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Vector analysis: a tool for preventing the introduction of invasive alien species into protected areas

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Abstract

Invasive alien species are the main agent of biodiversity loss in protected natural areas. Prevention is the most appropriate management tool for addressing this challenge, however, virtually all ongoing management efforts are focused on established populations. Although invasion processes include stochastic components, it is possible to compare the different vectors of introduction that operate in a particular area in terms of their potential to transport species of high risk of invasion efficiently and, once identified, to establish strategies of prevention, early detection and rapid action. This study proposes a system of prioritization of vectors of alien plant dispersal for optimizing the efforts for preventing invasion. The system was developed for the Ernesto Tornquist Provincial Park (province of Buenos Aires, Argentina), but it is directly applicable to other areas. Natural and anthropogenic vectors were evaluated and lists of the species potentially transported by each vector were elaborated according to the characteristics of their propagules. The system analyzes the relative importance of each vector according to: 1) the severity of the potential impact of transportable species, 2) the difficulty of controlling these species, and 3) the volume of transportable propagules. In the case under study, the maximum value of risk corresponds to cargo, followed by vehicles, streams, unintentional human transport, intentional human transport, wind and finally, animals. This analysis can lead to prevention strategies, mapping of dispersal routes and actions of early detection and rapid response.

Keywords

biological invasions, pathways, prevention, protected areas, vectors

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Introduction

The impact of invasive alien species is a key component of global change and it is considered one of the main causes of biodiversity loss worldwide (Sala et al. 2000, Lövei and Lewinsohn 2012, Simberloff et al. 2013, Alexander et al. 2014). All protected natural areas contain alien species that are recognized as the main threat to their conservation objectives. Predictions indicate that their importance will increase in the future unless effective management measures are adopted (McKinney 2002, Pyšek et al. 2002). The effects of invasions can be manifested at different scales and in various ways, including reduction in the richness and abundance of species of the native biota, genetic changes in native populations through hybridization and interruptions in mutualistic networks (Pyšek et al. 2012). In some cases, the effects of the presence of one or more invasive species are so profound that they disrupt the functioning of entire ecosystems and interfere with their resilience and ability to provide ecosystem services (Vilà et al. 2011, Simberloff et al. 2013).

Invasion processes involve the successful overcoming of several challenges: a potential invader must survive transport from its place of origin, become established in the new site, persist and reproduce until a sustainable population is formed that eventually expands (Theoharides and Dukes 2007, Blackburn et al. 2011, Jeschke et al. 2013). The ability to successfully overcome these stages depends not only on the species' own characteristics, but also on the characteristics of the invaded habitat that determine its susceptibility to invasion, the number of propagules and introduction events, the establishment of effective relationships with local dispersal agents and other symbionts and the particular conditions at the time of the arrival of the propagules (Marco et al. 2002, Colautti et al. 2006, Dechoum et al. 2015, Amodeo and Zalba 2017).

The management of invasive alien species includes four basic components: prevention, early detection, eradication and control that coincide with each stage of the invasion process (Wittenberg and Cock 2001, Lodge et al. 2006, Davies and Sheley 2007). The best cost-effective method for dealing with invasive alien species is in the area of prevention, since the costs and impacts generated by an invasion process increase and sometimes the problems become irreversible (Leung et al. 2002, Ziller and Zalba 2007, Anderson et al. 2014).

Vectors are the transfer mechanisms responsible for the introduction and spread of invasive species in a certain area, including a wide variety of physical means or agents, from ballast water to horticulture, biological control and aquaculture (Ruiz and Carlton 2003). Vector interception or disruption has been identified as "the most vulnerable and directly manageable portion of the invasion sequence", as they allow to simultaneously avoid the delivery of whole sets of transportable species (Carlton and Ruiz 2005).

Many risk analysis associated to the probabilities of introduction by certain vectors has been developed, mostly at national or state borders (Gordon et al. 2012, Grosholz et al. 2012, Conser 2013, Kelly et al. 2013). Most of them consider the capacity of the vectors to safely transport propagules, the volume that can be carried and the frequency of operation, as well as the impacts associated to the transportable taxa. This is not the case for protected areas, where these kind of analysis are extremely infrequent. Despite the consensus on the disproportionate importance of prevention in the management of biological invasions, most management actions developed in nature reserves focus on the control or eradication of established populations (Schüttler and Karez 2008, Genovesi and Monaco 2013, Pauchard et al. 2015). This situation could be explained, at least in part, since the extent and seriousness of the problems attract the attention of those responsible for the management of the reserves disproportionately. Apart from the causes of this scenario, the consequences seem clear: the lack of effective preventive actions compromises the sustainability of protected areas that face the threat of invasive alien species.

Moreover, the scarcity of tools for organizing actions that reduce the risk of introduction and establishment of new species is daunting (Davies and Sheley 2007). Although invasion processes include stochastic components, like the co-occurrence of propagule arrival and appropriate environmental conditions for establishment (Radford 2013), it is likely to anticipate which species are most likely to arrive in an area, the severity of their potential impacts, the most likely means of arrival, and which sites are most likely to be colonized. In particular, it is possible to compare the different vectors of introduction operating in a given area in terms of their potential to transport highly invasive species efficiently.

Vectors also travel through more or less predictable routes known as pathways (Mack et al. 2003). The combination of knowledge about vectors with higher chances of transporting high risk species and the routes that they travel to and within a particular area leads to the organization of preventive actions, early detection and rapid action (Lodge et al. 2006, Ziller and Zalba 2007). This alternative also has the advantage of simultaneously addressing the risk of introduction of complete sets of species sharing the same means of transport and / or pathways of introduction and dispersion.

The objective of this study is to create a system of risk analysis for the introduction of invasive or potentially invasive alien plants by identifying the vectors of the highest priority for control. We selected the Ernesto Tornquist Provincial Park, a nature reserve located in the southern part of the Pampas Biome, in the Argentine Republic, as a case of analysis for the elaboration and application of this system. The park is dominated by grass steppes and surrounded by an agricultural landscape. Vectors of plant dispersal in the area include physical means like wind and watercourses, dispersal by birds, mammals and invertebrates, and human mediated spread in association to footwear and clothing, vehicles and cargo (Zalba and Villamil 2002, Loydi and Zalba 2009, Amodeo and Zalba 2013).

The reserve undergoes intense invasions by alien species, including different species of trees and shrubs (Zalba and Villamil 2002, Zalba et al. 2009). Apart from this problem, there is a high number of introduced plant species in the region that have not yet become established in the reserve (Long and Grassini 1997), and preventing their entry should be a priority in the management of the area. The analysis of routes and vectors is an appropriate response to reduce the impact of invasive species by minimizing the risks of introduction, as well as lowering the very high costs associated with the control.

