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Supplementary material

Table S1. Hypotheses in biological invasions and their parallels in human epidemics. The list of hypotheses follows the classification provided in Enders et al. (2020).

Hypothesis	**Description for biological invasions**	**Parallelism with epidemics**	**References**
Disturbance	The invasion of non-native species is higher in disturbed than in relatively undisturbed ecosystems	There is a positive relation between disease outbreaks and ecosystem disturbance; host susceptibility also increases with altered body conditions	Elton (1958), Hobbs and Huenneke (1992), Wolfe et al. (2005), Keesing et al. (2010), Myers et al. (2013)
Reckless invader *aka* 'boom-bust'	A population of a non-native species that is highly successful shortly after its introduction can decline or disappear over time due to different reasons such as competition with other introduced species or adaptation of native species	The incidence of a pathogen can decline because of different reasons such as the extinction of the wildlife reservoir or acquired immunity of the host	Simberloff and Gibbons (2004), Yates et al. (2006)
Colonization pressure	As the number of introduced non-native species increases, the number of invasive species in that location is predicted to increase	Coinfections create heterogeneity in the host population, which can lead to evolutionary branching in the parasite population and the emergence of a hyper-virulent parasite strategy	Lockwood et al. (2009), Alizon et al. (2008), Alizon et al. (2013)
Ecological naivety *aka* eco-evolutionary naivety	The impact of a non-native species on biodiversity is influenced by experience of the invaded community. Thus, the evolutionary largest impacts are caused by species invading systems where no phylogenetically or functionally similar species exist	Pathogens are more virulent in naïve hosts than in previous infected hosts who have developed resistance to infection	Diamond and Case (1986), Ricciardi and Atkinson (2004), Pascual et al. (2008), Alizon et al. (2009), Domínguez-Andrés and Netea (2019)
Enemy release	The absence of enemies in the exotic range facilitates invasion	The absence of virophages and bacteriophagues in novel infested populations facilitates infections	Keane and Crawley (2002), Dalmasso et al. (2014)
Enemy reduction	The partial release of enemies in the exotic range facilitates invasion	The partial absence of virophages and bacteriophagues in novel infested populations increase infections	Colautti et al. (2004), Dalmasso et al. (2014)

Human commensalism	Species that live in close proximity to humans are more successful in invading new areas than other species	There is higher probability of zoonosis and pathogen spill over in human populations that are in close proximity to animal reservoirs and/or vectors populations	Jeschke and Strayer (2006), Gallardo et al. (2015)
Ideal weed	The invasion success of a non-native species depends on particular life-history traits (e.g. seed bank, clonality)	Human pathogens have life-history traits that increase their establishment and persistence (e.g. transmission modes, standing genetic variation, plasticity, production of exoenzimes)	Baker (1965), Rejmánek and Richardson (1996), Alcamí and Koszinowski (2000), Woolhouse et al. (2005), Easterday (2020)
Propagule pressure	The number and frequency of introduced individuals of a non-native species increases the probability of invasion	The amount of the pathogen exposed to the human host increase the likelihood of infection	Lockwood et al. (2005), Horrocks et al. (2011), Hartfield and Allizon (2013)
Darwin's naturalization	The invasion of non-native species is higher in areas that are poor in closely related species than in areas that are rich in closely related species	Pathogens that invoke an immune response immediately after infection can also provide partial cross-protection against other strains of the same or closely related pathogens	Daehler (2001), Horimoto and Kawaoka (2005), Bhattacharyya et al. (2015)
Adaptation	The likelihood of invasion depends on non-native species preadaptation to the conditions in the exotic range. Invasive species that are related to native species are more successful in this adaptation	Introduced pathogens that are more related to native pathogens will be more successful as they will be preadapted to the native hosts due to long-term co-evolutionary interactions	Duncan and Williams (2002), Gagneux et al. (2006), Prohaska et al. (2019)
Ecological imbalance	Invasion patterns are a function of the evolutionary characteristics of both the recipient region and potential donor regions. Species from regions with highly diverse evolutionary lineages are more likely to become successful invaders in less diverse regions	Pathogen evolution depend on human modification of the habitat	Fridley and Sax (2014), Myers et al. (2013)
Evolution of increased competitive ability	There is a trade-off between defense and competitive ability. After having been released from natural enemies, non-native species allocate more energy to growth and/or reproduction, which makes them more competitive	There is a trade-off between high transmission rates and long infectious periods. Selection for pathogen virulence and horizontal transmission is highest at the onset of an epidemic but decreases thereafter, as the epidemic depletes the pool of susceptible hosts	Blossey and Nötzold (1995), Bolker et al. (2010), Berngruber et al. (2013)

