevanz. Der Klimawandel und vor allem der weiter zunehmende globale Handel werden die Einfuhr, Etablierung, Ausbreitung, Abundanz, Physiologie und Phänologie von gesundheitsrelevanten Neobiota verändern und möglicherweise auch ihre Auswirkungen auf den Menschen. Trotz der starken Zunahme an invasionsbiologischer Forschung während der letzten Jahrzehnte gab es nur wenige Versuche, die jüngsten Veränderungen der Auswirkungen von Neobiota auf die menschliche Gesundheit zu quantifizieren.

In Aliens_Health wandten wir mehrere Methoden der Evidenzsynthese zu verschiedenen Themen und auf verschiedenen räumlichen Skalenebenen an. Die Ergebnisse wurden im Anschluss in spezifische Maßnahmen für die österreichische Umwelt- und Gesundheitspolitik umgesetzt. Einführend führten wir ein Scoping Review auf europäischer Ebene durch, dass Studien zu allen Invasionsphasen, zu Gesundheitsauswirkungen und zum Management potenziell gesundheitsrelevanter Neobiota umfasste. Im Rahmen einer systematischen Evidenzkartierung gingen wir dann der spezifischeren Frage nach, ob und in welchem Ausmaß die zunehmende Verbreitung und Abundanz von Neobiota nachweislich gesundheitsschädliche Auswirkungen hat. Mittels Anwendung des rigorosen Ansatzes einer systematischen Reviews untersuchten wir die Wirksamkeit der Managementoptionen für Ragweed (*Ambrosia artemisiifolia*). Weiters erhielten wir Informationen von österreichischen ExpertInnen über Herausforderungen und Lösungsansätze zum Thema der gesundheitsrelevanten Neobiota basierend auf Online-Umfragen und Tiefeninterviews. Schließlich stellten wir zwei wissenschaftliche Buchkapitel zusammen, zu Vektoren und Wirtsorganismen von sich ausbreitenden Krankheiten und zu den Auswirkungen des Klimawandels auf gesundheitsrelevante Neobiota.

Wichtigsten Erkenntnisse von Aliens_Health waren, dass (i) der Fokus der relevanten europäischen Literatur zu gesundheitsrelevanten Neobiota auf allergenen Pflanzen und krankheitsübertragenden Dipteren liegt, (ii) vergleichsweise häufig Verbreitung und Ausbreitung der Arten Studienthema ist (iii) relevante Arten meistens als Verunreinigungen im internationalen Warenverkehr eingeführt werden und (iv) überwiegend aus klimatisch ähnlichen Regionen der Nordhalbkugel stammen; (v) in den Studien, die Populationstrends untersuchen vor allem Zunahmen registriert wurden (vi) die Auswirkungen einzelner Arten kaum quantifiziert und (vii) die Auswirkungen des Klimawandels auf gesundheitsrelevante Arten zumeist nur diskutiert, viel seltener mit Daten belegt oder vorhergesagt wurden.

Weitere wichtige Erkenntnisse aus Aliens_Health sind, dass (viii) es einige Belege für Veränderungen der gesundheitlichen Folgen von Neobiota in Europa während der letzten 25 Jahre gibt, (ix) diese sind aber relativ spärlich, verglichen mit der Relevanz des Themas sind, und (x) sich auf nur wenige Arten und häufig auf spezifische Einzelfälle bezihen und selten

die gesundheitlichen Auswirkungen im konkreten Zusammenhang mit Ökologie, Abundanz oder Verbreitung der Arten untersuchen. (xi) Deshalb ist eine intensivere Zusammenarbeit zwischen InvasionsbiologInnen, UmweltmedizinerInnen und weiteren FachexpertInnen unabdingbar, um den Erkenntnisstand zu diesem Thema zu verbessern.

Wesentliche Erkenntnisse über die Wirksamkeit von Managementmaßnahmen gegen die allergenen Pflanze Ragweed (*Ambrosia artemisiifolia*) beinhalten, dass (xii) oftmals lokale Erfolge erzielen werden können, wenn die Maßnahmen über mehrere Jahre durchgeführt werden, (xiii) Maßnahmen zur Begrenzung der Ausbreitung über große Distanzen (z. B. durch Ferntransport von kontaminierten Boden oder Samen) für die Verhinderung von weiterer Ausbreitung entscheidend sind und weiter verstärkt werden müssen, und dass (xiv) Straßen- und Eisenbahnnetzwerke zu Ausbreitungsnetzwerken für Ragweed geworden sind und eine besondere Rolle bei Managementbemühungen spielen müssen.

Die wichtigsten Erkenntnisse aus der Online-Befragung unter österreichischen Entscheidungsträgern und ExpertInnen waren, dass (xv) Übereinkunft über die relevantesten Pflanzen- und (in geringerem Maße) Tierarten herrschte, (xvi) sowie über die relevantesten Herausforderungen durch gesundheitsrelevante Neobiota, (xvii) während die Übereinkunft wesentlich geringer bei Fragen zu den vielversprechendsten Maßnahmen zur Reduktion der Auswirkungen von Neobiota auf das Gesundheits- und Gesundheitssystem war.

Wesentliche Erkenntnisse über Überträger und Wirtsorganismen von sich ausbreitenden Krankheiten waren, dass (xix) Stechmücken und Zecken die wichtigsten Vektoren sind und eine Vielzahl verschiedener Neozoa als Wirtsorganismen dienen können, (xx) Verunreinigung im Warenverkehr und Haustierhandel die wichtigsten Einschleppungspfade für nichtheimische Vektoren und Wirtsorganismen sind, (xxi) globale Umweltveränderungen die Ausbrüche aufkommenden Krankheiten weiter erleichtern, und dass (xxii) natürliche Ökosysteme regulierend auf die Invasivität von Vektoren und Pathogenen wirken und Biodiversitätsverlust deshalb eine ernste Gefahr für die menschliche Gesundheit darstellt.

Die wichtigsten Erkenntnisse über die Auswirkungen des Klimawandels auf gesundheitsrelevante Neobiota waren, dass (xxiii) die Rolle des Klimawandels bei der Einfuhr der Organismen relativ moderat ist, (xxiv) es jedoch starke Hinweise darauf gibt, dass Etablierung und Ausbreitung der Organismen bei wärmeren Temperaturen häufiger, großflächiger und schneller ablaufen kann, und dass (xxv) die daraus resultierende Zunahme und Verschiebung der Verbreitungsgebiete vor allem in kälteren Regionen zu Folgen für die menschliche Gesundheit führen wird.

Für die wissenschaftliche Gemeinschaft liefert Aliens_Health ein besseres Verständnis der Auswirkungen zweier komplementärer Triebkräfte des globalen Wandels, Neobiota und Klimawandel, auf die öffentliche Gesundheit. Dementsprechend liefert Aliens_Health die wissenschaftliche Grundlage für weiterführende Forschung zur Minimierung aufkommender Gesundsheitsrisiken, die durch Neobiota unter Klimawandel verursacht wird. Es ist in diesem Zusammenhang bemerkenswert, dass Aliens_Health bereits während der Projektzeit (April 2014 bis Juni 2017) zu sieben wissenschaftlichen Fachpublikationen führte. Das Projekt

wurde in einem Artikel namens "Alienalarm" in der deutschen Qualitätszeitung "Die Zeit" erwähnt (27.8.2015).

2 Executive Summary

Alien species are frequently considered a serious environmental threat but negative impacts on human health through injury, allergy, or as vectors of disease sometimes have the most dire consequences for human livelihoods. Climate change and the increasing magnitude and frequency of introductions of species across geographic barriers as a result of international trade are likely to change their establishment, spread, abundance, physiology or phenology, potentially also altering their human health impacts. Yet despite receiving increasing attention in the scientific literature, there have been few attempts to quantify recent changes in human health impacts.

We applied several evidence syntheses on different topics and different scales applying different syntheses methods. We subsequently translated the findings into specific mitigation and adaptation measures for Austrian environmental and health policies. In detail, we conducted a scoping review at European scale that covered all invasion stages, impacts and management and all potentially relevant species. More narrowly focussed, but more deep going, we investigated the evidence base for relating increasing population trends of alien species to increasing health impact. Applying the rigorous approach of a systematic review, we investigated effectiveness of management options for Common Ragweed (*Ambrosia artemisiifolia*). Based on online surveys and in depth interviewed we obtained information on concerns and potential solutions provided by Austrian experts. Finally, we compiled literature reviews on vectors and reservoir hosts of emerging diseases and on the effects of climate change on alien species and their health impacts.

Main findings of Aliens_Health were that (i) the taxonomic focus of the relevant European literature was on a rather small subset of vascular plants (in particular species that have allergic pollen), and dipterans, (ii) mainly the spread of the study species was covered, while early invasion stages (transport, introduction) were less investigated, (iii) health relevant alien species were mostly introduced as contaminants and (iv) mostly originate from climatically similar regions of the Northern Hemisphere; (v) if investigated, population trends were mostly increasing, (vi) severity of the impacts was hardly investigated and (vii) effects of climate change were only discussed but very rarely evident or at least predicted. Further main findings include that (viii) there is some evidence for changes in the human health impacts of alien species within Europe over the last 25 years (ix) compared to the relevance of the topic for human well-being, there are few studies demonstrating changes in health impacts over time mapped to changing spread or abundance of the alien species; these studies (x) relate to only a few species, often report specific cases or outbreaks, and rarely link health impacts with ecology, distribution or spread of the species, or with public health, and (xi) better cooperation between invasion ecologists, health professionals and others working in affected areas are likely to be necessary to improve the evidence base on this topic for the future. Main findings on management effectiveness of the allergenic plant Common Ragweed include that (xii) management on rather small scales can often be effective if conducted over several years, (xiii) measures that are essential to limit long-range transport (e.g. via contaminated soil or seeds) are crucial to limit further range expansion and need to be

further strengthened (despite recent progress in implementation), and (xiv) that road and railway networks have become a network for the spread of ragweed over the landscape, calling for particular attention in allocation of management efforts.