Materials and methods

Study area

The Pampas biome is one of the most characteristic landscapes in southern South America, as well as being one of the most greatly transformed ecosystems by anthropogenic actions, with only a very small area that is protected effectively (Bertonatti et al. 2000, Bilenca and Miñarro 2004). The grasslands of South America face a serious and increasing challenge associated with the progress of invasive alien species, particularly woody plants (Fonseca et al. 2013). The Ernesto Tornquist Provincial Park (ETPP) represents one of the few protected areas of Pampas grassland in Argentina (Bilenca and Miñarro 2004, De Villalobos and Zalba 2010). The reserve covers an area of approximately 6700 ha in the central area of Sierra de la Ventana, in the province of Buenos Aires, Argentina (38°3.90'S, 61°58.33'W). The climate in the region is temperate and rainfall varies between 500 and 800 mm annually (Burgos 1968). The vegetation is dominated by grass steppes, including species of *Stipa*, *Nassella*, *Piptochaetium*, and *Festuca*, as well as herbs and shrubs of Asteraceae. The flora of the park includes some 550 species of native plants and some 140 alien species (Long and Grassini 1997, Long et al. 2004).

Damiani (2007) cites a total of 324 alien plant species growing within the ETPP and in an area of about 20 km around it, including agricultural and livestock fields, paved roads, secondary roads, and parks and gardens in small villages. Twenty-three species that behave as invasive in the area, extensively growing over natural and semi natural environments, and 23 others that can be considered to be of high risk on account of their biological characteristics and previous invasive behavior, have not yet been detected in ETPP, or are restricted to intensive use zones (Damiani 2007, Long and Grassini 1997, María Andrea Long, Systematic Botany, Universidad Nacional del Sur, pers. comm.). All these species can therefore be considered as high priority in a prevention strategy (Appendix 1).

Methods

The characteristics of the propagules (presence of wings, pappus, hooks, sweet pulp, etc.) and dispersal strategies of the 46 species considered to be of high priority for prevention were analyzed from the literature and the vectors that might intervene in their dispersion were identified.

In order to analyze the relative importance of each vector, the severity of the potential impact and the difficulty of controlling each transportable species were taken into account, as well as the volume of propagules that the vector could carry.

The potential impact of the vector index (PIV) was defined as the weighted sum of the number of species transportable by a vector for each category of potential impact:

PIV = 100 * number of species with high PI + 10 * number of species with medium PI + number of species with low PI.

The values of high, medium and low potential impact were taken from Damiani (2007), who established an impact index considering the risk of establishment of the species based on fourteen criteria: previous invasive behavior, niche width, density of growth, hybridization risk, allelopathy, toxicity for humans, toxicity for wildlife, flammability (capacity to increase fire frequency or intensity), palatability, capacity to host parasites and pathogens, life cycle, reproductive strategy, seed production and dispersal. Each criterion has different alternatives associated with corresponding numeric values that are combined in a final estimation of potential impact of the species.

The control difficulty index of the species transported by the vector **(CDV)** was defined as the weighted sum of the number of species transportable by the said vector corresponding to each category of control difficulty:

CDV = 100 * number of species with high CD + 10 * number of species with mean CD + number of species with low CD.

The values of high, medium and low control difficulty were also extracted from Damiani (2007), who calculated them considering six species features: presence of spines and stinging hairs, generation time, ability to regrow after cutting, response to grazing, response to fire, and persistence in the seed bank. Numerical indexes for each criterion were combined to assess the difficulty to control each species.

The severity of impact of each vector (SI) was calculated from the values of the potential impact and control difficulty indexes of the species transported by the vector, according to:

SI = (PIV + CDV) / SImax

Where SImax represents the maximum severity of impact obtained among the considered vectors.

The Transportable Volume **(TV)** was estimated by analyzing both the number of propagules available for transport (TP) and the carrying capacity of the vector (CC).

The number of available propagules (TP) for each vector was calculated by combining the information related to the abundance of the species in the area with the production and temporal availability of transportable propagules by that vector.

The abundance of each species in the study area was estimated on a relative scale, assigning a value of 1 to the rare species (few populations of a few individuals), the value of 2 to the abundant species (few populations with many individuals or many populations with few individuals) and the value of 3 to very abundant species (many populations with many individuals). This information was obtained from literature (Long and Grassini 1997) and from consultations with specialists of the regional flora. The number of propagules produced by each species was classified as low (1), moderate

(2), high (3) or very high (4), considering the ability of an adult plant to produce seeds and / or vegetative reproduction structures (bulbs, rhizomes, stolons, tubers and plant cuttings). This data was extracted from the bibliography. The proportion of months in the year during which the propagules of each species are available for eventual transport by each vector was also determined. Thus, for example, a plant producing fleshy fruits available for consumption and dispersal by vertebrates for two months each year would obtain a value of 2/12 = 0.17 for the animal vector; whereas we could expect an availability of 12/12 = 1 for vector loads, if their seeds remain viable in the soil.

These three variables were multiplied by each other to calculate the abundance of propagules for each species. The abundance values of propagules for all transportable species were added to obtain the total number of propagules available for transport by each vector (TP).

Two variables were considered for estimating the carrying capacity of each vector (CC): 1- the volume transported in each potential introduction event, defined in relative units: 1 small; 10 medium; 100 large; 1000 very large, and 2- the frequency of vector activity throughout the year in the study area, expressed in relative units: 1 low; 10 medium; 100 high; 1000 very high.

These two variables were multiplied to calculate the carrying capacity (CC) of each vector.

The transportable volume (TV) per vector was calculated by adding the propagation availability and carrying capacity:

$$TV = (TP + CC) / TVmax$$

Where TVmax represents the volume of transportable propagules by the vector with the greatest transport capacity.

Finally, the values of impact severity (SI) and transportable volume (TV) were combined to calculate the risk associated with each vector (RV):

$$RV = (2 * SI + TV) / 3$$

The impact severity value was multiplied by 2 to reflect its relative importance when analyzing the risk associated with each vector.

A diagram of this analysis is presented in Fig. 1.

Results

The analysis of the propagules and dispersal strategies of the species of high priority of prevention in the PPET allowed us to associate them with a total of three natural and three anthropogenic vectors. The natural vectors identified were streams, wildlife and wind. The anthropogenic vectors included transport by vehicles (in mud attached to the chassis and tyres), movement directly associated with people (unintentional: in

