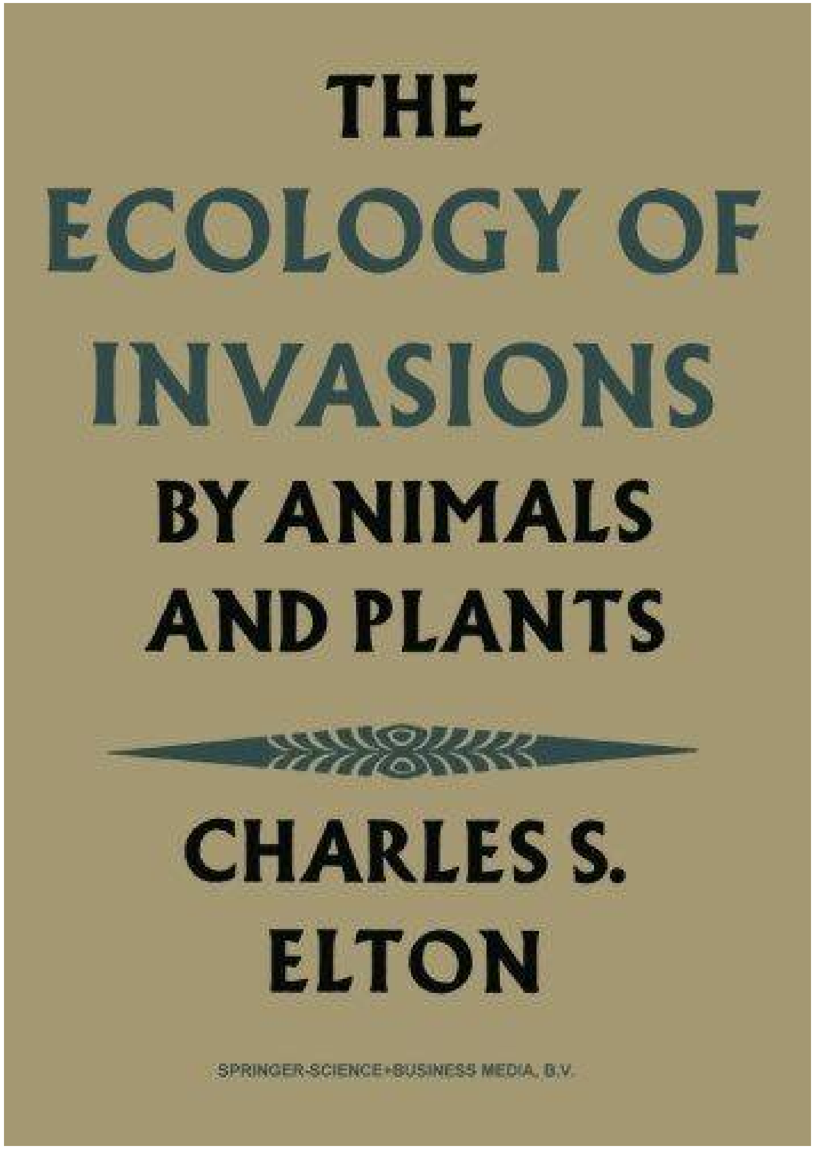
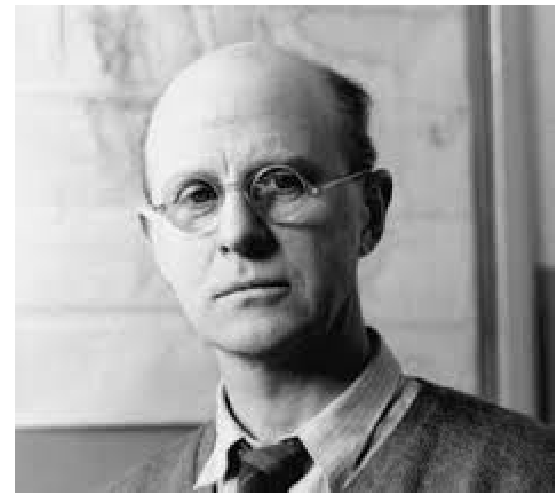
Amenazas a la biodiversidad: Invasiones biológicas

Material de lectura recomendado para esta clase

- Groom et al. (2006) Principles of Conservation Biology, caps. 8 y 9
- Lockwood, J. L.; Hoopes, M. F. & Marchetti, M. P. 2006. Invasion Ecology. Blackwell
- Otras referencias citadas en las diapositivas





Charles Elton

Principales factores de amenaza

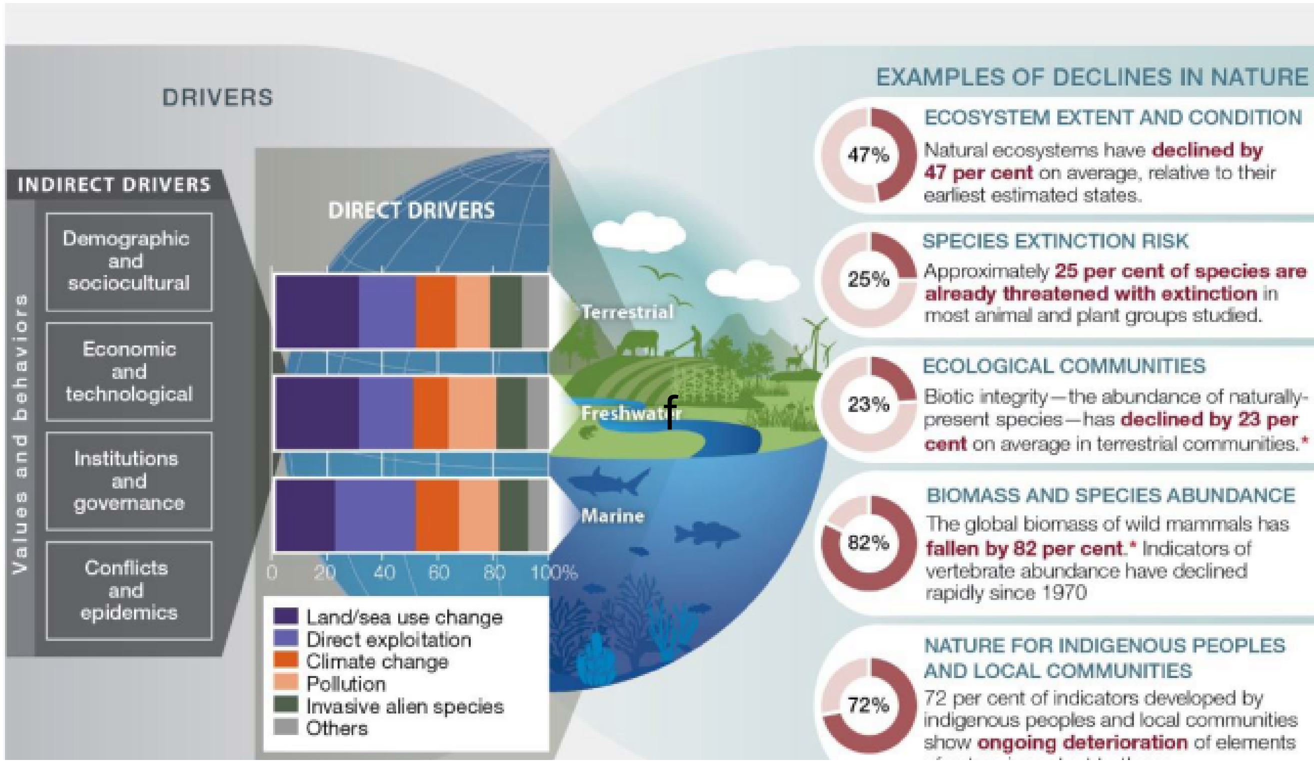


Figure 2. Examples of global declines in nature, emphasizing declines in biodiversity, that have been and are being caused by direct and indirect drivers of change. The direct drivers (land/sea use change; direct exploitation of organisms; climate change; pollution; and invasive alien species)[5] result from an array of underlying societal causes[6]. These causes can be demographic (e.g. human population dynamics), sociocultural (e.g. consumption patterns), economic (e.g. trade), technological or relating to institutions, governance, conflicts and epidemics; these are called indirect drivers[7], and are underpinned by societal values and behaviors. The colour bands represent the relative global impact of direct drivers on (from top to bottom) terrestrial, freshwater and marine nature as estimated from a global systematic review of studies published since 2005. Land and sea use change and direct exploitation account for more than 50 per cent of the global impact on land, in fresh water and in the sea, but each driver is dominant in certain contexts {2.2.6}. The circles illustrate the magnitude of the negative human impacts on a diverse selection of aspects of nature over a range of different time scales, based on a global synthesis of indicators {2.2.5, 2.2.7}.

Fuente: Díaz et al. (2019) IPBES Global Assessment Summary for Policymakers. IPBES

Esquema de la charla

- Qué son las invasiones biológicas
- Tendencias históricas en las invasiones
- La geografía de las invasiones
- Impactos de las invasiones
- Determinantes del éxito de las invasiones
- Manejo de invasiones

Terminología sobre invasiones

Table 1.1 **Terminology commonly used for non-native species in the English language.**

	Native	Non-native	Transported	Established	Spread	Impact	Invasive
Adventive	*	*		*	*		
Alien		*	*	*	*	*	*
Casual		*	*				
Colonizing		*	*	*	*		
Cryptogenic		*	*	*			
Escaped	*	*	*	*	*		
Established		*		*	*		
Exotic		*	*	*	*	*	*
Foreign		*	*	*			
Immigrant		*	*	*	*		
Imported		*	*	*	*		
Introduced	*	*	*	*	*		
Invasive	*	*	*	*	*	*	*
Naturalized		*	*	*	*		*
Non-indigenous		*	*	*	*	*	*
Noxious	*	*				*	*
Nuisance	*	*				*	*
Pest	*	*				*	*
Ruderal	*	*		*	*		*
Tramp		*	*	*	*		
Transformer		*				*	*
Transient		*	*				
Translocated	*	*	*	*			
Transplanted	*	*	*	*			
Transported	*	*	*				
Waif		*	*	*			
Weed	*	*	*	*	*	*	*

Notes: The list was compiled from the authors' readings of the invasion ecology literature. Other scientists may categorize the terms differently. This inconsistency of usage creates problems for synthesis and management. The columns indicate types of species and invasion stages to which the words apply. See Figure 1.2.

Lockwood et al. (2006) Invasion Ecology. Blackwell

Terminología sobre invasiones

- Criptogénica: Especie cuyo origen no se conoce.
- Indígena: Sinónimo de nativa.
- Introducida: Especie liberada fuera de su distribución nativa.
- Introducción: Liberación o escape de una especie no nativa.
- Invasión: Establecimiento y dispersión de una especie introducida.
- Nativa: Especie que llegó a un sitio sin ayuda humana.
- No indígena: Sinónimo de introducida.
- Reintroducida: Individuos liberados intencionalmente de una especie nativa que estuvo localmente amenazada o extinta.

El proceso de invasión

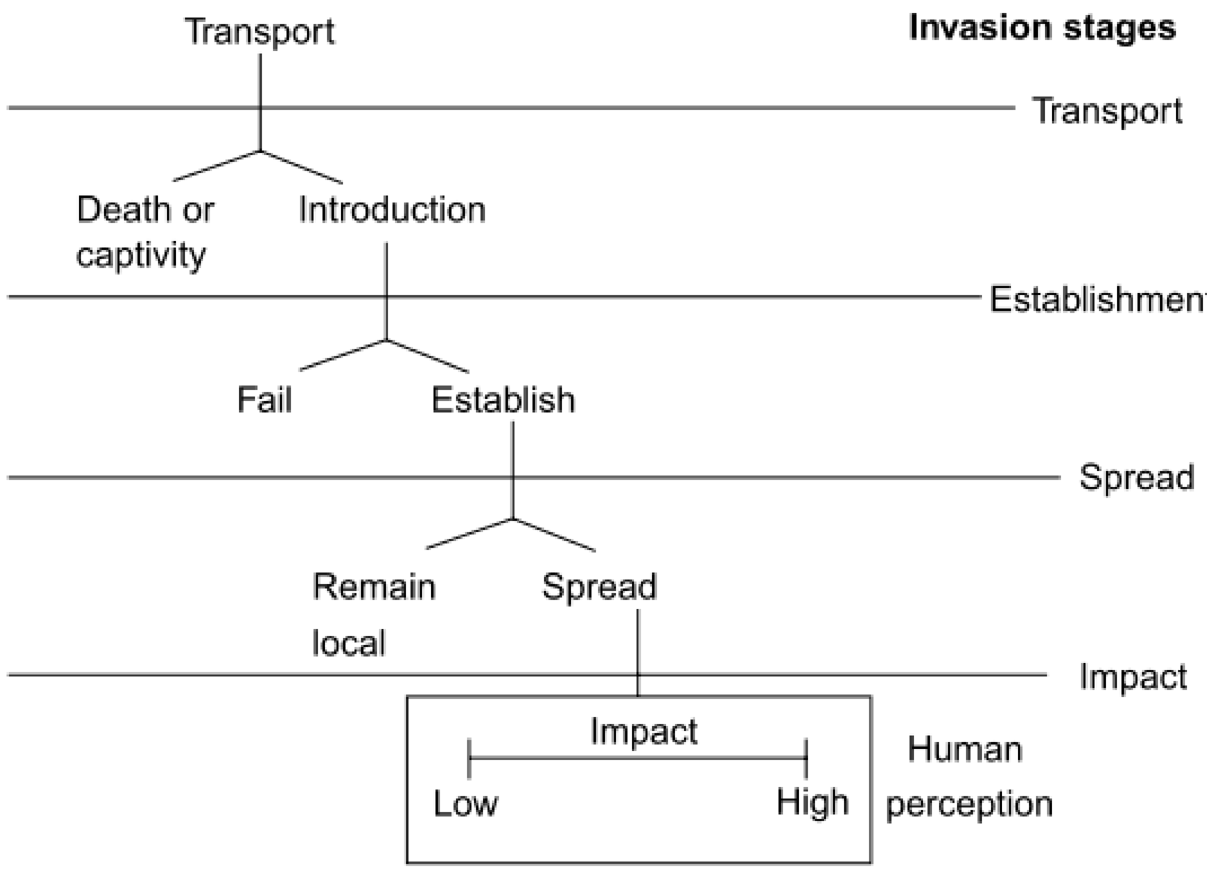


Figure 1.2 **Invasion process model depicting the discrete stages an invasive species passes through as well as alternative outcomes at each stage.**

Lockwood et al. (2006) Invasion Ecology. Blackwell

El proceso de invasión

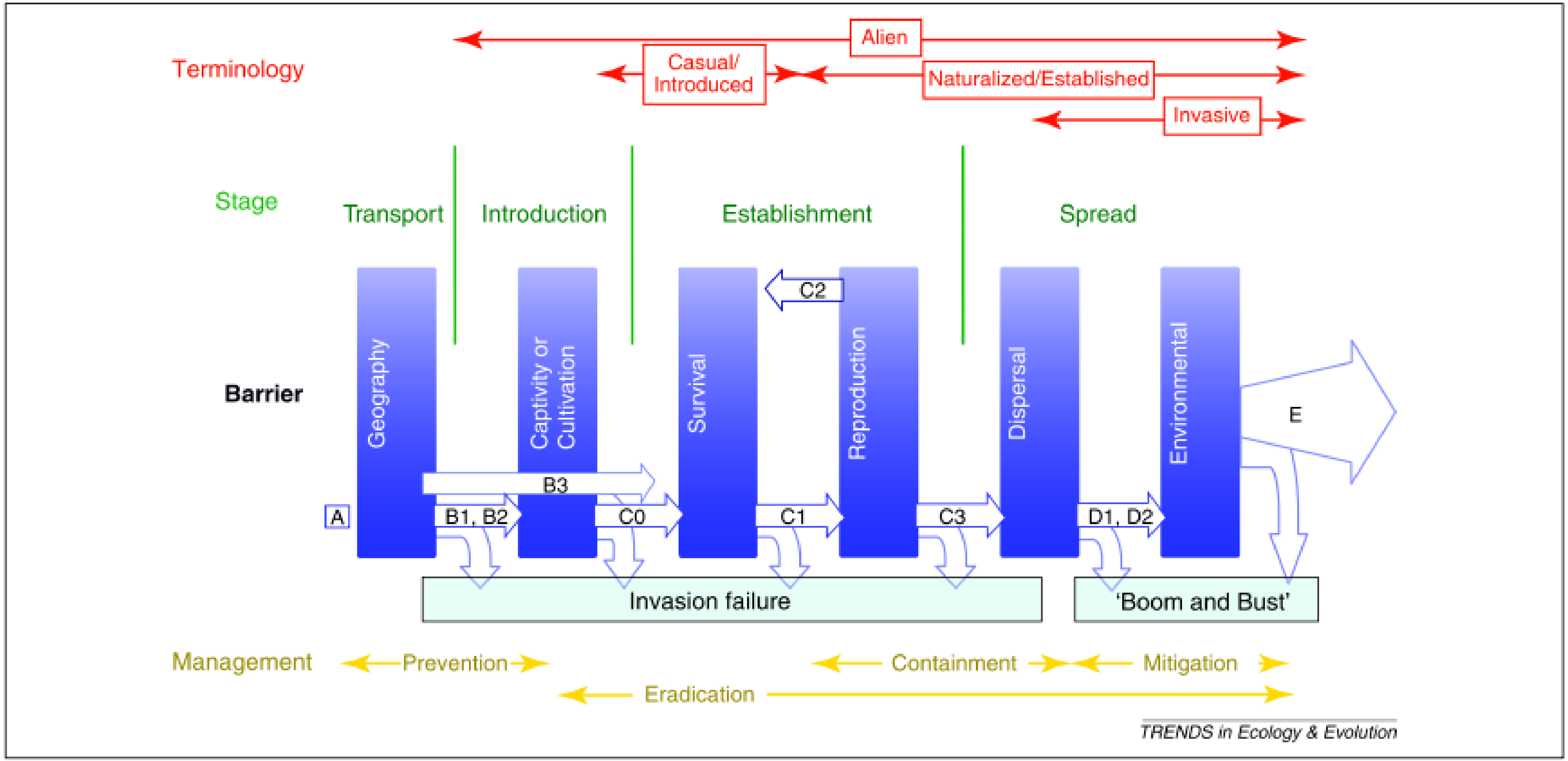


Figure 1. The proposed unified framework for biological invasions. The proposed framework recognises that the invasion process can be divided into a series of stages, that in each stage there are barriers that need to be overcome for a species or population to pass on to the next stage, that species are referred to by different terms in the terminology depending on where in the invasion process they have reached, and that different management interventions apply at different stages. Different parts of this framework emphasise views of invasions that focus on individual, population, process, or species. The unfilled block arrows describe the movement of species along the invasion framework with respect to the barriers, and the alphanumeric codes associated with the arrows relate to the categorisation of species with respect to the invasion pathway given in Table 1 (main text).

Blackburn et al. (2011) Trends Ecol Evol 26: 333-339

La ecología de las invasiones como disciplina científica

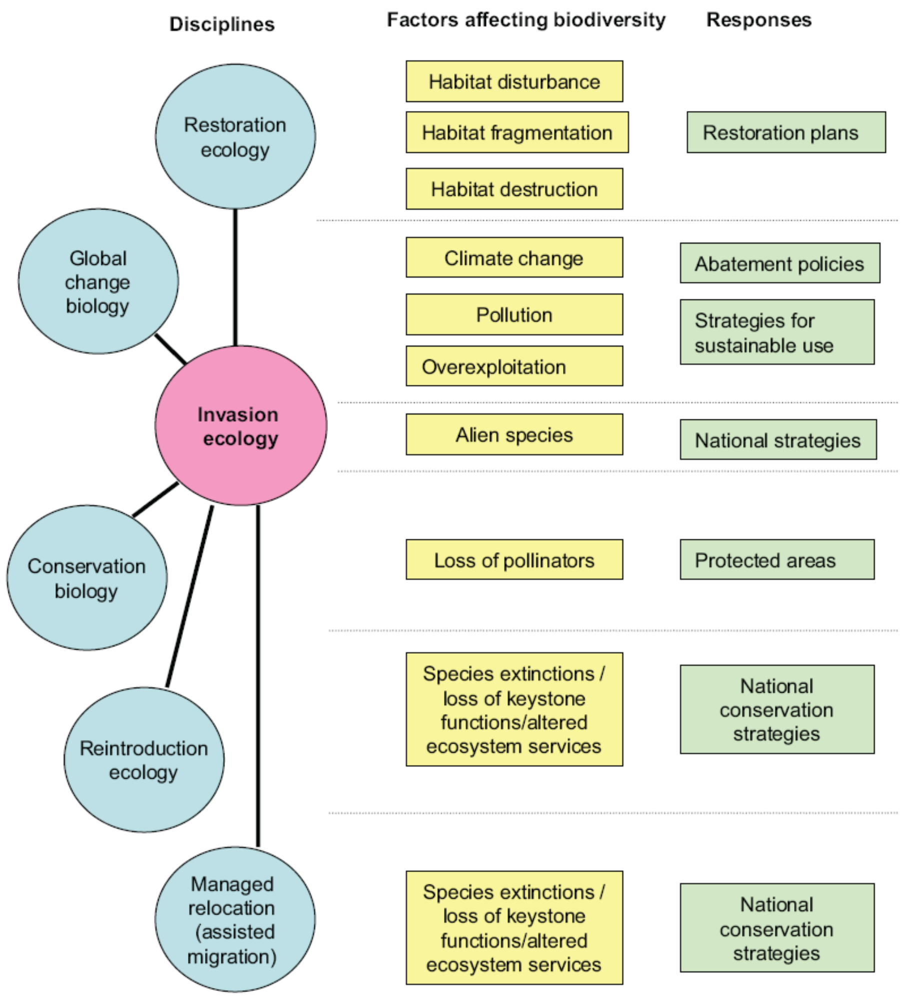


Figure 1

Invasion ecology has emerged as a discrete field, partly in response to the escalating level of threat that invasive species pose to global biodiversity together with other factors. The field of invasion ecology is increasingly drawing insights from (and lending some to) other disciplines that have themselves evolved in response to challenges in biodiversity conservation.

Fuente: Pysek & Richardson (2010) Ann. Rev. Env. Res. 35: 25-55

Esquema de la charla

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Tendencias en las invasiones

Table 1. Differences between prehistoric and human-assisted invasions.