The main findings obtained by the online survey among Austrian experts were that (xv) the experts greatly agree on the most relevant plant (and to a lesser extent) animal species, (xvi) they also agree on which consequences of health relevant species are important for the public health system, but (xvii) agree to a much lesser extent on which are the most promising kinds of measures required to mitigate impacts on health and health system. Main findings on vectors and hosts of emerging diseases were that (xix) mosquitoes and ticks are the most important alien vectors of human diseases, while many different species can serve as non-native reservoir hosts, (xx) contaminant with cargo and pet trade are the important pathways of introduction for alien vectors and reservoirs, (xxi) global environmental change will further facilitate emerging outbreaks of non-native human diseases, and (xxi) natural ecosystems provide a regulating service to human well-being and the loss of biodiversity therefore represents a serious threat to human health.

The main findings on effects of climate change were that (xxiii) introductions of alien species impacting human health can be enhanced by climate change but its role is moderate compared to the other aspects of (xxiv) there is strong evidence that establishment and spread of human health relevant alien species are crucially affected by changing climate characteristics, notably by warmer temperatures, and (xxv) resulting increase and shift in distribution might cause increasing health impact, particularly in cold regions including arctic regions or areas of higher elevation.

For the scientific community, Aliens_Health delivers a better understanding of the interplay of two complementary drivers of global change, i.e. climate change and alien species invasions on public health. Accordingly, it delivers the scientific basis for subsequent targeted research for minimizing emerging risks to public health caused by alien species under climate change. It is noteworthy in this context that Alien_Health already lead to seven scientific publications during the project time April 2014-June 2017. The project was mentioned in an article called “Alienalarm” in the German quality periodical “Die Zeit” (27/8/2015).

3 Hintergrund und Zielsetzung

Alien species invasions cause a multitude of impacts on environment and socio-economy. In particular, there is evidence for an increasing magnitude of human health impacts by alien species, as globalization increases the likelihood for the movement of disease, and has facilitated the transmission of tropical and subtropical pathogens to temperate regions. There, alien species may also benefit from climate change, causing additional pressure on human health. Health impacts of a few alien species have already received much attention in research related to public health and invasion ecology. In Europe, common ragweed (*Ambrosia artemisiifolia*) has become notorious for its highly allergenic pollen, giant hogweed (*Heracleum mantegazzianum*) for causing contact dermatitis, and the Asian tiger mosquito (*Aedes albopictus*) for serving as vector of several pathogens. However, the human health impacts of many other alien species are far less recognized. Consequently, the taxonomic and geographic biases in understanding the impacts of alien species at large may prevail also for alien species of human health concern and may hinder a balanced understanding of the scale, patterns and trends of these impacts.

While the effects of invasive alien species on environmental issues are increasingly synthesized, a thorough understanding of the joint health impacts caused by climate change and alien species invasions is lacking. In Aliens_Health, we aimed at closing this gap of knowledge for Europe and Austria. We applied several evidence syntheses on different topics and different scales applying different syntheses methods. We subsequently translated the findings into specific mitigation and adaptation measures for Austrian environmental and health policies.

4 Projektinhalt und Ergebnisse

Alien_Health dealt with evidence synthesis on different topics related to drivers, status impacts and management of health relevant alien species and the translation of the findings into specific mitigation and adaptation measures for Austrian environmental and health policies (Figure 1).

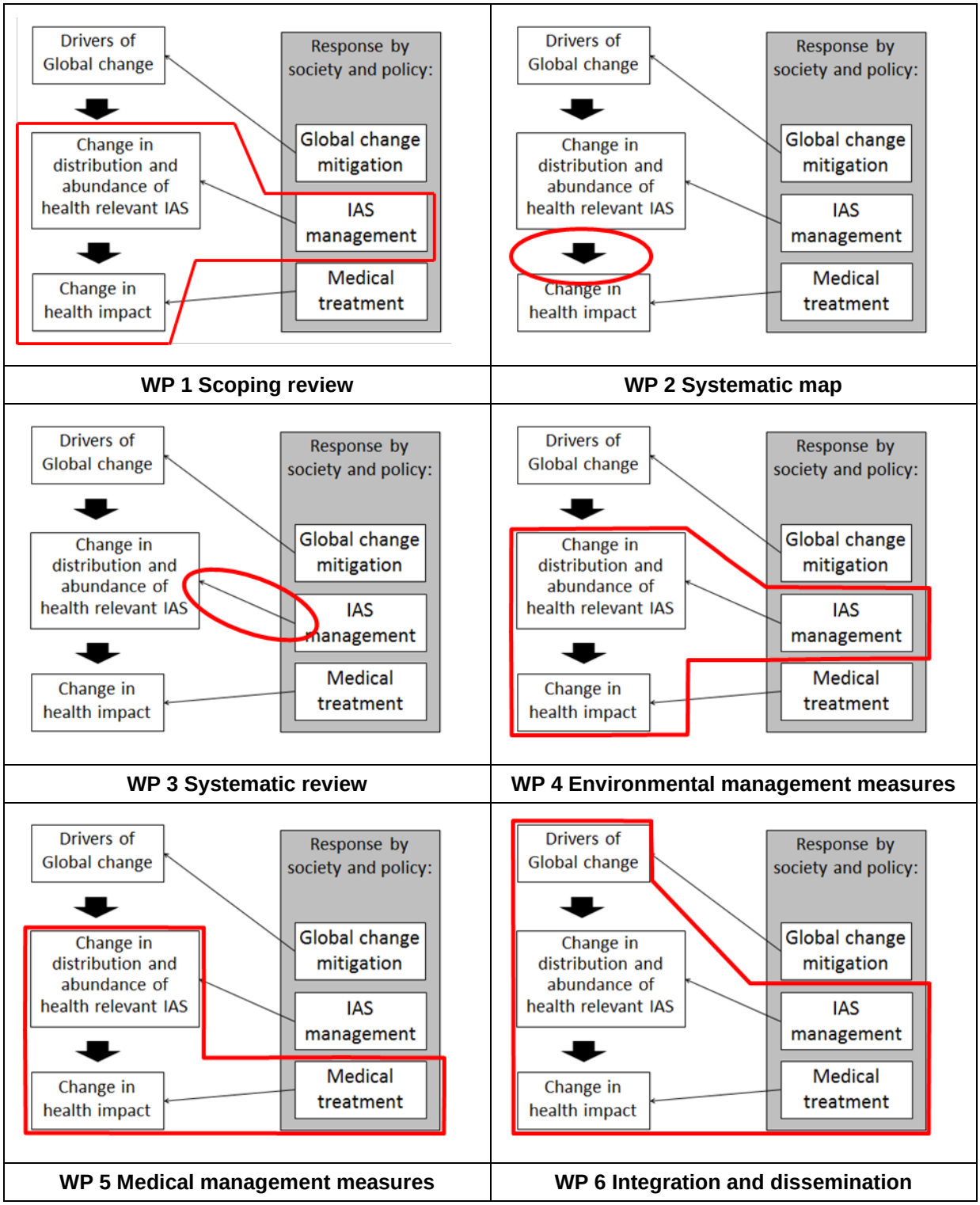

Figure 1. *Adapted Drivers-Pressures-Status-Impact-Response- (DPSIR)-Framework and coverage of the Aliens_Health work packages.*

The scoping review on the European literature of aliens species relevant to human health (WP1)

The project started with a scoping review on the European literature of aliens species relevant to human health (Schindler et al. 2015). We detected 77 articles, thereof 21 reviews and 56 original articles. None of the 21 review articles covered all relevant species of Europe. Eight of the 21 review articles were dealing with dipterans (Table 1), with some of them focusing on a single mosquito species, others on all alien mosquitos in Europe, vectors of Arboviruses, or vectors of West Nile Virus and Leishmaniasis. Four reviews were dealing with vascular plants (Table 1), three with singles species focus, and one considering all invasive plants of Ireland. Other reviews focused on the raccoon (*Procyon lotor*), presented short summaries on seven invasive birds, seven invasive amphibians and reptiles, or ten invasive arthropod species, or reviewed all human parasites and all pathogens transmitted by arthropods. Further reviews on multiple taxa (Table 1) include human parasites spreading by invasive plants, all vectors of vector borne diseases, and a comprehensive work covering all alien species in Europe, however health impacts played a very minor role in that assessment. The geographic scale of the reviews was mainly European (n=9) or global (n=6).

Table 1. *The taxonomic affiliation of alien species with human health impacts in Europe detected in 77 articles. Shown is the number of alien species with human health impacts, and the number of original research articles and reviews per taxonomic group.*

Taxonomic group	No of alien species	Original articles	Reviews	Total no of articles
Vascular plants (Tracheophyta)	28	27	4	31
True flies (Diptera)	6	17	8	25
Mammals (Mammalia)	2	3	1	4
Other arthropods (Arthropoda)	4	1	2	3
Mites and ticks (Acari)	7	2		2
Amphibians (Amphibia) and reptiles (Reptilia)	7	1	1	2
Birds (Aves)	53	1	1	2
Hymenoptera	1	1		1
Jellyfish (Cnidaria)	1	1		1
Multiple taxonomic groups	n.a.	*2*	*4*	*6*

Most of the 56 included original articles dealt with vascular plants concern (n=27), and dipterans (n=17), while only few articles dealt with other taxa such as mammals, ticks (acari), amphibians and reptiles, and birds (Table 1). The single species most frequently studied were Common ragweed *Ambrosia artemisiifolia* (n=19) and Asian tiger mosquito *Aedes albopictus* (n=12). Western, southern and central European countries had higher coverage by research articles, whereas little information was found for eastern and northern Europe (Figure 2). Also invasion stages were represented in an unbalanced manner. Most articles had a strong focus on spread (n=31 original articles), clearly fewer on introduction, establishment, and transport. Similarly, a moderate number of publications studied impact or

management. Fourteen articles dealt with multiple invasion stages. A large fraction of publications dealing with establishment (71%) and impact (50%) were short reports.