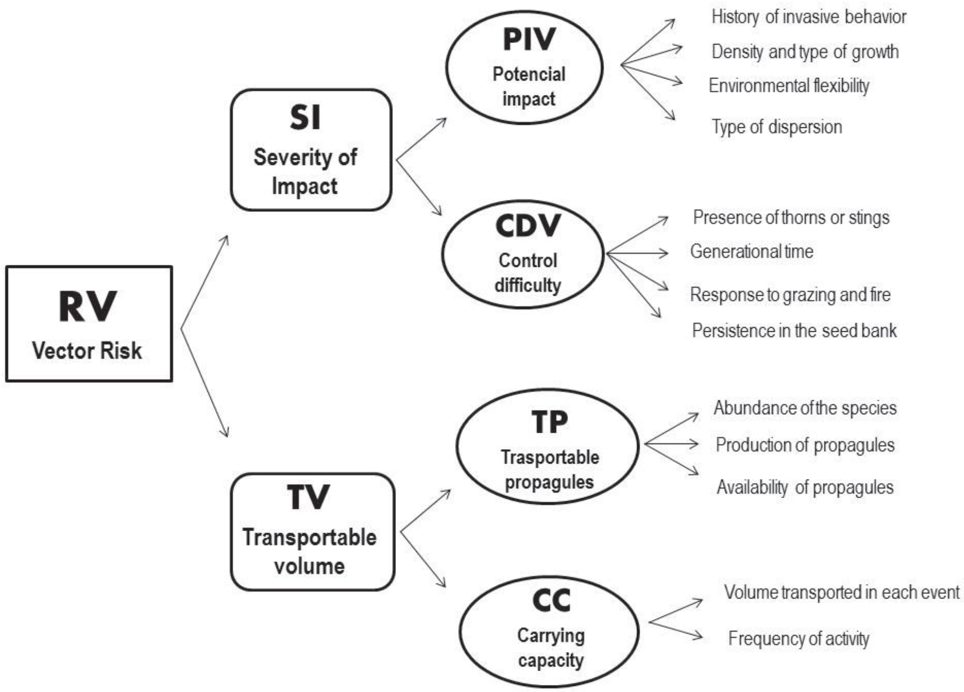

Figure 1. Vector analysis schema. Diagram of the analysis of the relative importance of vectors associated with the introduction and dispersal of invasive alien plants in Ernesto Tornquist Provincial Park (Buenos Aires, Argentina).

footwear and clothing, food, camping equipment, and intentional: ornamental plants and vegetables) and the movement associated with cargo (soil, sand, debris, and dry plant material).

Of the 46 species evaluated, 25 have propagules with structures that facilitate their dispersion by wind (e.g. small and light seeds, winged diasporas, feathery organs), 7 show seeds with traits that promote their dispersal by water (light seeds or floating vegetative structures) and 13 fruits are potentially dispersed by animals (edible or with hooks, barbs or awns that adhere to fur). We also concluded that all the propagules of the analyzed species could be transported in loads of materials (earth, debris, sand), whereas 39 show traits that would facilitate their transport by cars, trucks and other vehicles (small seeds, adherent propagules). Twenty-eight species could be easily dispersed directly and unintentionally by people (on footwear and clothing, such as fruits of food plants or associated with camping equipment). Finally, 23 species could be intentionally mobilized by the people for their ornamental value or cultivation for other human purposes (Appendix 1, Fig. 2A).

The analysis of the different vectors, combining the potential impact of the transportable species (Damiani 2007), resulted in an index of the potential impact of the vector that varied between 240 and 1693. On the other hand, the index of the difficulty of control of species transported by the vector takes values that go between 321 and 1891.

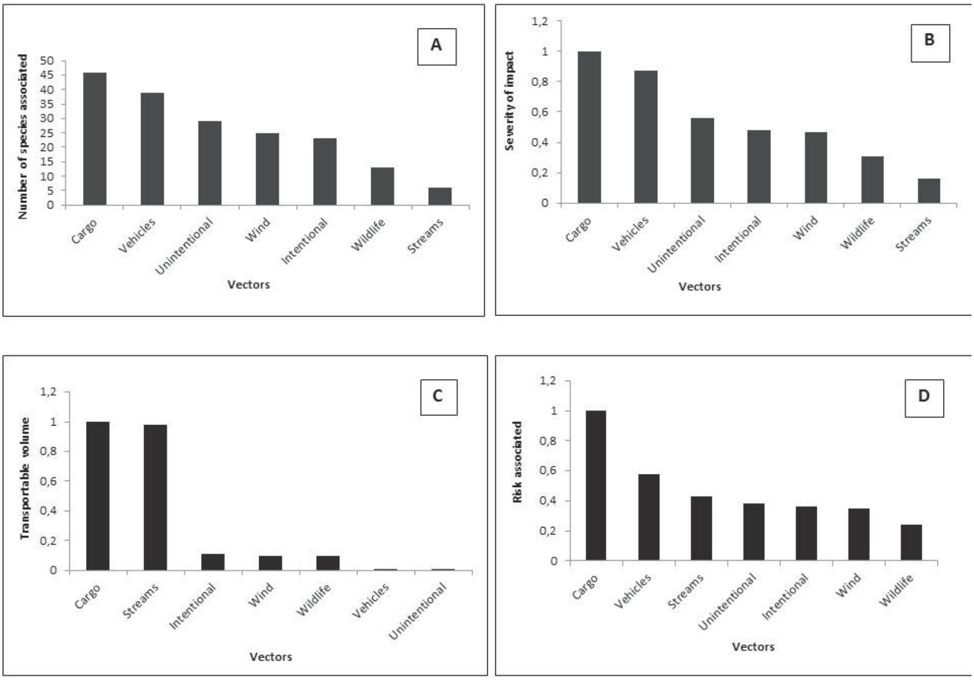

Figure 2. Vectors of introduction and spread of invasive and potentially invasive alien plants present in intensive use zones of the Ernesto Tornquist Provincial Park and it's surroundings (Buenos Aires, Argentina). **A** Number of species associated to each dispersion vector according to the characteristics of their fruits and seeds and their human use **B** Severity of impact of vectors depending on the potential impact of transportable species and the difficulty of their control **C** Relative capacity of vectors to transport propagules **D** Risk associated with vectors depending on the potential impact of transportable species, the difficulty of their control and the transport capacity of the vector.

In both cases, the maximum value corresponds to cargos and the smaller one to streams. Thus, the severity of impact of the vector index was maximized for cargo (1), followed by vehicles (0.87), unintentional human transport (0.56), intentional human transport (0.48), wind (0.47), wildlife (0.31) and streams (0.16) (Fig. 2B).

Regarding the transport capacity of the different vectors, the transportable propagules index varied between 11 and 226, again reaching the maximum value for cargo and the minimum for streams.

Twenty species were evaluated as very abundant, 16 as abundant and 10 as rare. A high number of propagules were produced by 30.4% of the species under study, moderate production by 50% and a low number of propagules by eight species (17.4%). Only one species (*Melia azedarach*) was considered as having a very high production of propagules.

It was defined that propagules of all plants that can be transported in association with cargo or intentionally by humans are available for these vectors for 12 months per year. Vehicles and unintentional human transport might transport species with available propagules for periods of two to five months per year; whereas animals and

Table 1. Vectors characterization. Potential impact (PIV), control difficulty (CDV), severity of impact (SI), transportable propagules (TP), individual transport capacity, activity frequency, carrying capacity (CC), transportable volume (TV) and resulting risk (RV) for vectors capable of transporting invasive and potentially invasive alien plants present in intensive use zones of the Ernesto Tornquist Provincial Park and it's surroundings (Buenos Aires, Argentina).

	Cargo	Vehicles	Streams	Unintencional by people	Intentional by people	Wind	Wildlife
PIV	1693	1461	240	1081	833	871	481
CDV	1891	1659	321	937	896	817	643
SI	1	087	0.16	0.56	0.48	0.47	0.31
TP	226	53.08	11	35.17	101.10	13	16.42
Indiv. Capacity	1000	10	1000	1	1000	1	10
Frequency	10	10	10	100	1	1000	100
CC	10000	100	10000	100	1000	1000	1000
TV	1	0.01	0.98	0.01	0.11	0.11	0.11
RV	1	0.58	0.43	0.38	0.36	0.35	0.24

streams could transport species with available propagules between one and 12 months per year. The wind vector could disperse species with available propagules between one and three months per year.