Characteristic	*Prehistoric invasions*	*Human-assisted invasions*
Frequency of long-distance dispersal events	very low	very high
Number of species transported per event	low, except during biotic interchange events	high
Propagule load per event	small, except during biotic interchange events	potentially large
Effect of geographic barriers	strong	nearly insignificant
Variation in mechanisms and routes of dispersal	low	extremely large
Temporal and spatial scales of mass invasion events	episodic; limited to adjacent regions	continuous; affects all regions simultaneously
Homogenization effect	regional	global
Potential for synergistic interactions with other stressors	low	very high

Fuente: Ricciardi (2007) Cons. Biol. 21: 329-336

Tendencias en las invasiones

Table 2. Rates of species invasion (numbers of established species per year) for various regions.[a]

Region	*Prebistoric rate*	*Modern rates* long term	*Modern rates* recent	*Reference*[b]
Terrestrial regions				
Galapagos Islands	0.0001	1	10	1, 2
Gough Island	0.00001	0.22	-	3
Hawaiian Islands	0.00003	20	-	4
Australia	0.002	13	-	5
Freshwater & marine regions				
Laurentian Great Lakes				
fishes	0.017	0.3	0.2	6
molluscs	0.011	0.09	0.17	7, 8
all biota	-	1.1	1.8	7
Caspian Sea				
invertebrates	0.0002	0.36	0.33	10
Black Sea				
invertebrates	0.0002	0.3	0.4	11
San Francisco Bay	0.05	1.7	3.7	12
Port Phillip Bay	0.08	1.25	2.6	13
Baltic Sea	0.09	0.3	0.7	14
Mediterranean Sea				
flora	-	0.18	1.28	15
Northeastern Atlantic				
flora	-	0.19	0.44	15

[a] *Prebistoric rates are before buman settlement and were estimated from the fossil record or by calculating numbers of native species (excluding endemics) that bave become establisbed in the region over time. Long-term modern rates are averaged over the past 150-300 years, and recent modern rates are averaged over the past 30-40 years.*

[b] *References: 1, Maucbamp 1997; 2, Porter 1983; 3, Gaston et al. 2003; 4, Loope et al. 1988; 5, Low 2002; 6, Mandrak 1989; 7, Ricciardi 2006; 8, Clarke 1981; 9, Vermeij 1991b; 10, Grigorovicb et al. 2003; 11, Grigorovicb et al. 2002; 12, Coben & Carlton 1998; 13, Hewitt et al. 1999; 14, Leppäkoski et al. 2002; 15, Ribera & Boudouresque 1995.*

Fuente: Ricciardi (2007) Cons. Biol. 21: 329-336

Tendencias en las invasiones

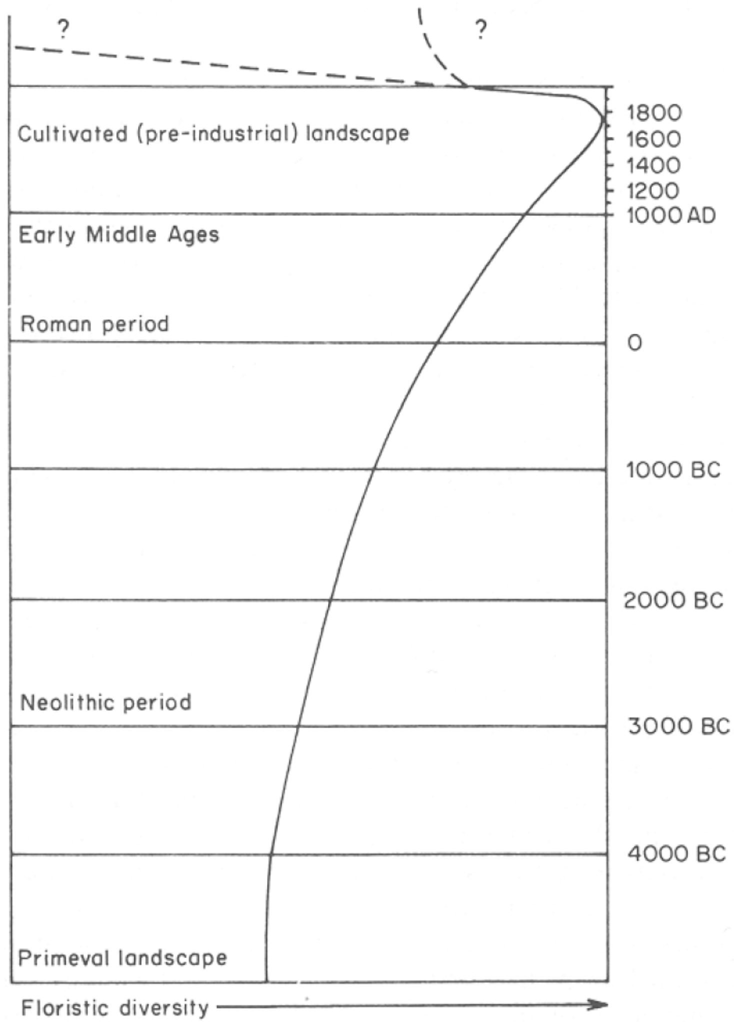


Figure 1.5. Changes in plant diversity in central Europe in prehistoric and historic times (after Kornas, 1982 and 1983, modified from Fukarek 1979)

Fuente: Di Castri (1989) En: Biological Invasions: A Global Perspective. SCOPE

Tendencias en las invasiones

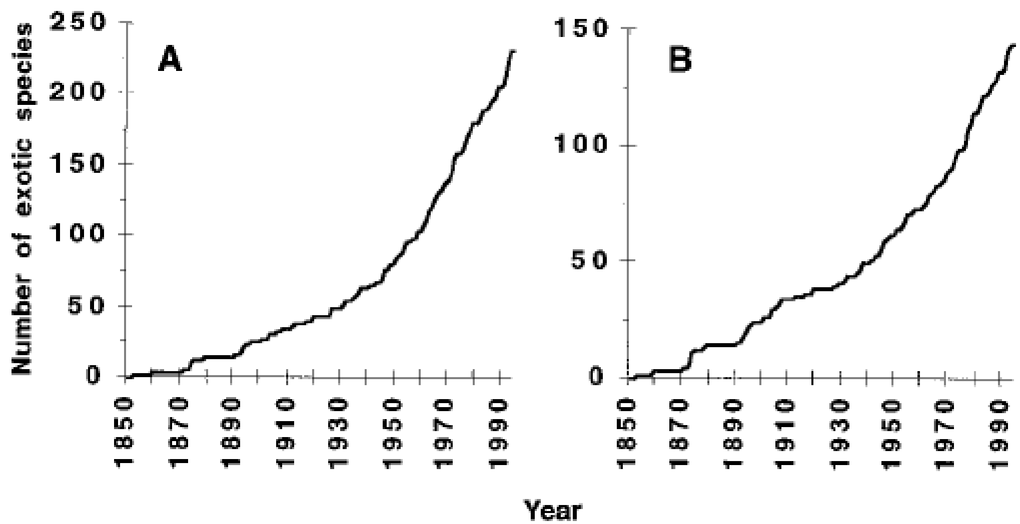


Fig. 1. Cumulative number of exotic species established in the San Francisco Estuary: (**A**) raw data; (**B**) modified data. A time series analysis conducted by C. Parmesan [Box-Jenkins methodology (*19*) on RATS (Regression Analysis of Time Series) software, version 4.0 (Estima); final models used only terms that contributed significantly at $P < 0.05$ and had uncorrelated residuals by Durban-Watson and Lung-Box *Q* statistics] showed a significant increase in the number of invasions over time (linear regression on raw and modified data separately, trend terms significant at $P < 0.001$). Trend = $(\text{time})^2$ models explained 5% and 2% more of the variation than did trend = time models for raw and modified data sets, respectively (final models: $R^2_{raw} = 0.34$, $R^2_{modified} = 0.21$). Additional lag terms on time were unnecessary (and when forced into the models were not significant at $P > 0.50$ for both data sets), indicating that invasion events are independent between years. A better fit of trend = $(\text{time})^2$ models indicates that the rate of invasions, as well as the absolute number, increases with time.

Fuente: Cohen & Carlton (1998) Science 279: 555-558

Tendencias en las invasiones

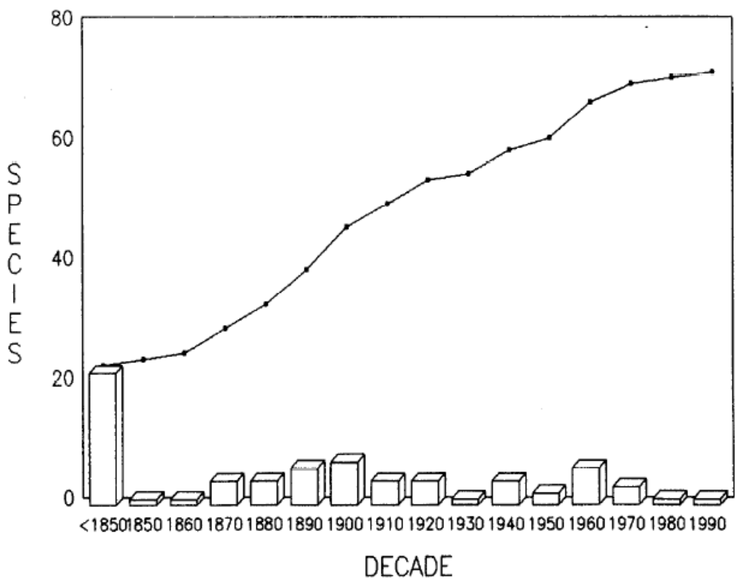


Fig. 1. Arrival of targeted pest species in Florida. Line is the cumulative number of species. Note that one species, *Aleurocanthus woglumi* Ashby, immigrated to Florida twice (Table 1).

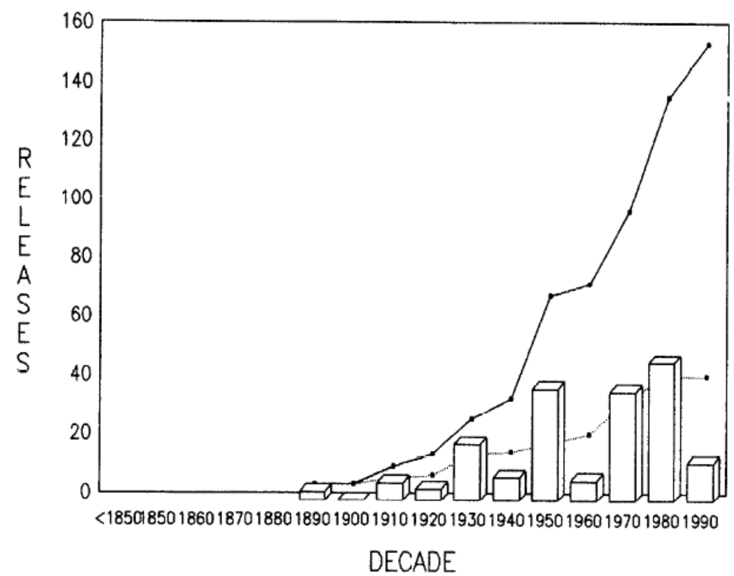


Fig. 2. Release of insect biological control agents in Florida (one release = one agent taxon introduced against one pest taxon in one decade). Upper line is the cumulative number of releases, lower line is the cumulative number of releases that resulted in establishment.

Fuente: Frank & McCoy (1993) Florida Entomol. 76: 2-54

Tendencias en las invasiones

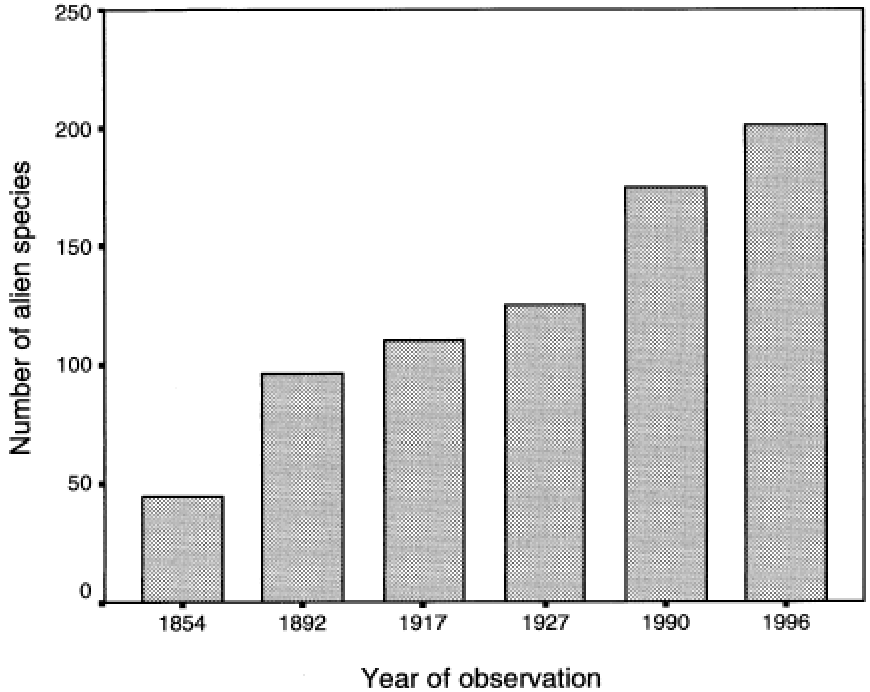


Figure 2. Increase of alien species on Robinson Crusoe Island (Isla Más a Tierra) according to Philippi (1856), Johow (1896), Skottsberg (1922), Looser (1927), Matthei et al. (1993), and Swenson et al. (1997).

Fuente: Greimler et al. (2002) Biol. Inv. 4: 73-85

Tendencias en las invasiones

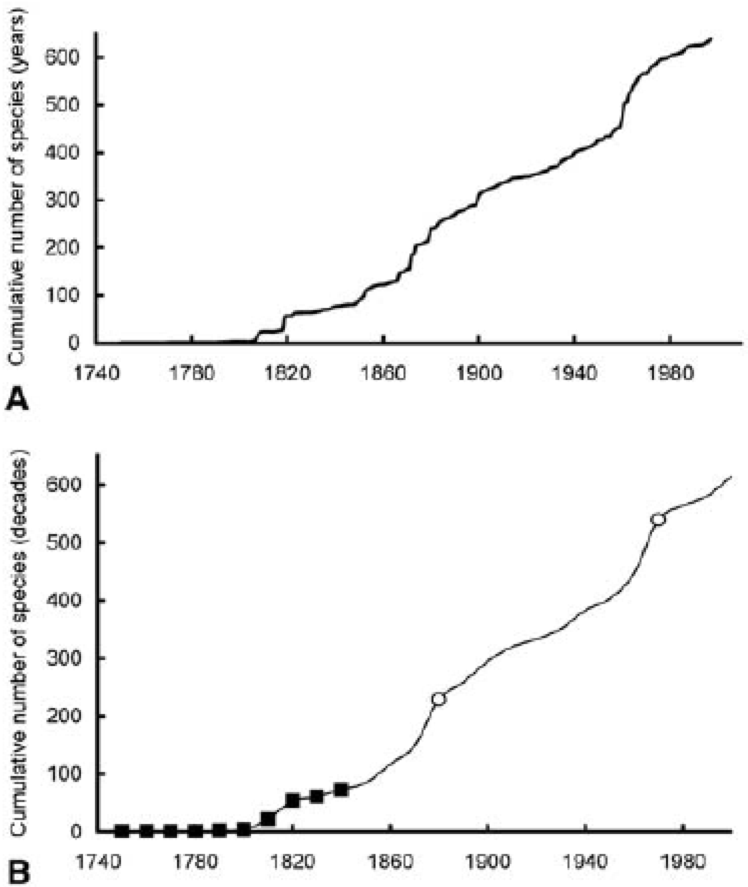


Fig. 1 Cumulative number of neophytes (y) plotted against time of invasion (x) in years (**A**) and decades (**B**). **A** Non-linear increase is y=218890−341.2x+0.18x^2−0.000030x^3 (F=3372.0; df=3, 160; P<0.001; R^2=98.4%). **B** *Squares* indicate decades from 1750 to 1840 that violate linear increase. Linear increase from 1850, indicated by the line, is y=1824+0.3x (F=736.4; df=1, 14; P<0.001; R^2=98.1%). *Empty circles* have the largest Cook's distances and correspond to decades 1870–1880 and 1960–1970

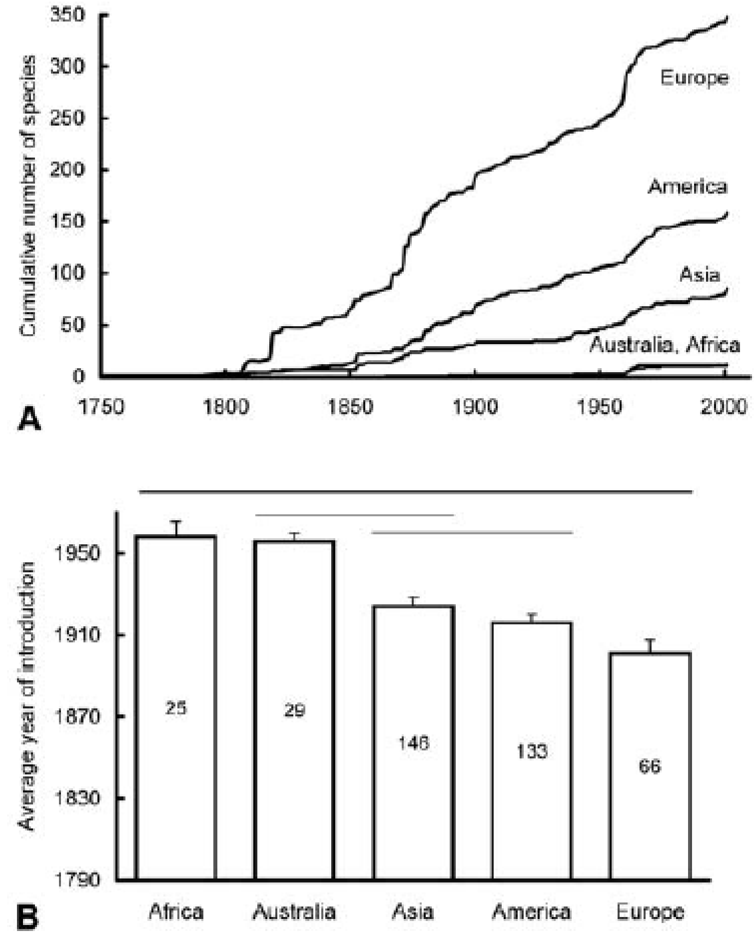
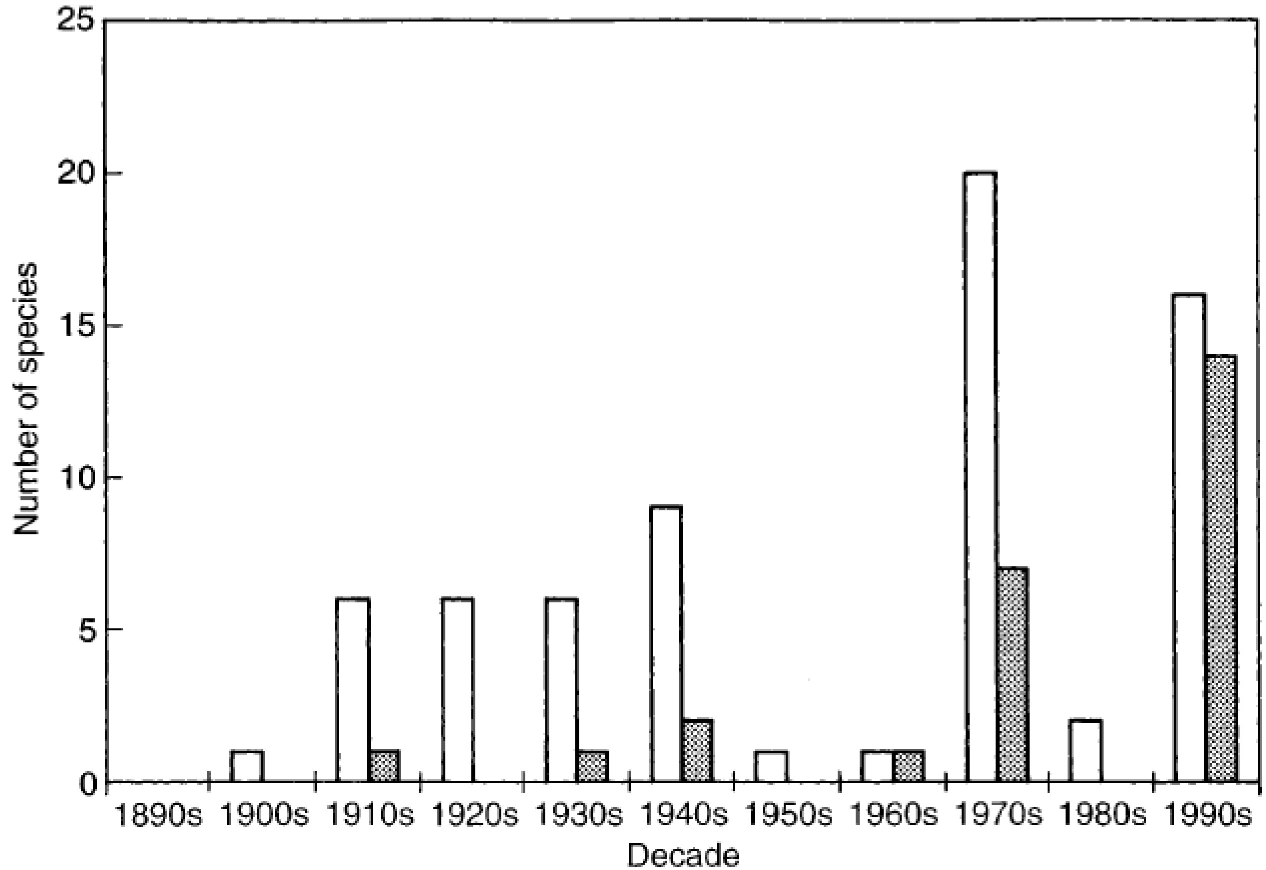


Fig. 2 **A** Increase with time in the cumulative number of species originating from particular continents. Note that the cumulative curves for Australia and Africa follow basically the same pattern because of the low number of species. **B** Average year of introduction (± standard error) shown for the continents. *Horizontal lines* show groups not significantly different by using least significant differences (LSD). *Numbers inside the bars* are sample sizes

Fuente: Pysek et al. (2003) Oecologia 135: 122-130

Tendencias en las invasiones

Fig. 2 First reports (recorded by decade) from 1890 to 1996 of introduced and cryptogenic species in Pearl Harbor in 1996 (*Gray bars* cryptogenic species; *open bars* non-indigenous species)