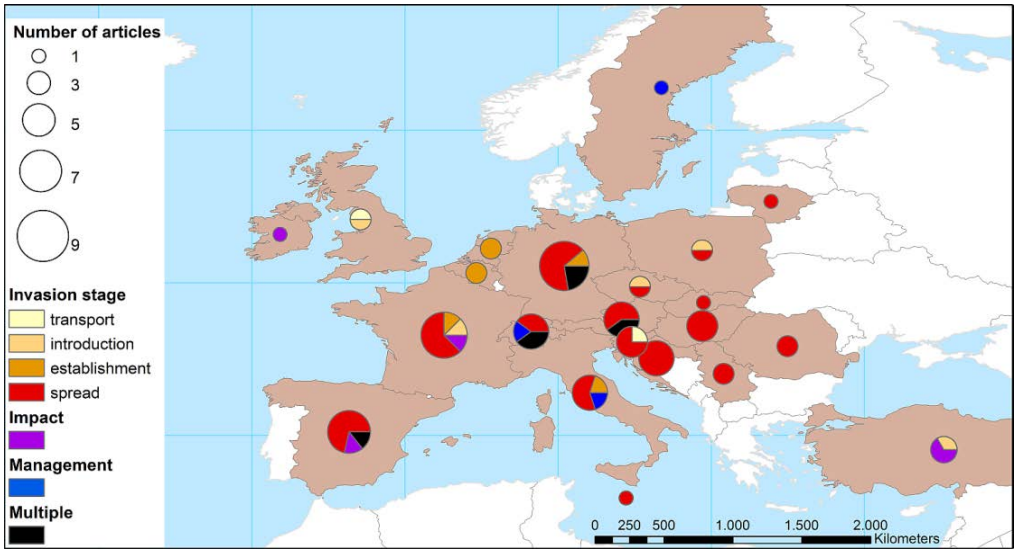

Figure 2. *Distribution of the detected original research articles on human health relevant alien species, broken down into invasion stages, impact and management (Schindler et al. 2015).*

Most investigated taxa originated from North America (n=22) and Asia (n=11), but several articles dealing with multiple taxa also considered alien species from the Southern Hemisphere (Figure 3). Thirty-five articles dealt with contaminants and eight articles with released and escaped species. The two articles on the marine environment dealt with introductions by stowaway (ballast water) and corridors (Lessepsian migration). Fourteen articles dealt with taxa of multiple origins or multiple pathways. Again, the covered species were predominantly introduced as contaminants (total n=21 taxa) from most continents, however some articles covered several taxa which escaped (n=19 taxa) or were released (n=9 taxa) (Figure 3).

A share of 36% of all articles, mainly those related to species distribution, also provided information on temporal trends. In most cases there was evidence of an observed or projected increase in distribution or impact (15 out of 20 articles, i.e. 75%), whereas no evidence was provided on decreasing distribution or impacts. In only two of the 56 original articles the severity of the impact was quantified and only in one of them (De Haro et al. 2010), the trend in impact was quantified by showing that no change occurred in the number of hymenoptera envenomations in the areas affected by Asian hornet (*Vespa velutina*) invasion.

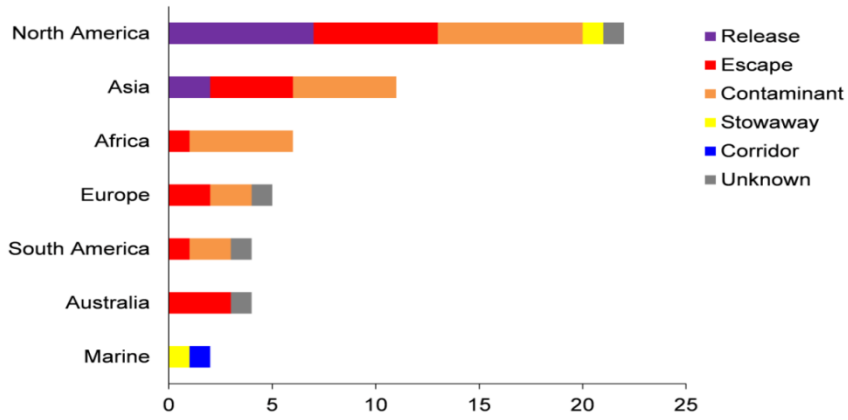

Figure 3. *Pathways of introduction and native ranges for 58 alien taxa of human health concern. Hybdridogenous species which have arisen in the native range (e.g. anecophytes) or such native on several continents are not included.*

Most of the 56 primary original articles did not consider potential effects of climate change. Only three articles assessed climate change impacts, and further 18 discussed potential impacts of climate change. In 15 original articles (27%) specific management measures were proposed, which were usually derived from the presented research. In further 20 articles (36%), general management measures were discussed or proposed. In the remaining 21 articles (38%), management measures were not mentioned. In only one original article the socioeconomic costs were assessed, in five articles management or socioeconomic costs of impact were discussed.

Thy systematic map on evidence of relations between spread of alien species and human health impacts (WP2)

I main product of Aliens_Health is a comprehensive systematic map (CEE 2013) on the evidence of relations between spread of alien species and human health impacts. (Bayliss et al. 2015, 2017). The bibliographic database and Google Scholar searches yielded a total of 15,776 search results (Figure 4). Of these, 2472 were removed as duplicates in EndNote. The remaining 13,304 results were screened at title, abstract and full text against the inclusion criteria and additional duplicates were removed manually. Results from the additional searches (specialist sources and hand searches of recent journal issues) yielded over 550 results and were screened at title level online. Although more than 200 articles were selected for assessment at full text, with 43 unobtainable and a number available in non-English languages, only 16 cases were included in the final systematic map of the evidence (Figure 4).

There is currently little evidence demonstrating a change in the occurrence, frequency or severity of human health impacts resulting from exposure to alien species in Europe. The evidence base predominantly constitutes data on arthropods, plants and algae taken from journal articles published since 2001 (Table 2), and much of the available evidence represents first reports of illness or injury resulting from exposure to alien species. Five studies provide the first reports of transmission of exotic diseases (two of Chikungunya virus

and three of dengue fever) by non-native mosquito species of the *Aedes* genus (*A. albopictus* and *A. aegypti*) established within Europe. Two adults were infected with dengue in France in 2010 (La Ruche et al. 2010) and around 17 in Croatia following identification of dengue fever in a returning German tourist the same year (Gjenero-Margan et al. 2011). An outbreak of dengue fever in Madeira, Portugal in 2012 (the first dengue epidemic reported in Europe since 1928) affected at least 1800 people within a matter of months (Sousa et al. 2012). In 2007 in Ravenna, Italy, an outbreak of Chikungunya virus perhaps introduced by a visitor from India affected two villages, leaving over 200 ill and one dead (Rezza et al. 2007). Two cases were identified in France in 2010, in young girls who were bitten during a sleepover near an imported case of Chikungunya virus (Grandadan et al. 2011). Although these studies represent outbreaks occurring at a relatively local scale, the number of individuals affected ranged from 2 to more than 2000.

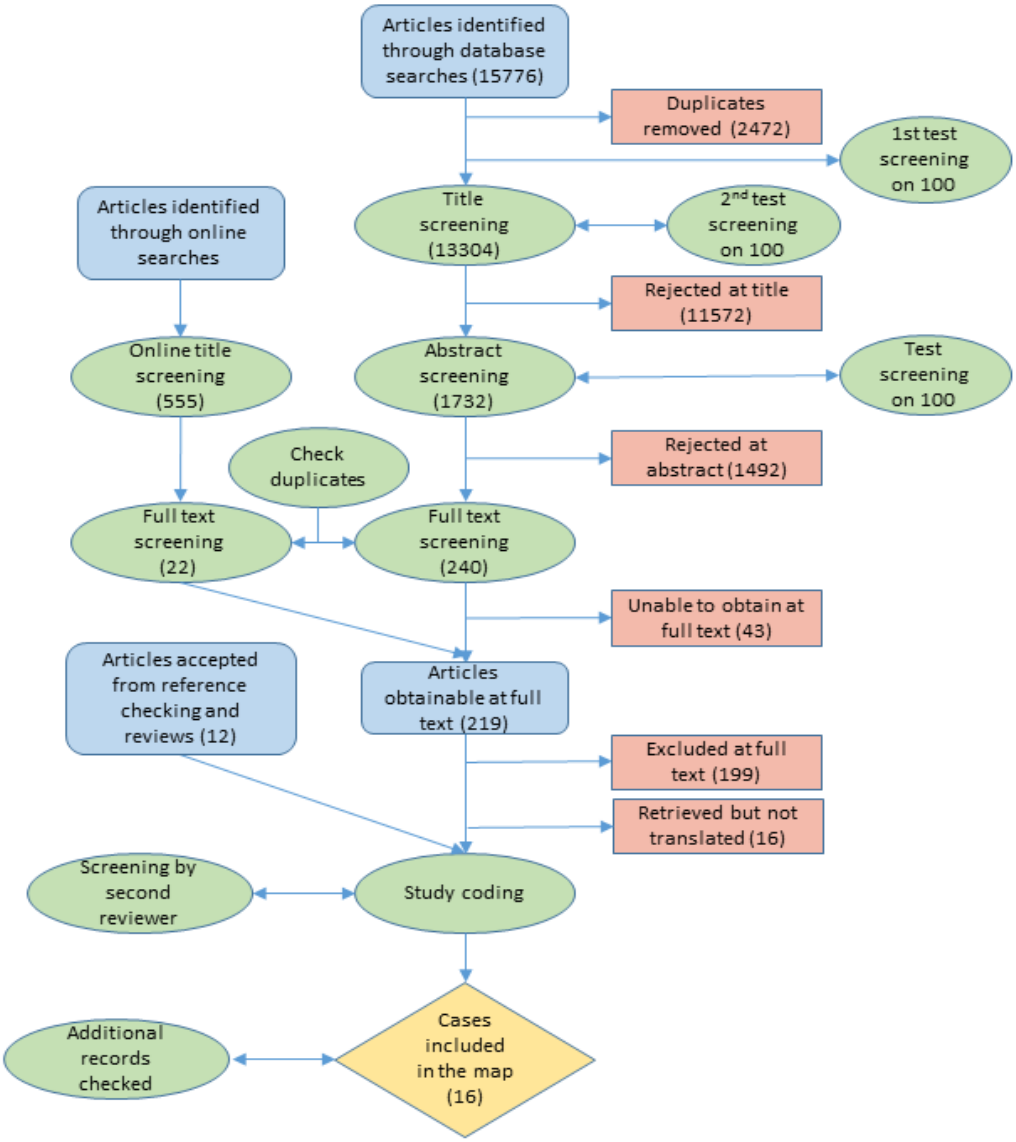

Figure 4. *Flowchart showing the number of articles captured and included or excluded at each stage of the systematic mapping process*

Another impact arising from contact with alien animal species is contact dermatitis. The first localised reports of dermatitis associated with contact with caterpillars of the oak

processionary moth *Thaumetopoea processionea* follow the accidental introduction of the species to London (UK) from continental Europe on imported trees (Mindlin et al. 2012). Local residents and management workers were affected.