The carrying capacity, for its part, was considered maximum for the cargo, stream and wind vectors, whereas the minimum value was for the vehicle and unintentional human transport vectors.

The volume transported at each potential introduction event was considered to be very large for cargo, streams, wind and intentional human transport; medium for vehicles and animals and small for unintentional human transport.

Only intentional human transport was considered to have a very low frequency of activity. For unintentional transport by humans and mediated by animals, the frequency is considered high, whereas it is classified as medium for cargo, wind, vehicles and streams.

Thus, the transportable volume index resulted maximum for cargo (1), followed immediately by streams and wind (0.98), whereas the rest of the vectors received values of ten to one hundred times lower in terms of their relative transport capacity (Fig. 2C).

The combination of the information described allowed us to calculate the risk associated with each vector, being maximum for cargo (1), followed by vehicles (0.58) and streams (0.43), unintentional human transport (0.38), intentional human transport (0.36), wind (0.35) and wildlife (0.24) (Fig. 2D, Table 1).

Discussion

In this study, we designed and applied a risk analysis system associated with vectors responsible for the introduction and dispersal of plant species, which constitutes a simple and novel alternative of high potential value for decreasing the risk associated to invasive species by reducing propagule pressure in a variety of ways: improving detection measures and border policies, limiting vector contamination, controlling invasive populations in source regions, helping to raise public awareness of problems to find alternatives for invasive species (Pyšek and Richardson 2010). As we previously mentioned, there are many antecedents aimed at reducing unwanted introductions by assessing the risk associated with vectors and pathways, most of them applied at national or state borders (Gordon et al. 2012, Grosholz et al. 2012, Conser 2013, Kelly et al. 2013). The main differences of our approach include it local focus, primarily designed for individual reserves, what can result in an improvement of the precision of the analysis. It is also based on a context-specific perspective that drives the attention of the administrators to real threats posed by potentially invasive species that are present in the surroundings.

As discussed in detail below, the ranking obtained in this work is consistent with particular features of our case study, including heavy transit of vehicles associated to tourism and cargo, strong and frequent winds (particularly during plant dispersal seasons), and a dense network of water courses. This situation will clearly change in other reserves, but the framework should still be useful to calculate a specific scoring of dispersal vectors.

The development of an index of the relative importance of vectors of introduction and dispersal presents some challenges, such as comparing vectors as different from each other as the wind and the sole of a shoe. Another weakness associated with this index is related to its need of information about the presence of invasive or potentially invasive species in the area surrounding the reserve that could be not available in some cases. On the other hand, data on previous invasive behavior of the species of interest is becoming easier to obtain with growing regional and national databases on invasive species. Something similar occurs with the characteristics of the species that permit to associate them to dispersal vectors, as most of the potentially invasive plants are regionally or even globally shared (Randall 2017). It is also important to recognize that the invasion process is dynamic and that some of the species that are classified as non-invasive at one time could become aggressive invaders if there are changes in the environmental conditions or the invasive population itself (Davis et al. 2000, Jiménez et al. 2011, Dechoum et al. 2014, Schrama and Bardgett 2016), possibly affecting the relative importance of the different vectors under analysis. It is therefore advisable to update the lists of species to be included in the analysis periodically.

Apart from the specific function of this analysis, the structure of the proposed indexes allows us to separate the different components associated with the potential impact of each vector and this could guide actions for reducing their potential impact on the area (Davies and Sheley 2007). Thus, management actions could be oriented, alternatively or complementarily, towards reducing the frequency or capacity of the individual transport of a vector, controlling its effects during periods of availability of transportable propagules and avoiding the transport of high risk species (e.g., through the elimination of the foci of invasion at the origin or in the path that a vector travels), etc. The structure of this system would also enable to evaluate more specific dispersal vectors (for example bicycles vs. walking or horseback riding), opening up interesting opportunities for the zoning and management of protected areas against the challenge of invasive alien species.

The vectors analyzed in our case study are clearly separated into two groups: on the one hand the anthropogenic agents (cargo, vehicles and intentional and unintentional transport by people) and, on the other hand, the natural means of dispersal (water, wind and animals). Due to their intrinsic characteristics, these two sets of vectors are associated with different and complementary management strategies, while the former allow and justify control and preventive actions; the latter are more naturally associated with early detection, since it is difficult or directly not feasible to reduce their transport capacity.

The results of the analysis place the vectors of cargo and transport associated with vehicles among the highest risks of entry of potentially invasive plant species in the study area. A number of studies have shown that unintentional transport by vehicles, either associated directly to the vehicle, or with cargo, is an important mechanism of seed dispersal (Clifford 1959, Lonsdale and Lane 1994, Von Der Lippe and Kowarik 2007, Ansong and Pickering 2013). The climatic conditions, the season of the year, the place where it is driven and the parts of the vehicle exposed to the environment affect this type of dispersal; as well as the weight and size of the seeds and the place where it is loaded (Zwaenepoel et al. 2006, Von der Lippe and Kowarik 2008, Veldman and Putz 2010, Taylor et al. 2012). While the relative importance of vehicles and transported freight is likely to vary between reserves, their particular relevance has an encouraging aspect, considering that the points of entry of freight vehicles and passenger cars are often few in number and are well defined, and that the same is true for the dispersal routes of these vectors within the reserves (internal roads and parking areas). The cleaning of vehicles before entering the area has proven to be an efficient measure for reducing the amount of propagules transported. The duration and type of washing will depend on the size and shape of the vehicle (Rew and Fleming 2011). Other preventive measures could include restricting vehicular traffic or creating invasive species free zones along roadsides (Davies and Sheley 2007). The handling of cargo allows specific actions, including quarantine systems (temporary deposit of the material entered in safe places that allow the detection and elimination of species that could germinate and settle there). There is also the option of evaluating the sites of origin of the materials, avoiding those affected by invasions of species transportable by this vector, in addition to thoroughly cleaning the containers before loading. These preventive measures should be complemented with periodic surveys along the internal roads in search of plants that might have entered these pathways, and their immediate removal (Lee and Chown 2009).

The wind vector represents a particular challenge (Davies and Sheley 2007) and preventive actions could be aimed at eliminating nuclei of transportable species located on the windward side of the reserve. If this were not possible, areas of high risk of invasion could be defined depending on the location of these nuclei and the prevailing winds during the months of seed production, which should be subject to regular monitoring and control tasks.

Streams as vectors follow in the order of risk. In this case the preventive measures are more complex and the effort should be directed at monitoring of the banks in search of points of entry of species (Cabra-Rivas et al. 2014). In general terms, the search actions should focus on streams that correspond to watersheds originating outside the reserve, concentrating the training efforts of personnel dedicated to detection on the set of species transportable by this vector, which clearly increases the chances of an efficient identification. In addition, resources could be devoted to the detection of nuclei of these species in sectors of the watershed located outside the reserve, where eradication would act as an efficient preventive measure that would save efforts and resources for the detection and control of internal foci of invasion (Säumel and Kowarik 2010).