Fuente: Coles et al. (1999) Marine Biology 135: 147-158

Tendencias en las invasiones

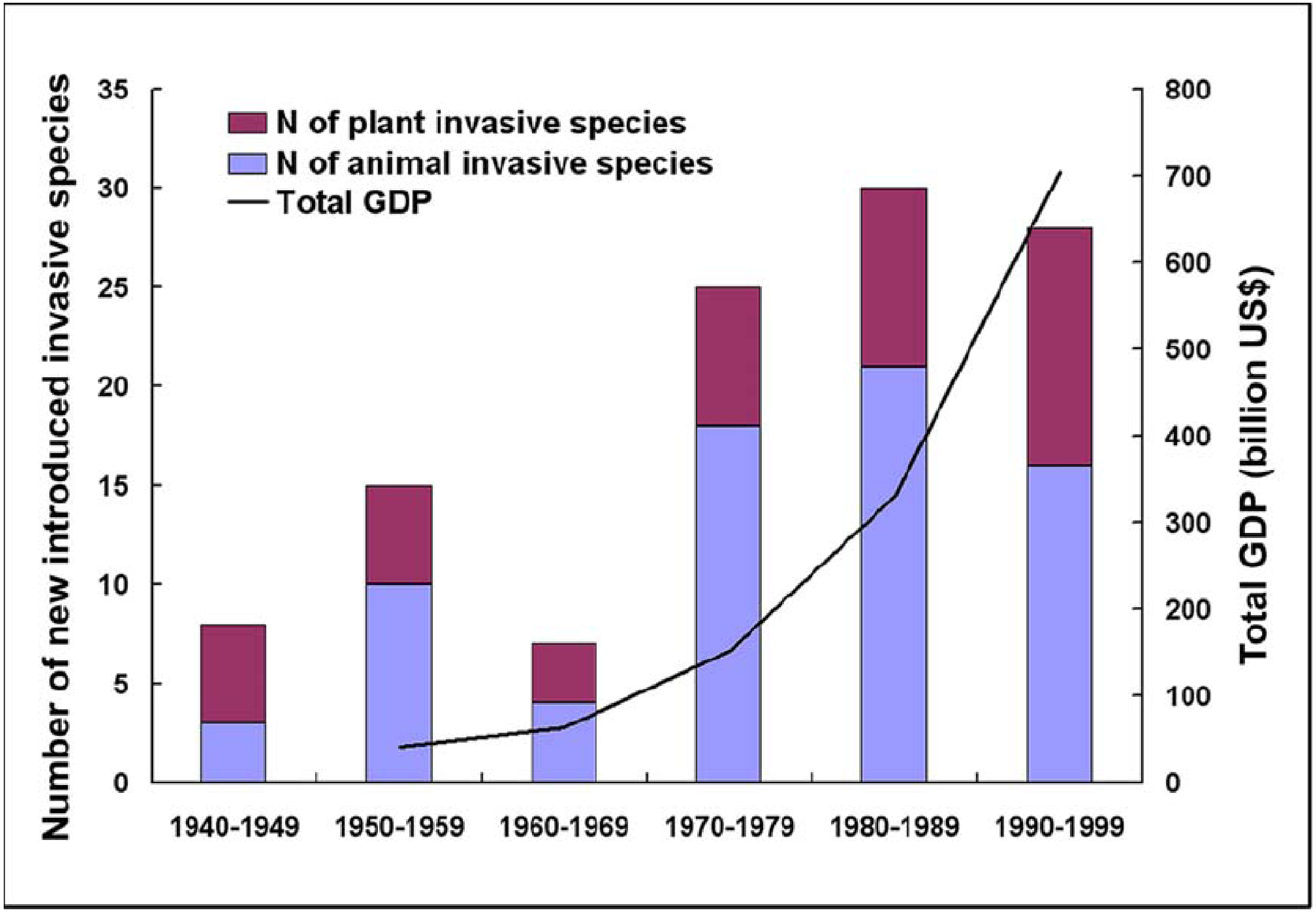


Figure 1. The total GDP and number of introduced invasive species into China. The total GDP is from 1959 to 1999, and the number of introduced invasive species into China is from 1940 to 1999.
doi:10.1371/journal.pone.0001208.g001

Fuente: Lin et al. (2007) PLoS One 2: e1208

La geografía de las invasiones

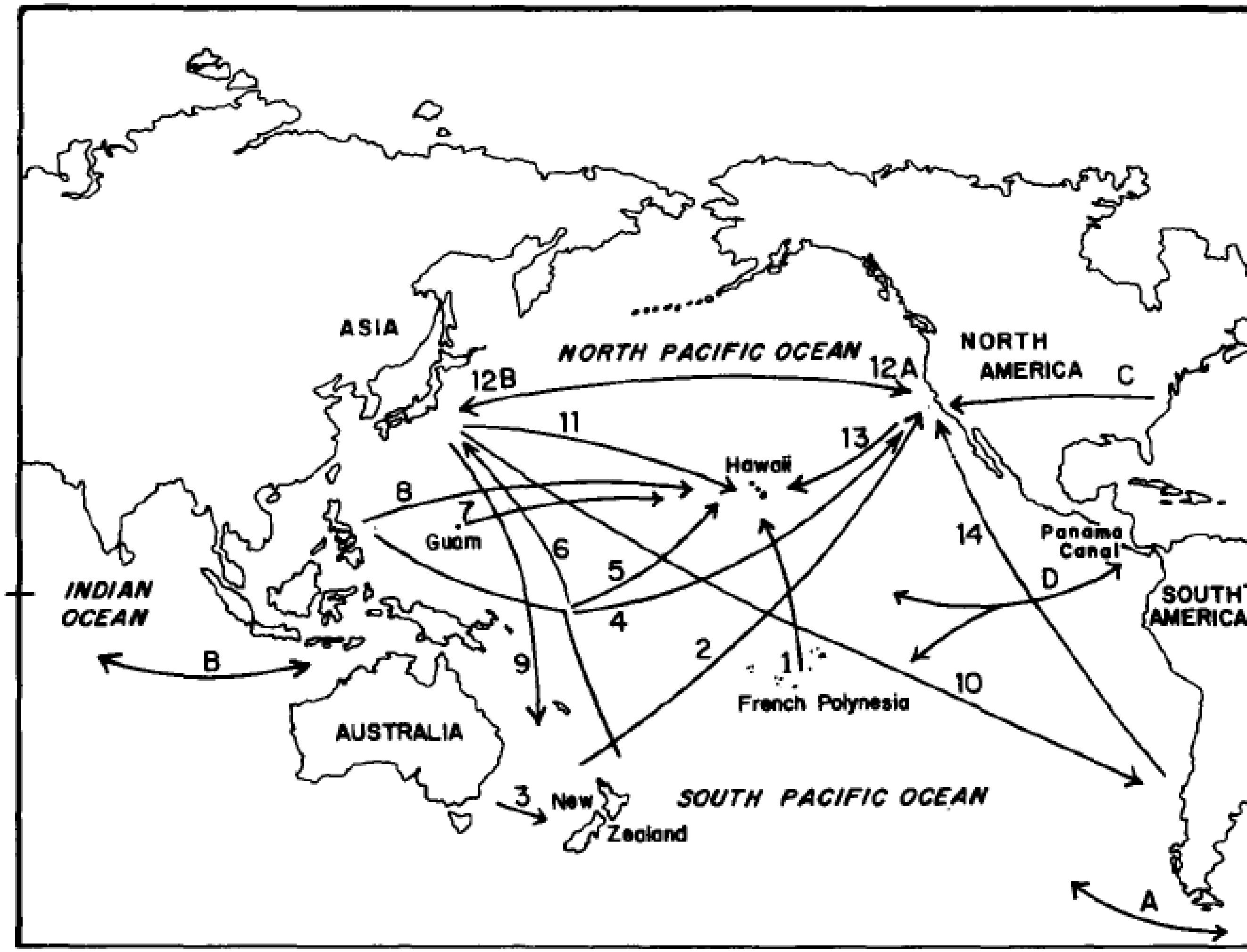


Figure 1. Dispersal routes (see Table 2) of introduced species in the North and South Pacific Oceans.

Fuente: Carlton (1987) Bull. Marine Science 41: 452-465

La geografía de las invasiones

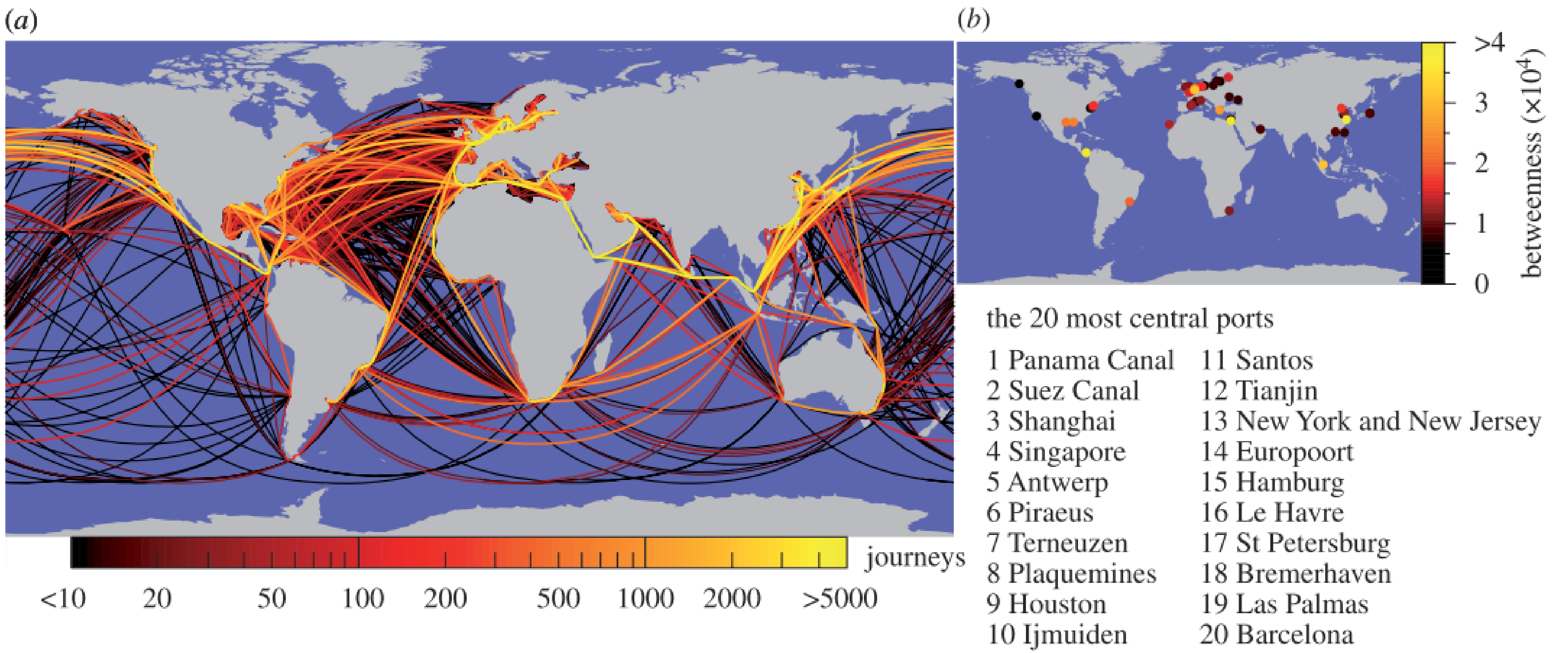


Figure 1. Routes, ports and betweenness centralities in the GCSN. (*a*) The trajectories of all cargo ships bigger than 10 000 GT during 2007. The colour scale indicates the number of journeys along each route. Ships are assumed to travel along the shortest (geodesic) paths on water. (*b*) A map of the 50 ports of highest betweenness centrality and a ranked list of the 20 most central ports.

Fuente: Kaluza et al. (2010) J. R. Soc. Interface 7: 1093-1103

La geografía de las invasiones

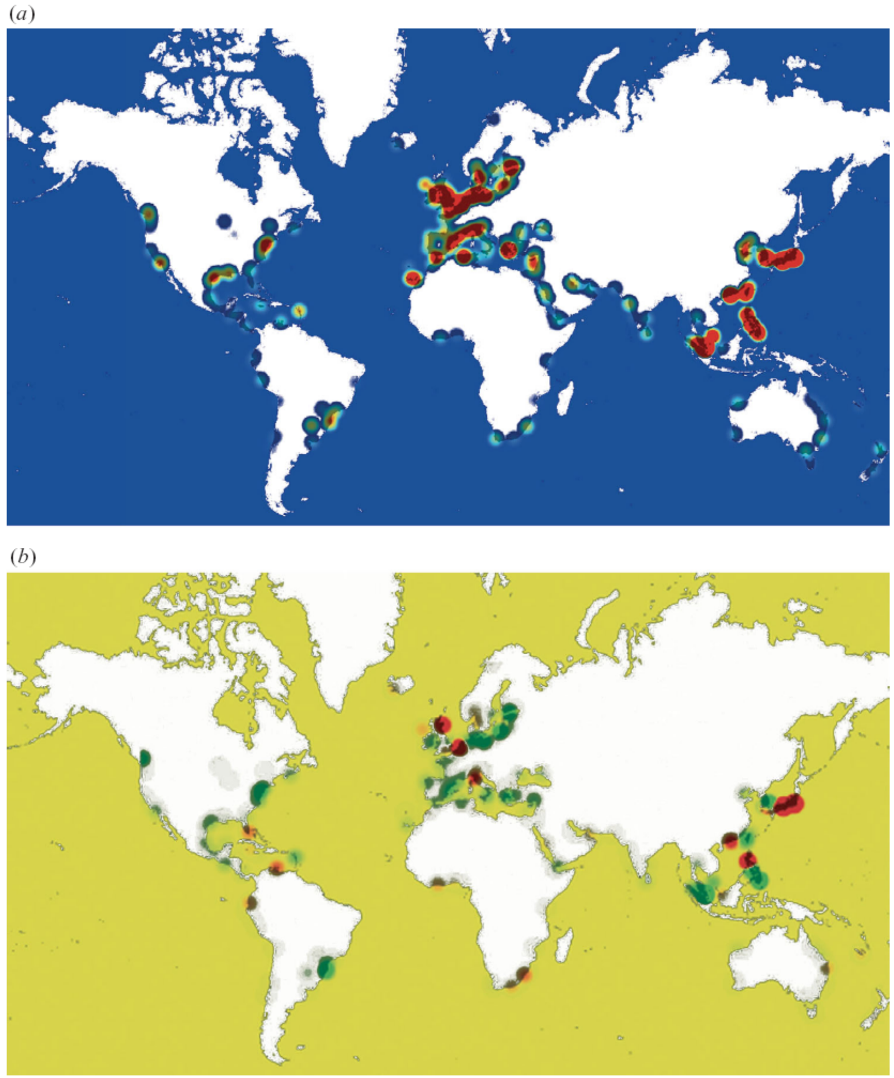


Figure 1. (*a*) Global hot spots for biological invasion from ballast water. The density of ship visits was estimated by a quartic approximation to a Gaussian kernel (McCoy & Johnston 2001). Expected invasion rates range from 0 (blue) to 2.94×10^{-4} species km^{-2} yr^{-1} (red). (*b*) Changes in the expected rate of invasion from 1996 to 2000 range from -4.58×10^{-8} species km^{-2} yr^{-1} (green) to 2.11×10^{-8} species km^{-2} yr^{-1} (red). Yellow indicates background rates of no change.

Fuente: Drake & Lodge (2004) Proc. R. Soc. B 271: 575-580

La geografía de las invasiones

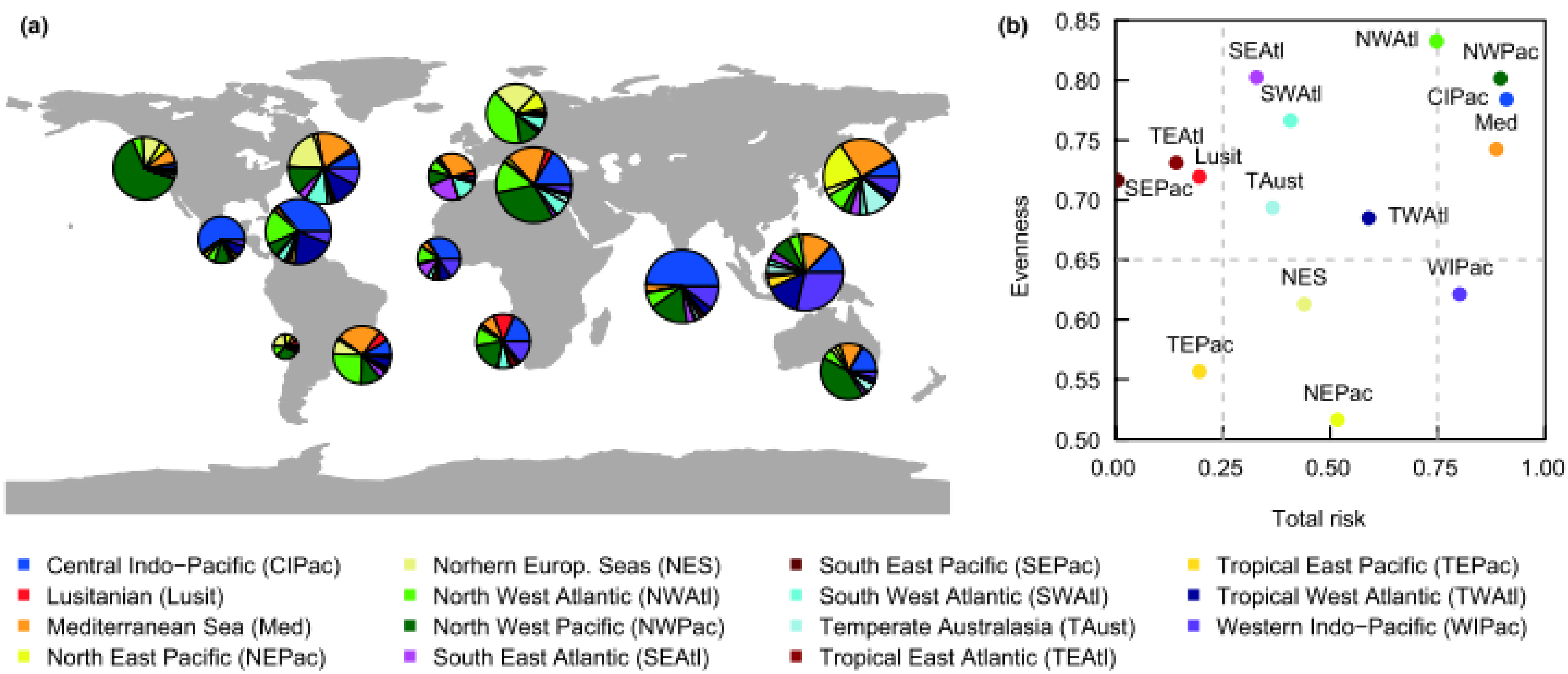


Figure 3 Predicted invasion risks aggregated over $n = 15$ coastal ecoregions (Table S3). (a) For each ecoregion j, the area of the pie chart indicates the aggregated risk of new invasions into that region $P_j(Inv) = 1 - \prod_i (1 - P_{ij}(Inv))$, with $P_{ij}(Inv)$ being the mutual invasion risk between ecoregions. The size of each pie sector indicates the relative contribution $p_{ij} = P_{ij}(Inv)/\sum_i P_{ij}(Inv)$ of source region i (indicated by colour coding) to the invasion risk of ecoregion j. (b) Characterisation of ecoregions by the total invasion risk $P_j(Inv)$ and the evenness of risk composition using Pielou's index (Pielou, 1966), $E_j = -\sum_i p_{ij} \log p_{ij} / \log(n)$.

Fuente: Seebens et al. (2013) Ecology Letters 16: 782-780

La geografía de las invasiones

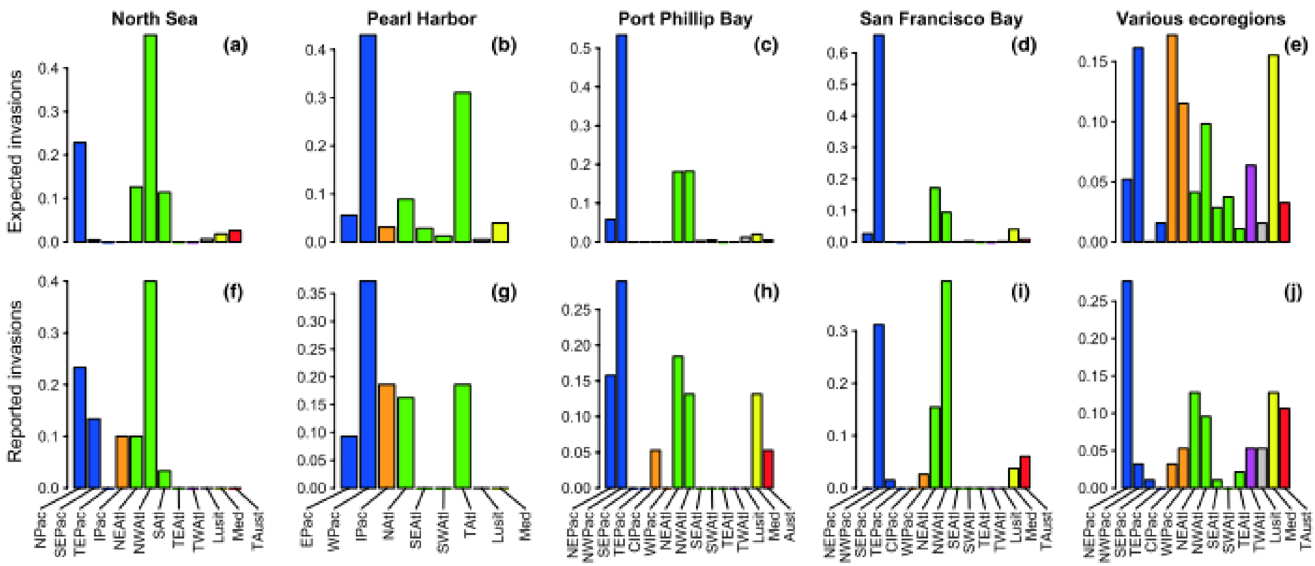


Figure 4 Comparison of invasion numbers predicted by the model (a–e) with reported invasion events in four highly invaded sites (f–i) and various ecoregions (j). For each of the four selected sites, the relative contribution of different source regions for the expected (a–d) and the reported (f–i) number of invasions into that site is shown. For the various ecoregions, the number of predicted (e) and reported (j) invasions into different ecoregions is shown, independent of the source regions. All distributions were normalised to one. Deviations between model predictions and field data according to root mean squared error [RMSE]: 0.06 (North Sea), 0.08 (Pearl Harbor), 0.08 (Port Phillip Bay), 0.12 (San Francisco Bay) and 0.08 (various ecoregions). Abbreviations of ecoregions (colours indicate different oceans): Pac: Pacific, IPac: Indo-Pacific, Atl: Atlantic, Med: Mediterranean Sea, Lusit: Lusitanian, Aust: Australasia, N: North, E: East, S: South, W: West, T: Tropical and C: Central.