Table 2. *Summary of studies demonstrating a change in the occurrence, frequency or severity of human health impacts resulting from exposure to alien species in Europe*

Species	Impact	Location	Description	Reference
Aedes aegypti	Disease transmission: dengue fever	Madeira	Outbreak with 1891 cases of dengue fever in 2012 following introduction of *A. aegypti* in 2005	Sousa et al. (2012)
Aedes albopictus	Disease transmission: dengue fever	France	Two cases of Dengue fever presented in adult males in France with no recent history of international travel. *A. albopictus* has been established since 2004	La Ruche et al. (2010)
Aedes albopictus	Disease transmission: dengue fever	Croatia	Two cases of dengue fever in Croatia, one in a German tourist and a second in a local resident, were identified in 2010. Serological assessment suggested at least seven other recent cases. *A. albopictus* was first recorded in Croatia in 2004	Schmidt-Chanasit et al. (2010); Gjenero-Margan et al. (2011)
Aedes albopictus	Disease transmission: Chikungunya virus	Italy	Over 200 cases in two contiguous villages in Italy. In most cases the disease was fairly mild, with one reported death. The virus was identified in *A. albopictus* suggesting local transmission	Rezza et al. (2007)
Aedes albopictus	Disease transmission: Chikungunya virus	France	Two female children developed Chikungunya after being bitten at a sleep over near to an imported case, suggesting local transmission	Grandadan et al. (2011)
Aedes japonicus	Nuisance behaviour	Switzer-land	Several reports of biting and nuisance behaviour identified as recently established *A. japonicus*	Schaffner et al. (2009)
Ambrosia artemisiifolia	Allergy: increasing sensitisation	Austria	Of 13,719 atopic patients diagnosed between 1997 and 2007, the frequency of ragweed pollen sensitization increased from 8.5% in 1997 to 17.5% in 2007	Hemmer et al. (2011)
Ambrosia artemisiifolia	Allergy: increasing sensitisation	Italy	Increase in the proportion of patients aged <20 years becoming allergic to ragweed was observed in a study of 665 patients over 15 years, from 0% 1990–1996 to 18% during the last 10 years	Asero (2007)
Ambrosia artemisiifolia	Allergy: increasing sensitisation	Germany	Twenty *A. artemisiifolia* scouts (tasked with finding and eliminating the weed) were assessed, and despite close contact to *A. artemisiifolia* over a median of 13.8 months, none of the participants became sensitized or allergic to it	Brandt et al. (2014)
Arthropods—mosquitoes, multiple	Nuisance biting	UK	No evidence of nuisance biting attributable to alien mosquitoes over a 10 year period according to a survey of local authorities	Medlock et al. (2012)
Ostreopsis ovata	Respiratory problems and skin irritation	Italy	First cases reported in 2003/2004, in 2005 around 200 people affected by respiratory symptoms resulting from exposure to sea spray containing toxins from *O. ovata*	Gallitelli et al. (2005), Brescianini et al. (2006) after Tichadou et al. (2010)
Ostreopsis ovata	Respiratory problems and skin irritation	Spain	Multiple cases resulting from exposure to *O. ovata* toxins	Kermarec et al. (2008) and Barroso García et al. (2008)

Species	Impact	Location	Description	Reference
				as cited in Tichadou et al. (2010)
Ostreopsis ovata	Respiratory problems and skin irritation	France	Five out of nine recorded blooms between 2006 and 2009 led to symptoms in divers, swimmers, and shoreline inhabitants, with a total of 47 patients presenting symptoms	Tichadou et al. (2010)
Thaumetopoea processionea	Itchy dermatitis	UK	Numerous cases of itchy rashes reported to the environmental health officer associated with *T. processionea* caterpillars on nearby oak trees	Mindlin et al. (2012)
Vespa velutina	Stings	France	A survey of French poison centres in 20 Departments showed no increase in the number of reported hymenoptera stings following the introduction of *V. velutina*	De Haro et al. (2010)
Vespa velutina	Stings	France	One case report where a patient suffered severe symptoms after being stung by *V. velutina* 12 times on the head	De Haro et al. (2010)

Evidence also suggests that harmful blooms of alien unicellular algae such as *Ostreopsis* species are causing significant health impacts along European coasts, with cases reported from Italy (Gallitelli et al. 2005; Brescianini et al. 2006), Spain and France (Kermarec et al. 2008; Tichadou et al. 2010). Numbers affected ranged from only a handful of cases to over two hundred depending on the outbreak. Those affected were beach users involved in a range of recreational activities including swimming and diving, and suffered from respiratory problems and skin irritations that regressed over time (Tichadou et al. 2010).

Not all studies present first reports of impacts. Several large-scale long term studies of individuals with allergic symptoms demonstrate changes in sensitisation levels to *Ambrosia artemisiifolia* among the general population across Europe, indicating that levels of sensitisation are rising and the proportion of young people sensitised is increasing (Asero et al. 2007; Hemmer et al. 2007). However, Brandt et al. (2014) found no sensitisation or allergy development in a sample of 20 ragweed workers resulting from exposure to *A. artemisiifolia*.

Other studies demonstrated no significant change in impacts over time. De Haro et al. (2010) reported no increase in the number of hospitalisations resulting from envenomations following the introduction of *Vespa velutina* to France, although evidence that at least one envenomation has occurred exists, and similarly, Medlock et al. (2012) reported no calls to local authorities resulting from nuisance biting caused by non-native mosquito species in England (all calls were for native species). However, in Switzerland, nuisance biting from the mosquito *Aedes japonicus* was reported following introduction (Schaffner et al. 2009).

Systematic Review on management effectiveness of Common ragweed (*Ambrosia artemisiifolia*) (WP3)

In the frame of the systematic review on management effectiveness of Common ragweed (methods see systematic review protocol, Schindler et al. 2016), we detected 385 articles dealing with management of ragweed, thereoff 69% dealing with chemical management, 10% with physical management, 15% with biological control, and 7% with any combination of these three. The articles on chemical management were largely rather old, applied partly herbicides that are meanwhile forbidden or out of use, did not assess side effects on biodiversity and human health and were often insufficient in terms of reproducibility (appr. 90% lacked clear information on sample size or standard deviation), we finally focussed on the biological control, a promising and emerging management option for Common ragweed. Based on the two applied methods, the search specified in the systematic review protocol (Schindler et al. 2016) and the particular search for biological control agents that were specified in Gerber et al. (2011), we detected 54 articles about the species that were listed by Gerber et al. (2011) as biological control agents, 29 of them were published between 2011 until 2017 (Table 3). For further species, 35 articles were detected, 20 of them with publication year between 2011 and 2017.

Table 3. *Number of articles detected before and after 2011 for the species proposed by Gerber et al. (2011) as biological control agents.*

			Articles	
Taxon	**Genus**	**Species**	**<2011**	**>2010**
Insecta - Coleoptera				
	Ophraella	*slobodkini*	2	4
	Smicronyx	*perpusillus*	0	2
	Smicronyx	*tesselatus*	1	0
	Trigonorhinus	*tomentosus*	4	8
	Zygogramma	*bicolorata*	0	3
	Zygogramma	*disrupta*	6	4
	Zygogramma	*tortuosa*	2	0
Insecta - Diptera	*Callachna*	*gibba*	1	0
	Contarinia	*partheniicola*	3	0
	Euaresta	*bella*	1	4
	Euaresta	*toba*	0	0
	Rhopalomyia	*ambrosiae*	2	0
Insecta - Hemiptera	*Stobaera*	*concinna*	0	1
Insecta - Lepidoptera	*Adania*	*ambrosiae*	0	0
	Bucculatrix	*agnella*	0	0
	Schinia	*rivulosa*	1	1
	Tarachidia	*candefacta*	0	0
	Tischeria	*ambrosiaeella*	0	0
Fungi - Capnodiales	*Septoria*	*ambrosiicola*	0	0
	Septoria	*epambrosiae*	2	1
	Passalora	*ambrosiae*	0	0
	Passalora	*trifidae*	0	0
Fungi - Pucciniales	*Puccinia*	*xanthii*	0	1

Mitigation and adaptation measures in the environmental and health sector (WP4 and WP5)

Four kind of activities were conducted in these two work packages, an online survey on challenges and solutions related to health relevant alien species in Austria, (ii) in-depth interviews on the same topic, (iii) reviews on management and legal aspects on the three most concerning species (Hutter et al. 2016, 2017), and a checklist of management options for the ten most concerning species.

For the online survey, we invited 131 Austrian experts, of which 53 responded (40 % return rate). Eleven of the respondents (21 %) specified health relevant aliens species as important responsibility in their daily work. In total, 59% of the respondents were active in the environmental sector, 47% in public administration, 35% in research, 25% in medicine, 24% in education, and 4% in other sectors. 49 respondents provided 149 answers to the question of most relevant alien species groups. 88% of the respondents assumed allergenic plants to be relevant, 55% opted for “other plants”, 51% for invertebrate disease vectors, 45% for pathogens, 27% for vertebrate disease vectors and 27% for other species groups. 78% of 49 respondents mentioned Common Ragweed (*Ambrosia artemisiifolia*), 65% Giant Hogweed (*Heracleum mantegazzianum*) and few mentioned any other species (Figure 5). Regarding particularly relevant animal species, 24% of 49 respondents mentioned the Asian Tiger Mosquito (*Aedes albopictus*), 14% the Racoon (*Procyon lotor*) and 12% other *Aedes* spp.