The management of intentional and unintentional anthropogenic transport vectors includes a significant component of education and awareness. In the case of the former, it is essentially a question of avoiding the use of potentially invasive plant species in the staff residences and in the recreation areas (parks, gardens, shade trees) and replacing high risk plants in these sites. The unintentional transportation in clothing, footwear, backpacks, or other personal items have been documented in numerous studies (e.g. Whinam et al. 2005, McNeill et al. 2008, Pickering and Mount 2010, Auffret and Cousins 2013). Some reserves regulate the number of visitors and the period of access to reduce the unwanted introduction of propagules. There are natural protected areas in U.S.A. and New Zealand that require footwear, clothing, vehicles and equipment to be cleaned prior to entry (Genovesi and Monaco 2013). Researchers and park rangers pose a particularly high risk as they go to areas that are not accessible to the public, including areas of special conservation value (Chown et al. 2012, Huiskes et al. 2014).

The control of dispersal by animals leaves an even smaller space for prevention tasks, but could motivate monitoring tasks at sites with greater frequency of use by agents of high dispersal efficiency (e.g., wire fences or trees used as perches by frugivorous birds, Gosper et al. 2005, Buckley et al. 2006, Amodeo and Zalba 2013).

Making a list of high-risk species for each place and adapting the vectors that transport them, the analysis developed in this paper can be applied to other protected areas, political units or as a basis for the allocation of prevention efforts, early detection and early control of invasive species, translating the prevention premises frequently seen in the literature on biological invasions into concrete actions.

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References

Alexander ME, Dick JTA, Weyl OLF, Robinson TB, Richardson DM (2014) Existing and emerging high impact invasive species are characterized by higher functional responses than natives. Biology Letters 10: 20130946. http://dx.doi.org/10.1098/rsbl.2013.0946

Amodeo MR, Zalba SM (2013) Wild cherries invading natural grasslands: unraveling colonization history from population structure and spatial patterns. Plant Ecology 214: 1299–1307. https://link.springer.com/article/10.1007/s11258-013-0252-4

Amodeo MR, Vázquez MB, Zalba SM (2017) Generalist dispersers promote germination of an alien fleshy-fruited tree invading natural grasslands. PLoS One 12: e0172423. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0172423

Amodeo MR, Zalba SM (2017) Sex morphs and invasiveness of a fleshy-fruited tree in natural grasslands from Argentina. Botany 95(9): 913–922. https://doi.org/10.1139/cjb-2017-0041

Anderson LG, White PC, Stebbing PD, Stentiford GD, Dunn AM (2014) Biosecurity and vector behaviour: evaluating the potential threat posed by anglers and canoeists as pathways for the spread of invasive non-native species and pathogens. PLoS One 9: e92788. https://doi.org/10.1371/journal.pone.0092788

Ansong M, Pickering C (2013) Are weeds hitchhiking a ride on your car? A systematic review of seed dispersal on cars. PLoS One 8: e80275. https://doi.org/10.1371/journal.pone.0080275

Auffret AG, Cousins SAO (2013) Humans as long-distance dispersers of rural plant communities. PLoS One 8(5): e62763. https://doi.org/10.1371/journal.pone.0062763

Azpiroz AB, Isacch JP, Dias RA, Di Giacomo AS, Fontana CS, Palarea CM (2012) Ecology and conservation of grassland birds in southeastern South America: a review. Journal of Field Ornithology 83:217–246. https://doi.org/10.1111/j.1557-9263.2012.00372.x

Bertonatti C, Corcuera J (2000) Situación ambiental argentina 2000. Fundación Vida Silvestre, Buenos Aires, 1–440.

Bilenca D, Miñarro F (2004) Identificación de áreas valiosas de pastizal en las pampas y campos de Argentina, Uruguay y sur de Brasil. Fundación Vida Silvestre, Buenos Aires, 352 pp.

Blackburn TM, Pyšek P, Bacher S, Carlton JT, Duncan RP, Jarošík V, Wilson JR, Richardson DM (2011) A proposed unified framework for biological invasions. Trends in ecology & evolution 26: 333–339. https://doi.org/10.1016/j.tree.2011.03.023

Buckley YM, Anderson S, Catterall CP, Corlett RT, Engel T, Gosper CR, Nathan R, Richardson DM, Setter M, Spiegel O et al. (2006) Management of plant invasions mediated by frugivore interactions. Journal of Applied Ecology 43: 848–857. https://doi.org/10.1111/j.1365-2664.2006.01210.x

Burgos J (1968) El clima de la Provincia de Buenos Aires en relación con la vegetación natural y el suelo. In: Cabrera AL (Ed.) Flora de la provincia de Buenos Aires. Colección Científica del INTA 4(1) (Buenos Aires): 33–100.

Cabra-Rivas I, Alonso Á, Castro-Díez P (2014) Does stream structure affect dispersal by water? A case study of the invasive tree *Ailanthus altissima* in Spain. Management of Biological Invasions 5: 179–186. https://doi.org/10.3391/mbi.2014.5.2.11

Carlton J, Ruiz G (2005) Vector science and integrated vector management in bioinvasion ecology: conceptual frameworks. Chapter 3. In: Mooney HA, Mack RN, McNeely JA, Neville LE, Schei PJ, Waage JK (Eds) Invasive Alien Species: A New Synthesis. Island Press, Washington DC, 36–58.

Chown SL, Huiskes AHL, Gremmen NJM, Lee JE, Terauds A, Crosbie K, Frenot Y, Hughes KA, Imura S, Kiefer K et al. (2012) Continent-wide risk assessment for the establishment of nonindigenous species in Antarctica. Proceedings of the National Academy of Sciences 109: 4938–4943. https://doi.org/10.1073/pnas.1119787109

Clifford HT (1959) Seed dispersal by motor vehicles. Journal of Ecology 47: 311–315. https://doi.org/10.2307/2257368

Colautti RI, Grigorovich IA, MacIsaac HJ (2006) Propagule pressure: A null model for biological invasions. Biological Invasions 8: 1023–1037. https://doi.org/10.1007/s10530-005-3735-y

Conser C (2013) Invasive Species Pathway Risk Analysis for California. University of California, Davis, 1–97. http://www.iscc.ca.gov/docs/reports/CISAC-Pathway-Report-July-2013-web.pdf

Damiani ML (2007) Plantas exóticas en Sierra de la Ventana (Buenos Aires): detección de invasores potenciales. PhD Thesis, Universidad Nacional del Sur, Bahía Blanca.