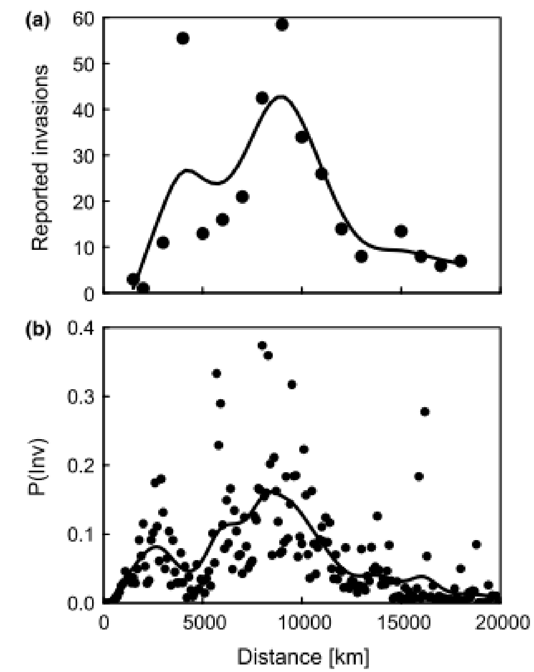


Figure 5 Intermediate distance hypothesis: invasion risk is largest for intermediate geographic distances. Sum of reported established species at different sites (a) and predicted invasion probabilities *P(Inv)* (b) as a function of the geographic distance d_{ij} between source and destination ports [dots, histogram in bins of 1000 km (a) and 100 km (b)] and spline fit (solid line).

Fuente: Seebens et al. (2013) Ecology Letters 16: 782-780

La geografía de las invasiones

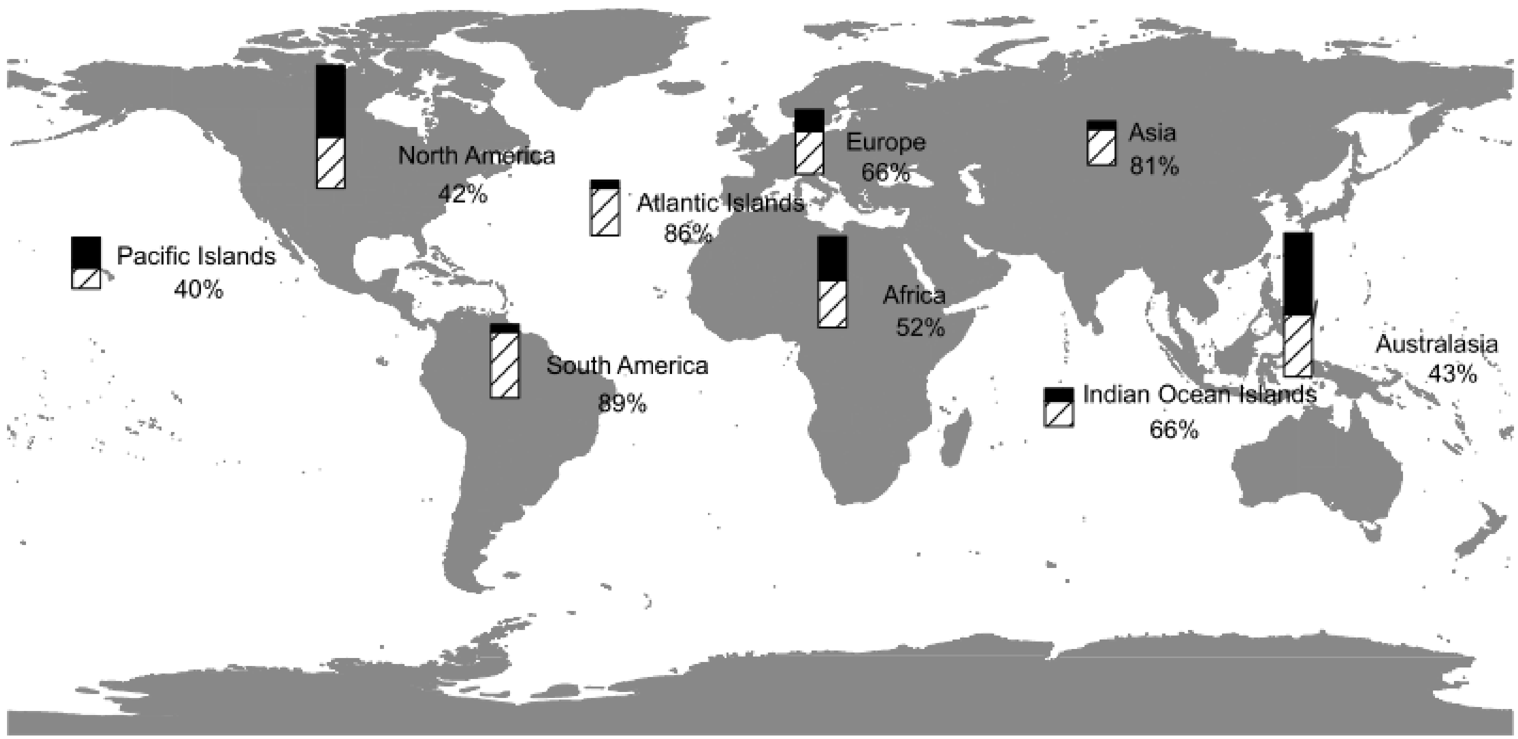


Fig. 1 Numbers of naturalized species in nine regions of the world. Data are from Weber (2003) and are based on global distributions of 450 species that are major invaders in natural and seminatural areas in at least one region (excluding weeds of agricultural and disturbed habitats). The percentages of species from the total pool of naturalized alien species (=total length of the bar) that are recorded as not invading (corresponding to Weber's 'introduced'; Pyšek, 2004) are indicated for each region. Black bars, invasive in natural areas; hatched bars, naturalized but not invasive.

Fuente: Richardson &Pysek (2012) New Phytologist 196: 383-396

La geografía de las invasiones

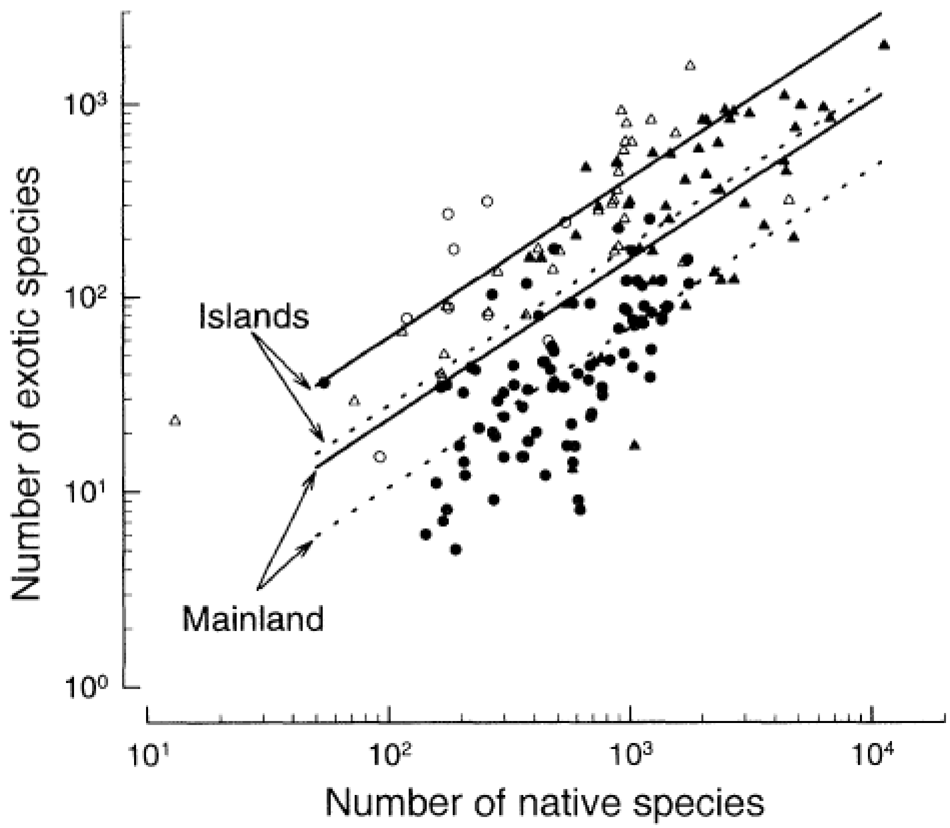


FIG. 4. The relationship between the number of exotic plant species (E) and the number of native plant species (N) for 177 sites and regions around the world, broken down into island reserves (○), island nonreserves (△), mainland reserves (●), and mainland nonreserves (▲). The fitted lines shown are from Eq. 4 (see also Model 4 in Table 3): solid lines are for nonreserve sites, and broken lines are for reserves. Both axes are log scales.

Fuente: Lonsdale (1999) Ecology 80: 1522-1536

La geografía de las invasiones

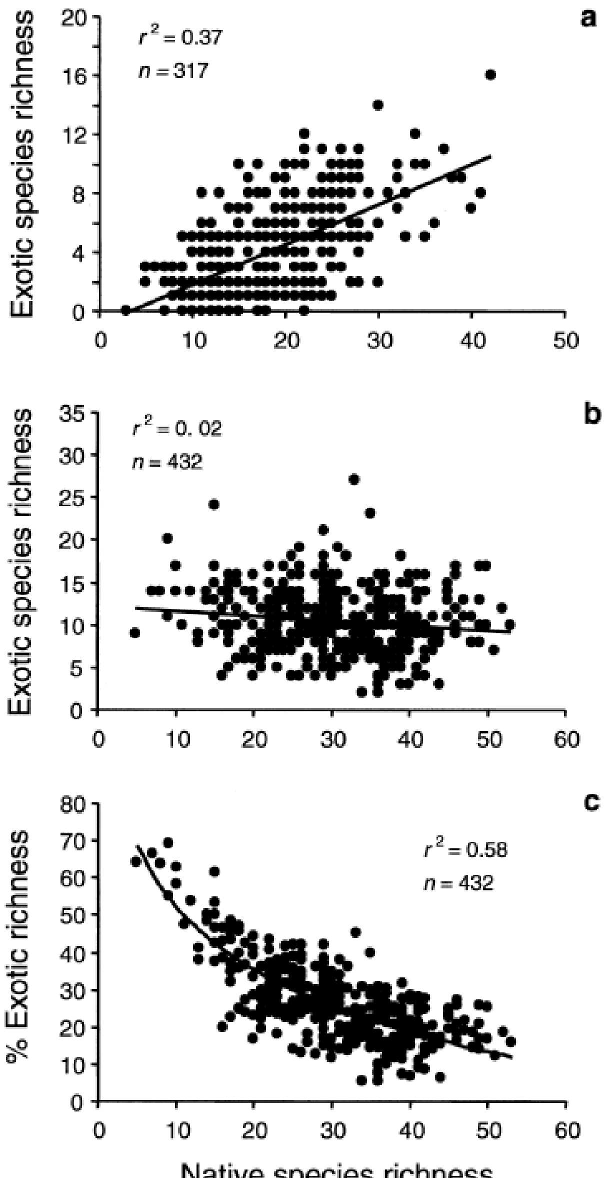


Figure 3. Relationship between native species richness and exotic species richness in (a) flood-prone grasslands on high-fertility (acidic) and low-fertility (alkaline/saline) soils, and (b–c) grasslands on well-drained soils of intermediate fertility. The data represent species numbers per stand, except for (c) where the proportion of exotics is shown. Note the change in axes scales between (a) and (b–c). Regression lines: (a) $y = 0.27x - 0.99$, $F = 184.8$, $P < 0.0001$; (b) $y = -0.06x + 12.29$, $F = 8.51$, $P < 0.01$; (c) $y = -23.94 \ln x + 107.03$, $F = 592.8$, $P < 0.0001$.

Fuente: Chaneton (2002) Biol. Inv. 4: 7-24

La geografía de las invasiones

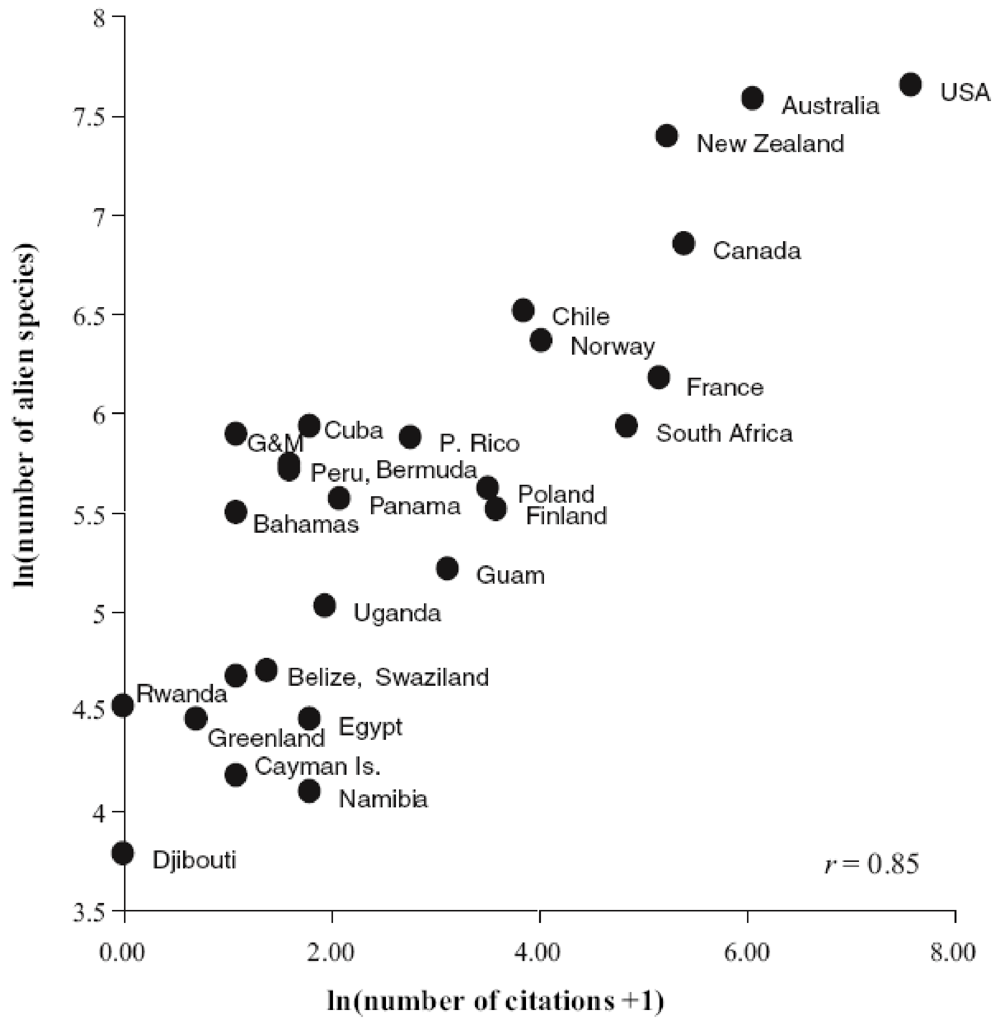


Figure 1. Number of alien plant species *vs.* number of citations on biological invasions by country. Number of alien species from Vitousek et al. (1996). The number of citations were obtained from the Biological Abstracts database, years 1985–2001, using the following search terms: [(biological invasion*) or (invasive species) or (exotic species) or (introduced species) or (alien species)] and country. The data label 'G&M' stands for 'Guadelupe and Martinique'.

Fuente: Vázquez & Aragón (2002) Biol. Inv. 4: 1-5

La geografía de las invasiones

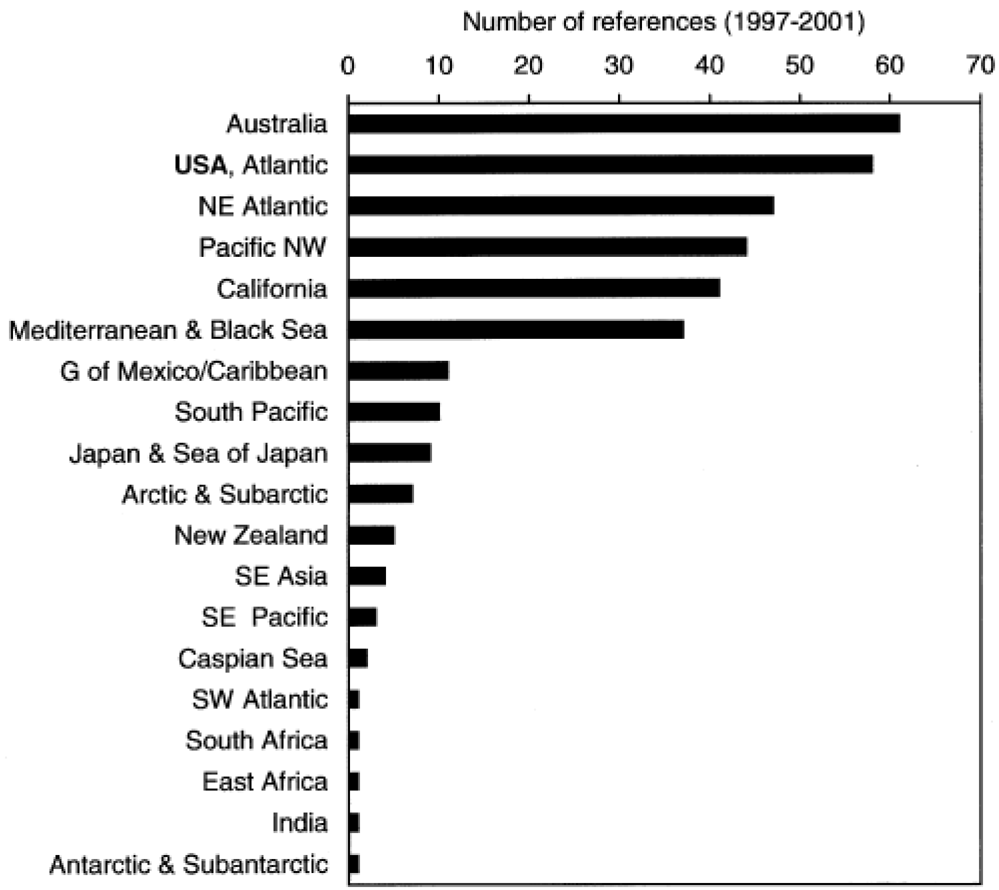


Figure 1. Geographic distribution of references to non-indigenous marine species in a sample from the literature. The latter ($n = 344$ references) was assembled through a search of the Aquatic Science and Fisheries Abstracts (ASFA), using the concatenation of the terms 'introduced species' and 'marine'. Only references that document geographic-specific references on non-indigenous species were retained as part of the sample. The list provides only an indicator; by no means is it presumed to be comprehensive.

Fuente: Orensanz et al. (2002) Biol. Inv. 4: 115-143

La geografía de las invasiones

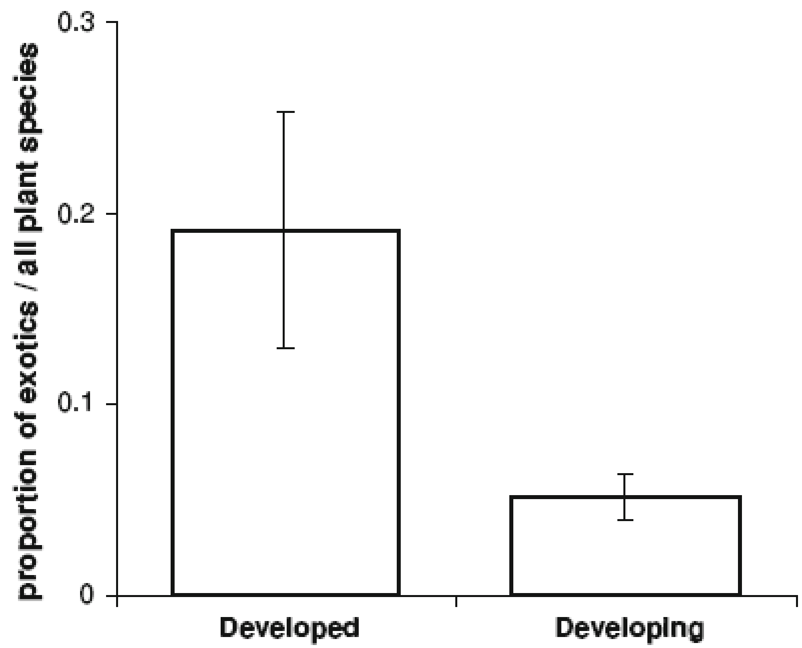


Fig. 1 Proportion of the number of exotic plants versus the numbers of all plant species in developed and developing countries. These data is extracted from Dalmazzone (2000), from which we used her entire list of countries and associated states. Countries and associated states included as developed: Australia, Canada, Finland, France, Greenland, New Zealand, Norway, Puerto Rico, and Continental USA. Countries included as developing: Belize, Chile, Cuba, Djibouti, Egypt, Namibia, Panama, Peru, Poland, Rwanda, Swaziland and Uganda

Fuente: Nuñez & Pauchard (2010) Biol. Inv. 12: 707-714

La geografía de las invasiones

Table 1. Numbers of native and exotic terrestrial and freshwater species for several taxa in Argentina and Chile.

Environment	Taxon	Region	Natives	Exotic[a]	% exotic	Source[b]
Terrestrial	Plants	Chile	4681	690	12.8	1, 2
		Islas Juan Fernández, Chile	209	232	52.6	3
		Central Chile	2395	507	17.5	2
		Tierra del Fuego (Arg. and Chile)	545	128	19.0	2
		Buenos Aires Province (Arg.)	1326	404	23.4	5
		Sierra de San Javier, Tucumán (Arg.)[c]	79	15	16.0	6, 7
	Amphibians	Pampa-Monte (Arg.)	83	0	0	8, 9
		Patagonian steppe	10	0	0	8, 9
		Chile	42	1	2.3	10
	Reptiles	Argentina	—[d]	1	—[d]	9
		Chile	89	6	6.3	10
	Birds	Argentina	951	11	1.1	9, 11
		Chile	380	5	1.3	10
	Mammals	Argentina	300	19	6.0	9, 12
		Chile	147	15	9.3	10
	Aphids	Chile	31	104	77.0	13
	Bees	Chile	348	2	0.6	14
	Oligochaetes	Sierras Chicas, Córdoba (Arg.)	5	12	70.6	15
	Mollusks	Chile	132	9	6.4	16
Freshwater	Bivalves	Río de la Plata	23	3	11.5	17
	Mollusks	Chile	83	0	0.0	16
	Fish	Argentine Patagonia	20	10	33.3	18
		Río Tercero, Córdoba (Arg.)	29	4	12.1	19

[a]For marine groups, the number of cryptogenic species is also given between parentheses. [b]Data sources: (1) Marticorena and Quezada (1985); (2) Arroyo et al. (2000); (3) Greimler et al. (this issue); (4) Rapoport and Brion (1991); (5) Söyrinki (1991); (6) Morales (1995); (7) Grau and Aragón (2000); (8) Duellman (1999); (9) Navas (1987); (10) Jaksic (1998); (11) Narosky and Yzurieta (1987); (12) Olrog and Lucero (1980); (13) Fuentes-Contreras et al. (1997); (14) Toro (1986); (15) Mischis (1999); (16) Valdovinos-Zarges (1999); (17) Darrigran (1995); (18) Pascual et al. (this issue); (19) Haro et al. (1996). [c]Only trees were included. [d]No data available.