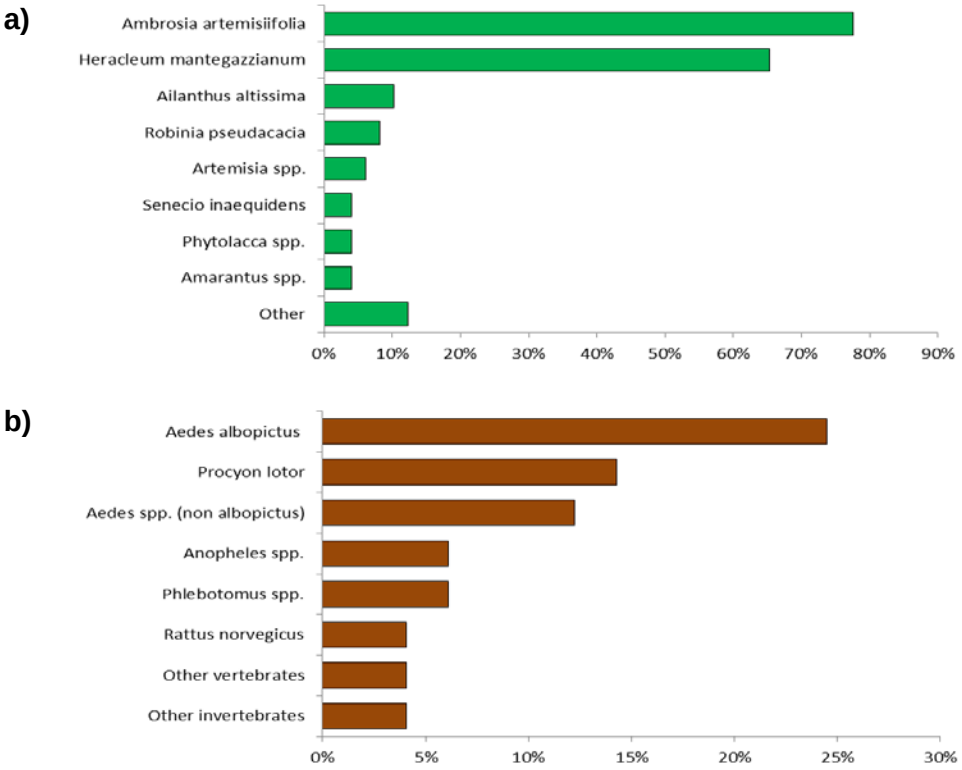

Figure 5. *Response to the question “Which health relevant alien species are the most important (multiple answers were allowed; n=49 respondents). (a) plants; (b) animals.*

In the context of health relevant alien species, 94% of the respondents stated that awareness raising is important (including categories “very important” and “important”), 88% that a future

increase in health impacts has to be considered, 83% that the health system will need additional resources, 80% that health impacts of these species will be severe and 78% that the health system is not prepared for expected impacts (Figure 6).

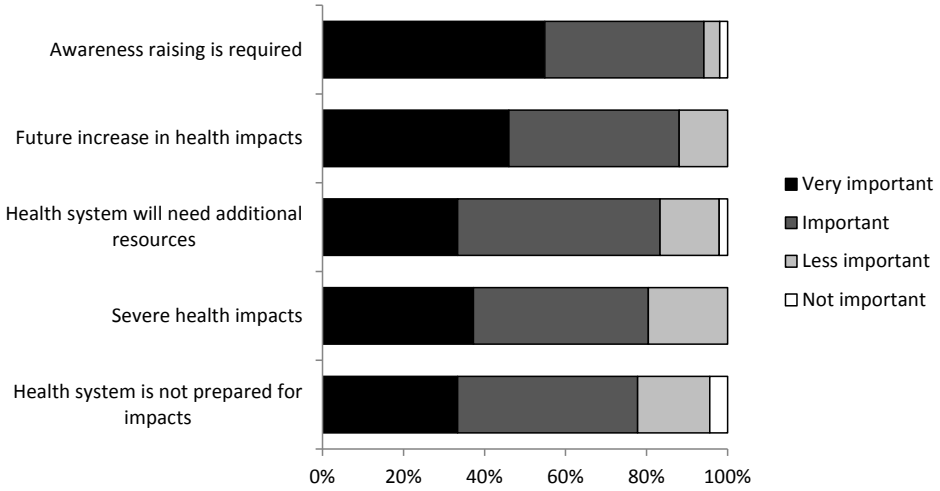

Figure 7. *Which of the following issues related to health relevant alien species do you consider as important (n=45 to 51 respondents).*

The questions regarding implemented, discussed and recommended measures were answered by 51-52 respondents. Preventive environmental measures were often implemented (37%), discussed (52%) and recommended (58%) by respondents or their institutions (Figure 7). Also measures related to environmental control were often mentioned (31% implemented / 54% discussed / 37% recommended). Measures relate to education were implemented by 31%, discussed by 44% and recommended by 35% of the respondents. Research on health relevant alien species was implemented by 22%, discussed by 40%, and recommended by 35% of the respondents. Legislative measures, structural measures in public administration and the public health system, and therapies were implemented, discussed and recommended to a lesser extent (Figure 7).

All kinds of measures were more frequently recommended than implemented with particularly large discrepancies (i.e. “implementation debts”) for preventive environmental measures and legislative measures. Among the recommended measures given by the eleven experts in the frame of the in-depth interviews were clarification of responsibilities, implementations of recommendations, import restrictions, better reporting of diseases, professional trainings, and increased information. Allergies, infectious diseases, AMR, and toxic effects were considered as most important health effects caused by IAS.

In the frame of the extensive, systematic literature research on *Ambrosia artemisiifolia, Heracleum mantegazzianum* and *Aedes albopictus* 736 papers were evaluated. The results showed that there are currently only few papers which focus on Public Health interventions on an evidence-based level (Hutter et al. 2016 – see Annex MS9). The literature research on reports, recommendations and official regulations including policy recommendations from a medical point of view and useful information concerning eradication and other management options was summarised by Hutter et al. (2017) (see Annex MS10).

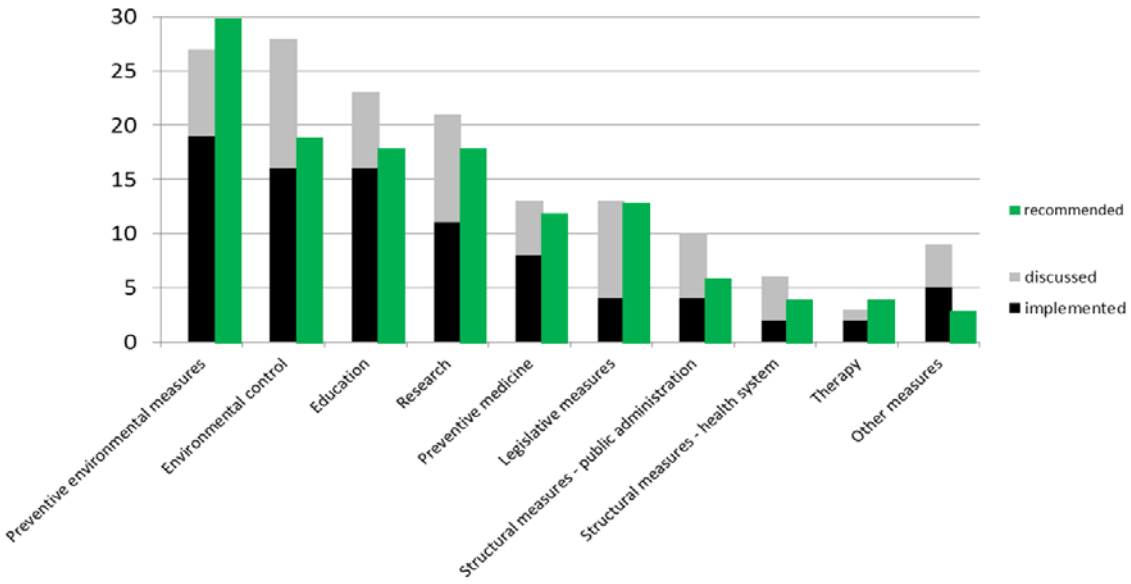

Figure 7. *Which kind of measures were discussed or implemented in you institution? Which kind of measures could you recommend? (n=51 to 52 respondents)*

An overview of proposed management measures for plants and animals was derived from work in these work packages and literature reviewed in other work packages (Table 4).

Table 4. *Overview of proposed management measures for plants and animals derived from work in this work package and literature reviewed in other work packages.*
Legend: ☑ already (largely) completed; ☒ not required; ✓ to be implemented; NA: not applicable

Measures–PLANTS		***Ambrosia artemisiifolia***	***Heracleum mantegezzianum***	***Iva xanthifolia***	***Artemisia annua***	***Ambrosia trifida***
Prevention						
	improve border control	☑	☑	☒	☒	☑
	ban of plantation and trade	☑	☑	☒	☒	☒
	public Information campaigns	✓	✓	✓	✓	✓
Control						
	management of roadsides and railway sites	✓	☒	✓	✓	✓
	improved agricultural management	✓	☒	✓	✓	✓
	avoidance of spread with contaminated soil	✓	✓	✓	✓	✓
	biological control	✓	☒	☒	☒	☒
	management of abandoned grasslands	☒	✓	☒	☒	☒
Measures–ANIMALS		***Aedes albopictus***	***Aedes aegypti***	***Ochlerotatus japonicus***	***Vespa velutina***	***Thaumetopoea pityocampa***
Prevention						
	establishment of a surveillance system able to detect invasions early	☑	☑	☑	✓	✓
	border control of pathways	☑	☑	☑	NA	☑
	public Information campaigns	✓	✓	✓	✓	✓
Control						
	chemical treatment (insecticides)	☑	☑	☑	☑	☑
	biological control techniques	☑	☑	☑	☒	☒
	habitat modification	☑	☑	☑	☒	☒
	removal of nests	NA	NA	NA	✓	NA

Alien vectors and reservoirs of human diseases

Pathogens, animal vectors and reservoir species have been unintentionally displaced across natural geographic boundaries resulting in serious human suffering and enormous economic costs. Thus, as part of the Aliens_Health dissemination activities, a dedicated book chapter was compiled on we compiled on alien vectors and reservoirs of human diseases (Rabitsch et al. 2017). Different kinds of interactions between native and non-native organisms can affect human health (Figure 8).