Davies KW, Sheley RL (2007) A conceptual framework for preventing the spatial dispersal of invasive plants. Weed Science 55: 178–184. https://doi.org/10.1614/WS-06-161

Davis MA, Grime JP, Thompson K (2000) Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88: 528–534. https://doi.org/10.1046/j.1365-2745.2000.00473.x

Dechoum MS, Castellani TT, Zalba SM, Rejmánek M, Peroni N, Tamashiro JY (2014) Community structure, succession and invasibility in a seasonal deciduous forest in southern Brazil. Biological Invasions 17: 1697–1712. https://doi.org/10.1007/s10530-014-0827-6

Dechoum MS, Rejmánek M, Castellani TT, Zalba SM (2015) Limited seed dispersal may explain differences in forest colonization by the Japanese raisin tree (*Hovenia dulcis* Thunb.), an invasive alien tree in Southern Brazil. Tropical Conservation Science 8: 610–622. https://doi.org/10.1177/194008291500800303

De Villalobos A, Zalba SM (2010) Continuous feral horse grazing and grazing exclusion in mountain pampean grasslands in Argentina. Acta Oecologica 36: 514–519. https://doi.org/10.1016/j.actao.2010.07.004

Fonseca CR, Guadagnin DL, Emer C, Masciadri S, Germain P, Zalba SM (2013) Invasive alien plants in the Pampas grasslands: a tri-national cooperation challenge. Biological Invasions 15: 1751–1763. https://doi.org/10.1007/s10530-013-0406-2

Genovesi P, Monaco A (2013) Guidelines for addressing invasive species in protected areas. In Plant Invasions in Protected Areas. In: Foxcroft L, Pyšek P, Richardson DM, Genovesi P (Eds) Plant Invasions in Protected Areas: Patterns, Problems and Challenges, Invading Nature. Springer Series in Invasion Ecology 7: 487–506. https://doi.org/10.1007/978-94-007-7750-7_22

Gosper CR, Stansbury CD, Vivian-Smith G (2005) Seed dispersal of fleshy-fruited invasive plants by birds: contributing factors and management options. Diversity and Distributions 11: 549–558. https://doi.org/10.1111/j.1366-9516.2005.00195.x

Gordon DR, Gantz CA, Jerde CL, Chadderton WL, Keller RP, Champion PD (2012) Weed Risk Assessment for Aquatic Plants: Modification of a New Zealand System for the United States. Plos One 7: e40031. https://doi.org/10.1371/journal.pone.0040031

Grosholz E, Crafton RE, Fontana RE, Pasari J, Williams S, Zabin C (2012) Aquatic Invasive Species Vector Risk Assessments: An Analysis of Aquaculture as a Vector for Introduced Marine and Estuarine Species in California.University of California Davis, 1–77. http://www.opc.ca.gov/webmaster/ftp/project_pages/AIS/AIS_Aquaculture.pdf

Huiskes AH, Gremmen NJ, Bergstrom DM, Frenot Y, Hughes KA, Imura S, Kiefer K, Lebouvier M, Lee JE, Tsujimoto M (2014) Aliens in Antarctica: assessing transfer of plant propagules by human visitors to reduce invasion risk. Biological Conservation 171: 278–284. https://doi.org/10.1016/j.biocon.2014.01.038

Jeschke JM, Keesing F, Ostfeld RS (2013) Novel Organisms: comparing invasive species, GMOs, and emerging pathogens. AMBIO 42: 541–548. https://doi.org/10.1007/s13280-013-0387-5

Jiménez MA, Jaksic FM, Armesto JJ, Gaxiola A, Meserve PL, Kelt DA, Gutiérrez JR (2011) Extreme climatic events change the dynamics and invasibility of semi-arid annual plant communities. Ecology Letters 14: 1227–1235. https://doi.org/10.1111/j.1461-0248.2011.01693.x

Kelly J, O'Flynn C, Maguire C (2013). Risk analysis and prioritisation for invasive and non-native species in Ireland and Northern Ireland. Report prepared for the Northern Ireland Environment Agency and National Parks and Wildlife Service as part of Invasive Species Ireland, 1–59. http://invasivespeciesireland.com/wp-content/uploads/2013/03/Risk-analysis-and-prioritization-29032012-FINAL.pdf

Lee JE, Chown SL (2009) Breaching the dispersal barrier to invasion: quantification and management. Ecological Applications 19: 1944–1959. https://doi.org/10.1890/08-2157.1

Leung B, Lodge DM, Finnoff D, Shogren JF, Lewis MA, Lamberti G (2002) An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proceedings of the Royal Society of London B: Biological Sciences 269: 2407–2413. https://doi.org/10.1098/rspb.2002.2179

Lodge DM, Williams S, MacIsaac HJ, Hayes KR, Leung B, Reichard S, Mack RN, Moyle PB, Smith M, Andow DA et al. (2006) Biological Invasions: Recommendations for U.S. Policy and Management.. Ecological Applications 16: 2035–2054. https://doi.org/10.1890/1051-0761(2006)016[2035:BIRFUP]2.0.CO;2

Loydi A, Zalba SM (2009) Feral horses dung piles as invasion windows in natural grasslands. Plant Ecology 201(2): 471–480. https://doi.org/10.1007/s11258-008-9468-0

Long MA, Grassini CM (1997) Actualización del Conocimiento Florístico del Parque Provincia E. Tornquist. Buenos Aires, Argentina. Final Report Ministerio de Asunto Agrarios, Provincia de Buenos Aires and Universidad Nacional del Sur,Bahía Blanca, 276 pp.

Long MA, Peter G, Villamil CB (2004) La familia Asteraceae en el sistema de Ventania (Buenos Aires, Argentina). Boletín Sociedad Argentina de Botánica 39: 159–169.

Lonsdale WM, Lane AM (1994) Tourist vehicles as vectors of weed seeds in Kakadu National Park, Northern Australia. Biological Conservation 69: 277–283. https://doi.org/10.1016/0006-3207(94)90427-8

Lövei GL, Lewinsohn TM (2012) Megadiverse developing countries face huge risks from invasives. Trends in Ecology & Evolution 27: 2–3. https://doi.org/10.1016/j.tree.2011.10.009

Mack RN, Ruiz G, Carlton J (2003) Global plant dispersal, naturalization, and invasion: pathways, modes, and circumstances. In: Ruiz G, Carlton J (Eds) Invasive species: Vectors and management strategies. Island Press,Washington, 3–30.

Marco DE, Páez SA, Cannas SA (2002) Species Invasiveness in Biological Invasions: A Modelling Approach. Biological Invasions 4: 193–205. https://doi.org/10.1023/A:1020518915320

McKinney ML (2002) Influence of settlement time, human population, park shape and age, visitation and roads on the number of alien plant species in protected areas in the USA. Diversity and Distributions 8: 311–318. https://doi.org/10.1046/j.1472-4642.2002.00153.x

McNeill M, Payne T, Bewsell D (2008) Tourists as vectors of potential invasive alien species and a strategy to reduce risk. In: Fountain J, Moore K (Eds) Re-creating tourism: New Zealand Tourism and Hospitality Research Conference. Hanmer Springs (New Zealand), December 2008. Lincoln University, Canterbury, New Zealand, 3–5.