Fuente: Vázquez & Aragón (2002) Biol. Inv. 4: 1-5

La geografía de las invasiones

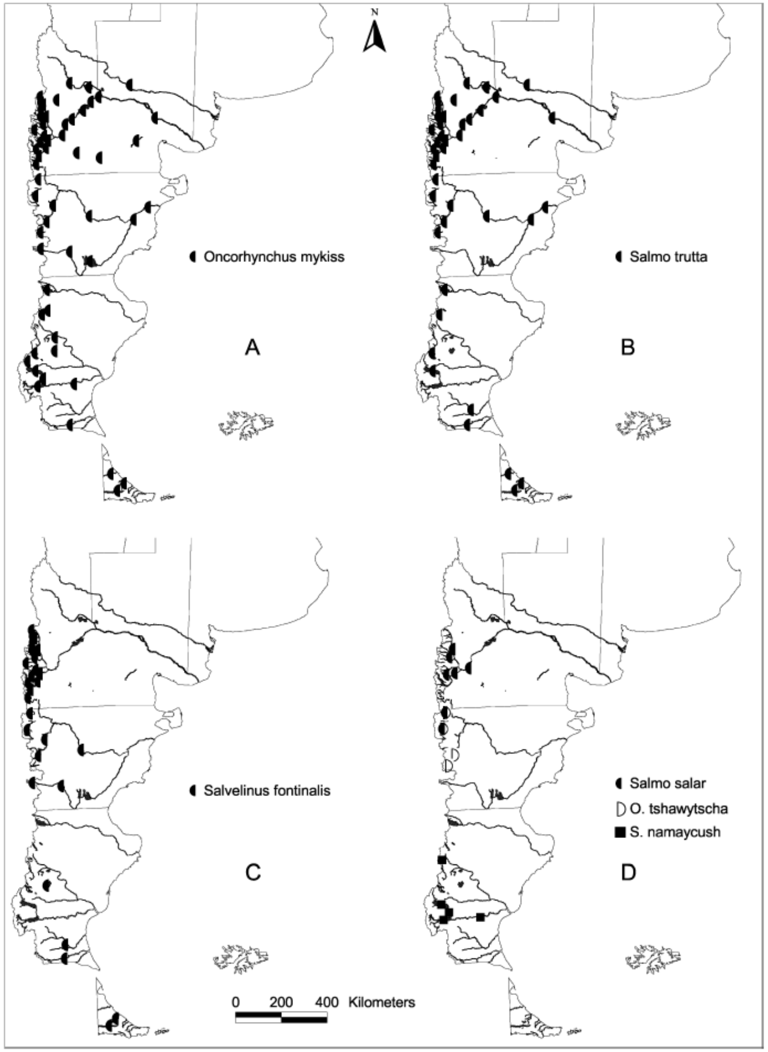


Figure 4. Distribution of major groups of exotic fish. A: rainbow trout, *Oncorhynchus mykiss*; B: brown trout, *Salmo trutta*; C: brook trout, *Salvelinus fontinalis*; D: Atlantic salmon, *Salmo salar*, chinook salmon, *Oncorhynchus tshawytscha*, and lake trout, *Salvelinus namaycush*.

Fuente: Pascual et al. (2002) Biol. Inv. 4: 101-113

La geografía de las invasiones

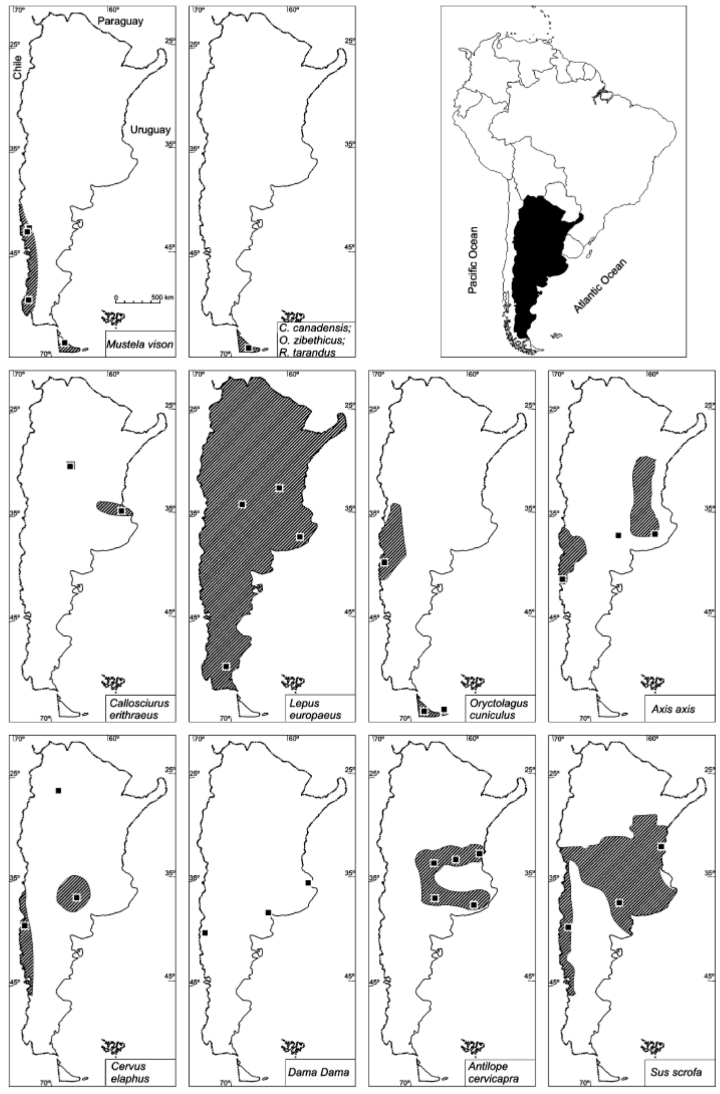


Fig. 1 Port of entry (localities) of invasive mammals in Argentina and current distribution

Fuente: Novillo & Ojeda (2008) Biol. Inv. 10: 1333-1344

La geografía de las invasiones

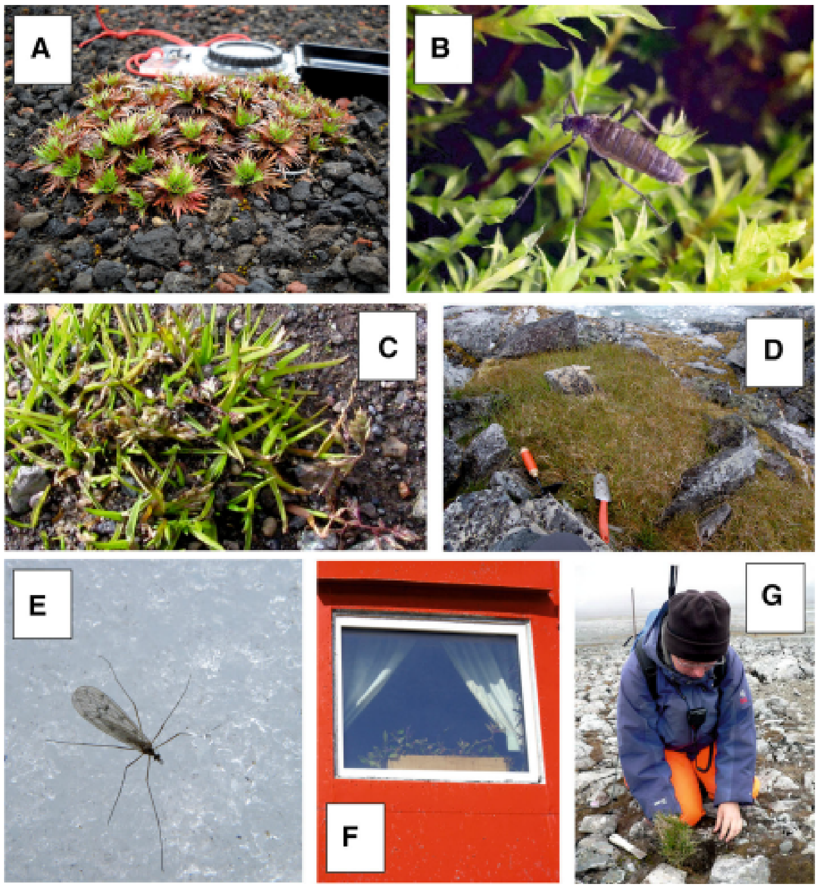


Fig. 1 **a** *Nassauvia magellanica* eradicated from Deception Island in January 2010 (Photo: K. A. Hughes). **b** The flightless chironomid midge *Eretmoptera murphyi*, introduced to Signy Island, South Orkney Island from South Georgia (Photo: P. Bucktrout). **c** *Poa annua* on Deception Island and subsequently eradicated (Photo: M. Molina-Montenegro).]. **d** *Poa pratensis* on Cierva Point, Antarctic Peninsula, where it was first introduced during transplantation experiments in 1954/1955 (Photo: L. R. Pertierra). **e** *Trichocera maculipennis* found in Artigas Base (King George Island, South Shetland Islands) sewage system in 2006/2007 and in surrounding terrestrial habitats (Photo: O. Volonterio). **f** Non-native potted plant in the window of Bellingshausen Station in 2010 (King George Island) (Photograph: K. A. Hughes). **g** Removal of an alien grass species from the vicinity of Great Wall Station, Fildes Peninsula, King George Island in 2006 (Photo: S. Pfeiffer)

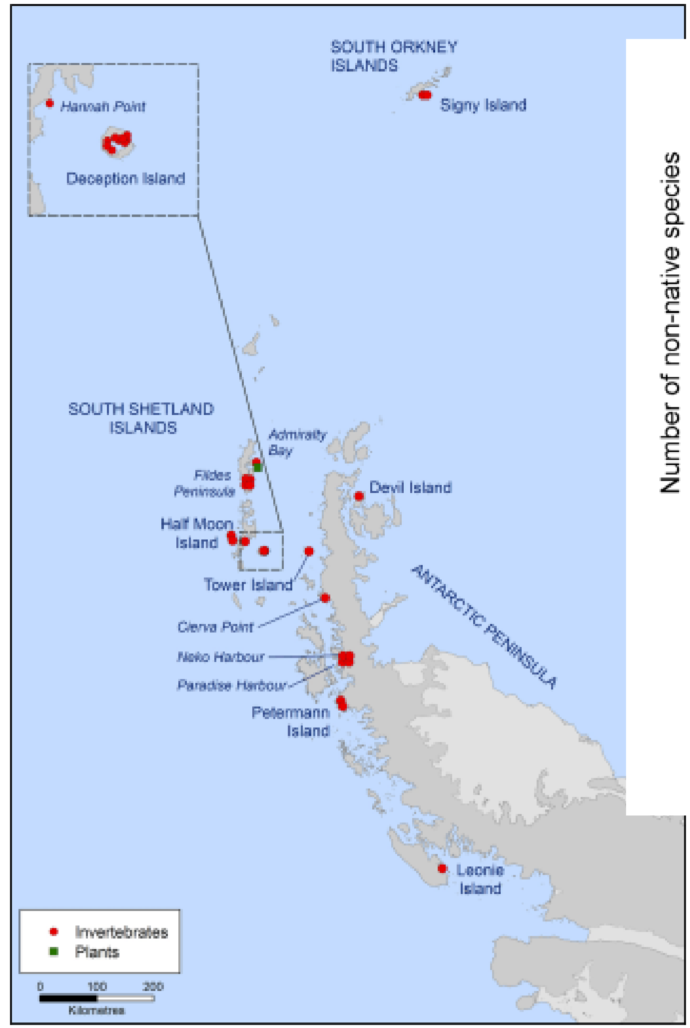


Fig. 2 Map of the Antarctic Peninsula region showing the distribution of known non-native species (*Cryptopygus caecus* has not been included on this and subsequent maps due to uncertainty over its native/non-native status (see Russell et al. 2013), while *Alicorhagia* sp. has not been included as the single report recorded only a single individual and it was unclear whether or not this species had established)

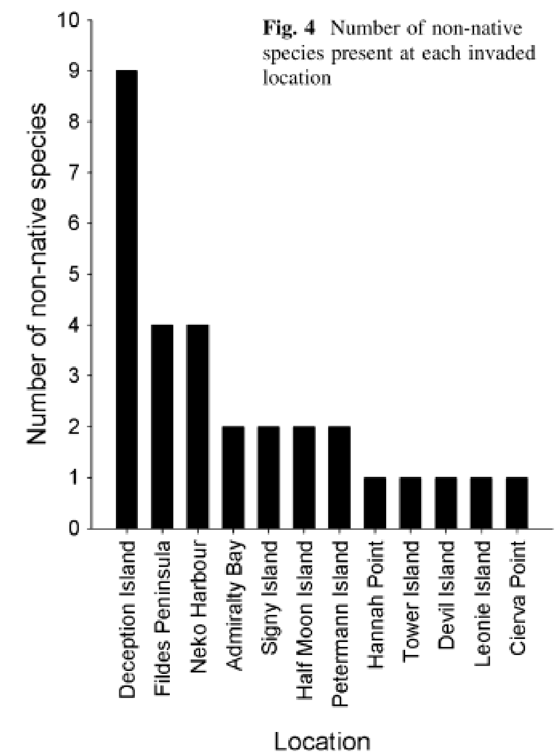


Fig. 4 Number of non-native species present at each invaded location

Fuente: Hughes et al. (2015) Biodiv Conserv 24: 1031-1055

La geografía de las invasiones

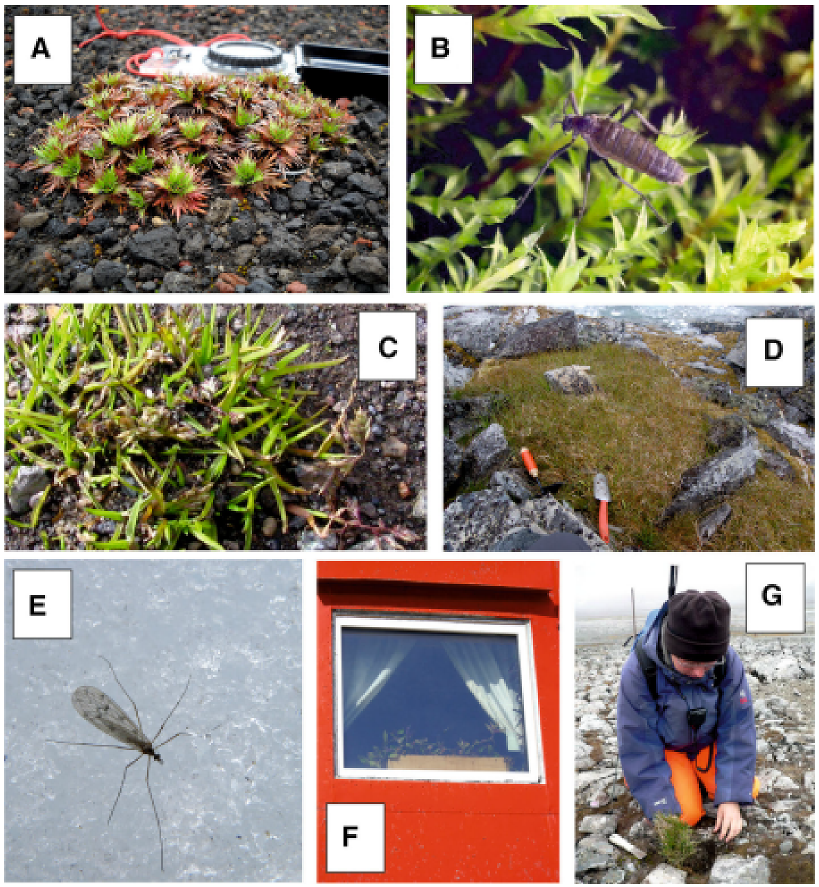


Fig. 1 **a** *Nassauvia magellanica* eradicated from Deception Island in January 2010 (Photo: K. A. Hughes). **b** The flightless chironomid midge *Eretmoptera murphyi*, introduced to Signy Island, South Orkney Island from South Georgia (Photo: P. Bucktrout). **c** *Poa annua* on Deception Island and subsequently eradicated (Photo: M. Molina-Montenegro).]. **d** *Poa pratensis* on Cierva Point, Antarctic Peninsula, where it was first introduced during transplantation experiments in 1954/1955 (Photo: L. R. Pertierra). **e** *Trichocera maculipennis* found in Artigas Base (King George Island, South Shetland Islands) sewage system in 2006/2007 and in surrounding terrestrial habitats (Photo: O. Volonterio). **f** Non-native potted plant in the window of Bellingshausen Station in 2010 (King George Island) (Photograph: K. A. Hughes). **g** Removal of an alien grass species from the vicinity of Great Wall Station, Fildes Peninsula, King George Island in 2006 (Photo: S. Pfeiffer)

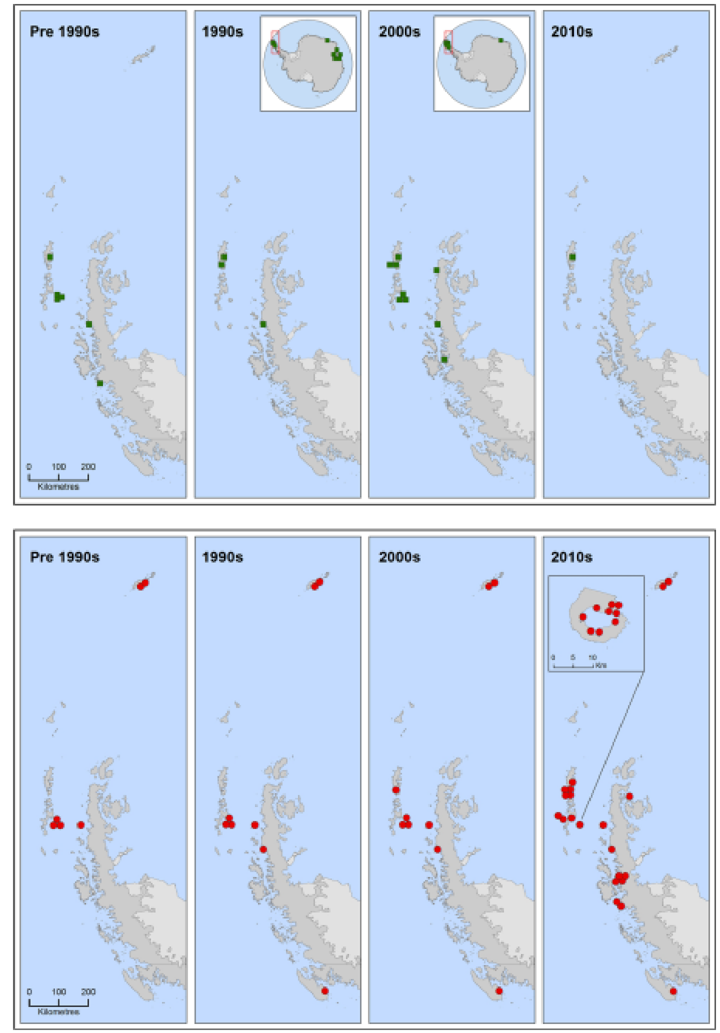


Fig. 5 Location of known non-native plants (*upper panel*) and invertebrates (*lower panel*) within Antarctica up until 1990 and during the 1990s, 2000s and 2010s. Plants eradicated or removed are not shown in subsequent figures. No records of non-native invertebrates exist outside the Antarctic Peninsula region and no eradications have been attempted

Fuente: Hughes et al. (2015) Biodiv Conserv 24: 1031-1055

La geografía de las invasiones

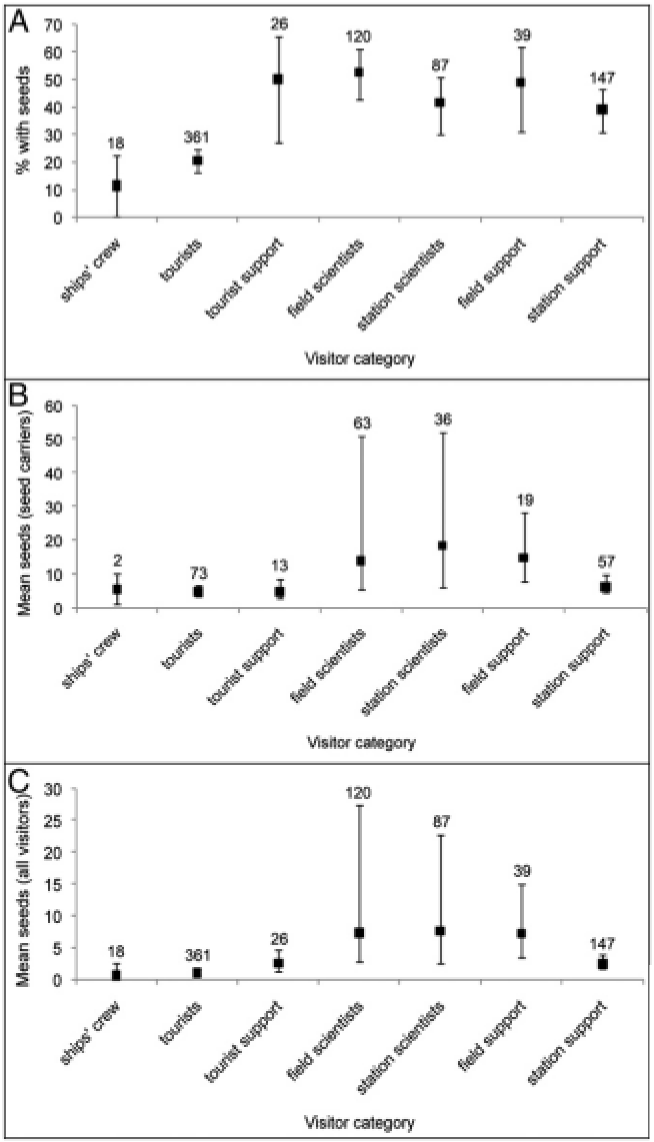


Fig. 1. Proportion of visitors carrying seeds, number of seeds per visitor carrying seeds, and number of seeds per visitor across all visitors. (*A*) Proportion of visitors (mean and 95% bootstrapped CI) carrying seeds within each of the visitor categories. (*B*) Mean (and 95% bootstrapped CI) number of seeds per visitor by category for those visitors carrying seeds. (*C*) Mean (and 95% bootstrapped CI) number of seeds per visitor by category for all visitors (i.e., those with and without seed loads). Sample sizes are given above all bars.