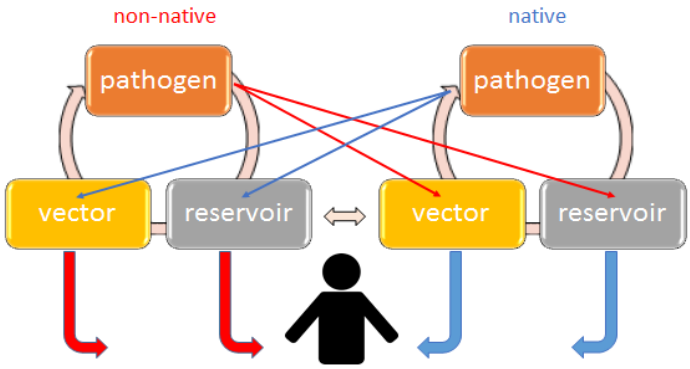

Figure 8. *Kinds of interactions between native and non-native organisms that affect human health.*

Mosquitoes and ticks are the most important alien vectors of human diseases, while many different species can serve as non-native reservoir hosts (Table 5). For instance semi-domesticated and pet rodents and birds may host and transmit native and non-native pathogens to humans (Figure 9). Their presence in urban habitats increases the likelihood of transmission.

Figure 9. *Introduced Grey Squirrel (Sciurus carolinenis) (left) and Canada goose (Branta canadensis) (right): Introduced semi-domesticated and pet rodents and birds may host and transmit native and non-native pathogens to humans. © W. Rabitsch*

Contaminant with cargo and pet trade are the important pathways of introduction for alien vectors and reservoirs. Evidence suggests that global environmental change will further facilitate emerging outbreaks of non-native human diseases, some of which may be re-emerging old foes. The complex interrelations between native and non-native hosts, vectors and pathogens entail inherent uncertainties and make predictions about future outbreaks

very challenging. Natural ecosystems provide a regulating service to human well-being and the loss of biodiversity therefore represents a serious threat to human health.

Table 5 *Selected human diseases, causing agents and their origin, vectors and recent outbreaks in non-native regions. Table compiled from different sources, a fine selection of references can be found at www.cdc.gov*

Disease	Pathogen or Parasite	Origin	Vector(s)	Pathogen introduced with	Selected outbreaks in non-native regions
Chikungunya Fever	Chikungunya Virus	Africa-Asia (India)	*Aedes aegypti*, *A. albopictus*	Reservoir (human)	Italy (2007-2008), France (2010, 2014) Caribbean (2013), N and S America (2014)
Dengue Fever	Dengue Virus	Tropical	*Aedes* spp.	Reservoir (human)	France, Croatia (2010), Madeira (2012)
Dirofilariasis	*Dirofilaria repens*	Southern Europe, Africa, Asia	*Aedes* spp. and other mosquitoes	Reservoir (animal), Vector?	Belarus, Ukraine, Russia, Hungary, Poland, Austria, Czech Rep., Germany (2000s)
Leishmaniasis	*Leishmania* spp.	(sub)tropical, southern Europe	*Phlebotomus* spp., *Lutzomyia* spp.	Reservoir (animal)	northern Italy, Germany (1990s)
Malaria	*Plasmodium* spp.	Africa, (southern Europe)	*Anopheles* spp.	Reservoir (human), Vector	Brazil, Colombia (2000s)
Plague	*Yersinia pestis*	China	Fleas (e.g. *Xenopsylla cheops*)	Reservoir (animal)	Madagascar (1990s)
Usutu Fever	Usutu Virus	Africa	Mosquitoes	Reservoir (animal)	Italy (2009)
West Nile Fever, West Nile Encephalitis	West Nile Virus	Africa	*Culex* spp., *Aedes* spp. and other mosquitoes	Vector?	North America (1999)
Yellow Fever	Yellow Fever Virus	Africa	*Aedes* spp. and other mosquitoes	Reservoir (human)	South America (since 1980s)
Zika Fever	Zika virus	Africa-Asia	*Aedes* spp.	Reservoir (human)	Pacific (since 2007), Brazil (2015)

Climate change impacts on health relevant alien species

A further dissemination activity was to summarize evidence and predictions for climate change impacts on health relevant alien species in a book chapter (Schindler et al. 2018). Climate change effects introduction, establishment and spread of human health relevant alien species and management responses of society and policy aiming at mitigation and adaptation (Figure 10). The current level of responses from society is insufficient to halt the introduction of new alien species (Tittensor et al. 2014; Seebens et al. 2017). Thus, prevention and medical treatment of human health impacts are of increasing importance.

The process of alien species invasion can be well described by the modell of invasion stages (Blackburn et al. 2011), with introduction (including transport), establishment and spread being the main stages. We found that introductions of alien species impacting human health can be enhanced by climate change (Streftaris and Zenetos 2006; Raitsos et al. 2010; Gale et al. 2010) but its role is moderate compared to the other aspects of globalization such as increased trade and people's increased mobility (Essl et al. 2011). There is strong evidence that establishment and spread of human health relevant alien species are crucially affected by changing climate characteristics, notably by warmer temperatures (Essl et al. 2015; Medlock et al. 2015). This is particularly the case for subtropical and tropical species (Roy et

al. 2009), Lessepsian migrants (Öztürk & İşinibilir 2010; Raitsos et al. 2010; Kletou et al. 2016), and Mediterranean species (Battisti et al. 2017). Resulting increase and shift in distribution might cause increasing health impact, particularly in cold regions including arctic regions (Parkinson et al. 2014; Dudley et al. 2015) or areas of higher elevation (Neteler et al. 2011).

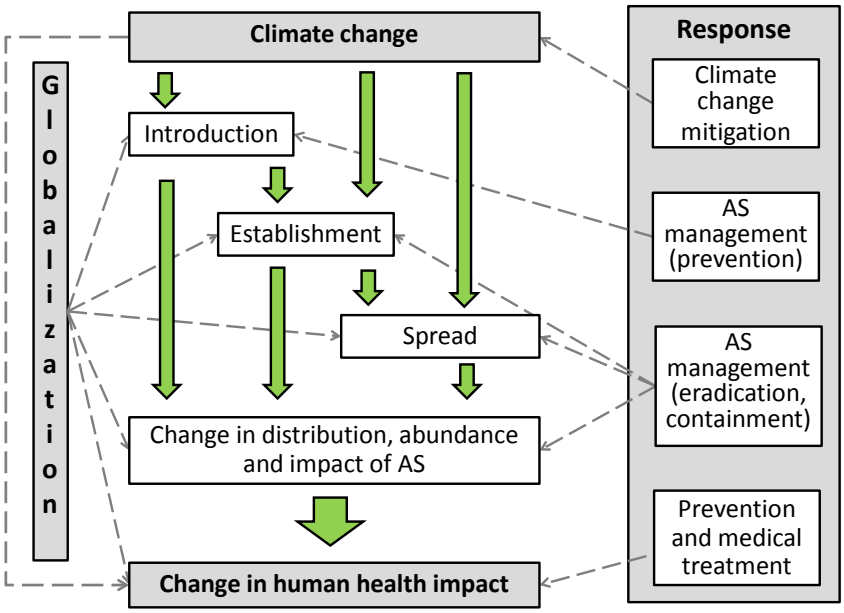

Figure 10. *Climate change impacts on introduction, establishment and spread of human health relevant alien species (AS) and management responses of society and policy aiming at the mitigation of climate change and the management of AS. Green arrows indicate processes that are subject of this chapter. Figure modified from Bayliss et al. (2015) and Blackburn et al. (2011).*

Interdisciplinarity in invasion science

As relevant result of our evidence syntheses, we detected that interdisciplinary efforts of environmentalists and medical researchers to understand invasion ecology and impact of alien species were often lacking. Thus, we participated in biometrical study that assessed the interdisciplinarity of invasion science (Vaz et al. 2017). Lack of interdisciplinarity is hindering the gain of knowledge on the human dimensions of biological invasions. The bobliometric study showed that interdisciplinarity in invasion science is mainly taking place among ecological subdisciplines, because 92.4% of interdisciplinary publications (out of 9192) focus on ecological questions, 4.4% on social ones, and only 3.2% on social–ecological ones. The emergence of invasion science out of ecology (Figure 11) might explain why interdisciplinarity has remained mostly within the natural sciences. Nevertheless, invasion science is attracting social–ecological collaborations to understand ecological challenges, and to develop novel approaches to address new ideas, concepts, and invasion-related questions between scholars and stakeholders. We discuss ways to reframe invasion science as a field centred on interlinked social–ecological dynamics to bring science, governance and society together in a common effort to deal with invasions.

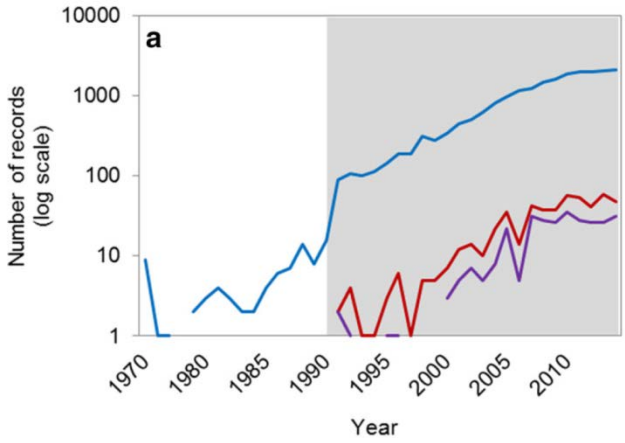

Figure 11. *Number of records attributed to ecological, social, and social–ecological RAs in a logarithmic scale. The 1990s and 2000s were characterised by the advent of purely social (1990s) and then coupled social–ecological research (2000s).*

5 Schlussfolgerungen und Empfehlungen

For the scientific community, Aliens_Health delivers a much better understanding of the interplay of two complementary drivers of global change, i.e. climate change and alien species invasions on public health. Accordingly, it provides the scientific basis for subsequent targeted research for minimizing emerging risks to public health caused by alien species under climate change. It is noteworthy in this context that Alien_Health already lead to seven scientific publications during the project time April 2014-June 2017 (see Chapter 8).