Overbeck GE, Vélez-Martin E, Scarano FR, Lewinsohn TM, Fonseca CR, Meyer ST, Müller SC, Ceotto P, Dadalt L, Durigan G, et al. (2015) Conservation in Brazil needs to include non-forest ecosystems. Diversity and Distributions 21: 1455–1460. https://doi.org/10.1111/ddi.12380

Pauchard A, García R, Zalba SM, Sarasola M, Zenni R, Ziller S, Nuñez MA (2015) 14 Pine Invasions in South America: Reducing Their Ecological Impacts Through Active Management. In: Canning-Clode J (Org.) Biological Invasions in Changing Ecosystems. 1ed. De Gruyter Open Ltd, Berlin.

Pickering C, Mount A (2010) Do tourists disperse weed seed? A global review of unintentional human-mediated terrestrial seed dispersal on clothing, vehicles and horses. Journal of Sustainable Tourism 18: 239–256. http://dx.doi.org/10.1080/09669580903406613

Pretelli MG, Isacch JP, Cardoni DA (2015) Effects of fragmentation and landscape matrix on the nesting success of grassland birds in the Pampas grasslands of Argentina. Ibis 157, 688–699. https://doi.org/10.1111/ibi.12292

Pyšek P, Richardson DM (2010) Invasive Species, Environmental Change and Management, and Health. Annual Review of Environment and Resources 35: 25–55. http://dx.doi.org/10.1146/annurev-environ-033009-095548

Pyšek P, Jarošík V, Kučera T (2002) Patterns of invasion in temperate nature reserves. Biological Conservation 104: 13–24. https://doi.org/10.1016/S0006-3207(01)00150-1

Pyšek P, Jarošík V, Hulme PE, Pergl J, Hejda M, Schaffner U, Vilà M (2012) A global assessment of invasive plant impacts on resident species, communities and ecosystems: the interaction of impact measures, invading species' traits and environment. Global Change Biology 18: 1725–1737. https://doi.org/10.1111/j.1365-2486.2011.02636.x

Radford IJ (2013) Fluctuating resources, disturbance and plant strategies: diverse mechanisms underlying plant invasions. Journal Arid Land 5(3): 284–297. https://doi.org/10.1007/s40333-013-0164-0

Randall RP (2017) A Global Compendium of Weeds. 3rd Edition. Randall RP, Perth, Australia, 1–3653.

Rew LJ, Fleming J (2011) Developing functional parameters for a science-based vehicle cleaning program to reduce transport of non-indigenous invasive plant species. Montana State Univ., Bozeman, 1–58. https://doi.org/10.21236/ADA553532

Ruiz GM, Carlton JT (2003) Invasion vectors: a conceptual framework for management. In: Ruiz G, Carlton J (Eds) Invasive species: Vectors and management strategies. Island Press,Washington, 459–504.

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A (2000) Global biodiversity scenarios for the year 2100. Science 287: 1770–1774. https://doi.org/10.1126/science.287.5459.1770

Säumel I, Kowarik I (2010) Urban rivers as dispersal corridors for primarily wind-dispersed invasive tree species. Landscape and Urban Planning 94: 244–249. https://doi.org/10.1016/j.landurbplan.2009.10.009

Schrama M, Bardgett RD (2016) Grassland invasibility varies with drought effects on soil functioning. Journal of Ecology 104: 1250–1258. https://doi.org/10.1111/1365-2745.12606

Schüttler E, Karez CS (2008) Especies exóticas invasoras en las Reservas de Biosfera de América Latina y el Caribe. Un informe técnico para fomentar el intercambio de experiencias entre las Reservas de Biosfera y promover el manejo efectivo de las invasiones biológicas. Oficina Reg. Cienc. UNESCO para América Lat. El Caribe, Montevideo, 1–305.

Simberloff D, Martin J-L, Genovesi P, Maris V, Wardle DA, Aronson J, Courchamp F, Galil B, García-Berthou E, Pascal M et al. (2013) Impacts of biological invasions: what's what and the way forward. Trends in Ecology & Evolution 28: 58–66. https://doi.org/10.1016/j.tree.2012.07.013

Taylor K, Brummer T, Taper ML, Wing A, Rew LJ (2012) Human-mediated long-distance dispersal: an empirical evaluation of seed dispersal by vehicles. Diversity and Distributions 18: 942–951. https://doi.org/10.1111/j.1472-4642.2012.00926.x

Theoharides KA, Dukes JS (2007) Plant invasion across space and time: factors affecting nonindigenous species success during four stages of invasion. New Phytologist 176: 256–273. https://doi.org/10.1111/j.1469-8137.2007.02207.x

Veldman JW, Putz FE (2010) Long-distance Dispersal of Invasive Grasses by Logging Vehicles in a Tropical Dry Forest. Biotropica 42: 697–703. https://doi.org/10.1111/j.1744-7429.2010.00647.x

Vilà M, Espinar JL, Hejda M, Hulme PE, Jarošík V, Maron JL, Pergl J, Schaffner U, Sun Y, Pyšek P (2011) Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. Ecology Letters 14: 702–708. https://doi.org/10.1111/j.1461-0248.2011.01628.x

Von Der Lippe M, Kowarik I (2007) Long-distance dispersal of plants by vehicles as a driver of plant invasions. Conservation Biology 21: 986–996. https://doi.org/10.1111/j.1523 1739.2007.00722.x

Von der Lippe M, Kowarik I (2008) Do cities export biodiversity? Traffic as dispersal vector across urban–rural gradients. Diversity and Distributions 14: 18–25. https://doi.org/10.1111/j.1472-4642.2007.00401.x

Ware C, Bergstrom DM, Müller E, Alsos IG (2012) Humans introduce viable seeds to the Arctic on footwear. Biological Invasions 14: 567–577. https://doi.org/10.1007/s10530-011-0098-4

Whinam J, Chilcott N, Bergstrom DM (2005) Subantarctic hitchhikers: expeditioners as vectors for the introduction of alien organisms. Biological Conservation 121: 207–219. https://doi.org/10.1016/j.biocon.2004.04.020

Wittenberg R, Cock MJW (2001) Invasive Alien Species: A Toolkit of Best Prevention and Management Practices. CAB International, Wallingford/Oxon, 1–228. https://doi.org/10.1079/9780851995694.0000

Zalba SM, Villamil CB (2002) Woody Plant Invasion in Relictual Grasslands. Biological Invasions 4: 55–72. https://doi.org/10.1023/A:1020532609792

Zalba S, Cuevas Y, De Villalobos A (2009) Lecciones aprendidas durante siete años de control de pinos invasores en pastizales naturales. In: Zalba S, Cuevas Y, De Villalobos A (Eds) Ambientes y recursos naturales del sudoeste bonaerense: producción, contaminación y conservación. EdiUNS, Bahia Blanca, Argentina, 325–340.

Ziller SR, Zalba S (2007) Proposals to prevent and control exotic invasive species. Natureza & Conservação 5: 78–85.

Zwaenepoel A, Roovers P, Hermy M (2006) Motor vehicles as vectors of plant species from road verges in a suburban environment. Basic and Applied Ecology 1: 83–93. https://doi.org/10.1016/j.baae.2005.04.003

Appendix I

Potentially invasive species assessed. Species of invasive and potentially invasive alien plants present in intensive use zones of the Ernesto Tornquist Provincial Park and it's surroundings (Buenos Aires, Argentina)., potential impact (PIV), control difficulty (CDV), abundance, propagule production and proportion of months per year in which they are available for transport by each of the vectors identified in the area.