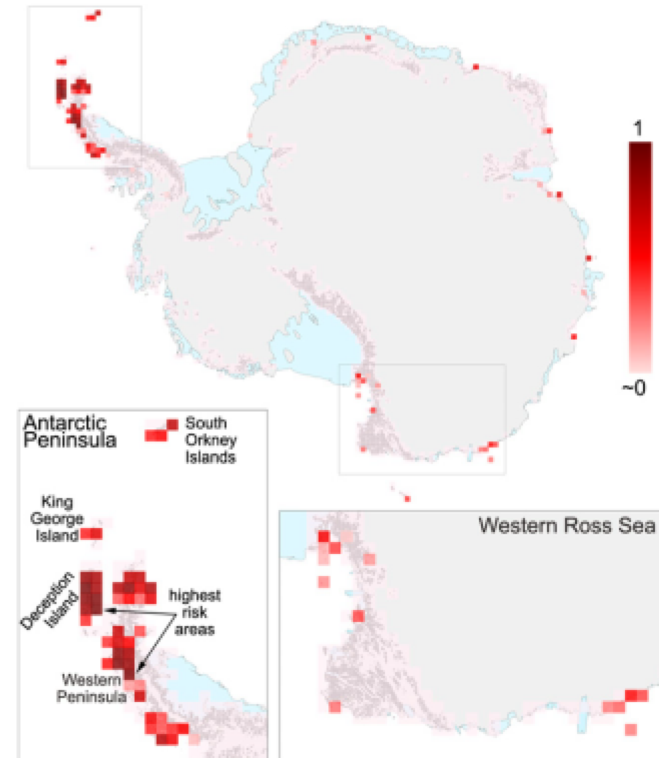


Fig. 3. Relative risk of alien vascular plants establishing in Antarctica. Visitor-free, ice-free areas are allocated a small value to represent the minor chance of establishment in the absence of visitor landings. *Insets* show risk index detail for the Antarctic Peninsula and the western Ross Sea. Ice-free areas are shown in dark gray, continental areas in light gray, and ice shelf/ice-tongue areas in light blue.

Fuente: Chown et al. (2012) PNAS 109: 4938-4943

Impactos de las invasiones

- Impactos económicos
- Impactos sobre poblaciones y comunidades
  - Predadores
  - Competidores
  - Parásitos
- Impactos morfológicos y comportamentales
- Impactos genéticos y evolutivos
- Impactos a nivel ecosistémico

Impacto de las invasiones

TABLE 1
Estimated Annual Cost of Invasive Species (USD billion)

	U.S.	UK	Australia	South Africa	India	Brazil	Total
Plants	0.148			0.095			0.243
Mammals							0.000
Rats	19.000	4.100	1.200	2.700	25.000	4.400	56.400
Other	18.106	1.200	4.655				23.961
Birds	1.100	0.270					1.370
Reptiles/Amphibians	0.006						0.006
Fishes	1.000						1.000
Arthropods	2.137		0.228				2.365
Molluscs	1.305						1.305
Diseases							0.000
Livestock	9.000		0.249	0.100			9.349
Human	6.500	1.000	0.534	0.118		2.333	10.485
Total	58.299	6.570	6.866	3.013	25.000	6.733	106.484

SOURCE: Pimentel, D., S. McNair, S. Janecka, J. Wightman, C. Simmonds, C. O'Connell, E. Wong, L. Russel, J. Zern, T. Aquino, and T. Tsomondo. 2001. Economic and environmental threats of alien plant, animal and microbe invasions. *Agriculture, Ecosystems and Environment* 84: 1–20. These estimates represent a subset of the costs of invasions only, and are based on readily available data. The data for countries outside the United States cover fewer categories and are likely to be less accurate. The total costs are indicative only, and should be thought of as a lower bound.

Fuente: Perrings (2011) En: Encyclopedia of Biological Invasions

Impacto de las invasiones

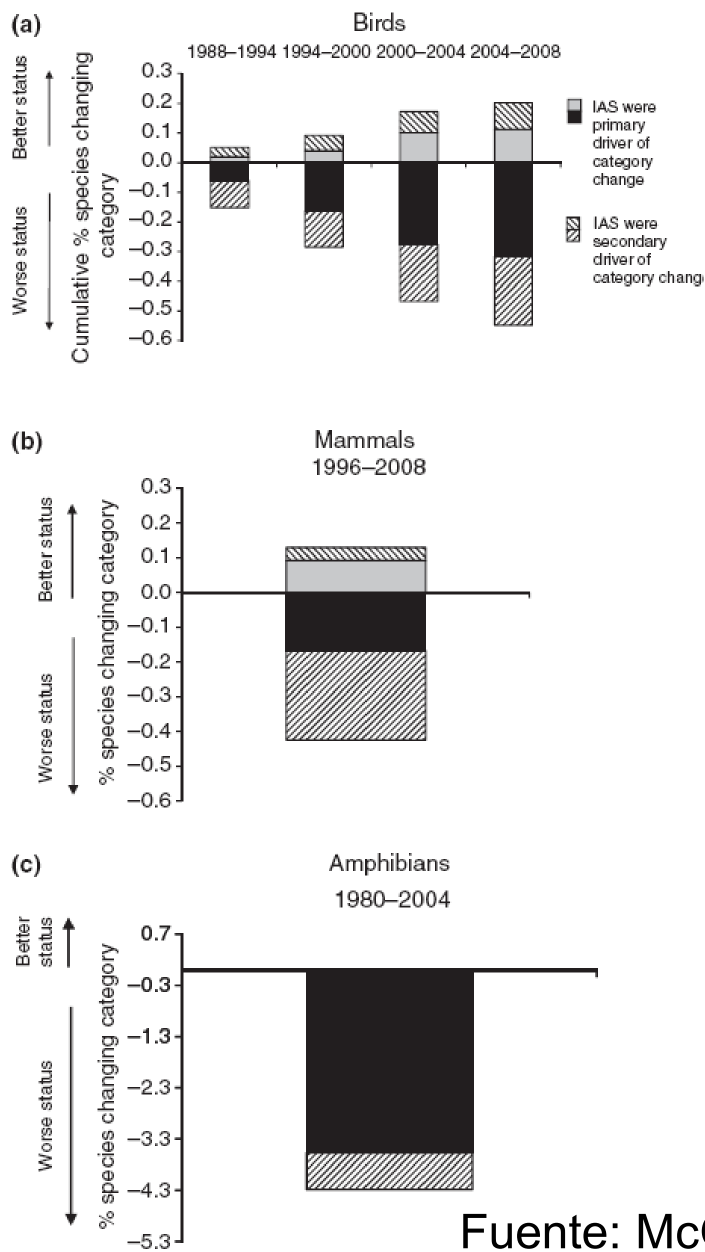


Figure 4 Number of (a) bird, (b) mammal and (c) amphibian species (expressed as a cumulative percentage of all species in each group) undergoing genuine IUCN Red List category changes driven by the impacts of invasive alien species (IAS). This includes impacts leading to deterioration in status (< 0.0) and conservation measures (such as control or eradication of IAS) leading to improvements in status (> 0.0). Solid bars show category changes for which IAS were the primary driver, hatched bars show category changes for which they were a secondary driver. Time periods refer to the intervals between comprehensive reassessments of all species in each group; n = 9,857 extant bird, 5,412 mammal and 5,718 amphibian species at start of period.

Fuente: McGeoch et al. (2010) Divers. Distr. 16: 95-108

Impactos poblacionales y comunitarios: Predadores

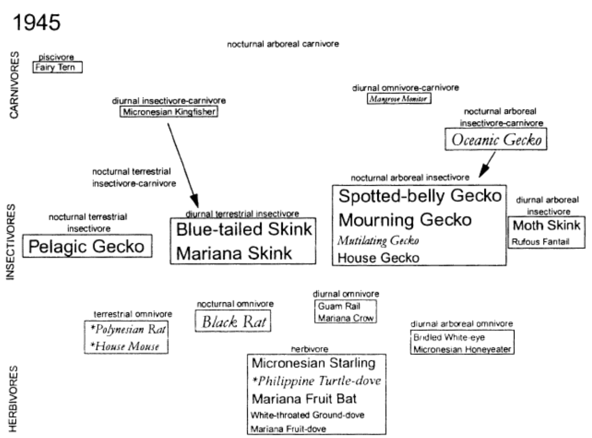


Figure 1 Typical vertebrate food web for northern Guam in 1945. *Italic*, introduced species; *asterisks*, historic introductions; *type size*, relative biomass abundance by order of magnitude from 0.01 to >10 kg/hectare (ha). Biomass densities were grouped by order of magnitude into four classes (0.01–0.099 kg/ha; 0.1–0.99 kg/ha; 1.0–9.9 kg/ha; and >10 kg/ha). Species represented by <0.01 kg/ha were considered trophically insignificant and were omitted from the figures. The figures show major trophic interactions within the vertebrates, and the niche box labels indicate the major trophic interactions between vertebrate and nonvertebrate species (Figures 1–3). See text and Table 1 for additional information.

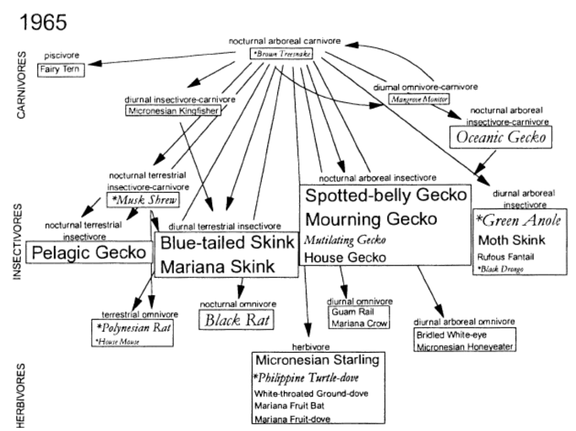


Figure 2 Typical vertebrate food web for northern Guam in 1965. *Italic*, introduced species; *asterisks*, historic introductions; *type size*, relative biomass abundance by order of magnitude from 0.01 to >10 kg/hectare (ha). Biomass densities were grouped by order of magnitude into four classes (0.01–0.099 kg/ha; 0.1–0.99 kg/ha; 1.0–9.9 kg/ha; and >10 kg/ha). Species represented by <0.01 kg/ha were considered trophically insignificant and were omitted from the figures. The figures show major trophic interactions within the vertebrates, and the niche box labels indicate the major trophic interactions between vertebrate and nonvertebrate species (Figures 1–3). See text and Table 1 for additional information.

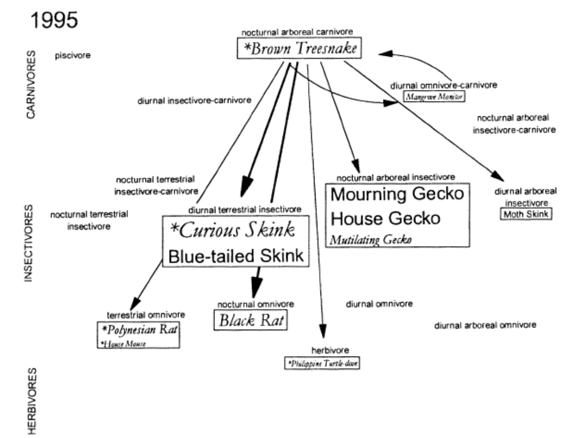
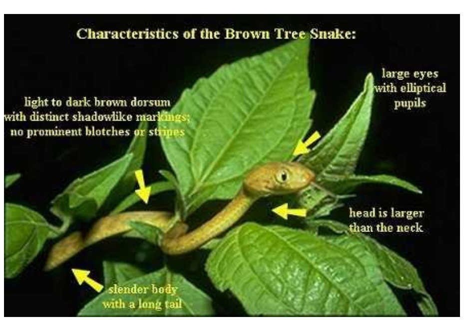
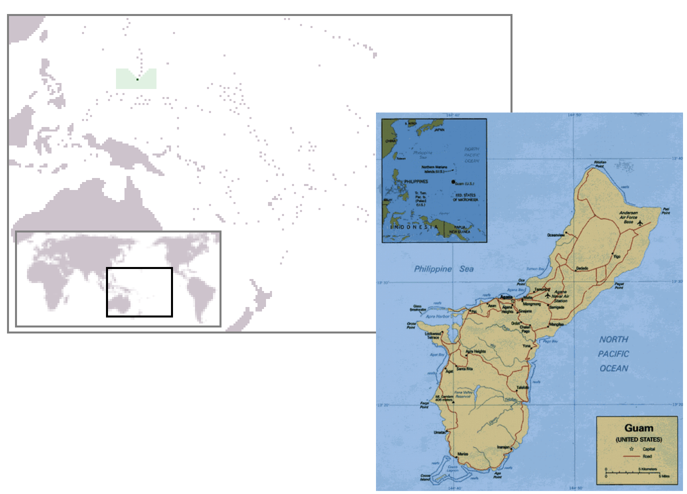


Figure 3 Typical vertebrate food web for northern Guam in 1995. *Italic*, introduced species; *asterisks*, historic introductions; *type size*, relative biomass abundance by order of magnitude from 0.01 to >10 kg/hectare (ha). Biomass densities were grouped by order of magnitude into four classes (0.01–0.099 kg/ha; 0.1–0.99 kg/ha; 1.0–9.9 kg/ha; and >10 kg/ha). Species represented by <0.01 kg/ha were considered trophically insignificant and were omitted from the figures. The figures show major trophic interactions within the vertebrates, and the niche box labels indicate the major trophic interactions between vertebrate and nonvertebrate species (Figures 1–3). See text and Table 1 for additional information.



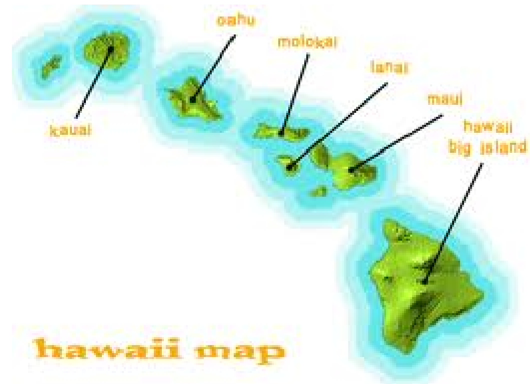
Serpiente arborícola marrón (*Boiga irregularis*)



De las 18 especies de aves nativas de Guam, 9 se extinguieron por la depredación de *B. irregularis*, y el resto están seriamente amenazadas

Impactos poblacionales y comunitarios: Predadores

Caracol gigante africano
(*Achatina fulica*)



Achatinella spp.

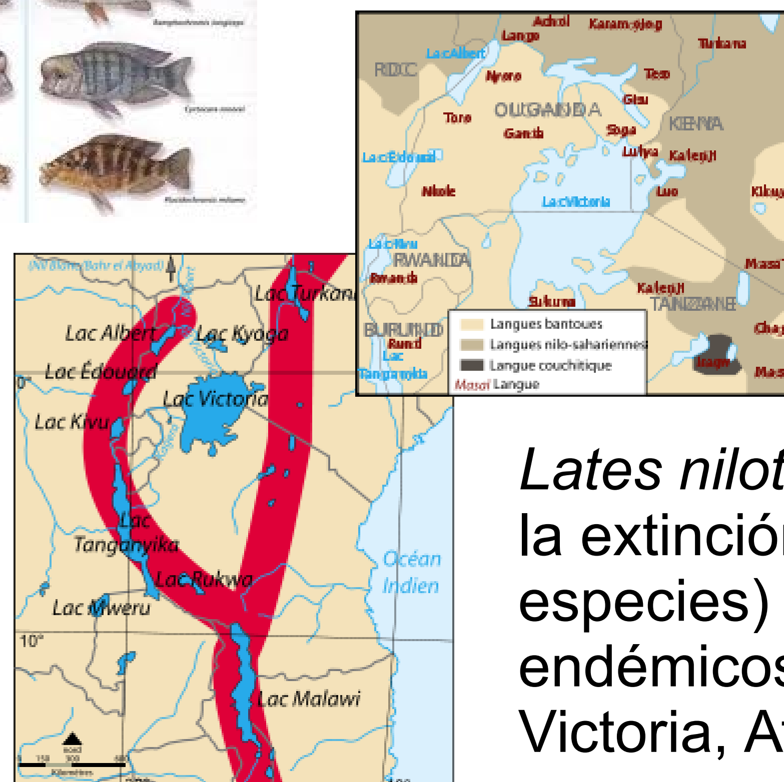
Caracol lobo rosado
(*Euglandina rosea*)

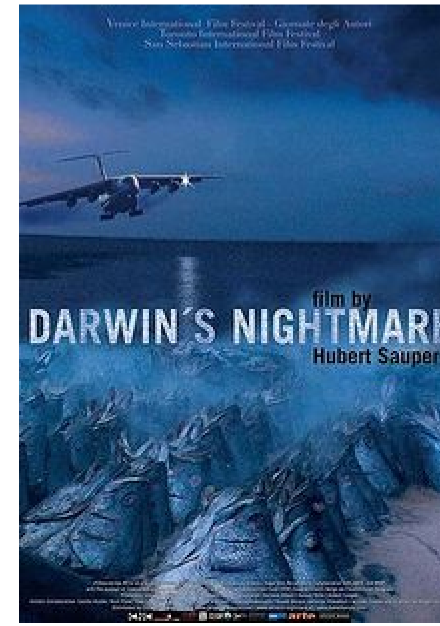
Euglandina rosea contribuyó a la extinción de 15 de las 20 especies endémicas de caracoles *Achatinella* en Hawaii

Hadfield et al. (1993) Amer Zool 33: 610-622

Impactos poblacionales y comunitarios: Predadores

Perca del Nilo
(*Lates niloticus*)





Lates niloticus contribuyó a la extinción de 65% (~200 especies) de cíclidos endémicos del Lago Victoria, Africa

Witte et al. (1991) Env Biol Fishes 34: 1-28

Impactos poblacionales y comunitarios: Competidores

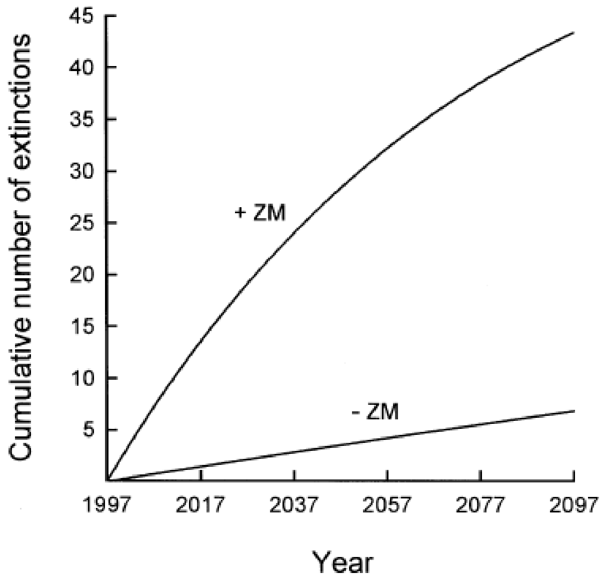


Fig. 1. Projected extinction curves for the mussel species restricted to the Mississippi River and Great Lakes basins. The lower curve (−ZM) denotes an extinction rate of 1·2% per decade, extrapolated from the number of extinctions that have occurred prior to the zebra mussel (*D. polymorpha*) invasion. The upper curve (+ZM) denotes extinction (12% per decade) due to the combined effects of environmental degradation and the zebra mussel, based on data from other invaded systems in North America.

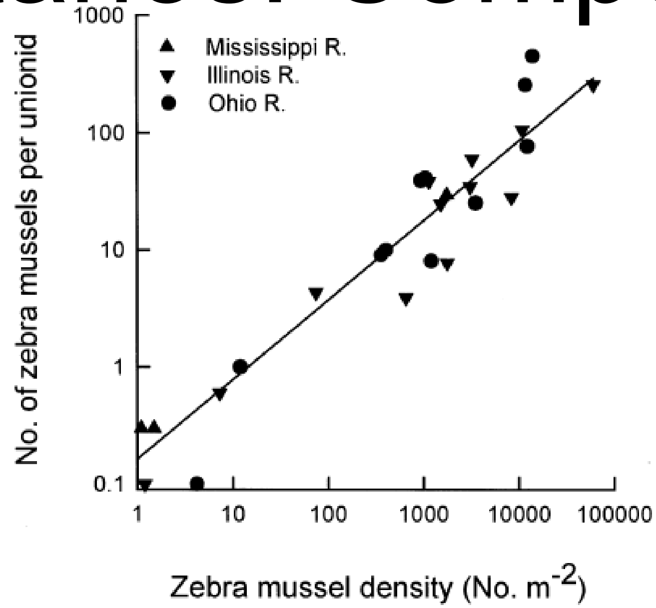


Fig. 2. Relationship between zebra mussel (*D. polymorpha*) field density and mean infestation on native unionid mussels for various unionid populations in the Mississippi River basin (line fitted by least-squares regression: $y = 0{\cdot}678x - 0{\cdot}785$, $r^2 = 0{\cdot}91$, $P < 0{\cdot}0001$). Data from Tucker *et al.* (1993); Tucker (1994); R. Hart, personal communication (Mississippi River); Whitney *et al.* 1995 (Illinois River); P. Morrison, personal communication (Ohio River).