In detail, the main findings of the scoping review (Schindler et al. 2015) were that (i) the taxonomic focus of the literature was on vascular plants, and dipterans, (ii) mainly the spread of the study species was covered, while early invasion stages (transport, introduction) were less investigated, (iii) species were mostly introduced as contaminants and (iv) mostly originate from climatically similar regions of the Northern Hemisphere. (v) If investigated, population trends were mostly increasing, (vi) severity of the impacts was hardly investigated and (vii) effects of climate change were only discussed and very rarely evident or at least predicted.

The main findings of the systematic map (Bayliss et al. 2015, 2017) were that (i) there is some evidence for changes in the human health impacts of alien species within Europe over the last 25 years (ii) compared to the relevance of the topic for human well-being, there are few studies demonstrating changes in health impacts over time mapped to changing spread or abundance of the alien species; these studies (iii) relate to only a few species, often report specific cases or outbreaks, and rarely link health impacts with ecology, distribution or spread of the species, or with public health, and (iv) better cooperation between invasion ecologists, health professionals and others working in affected areas are likely to be necessary to improve the evidence base on this topic for the future.

Main (preliminary) findings of the systematic review on management effectiveness of the allergenic plant Common Ragweed (Schindler et al. 2016, in prep.) include that management on rather small scales can often be effective if conducted over several years, measures that are essential to limit long-range transport (e.g. via contaminated soil or seeds) are crucial to limit further range expansion and need to be further strengthened (despite recent progress in implementation), and that road and railway networks have become a network for the spread of ragweed over the landscape, calling for particular attention in allocation of management efforts.

The main findings of the online survey among Austrian experts (Schindler et al. in prep) were that (i) the experts greatly agree on the most relevant plant (and to a lesser extent) animal species, (ii) they also agree on which consequences of health relevant species are important for the public health system, but (iii) agree to a much lesser extent on which are the most promising kinds of measures required to mitigate impacts on health and health system. This was largely confirmed by the in-depth interviews.

The literature research on Ragweed, Hogweed and Tiger Mosquito conducted by Hutter et al. (2016) showed again that there is little research with a focus on Public Health

interventions on an evidence-based level. The literature research on reports, recommendations and official regulations for each of the three species developed policy recommendations from a medical point of view and summarized information concerning eradication and other management options (Hutter et al. 2017).

The main findings of the literature review on vectors and hosts of emerging diseases (Rabitsch et al. 2017) were that (i) mosquitoes and ticks are the most important alien vectors of human diseases, while many different species can serve as non-native reservoir hosts, (ii) contaminant with cargo and pet trade are the important pathways of introduction for alien vectors and reservoirs, (iii) global environmental change will further facilitate emerging outbreaks of non-native human diseases, and (iv) natural ecosystems provide a regulating service to human well-being and the loss of biodiversity therefore represents a serious threat to human health.

The main findings of the literature review on effects of climate change (Schindler et al. 2018) were that (i) introductions of alien species impacting human health can be enhanced by climate change but its role is moderate compared to the other aspects of (ii) there is strong evidence that establishment and spread of human health relevant alien species are crucially affected by changing climate characteristics, notably by warmer temperatures, (iii) resulting increase and shift in distribution might cause increasing health impact, particularly in cold regions including arctic regions or areas of higher elevation.

Evidence and expert opinions indicate clearly that the main health impact of alien species will probably be caused by allergenic plants (mainly common ragweed) and vectors and reservoir hosts of diseases. Both groups of organisms may benefit from climate change and further increasing global trade and further increase in establishment and spread has to be expected.

The accidental introduction of the ragweed leaf beetle (*Ophraella communa*) into Northern Italy a few years ago is substantially affecting the fitness of common ragweed there. Consequently, ragweed pollen levels have fallen in the region around Milan, where this beetle has been first recorded (Bonini et al. 2015). The ragweed leaf beetle is currently expanding, and has recently been found for the first time in Slovenia. It is expected that it will spread into Austria in the years to come (cf. Sun et al. 2017). Monitoring the spread of this beetle into Austria and assessing the impact of the beetle on ragweed populations and pollen levels in Austria would be highly relevant, as it represents an excellent case study for assessing the role of a newly introduced enemy on this allergenic alien plant species.

Important drivers of introduction and spread of alien vectors of diseases are global trade, international travel, animal pet trade, habitat fragmentation, destruction and deterioration, urbanization, and climate change (Rabitsch et al. 2017). Pathways management and control must be enforced and natural ecosystems can provide a regulating service for human well-being, and their conservation and restoration represents a relevant environmental mitigation measure. The ‘One World One Health’ initiative, which promotes better understanding and collaborative efforts for health of people, animals and the environment, advocates for a better understanding of the introduction, spread, and control of nonnative diseases and vectors, as

well as joint efforts in education and outreach to the public and decision makers. At global level, the Convention on Biological Diversity (CBD) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) should reinforce their participation to this strategic framework, developed by the FAO, WHO, and OIE (Rabitsch et al. 2017).

Better cooperation between invasion ecologists and health professionals working in affected areas are likely to be necessary to improve the evidence base on this topic for the future. Future studies could helpfully compare spread or abundance with reported, rather than potential, health impacts. Increased monitoring and data collection regarding case numbers are considered an important basis for such studies and the basis of risk assessment and evidence based public health policy.

C) Projektdetails

6 Methodik

Alien species are frequently considered a serious environmental threat but negative impacts on human health through injury, allergy, or as vectors of disease sometimes have the most dire consequences for human livelihoods. Climate change and the increasing magnitude and frequency of introductions of species across geographic barriers as a result of international trade are likely to change their establishment, spread, abundance, physiology or phenology, potentially also altering their human health impacts. Yet despite receiving increasing attention in the scientific literature, there have been few attempts to quantify recent changes in human health impacts.

We applied several evidence syntheses on different topics and different scales applying different syntheses methods. We subsequently translated the findings into specific mitigation and adaptation measures for Austrian environmental and health policies. In detail, we conducted a scoping review at European scale that covered all invasion stages, impacts and management and all potentially relevant species. More narrowly focussed, but more deep going, we investigated the evidence base for relating increasing population trends of alien species to increasing health impacts. Applying the rigorous approach of a systematic review, we investigated effectiveness of management options for Common Ragweed (Ambrosia artemisiifolia). Based on online surveys and in depth interviewed we obtained information on concerns and potential solutions provided by Austrian experts. Finally, we compiled literature reviews on vectors and hosts of emerging diseases and on the effects of climate change on alien species and their health impacts.

Methods per Work package

Scoping review

In the scoping review we preliminarily assessed size, scope and content of the research literature in respect to emerging risks to public health from alien species in Europe (Schindler et al. 2015). The scoping review dealt with all invasion stages, impact and management aspects (Figure 1). We included peer-reviewed articles dealing with species alien to Europe or being native in parts of Europe but alien to others that cause negative impacts on human health. We included alien species of direct health impact (e.g. allergenic plants), but also alien vector species (e.g. mosquitos, ticks, sandflies), which carry and transmit infectious pathogens to humans, and alien reservoir species (e.g. mammals), which are long-term hosts of pathogens of infectious diseases. In contrast, we excluded (i) alien pathogens (e.g. virus, bacteria), if they did not arrive with alien species and were exclusively transmitted by native vectors or reservoir species, (ii) domestic animals that serve as vectors or reservoirs, and (iii) European species that do not fall under the definition of alien species.

Titles of detected articles and subsequently their abstracts were screened to eliminate unsuitable articles that dealt for instance with pests and diseases impacting agriculture,

livestock or wildlife. After this screening, 115 articles remained. Of these, 15 full texts were not available (these ones were mostly published in local journals in non-English language), 23 were excluded after reading the full version (mainly because the focal species did not fall under our inclusion criteria of being alien) and the remaining 77 were considered for further analyses. The 77 analyzed articles consisted of 21 review articles and 56 original research articles (42 full articles, 14 short reports). Interestingly, the 77 included articles were exclusively published recently, i.e. from 2002 onward.

WP2 Systematic Map

WP2 dealt with the relations between species distribution and health impacts (Figure 1). It produced a systematic map, which assessed kind and amount of evidence for changes in the occurrence, frequency or severity of human health impacts resulting from exposure to invasive alien species in Europe (Bayliss et al. 2017). The systematic map is stock-taking by hierarchically categorizing literature and identifying research gaps. It investigated the following parameters: (i) impacted human population (location of exposure and of recorded impact, activity at exposure); (ii) impacting alien species (species name, taxonomic group, habitat and biome at location of exposure), (iii) type of human health impact (disease or pathogen transmission, allergen or irritant) and kind of recorded change (occurrence, frequency, severity), (iii) kinds of study approach and other study parameters (e.g. before-after-control-impact design, sample size, kind of comparators, spatial and temporal scale). All methodological issues are carefully described in the Systematic Map protocol (Bayliss et al. 2015), which was externally peer reviewed and published in the journal Environmental Evidence.

WP3 Systematic Review

WP3 dealt with environmental management options for the allergenic plant common ragweed (Figure 1). It is a wind-pollinated herb native to North America that was first introduced to Europe during the seventeenth century. It has since become widespread and is currently in an ongoing phase of rapid spread and increasing abundance. Several management approaches are currently implemented and effective control of the species can have strong socioeconomic benefits (Richter et al. 2013). However, evidence for management effectiveness is scattered and has not yet been synthesised systematically. We systematically reviewed the evidence to assess (a) what is the effectiveness of management options used for control of Common ragweed and (b) what is the effect of confounding factors such as habitat, climate and frequency and timing of treatment?