Species	Family	Category	PI	CD	Abundance	Propagule production	WIND	WILDLIFE	STREAMS	UNINTE-TIONAL by people	INTEN-TIONAL by people	VEHICLES	CARGO
Acacia saligna	Fabaceae (Mi-mosoideae)	Invasive	Medium	High	Rare	High	0	0.25	0	0	1	0.25	1
Achillea milefol-lium	Asteraceae	Invasive	Medium	High	Rare	High	0.17	0	0	0	0	0.17	1
Aira elegantísima	Poaceae	Potentially Invasive	Medium	Low	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Argemone mexi-cana	Papaveraceae	Invasive	Medium	Medium	Rare	Moderate	0	0.17	0	0.25	0	0.25	1
Arundo donax	Poaceae	Invasive	Medium	High	Abundant	High	0	0	1	0	1	0	1
Bromus hordeaceus	Poaceae	Invasive	High	Medium	Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Buddleja davidii	Scrophularia-ceae	Invasive	Medium	Medium	Abundant	Moderate	0.25	0	0	0	1	0.33	1
Carduus picno-cephalus	Asteraceae	Potentially Invasive	High	Medium	Abundant	High	0.08	0	0	0.17	0	0.17	1
Carduus thoermeri	Asteraceae	Potentially Invasive	Medium	High	Very Abundant	High	0.08	0	0	0.17	0	0.17	1
Catapodium rigidum	Poaceae	Potentially Invasive	Medium	Low	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Chrysanthemum frutescens	Asteraceae	Invasive	Medium	High	Rare	Low	0.08	0	0	0	0	0.17	1
Convolvulus arvensis	Convolvulaceae	Invasive	Medium	High	Very Abundant	High	0	0	0	0	0	1	1
Cynodon dactylon	Poaceae	Invasive	High	High	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Cynosurus echi-natus	Poaceae	Potentially Invasive	Medium	Low	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1

Species	Family	Category	PI	CD	Abundance	Propagule production	WIND	WILDLIFE	STREAMS	UNINTENTIONAL by people	INTENTIONAL by people	VEHICLES	CARGO
Datura ferox	Solanaceae	Invasive	Medium	High	Abundant	High	0	0.25	0	0	0	0.33	1
Digitaria sanguinalis	Poaceae	Potentially Invasive	Medium	Low	Abundant	High	0.08	0	0.08	0.17	0	0.17	1
Echinochloa crusgalli	Poaceae	Invasive	Medium	Medium	Very Abundant	Moderate	0.08	0	0.08	0.17	0	0.17	1
Eragrostis curvula	Poaceae	Potentially Invasive	High	High	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Eucalyptus globulus	Myrtaceae	Invasive	High	Medium	Abundant	High	0.25	0	0.25	0.33	1	0.33	1
Helianthus tuberosus	Asteraceae	Potentially Invasive	Low	Medium	Rare	Low	0.08	0	0	0.17	1	0.17	1
Ibicea lutea	Martyniaceae	Potentially Invasive	Medium	Medium	Rare	Low	0	0.17	0	0	1	0	1
Lantana montevidensis	Verbenaceae	Invasive	High	High	Abundant	Moderate	0	0.17	0	0	1	0.25	1
Ligustrum sinense	Oleaceae	Invasive	Medium	High	Very Abundant	High	0	0.17	0.17	0.25	1	0.25	1
Linaria texana	Scrophulariaceae	Potentially Invasive	Medium	Low	Rare	Low	0	0.08	0	0	1	0	1
Lolium multiflorum	Poaceae	Potentially Invasive	Medium	Medium	Very Abundant	Moderate	0.08	0	0	0.17	1	0.17	1
Lonicera japonica	Caprifoliaceae	Invasive	Medium	High	Abundant	Moderate	0	0.17	0	0.25	1	0.25	1
Lotus glaber	Fabaceae (Faboideae)	Potentially Invasive	Medium	High	Abundant	High	0	0	0	0.33	1	0.33	1
Matricaria recutita	Asteraceae	Potentially Invasive	Medium	Low	Very Abundant	Low	0.08	0	0	0.17	1	0.17	1
Melia azedarach	Meliaceae	Potentially Invasive	High	High	Rare	Very High	0	0.33	0	0.42	1	0.42	1
Melissa officinalis	Lamiaceae	Potentially Invasive	Low	Medium	Abundant	Low	0	0	0	0	1	0	1
Miriabilis jalapa	Nyctaginaceae	Invasive	High	High	Abundant	Moderate	0.17	0	0	0.25	1	0.25	1
Oenothera rosea	Onagraceae	Potentially Invasive	Low	Low	Rare	Low	0	0.17	0	0	1	0	1

Species	Family	Category	PI	CD	Abundance	Propagule production	WIND	WILDLIFE	STREAMS	UNINTE-TIONAL by people	INTEN-TIONAL by people	VEHICLES	CARGO
Picris echiodes	Asteraceae	Potentially Invasive	Medium	Low	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Poa annua	Poaceae	Potentially Invasive	Medium	Medium	Very Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Polypogon monspe-liensis	Poaceae	Potentially Invasive	Medium	Medium	Abundant	Moderate	0.08	0	0	0.17	0	0.17	1
Portulaca oleracea	Portulacaceae	Invasive	High	Medium	Very Abundant	High	0	0	0	0.25	1	0.25	1
Prunella vulgaris	Lamiaceae	Potentially Invasive	Medium	Low	Abundant	Low	0.17	0	0	0	1	0.25	1
Rapistrum rugosum	Brassicaceae	Potentially Invasive	Medium	Medium	Very Abundant	Moderate	0	0	0	0.25	0	0.25	1
Rhamnus alaternus	Rhamnaceae	Invasive	High	Medium	Very Abundant	High	0	0.25	0	0.33	0	0.33	1
Salix viminalis	Salicaceae	Potentially Invasive	Medium	Medium	Very Abundant	Moderate	0.17	0	1	0.25	1	0.25	1
Salsola kali	Quenopodia-ceae	Invasive	High	High	Very Abundant	Moderate	0.17	0	0	0	0	0	1
Sisymbrium orientale	Brassicaceae	Potentially Invasive	Medium	Low	Very Abundant	Moderate	0	0	0	0.33	1	0.33	1
Solanum pseudo-capsicum	Solanaceae	Potentially Invasive	High	Low	Abundant	Moderate	0	0.25	0	0	1	0.33	1
Tecoma stans	Bignoniaceae	Invasive	Medium	Medium	Rare	Moderate	0.08	0	0	0	0	0.17	1
Tradescanthia fluminensis	Commelinaceae	Invasive	Medium	Medium	Very Abundant	High	0	1	0	0	1	0	1
Ulex europeus	Fabaceae (Faboideae)	Potentially Invasive	High	High	Abundant	Moderate	0	0	0.25	0	0	0.33	1