Mejillón zebra
(*Dreissena polymorpha*)

Fuente: Ricciardi et al. (1998) J. Anim. Ecol. 67: 613-619

Impactos morfológicos y comportamentales

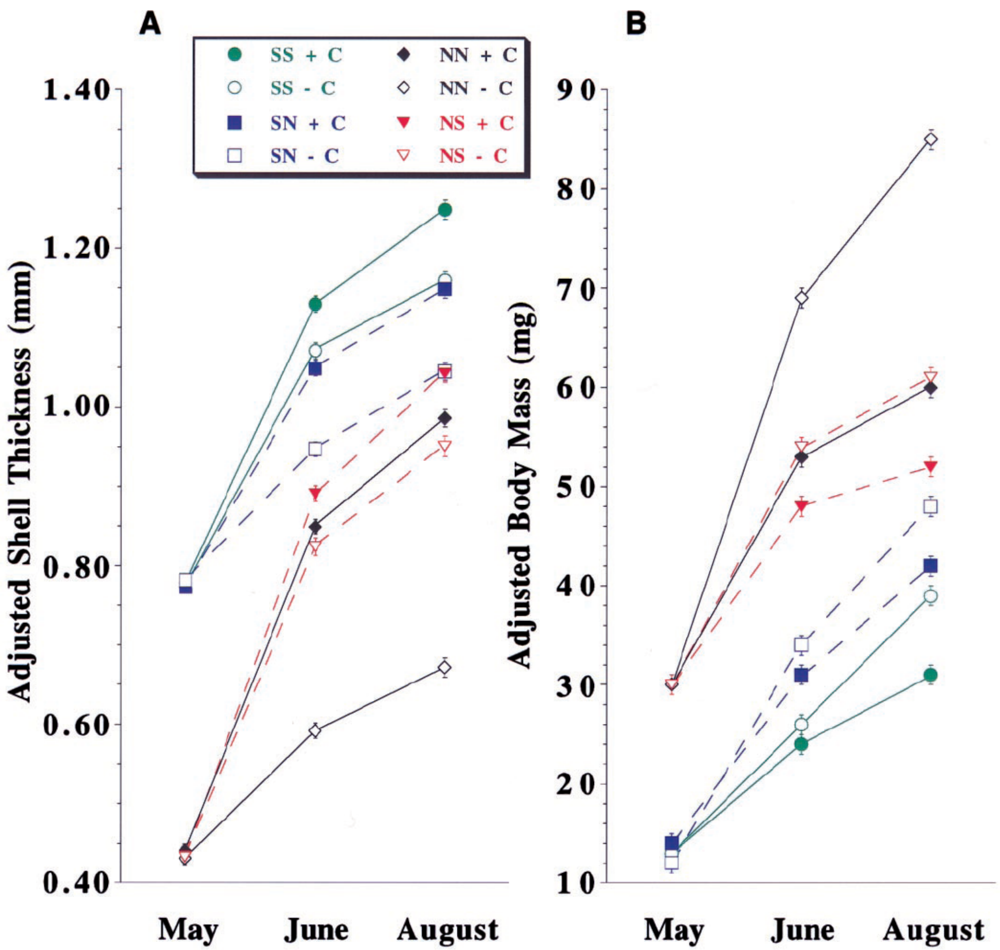


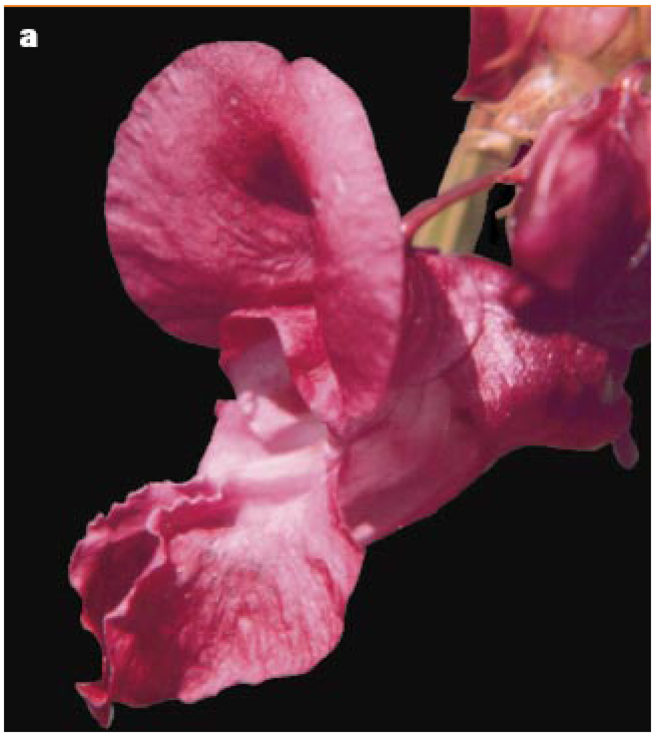
Fig. 2. Phenotypic plasticity in shell thickness (*A*) and body mass (*B*) for *L. obtusata* that were reciprocally transplanted between a southern (S; Manchester, MA) and northern (N; Lubec, ME) site and exposed to the presence (+C; solid symbols) or absence (−C; open symbols) of *C. maenas* effluent. Data are least squares-adjusted means (±SE) generated by ANCOVA (see *Methods*) for shell thickness (Y) vs. shell length (X) (*A*) and body mass (Y) vs. shell mass (X) (*B*). At each location, snails from each source population produced significantly thicker shells after 45 and 90 days (both $P < 0.0001$, ANCOVA) and significantly less body mass after 45 and 90 days (both $P < 0.0001$, ANCOVA) when raised with *C. maenas*. See Table 1 for linear contrasts. SS, South to South (green, solid line); SN, South to North (blue, dashed line); NN, North to North (black, solid line); NS, North to South (red, dashed line). May, initial phenotypic values; June, midpoint phenotypic values (45 days); August, final phenotypic values (90 days).

Littorina obtusata (caracol nativo)

Carcinus maenas (cangrejo introducido)

Fuente: Trussell & Smith (2000) PNAS 97: 2123-2127

Impactos morfológicos y comportamentales



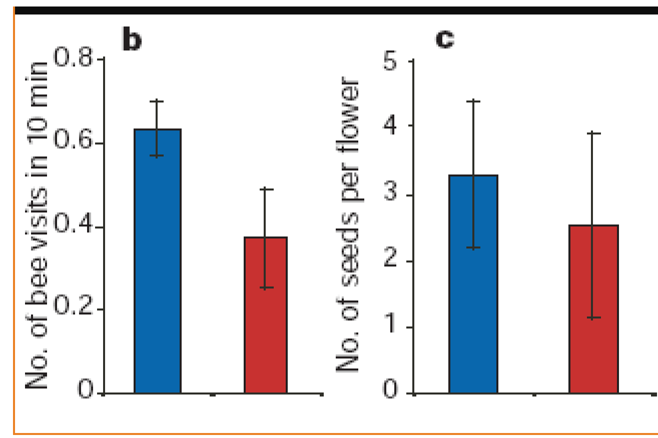


Figure 1 *Impatiens glandulifera*, an Asian beauty that has conquered Europe's river-banks. **a,** The strongly scented flowers of *I. glandulifera* are extremely rich in nectar and therefore very attractive to bumblebee pollinators. Photograph by J. Bitz. **b,** Pollinator visitation to *Stachys palustris* growing in uninterrupted patches (left) or in patches intermingled with *I. glandulifera* (right). **c,** Effect of the presence of *I. glandulifera* (right) on seed set of *S. palustris* (left, uninterrupted). *S. palustris* normally produces up to four seeds per flower. Error bars indicate standard deviation.

Fuente: Chittka & Schürkens (2001) Nature 411: 653

Impactos evolutivos y genéticos: hibridización e introgresión

Anas platyrhynchos

+

Pato hawaiiano
(*Anas wyvilliana*)

Pato del Pacífico
(*Anas superciliosa*)

Pato pico
amarillo africano
(*Anas undulata*)

Pato pico manchado chino
(*Anas poecilorhyncha*)

Rhymer & Simberloff (1996) Ann Rev Ecol Evol Syst 27: 83-109

Impactos ecosistémicos

Efectos de vertebrados invasores en Tierra del Fuego en los niveles de población, comunidad y ecosistema. Los efectos en el nivel poblacional están subdivididos en efectos tróficos (la especie depreda algún componente de la biota nativa o es depredada por él), facilitación (de otros invasores) y efectos en la abundancia de poblaciones nativas. Los efectos en el nivel comunitario están subdivididos en cambios sobre la riqueza, la abundancia y competencia con otras especies. Los efectos en el nivel ecosistémico están subdivididos en cambios en los ciclos de nutrientes, el suelo o el sedimento y el flujo de agua. Un taxón o grupo de taxa es marcado con un P para efectos potenciales y una X para efectos comprobados en Tierra del Fuego

Taxa	Level of effect								
	Population			Community			Ecosystem		
	Trophic effect	Facilitation	Abundance	Richness	Competition	Composition	Nutrient cycles	Soil or sediment	Water flow
Salmonids	P		P	P	P	P			
Beaver	X	X / P	X	X		X	X / P	X	X
Muskrat	X	P	P	P		P	P	P	
Rabbit	X / P		P	P		P		P	
Chilla fox	X / P		P						
Mink	X		X	P	P				
Wild pig	P		P	P		P	P	P	

Fuente: Silva & Saavedra (2008) Rev. Chil. Hist. Nat. 81: 123-136

Impactos ecosistémicos

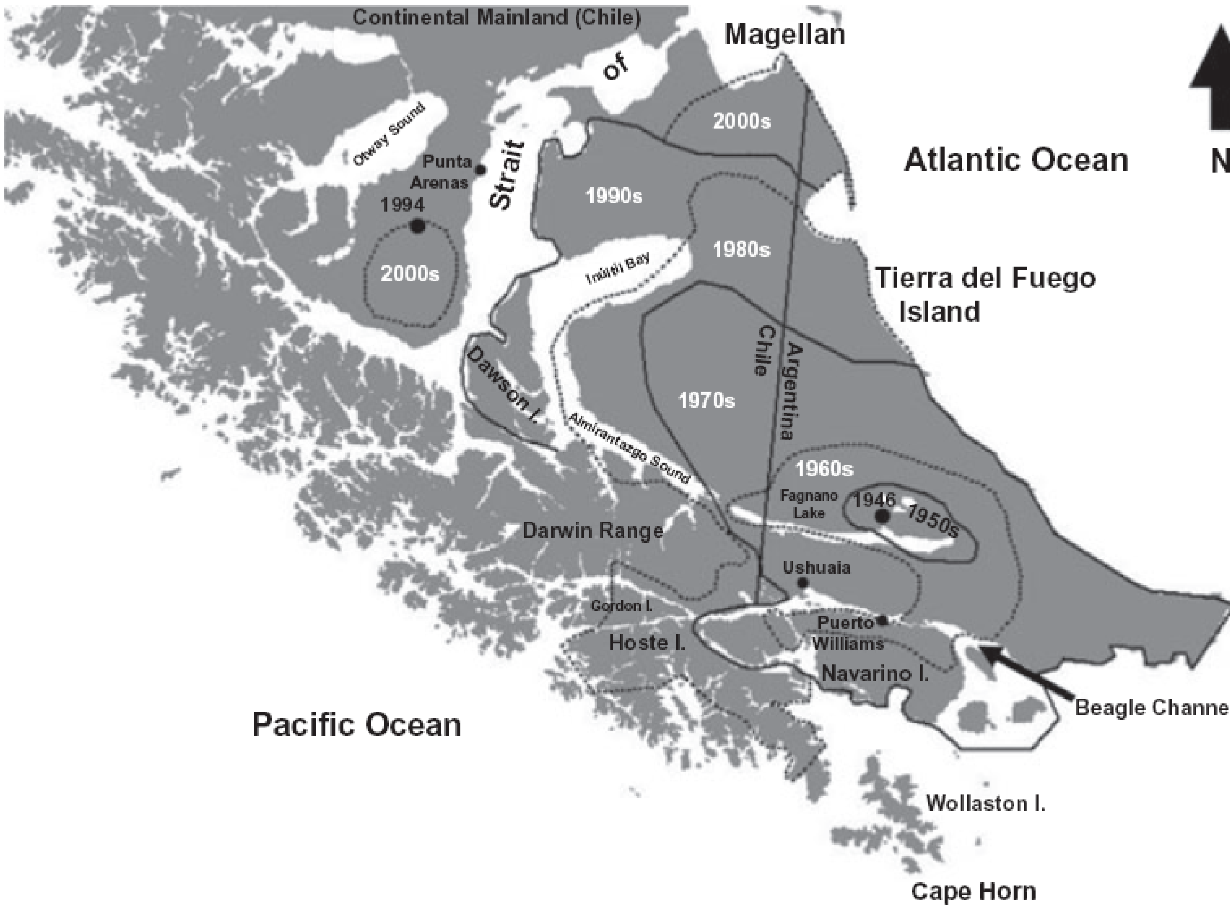


Fig. 1. Map of the archipelagic region of southern South America, showing the approximate dates of expansion of *Castor canadensis* throughout the area. The initial introduction of 25 pairs of beavers in 1946 took place near Fagnano Lake on Tierra del Fuego, an island shared between Argentina and Chile. By the 1960s, invasive beavers had reached the Chilean islands south of the Beagle Channel, and today a resident population is also found on mainland Chile.

Castor norteamericano
(*Castor canadensis*)

Fuente: Anderson et al. (2009) Mammal Review 39: 33-52

Impactos ecosistémicos

Table 2. The direction of impacts caused by *Castor canadensis* on habitat, community and ecosystem variables, comparing responses from North and South American riparian and stream ecosystems

Riparian	North America	South America	Stream	North America	South America
Habitat – Resource availability (g/m^2 and %)					
Soil organic matter	+	+	Benthic organic matter	+	+
Canopy cover	–	–	Canopy cover	–	–
Community – Species richness (taxa/m^2)					
Trees	–	–	Macroinvertebrates	–	–
Herbaceous plants	0, +	+	Fish	+	0
Exotic plants	0, +	+	Exotic fish	NA	0
Ecosystem – Biomass (g/m^2)					
Trees	–	–	Fish	+	+
Herbaceous plants	+	+	Macroinvertebrates	+	+
Dicotyledons	+	+	C-G & Pred	+	+
Monocotyledons	+	+	Sc, Sh & Fil	–	–

NA, not assessed; Macroinvertebrate functional feeding guilds; C-G, collector-gatherer; Pred, predator; Sc, scraper; Sh, shredder; Fil, filterer.

Castor norteamericano
(*Castor canadensis*)

Fuente: Anderson et al. (2009) Mammal Review 39: 33-52

Esquema de la charla

- Qué son las invasiones biológicas
- Tendencias históricas en las invasiones
- La geografía de las invasiones
- Impactos de las invasiones
- Determinantes del éxito de las invasiones
- Manejo de invasiones

¿Qué determina el éxito de las invasiones?

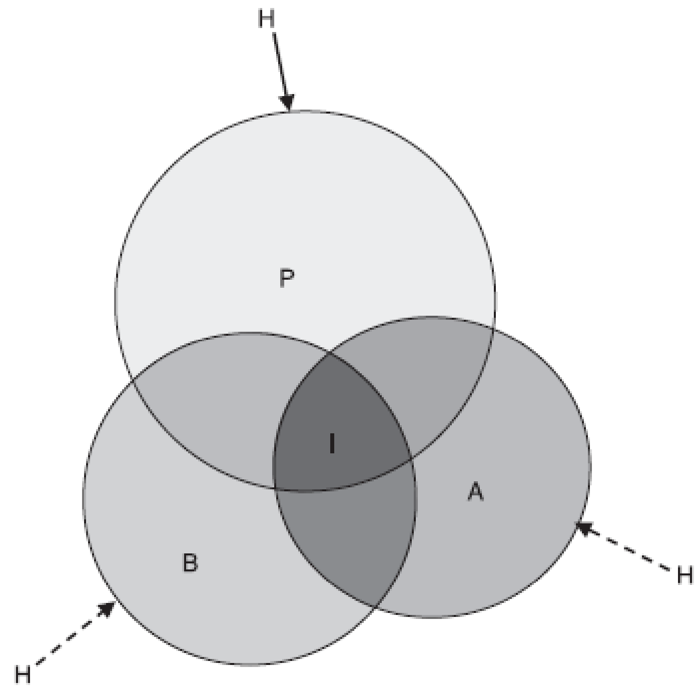


Figure 1 Schematic diagram illustrating how propagule pressure (P), abiotic characteristics (A) and biotic characteristics (B) interact to drive invasion (I), and how humans (H) may modify P, A and B. Invasion occurs where all three factors (i.e. circles) overlap. PAB must all be accommodating for invasion to be successful but the strength and extent of influence from each factor can vary. The circles also illustrate situations where one or two factors might limit invasion. The depth of shading represents the strength of factor influence and the size of the circles indicates the extent of their influence, both of which can change in space and time. In this example, the darker circle of A indicates that A drives invasion, followed by B, then P. P has the greatest extent (time and space) so limits invasion the least. The arrows indicate human interference, which may not necessarily occur but is highly likely with P (solid line; as opposed to dashed lines for A and B).

Fuente: Catford et al. (2009) Diversity and Distributions 15: 22-40

Filtros a las invasiones

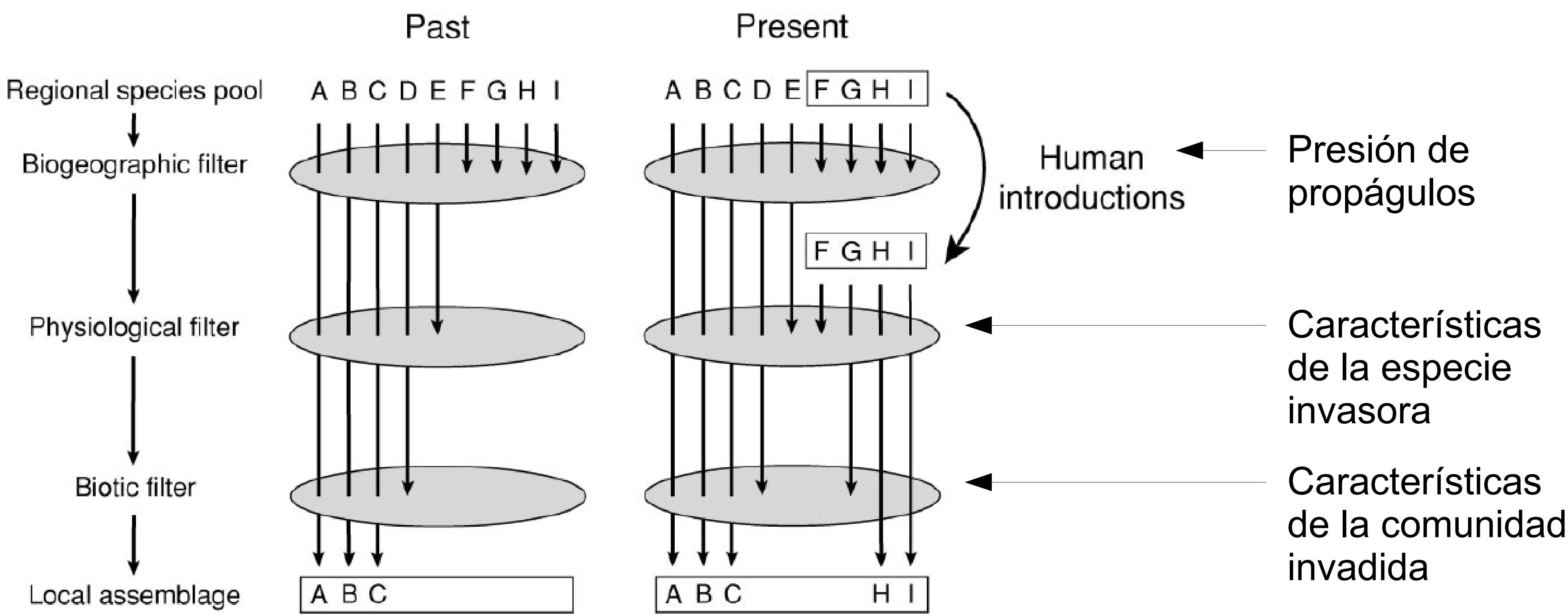


Figure 1 The species present at a local scale are the result of several filters. At the regional scale there is a pool of species present as a result of continental movement patterns and evolutionary events. Biogeographic filters such as glaciation and geographic barriers prevent some species from colonizing certain water bodies or drainage systems. Species that make it through this filter must be able to tolerate the abiotic conditions (physiological filter) and then interact successfully with the other species present (biotic filter). In the past, species such as A, B, and C that made it through all three filters comprised the local assemblage. Humans act to circumvent biogeographic filters by introducing species into areas they would not be able to colonize on their own. Introduced species such as H and I that subsequently pass through the physiological and biotic filters then become members of the local assemblage.

Fuente: Rahel (2002) Ann. Rev. Ecol. Syst. 33: 291-315

Presión de propágulos

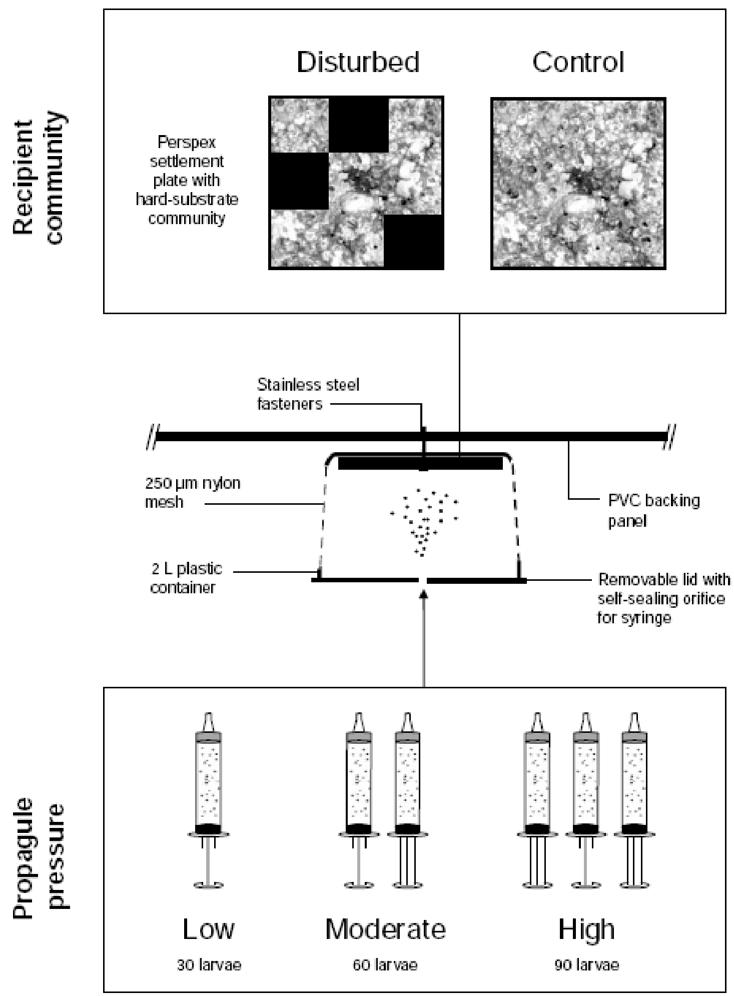


Figure 1. Schematic diagram of experimental design and apparatus. Three levels of propagule pressure were applied to communities with two levels of disturbance, via larval dosing containers.