Search terms relating to the population and the intervention (type of management) were combined and searched in a range of databases and other sources. Specific inclusion criteria are (i) any population of common ragweed at any habitat including populations in agricultural settings and such used for experimental research at any geographic location (including its native range), (ii) any physical, chemical, biological or combined management action; (iii) direct outcome measures including change in coverage, abundance, biomass, survival, reoccurrence, biology (e.g. growth, height, leaf area) or pollen production. The wide range of

quality of primary literature has been evaluated with a tailored system for assessing susceptibility to bias and the reliability of the studies. All methodological issues are carefully described in the Systematic Review protocol (Schindler et al. 2016), which was externally peer reviewed and published in the journal Environmental Evidence.

A second search was conducted with a focus on biocontrol agents and it is built up on the review of Gerber et al. (2011). The aim was to get an overview of studies and their results of success of biocontrol agents. Search strings relating to the different insects, bacteria and fungi in combination with the keywords “biological control Ambrosia” have been entered in the search engine “Google Scholar”. If the study was available, it was evaluated if the test for evidence was a field observation (O-F), a field-experiment (E-F), a laboratory-experiment (E-L) or a combination of them. Evidence for biological control was further categorized as successful, not successful or unclear.

WP4 Environmental mitigation and adaptation measures and WP5 Public Health mitigation and adaptation measures

The online survey among Austrian experts contained seven questions and was online from 23rd of May until 7th of September 2016. 131 Austrian experts were invited to participate in the online survey, 53 of them responded (40 % return rate). Additionally to the online survey, eleven experts of different health-related fields were interviewed during 2016. Eleven questions were prepared, and experts were asked e.g. which species and health effects they found most important, if the health system was sufficiently prepared for increased negative effects, which measures concerning health-related IAS in their working environment were debated or implemented, what measures they would recommend and if there was enough awareness regarding IAS and health among doctors, politicians and the public.

As a further part of WP5, three highly relevant IAS were investigated in detail regarding public heath aspects: *Ambrosia artemisiifolia, Heracleum mantegazzianum* and *Aedes albopictus*. Two investigations were carried out: An extensive, systematic literature research using scientific databases (Pubmed, Embase, Web of Science) to identify Public Health interventions on the European level and to evaluate the measures regarding efficiency and application in Austria and a systematic literature research, using specific search terms to give an overview on reports, recommendations and official regulations which are publically available on the internet (with a focus on German-speaking). Furthermore, for each of the three species, measures including policy recommendations were generated from a medical point of view and useful information concerning eradication and other management options was summarised.

WP6 Integration, dissemination, policy and research recommendations

Based on the work in the other work packages, we conducted the following integration and dissemination activities:

- The scoping review on the topic (Schindler et al. 2015). It published as research article in the journal Neobiota and based on the work conducted in WP1;

- One literature review about the rise of non-native vectors and reservoirs of human diseases (Rabitsch et al. 2017). It is published as book chapter based on work conducted in WP1, 2, 4, and 5;
- One literature review about climate change impacts on health relevant alien species (Schindler et al. 2018) published as book chapter based on work conducted in WP1-5;
- One summary of the project results for Austrian stakeholders in German language (Schindler et al. 2017). It is published as front cover-article in an Austrian medical bulletin and based on the work of the WPs 1-5;
- One stakeholder workshop in WP1;
- One online survey in the WPs 4 and 5;
- In-depth interviews in the WP5;
- Four participations and presentations at international conferences
- Two participations and presentations at the annual Austrian Climate Day conferences

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7 Arbeits- und Zeitplan

Kurze Übersichtsdarstellung des Arbeits- und Zeitplans:

	09.14			03.15			09.15			03.16			09.16			03.17			09.17
WP/ Months			**6**			**12**			**18**			**24**			**30**			**36**			**42**
1. Scoping review																				
2. Systematic Map																				
3. Systematic Review																				
4. Environmental Mitigation and Adaptation Measures																				
5. Public Health Mitigation and Adaptation Measures																				
6. Integration, dissemination, policy and research recommendations																				
7. Project Management																				

8 Publikationen und Disseminierungsaktivitäten

Publictaions in international peer reviewed scientific journals or books	
1	Schindler S, Rabitsch W, Essl F (2018) Climate change and increase of impacts on human health by alien species. In: Tricario E, Mazza G (eds) Invasive Species and Health. CABI, in press.
2	Bayliss H, Schindler S, Adam M, Essl F, Rabitsch W (2017) Evidence for changes in the occurrence, frequency or severity of human health impacts resulting from exposure to species alien to Europe: a systematic map. Environmental Evidence 6:21.
3	Rabitsch W, Essl F, Schindler S (2017) The rise of non-native vectors and reservoirs of human diseases. In: Vilà M, Hulme PE (eds), Impact of Biological Invasions on Ecosystem Services. Invading Nature - Springer Series in Invasion Ecology, Vol. 12, pp. 263-276.
4	Vaz AS, Kueffer C, Kull C, Richardson D, Schindler S, Muñoz-Pajares AJ, Vicente JR, Martins J, Hui C, Kühn I, Honrado JP (2017) The progress of interdisciplinarity in invasion science. AMBIO 46, 428-442.
5	Schindler S, Bayliss H, Essl F, Rabitsch W, Follak S, Pullin AS (2016) Management effectiveness of invasive common ragweed Ambrosia artemisiifolia: A systematic review protocol. Environmental Evidence 5:11.
6	Schindler S, Staska B, Adam M, Rabitsch W, Essl F (2015) Alien species and public health impacts in Europe: a literature review. NeoBiota 27, 1-23.
7	Bayliss H, Schindler S, Essl F, Rabitsch W, Pullin AS (2015) What evidence exists for changes in the occurrence, frequency or severity of human health impacts resulting from exposure to alien invasive species in Europe? A systematic map protocol. Environmental Evidence 4:10.
Publications for international peer reviewed scientific journals in preparation	
8	Adam M, Schindler S, Follak S, Essl F (in prep.) Biological control of Common ragweed: potential agents and level of evidence. Journal of Environmental Management.
9	Schindler S, Hutter H-P, Essl F, Wallner P, Lemmerer K, Rabitsch W (in prep.) Alien species and human health: challenges and solutions. Neobiota.

summary publication in German language	
10	Schindler S, Adam M, Essl F, Lemmerer K, Wallner P, Hutter H-P, Rabitsch W (2017) Sind Neobiota eine Gefahr für die menschliche Gesundheit? Medi.um 2017/4, 2-5.
Online publications (not peer reviewed)	
11	Hutter H-P, van Hove M, Unterhofer F, Wallner P (2016) Invasive Alien Species und Public Health. Literaturreview zu Ragweed, Hogweed und Tigermücke. Still to be uploaded at http://www.neobiota-austria.at/
12	Hutter H-P, van Hove M, Lemmerer K, Unterhofer F, Wallner P (2017) Invasive Alien Species und Public Health: Übersicht über die vorhandenen Berichte, Empfehlungen und Verordnungen. http://www.neobiota-austria.at/fileadmin/inhalte/neobiota/pdf/RagweedHogweedAedes__170718.pdf
Presentation at international conferences	
13	Schindler S, Essl F, Bayliss HR, Adam M, Hutter H-P, Pullin AS, Follak S, Wallner P, van Hove M, Unterhofer F, Lemmerer K, Rabitsch W (2017) Alien species and human health impacts: Evidence syntheses and the role of climate change. Biodiversity and Health in the face of climate change: Challenges, opportunities and evidence gaps. 27-29 Jun 2017, Bonn, Germany.
14	Schindler S, Bayliss HR, Adam M, Rabitsch W, Essl F, Hutter H-P, Wallner P, Follak S, Pullin AS (2016) Alien species of human health concern: Evidence syntheses for impacts and management effectiveness. NEOBIOTA 2016. Biological Invasions: Interactions with Environmental Change. 9th International Conference on Biological Invasions. Book of Abstracts. 14-16 Sep 2016, Vianden, Luxembourg. p. 51.
15	Bayliss H, Schindler S, Adam M, Essl F, Rabitsch W, Pullin AS (2015) Evidence for changes in the occurrence, frequency or severity of human health impacts resulting from exposure to species alien to Europe: a systematic map. Britisch Ecological Society 2015 Annual Meeting 13 – 16 Dec, Edinburgh, UK.
16	Schindler S, Staska B, Adam M, Rabitsch W, Essl F (2014) Impacts of alien species on human health in Europe: A scoping review. 8th International Conference on Biological Invasions: from understanding to action. Proceedings. 3-8 Nov 2014, Antalya, Turkey. p. 118.

Presentation at the Austrian Climate Day	
17	Schindler S, Bayliss HR, Adam M, Pullin AS, Staska B, Wallner P, Hutter H-P, Rabitsch W, Essl F (2016) Aliens_Health: Gesundheitsauswirkungen invasiver nicht-heimischer Tier- und Pflanzenarten. 17. Österreichischer Klimatag. 6-8 Apr 2016, Graz, Austria.
18	Schindler S, Staska B, Adam M, Rabitsch W, Essl F (2015) ALIENS-HEALTH: Gesundheitsrelevante Neobiota in Europa. Tagungsband 16. Österreichischer Klimatag. Aktuelle Klimaforschung in Österreich. 28-30 Apr 2015, Vienna, Austria. pp. 100-101.
Further presentations (not peer reviewed)	
19	Schindler S (2015) Public health impact of alien species. Workshop “Enhancing understanding of invasive alien pathogens” of the COST Action TD1209. 18-19 Mar 2015, Wallingford, UK.
20	Schindler S (2015) Invasive Alien Species: global trends of introductions, pathway information and health impact. Models in Ivasion ecology: challenges and applications. Traing course of the COST Action TD1209. 2-4 Mar 2015, Vairão, Portugal.
21	Schindler S (2014) Alien species and public health impacts in Europe: a synthesis of evidence”, Seminars of the Conservation Group, School of Environment, Natural Resources and Geography, Bangor University; Bangor, UK: 16 Oct 2014.