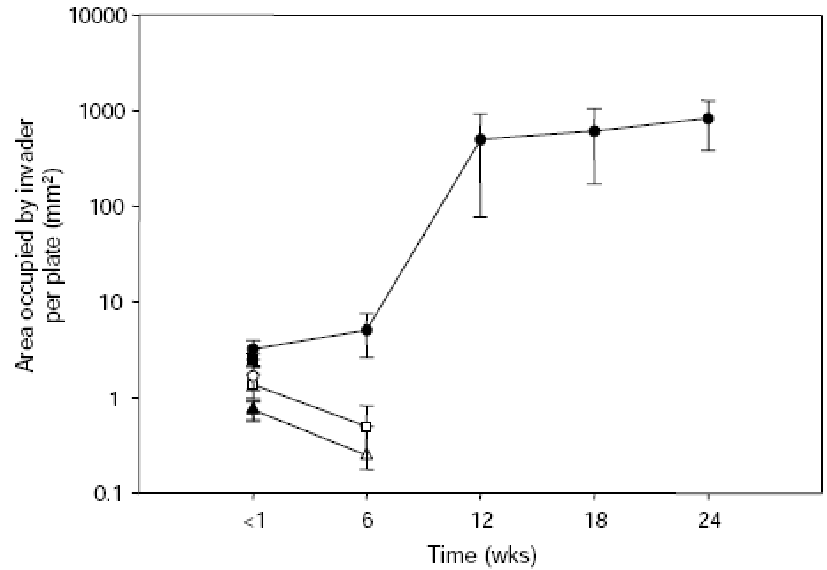
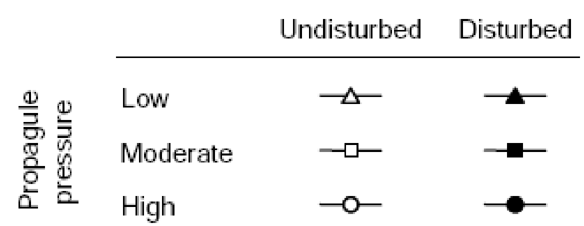


Figure 2. Area (±SE) occupied by invader in relation to propagule pressure and disturbance over 6 months post larval dose. Area is plotted on $\log_{10}$ scale which does not include zero, so time-series are truncated when densities reach zero. All treatments had reached zero densities after 12 weeks except for those where high propagule pressure was applied to disturbed communities. Symbols use the legend:



Fuente: Clark & Johnston (2009) Oikos 118: 1679-1686

Características de los invasores

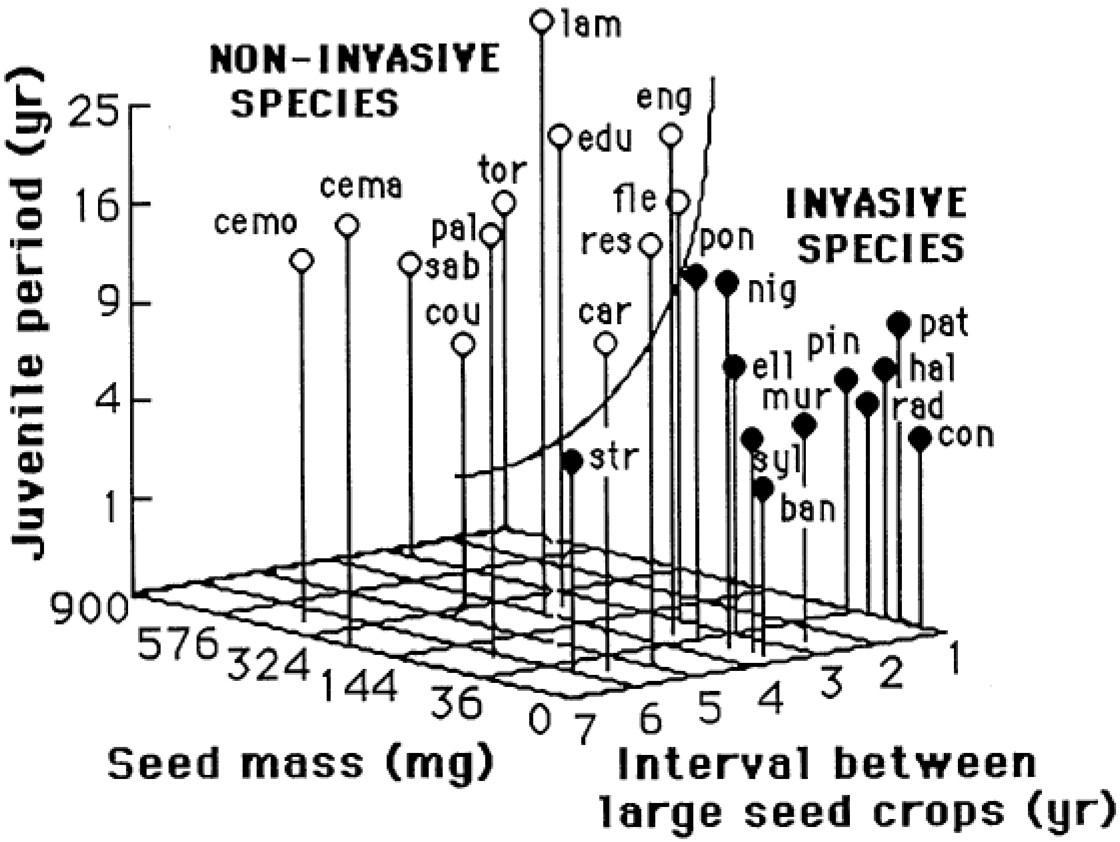


FIG. 1. Distribution of 24 frequently cultivated pines in a space created by three biological variables used for calculation of the discriminant function separating invasive (●) and non-invasive (○) species. The *r–K* selection continuum can be visualized as an arrow pointing from the lower right to the upper left corner of the diagram. See Table 1 for an explanation of abbreviations.

Fuente: Rejmánek & Richardson (1996) Ecology 77: 1655-1661

Características de los invasores

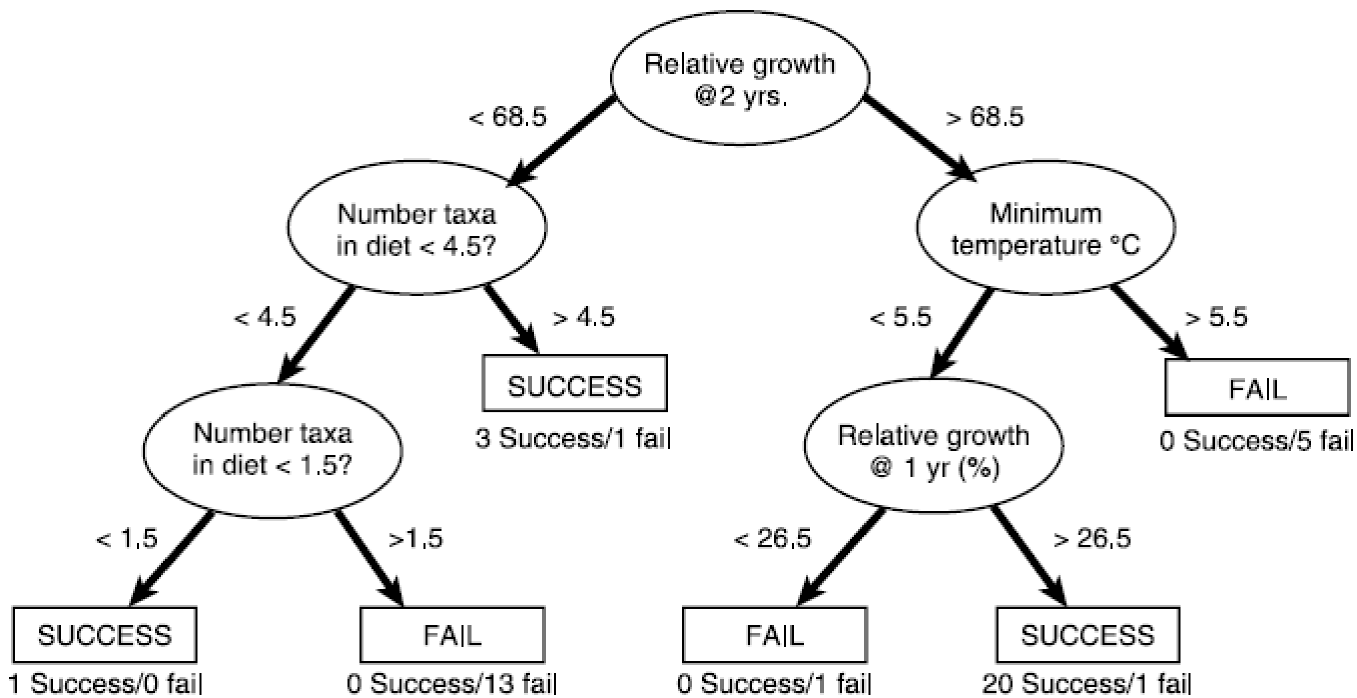


Fig. 2. CART decision tree of successful and failed introduced fishes in the Great Lakes. Ovals represent decision points; rectangles are terminal points in the tree resulting in classification. The numbers of known successful and failed alien species categorized into each terminus are given, illustrating that 2 of 45 species were misclassified.

Fuente: Kolar & Lodge (2002) Science 298: 1233-1236

Características de las comunidades: resistencia biótica

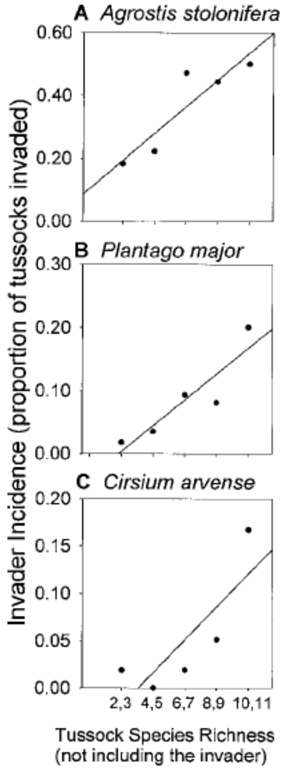


Fig. 1. Natural patterns of invasion by (**A**) *Agrostis stolonifera*, (**B**) *Plantago major*, and (**C**) *Cirsium arvense* relative to the richness of species on the tussocks. Data for adjacent richness levels were pooled to better estimate the incidences because some richness levels contained as few as five tussocks. Presented are the best-fit lines from simple linear regression (*Agrostis*, $R^2 = 0.82$, $P = 0.035$; *Plantago*, $R^2 = 0.89$, $P = 0.017$; *Cirsium*, $R^2 = 0.67$, $P = 0.092$), although I also conducted more statistically powerful logistic regressions showing significant ($P < 0.01$) effects of richness on invasion by each of the three invaders (see text).

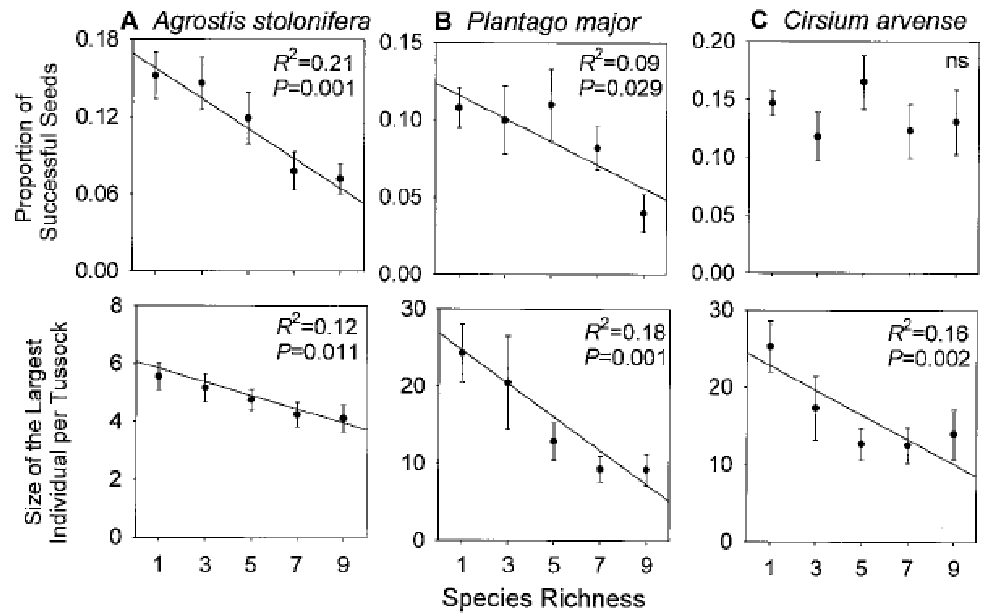


Fig. 2. Results of a direct manipulation of species richness on the invasion success and size of (**A**) *Agrostis stolonifera*, (**B**) *Plantago major*, and (**C**) *Cirsium arvense*. Presented are the proportion of seeds that germinated and survived to the end of the growing season (*29*) and a nondestructive measure of the size of the largest individual per tussock. For the grass, *Agrostis*, this measure was height (in centimeters); for the two dicots, it was the product of leaf number and maximum leaf size (in centimeters). Overall, nonlinear curves were not statistically ($P < 0.05$) better fits than linear curves; however, for *Plantago* success and *Cirsium* size, adding a squared term to the regression ($P = 0.111$ and 0.058, respectively) increased R^2 by 0.04 and 0.06. Data points are means ± 1 SE; ns, not significant.

Fuente: Levine (2000) Science 288: 852-854

Características de las comunidades: perturbaciones

No reservas
Reservas

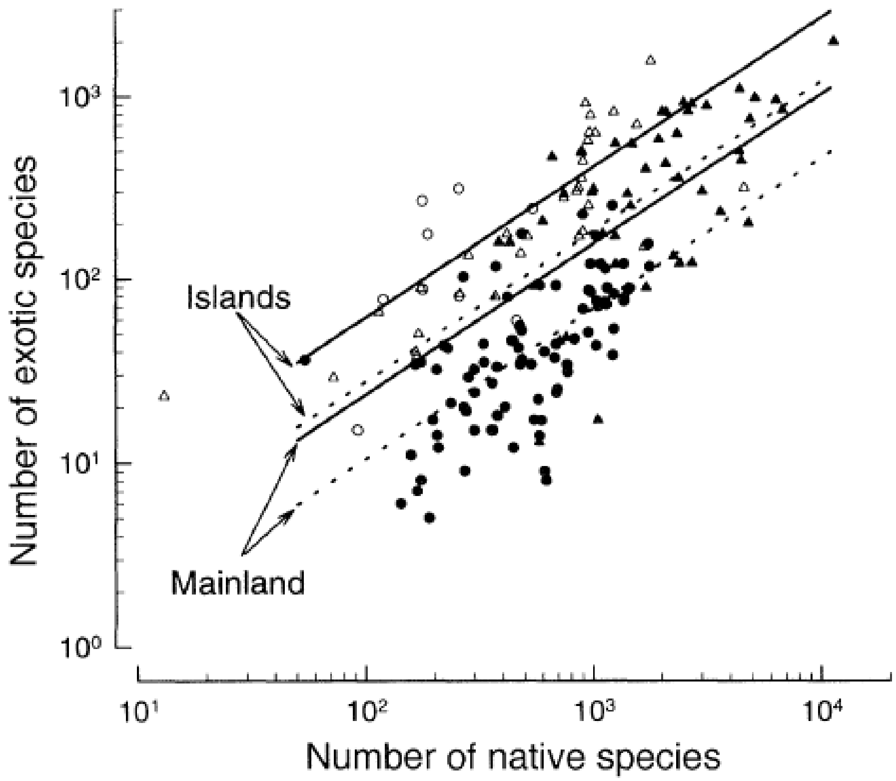


FIG. 4. The relationship between the number of exotic plant species (E) and the number of native plant species (N) for 177 sites and regions around the world, broken down into island reserves (○), island nonreserves (△), mainland reserves (●), and mainland nonreserves (▲). The fitted lines shown are from Eq. 4 (see also Model 4 in Table 3): solid lines are for nonreserve sites, and broken lines are for reserves. Both axes are log scales.

Fuente: Lonsdale (1999) Ecology 80: 1522-1536

Esquema de la charla

- Qué son las invasiones biológicas
- Tendencias históricas en las invasiones
- La geografía de las invasiones
- Impactos de las invasiones
- Invasibilidad de ecosistemas
- Manejo de invasiones

Manejo de invasiones

- Evaluación de riesgos
- Manejo de vías y vectores de introducción
- Detección temprana y respuesta rápida
- Erradicación
- Mitigación y restauración

Fuente: Pysek & Richardson (2010) Ann. Rev. Env. Res. 35

Manejo de invasiones

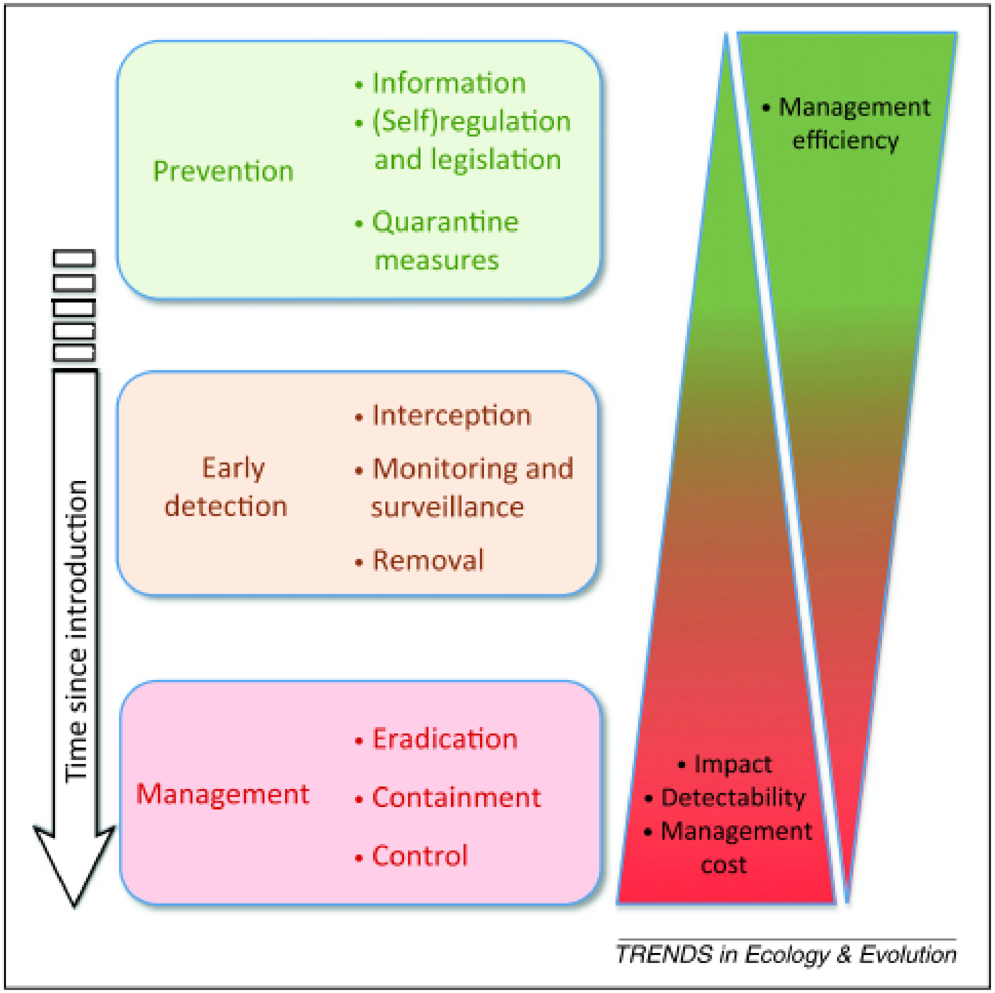


Figure 1. Management strategy against invasive species. The optimal strategy evolves with time since introduction, with management efficiency decreasing and management costs increasing with time since introduction.

Fuente: Simberloff et al. (2012) Trends Ecol & Evol 28: 58-66

Manejo de invasiones

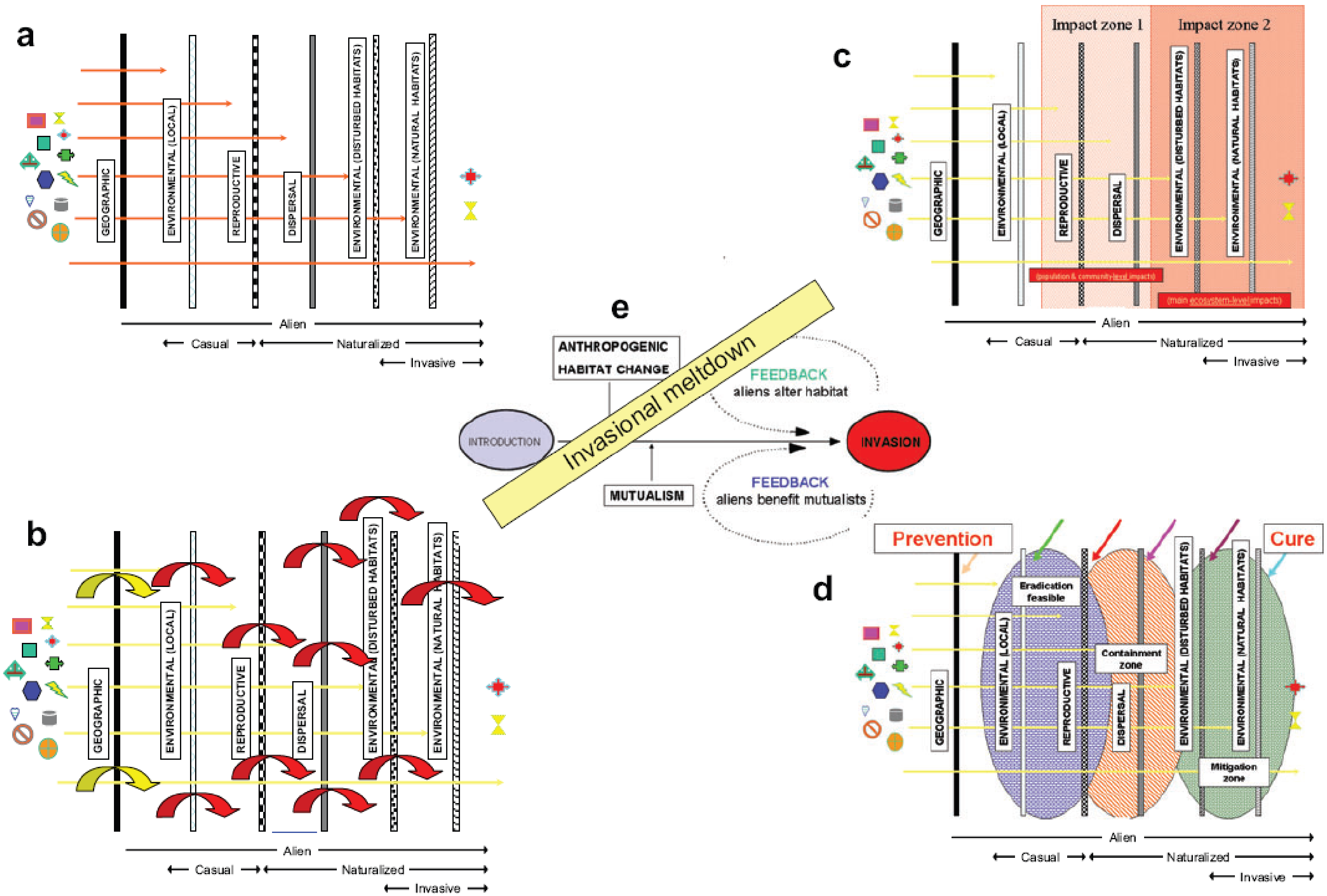


Figure 2

The naturalization-invasion continuum [modified from Richardson et al. (8)], depicting (*a*) the barriers that an invasive species must overcome during invasion and (*b*) losses in transitions among stages. (*c*) The type and magnitude of impact on native biota and environment increases from population and species to community and ecosystem effects, and (*d*) measures to mitigate the effects of invasion need to be appropriate for the given stage of invasion. (*e*) The outcome of invasion of an introduced species results from a complex interplay of a number of factors, including mutualistic relationships with both native and other alien biota, and may result in invasional meltdown [modified from Richardson et al. (13)].

Fuente: Pysek & Richardson (2010) Ann. Rev. Env. Res. 35

Resumen de la charla

- Las invasiones biológicas han aumentado dramáticamente en las últimas décadas por las actividades humanas
- Las especies exóticas tienen múltiples impactos ecológicos, evolutivos y económicos
- La invasibilidad de los ecosistemas depende en parte de sus características, incluyendo su riqueza y su nivel de perturbaciones
- El manejo de las invasiones debe integrar prevensión, manejo temprano de invasiones y actividades de control, erradicación y restauración