Empty niche	The invasion of non-native species increases with the availability of empty niches in the exotic range	Infections increase in human populations not previously exposed to the pathogens	MacArthur (1970), Conn (2009)
Invasional meltdown	The presence of non- native species in an ecosystem facilitates invasion by additional species, increasing their likelihood of survival or ecological impact	Coinfections migh lead to increased suscepibilityto other infections though inmunosuppresion, but not always	Simberloff and Holle (1999), Graham (2008), Alizon and van Baalen (2008)
Tens rule	Approximately 10% of species successfully take consecutive steps of the invasion process	To be tested	Williamson and Brown (1986)
Biotic acceptance *aka* 'the rich get richer'	Ecosystems tend to accommodate the establishment and coexistence of non-native species despite the presence and abundance of native species	Several pathogens can accumulate and coexist in the body after competitive interactions. Hyper-virulent strains cannot coexist	Stohlgren (2003), Alizon and van Baalen (2008), Mideo (2009)
Biotic indirect effects	Non-native species benefit from different indirect effects triggered by native species	New pathogens can profit from endemic pathogens (e.g. that have induced immunodepression, immune evasion)	Callaway (2004), Alizon and van Baalen (2008), Mideo (2009)
Biotic resistance *aka* diversity invasibility hypothesis	An ecosystem with high biodiversity is more resistant against non-native species than an ecosystem with lower biodiversity	Microbial diversity reduce the establishment of pathogens	Elton (1958), Levine and D'Antonio (1999), Mallon et al. (2015), Libertucci and Young (2019)
Dynamic equilibrium model	The establishment of a non-native species depends on natural fluctuations of the ecosystem, which influence the level of competition from local species	Altered physiological, immunological or physiological conditions affect host susceptibility to infection and the severity of the disease	Huston (1979), Plowright et al. (2017)
Enemy of my enemy *aka* accumulation-of-local pathogens hypothesis	Introduced enemies of a non-native species are less harmful to the non-native than to the native species	Pathogens are less virulent in the hosts with whom they have coevolved than in new hosts	Eppinga et al. (2006), Bolker et al. (2010)
Enemy inversion	Introduced enemies of non-native species are less harmful in the exotic than the native range, due to altered biotic and abiotic conditions	This contradicts the hypothesis that pathogens are less virulent in the hosts with whom they have coevolved than in new hosts	Colautti et al. (2004), Bolker et al. (2010)
Environmental heterogeneity	The invasion of non-native species is high if the introduced range has a highly heterogeneous environment	An epidemic spreads more rapidly in contact with heterogeneous human populations (genetic variation, age, sex, nutritional status, drug	Melbourne et al. (2007), Stecher et al. (2007), Cousineau and Alizon (2014)

		exposure, etc.) and also within host heterogeneities	
Global competition	A large number of different non-native species is more successful than a small number	This is controversial. An infected host might be immune-compromised and be more susceptible to new hosts. However, an infected host might also be prevented to be further infested because not providing the required resources or environmental conditions.	Colautti et al. (2006), Kamiya et al. (2018)
Habitat filtering	The invasion of non-native species in the new area is high if they are pre-adapted to the habitat conditions of the area	The host immune system acts as an important environmental filter to limit the extent of available niches to pathogens.	Weiher and Keddy (1995), Costello et al. (2012)
Increased resource availability	The invasion of non-native species increases with the availability of resources	Disease outbreaks increase with availability of resources	Sher and Hyatt (1999), Watson et al. (2007)
Increased susceptibility	If a non-native species has a lower genetic diversity than the native species, there will be a low probability that the non-native species establishes itself	Slow evolving pathogens and with low genetic variation, would infest less efectively. To be tested	Colautti et al. (2004)
Island susceptibility	Non-native species are more likely to become established and have major ecological impacts on islands than on continents	Emerging pathogens are more likely to become established and have major impacts on islands than on continents. To be tested	Jeschke (2008)
Limiting similarity	The invasion of non-native species is high if they strongly differ from native species, and low if they are similar to native species	The lack of evolutionary adaptation to a novel pathogen cause higher infections	MacArthur and Levins (1967), Brown et al. (2012), Harimoto and Kawaoka (2005)
Missed mutualisms	In their exotic range, non-native species suffer from missing mutualists	In a new range, missing vectors or reservoirs can deter the infection process	Mitchell et al. (2006), Plowright et al. (2017)
New associations	New relationships between non-native and native species can positively or negatively influence the establishment of the non-native species	In zoonotic diseases, the existence of encountering new reservoirs can definitely influence the spread of the pathogen	Colautti et al. (2006), Plowright et al. (2017)

Novel weapons	In the exotic range, non-native species can have a competitive advantage against native species because they possess a novel weapon, that is, a trait that is new to the resident community of native species and, therefore, affects them negatively	Emerging pathogens have new weapons to which the host has not been exposed before	Callaway and Ridenour (2004), Alizon et al. (2009)
Opportunity windows	The invasion of non-native species increases with the availability of empty niches in the exotic range, and the availability of these niches fluctuates spatio-temporally	The environment created by the host determines the number of potential niche opportunities	Johnstone (1986), Costello et al. (2012), Buffie and Pamer (2013)
Plasticity hypothesis	Invasive species are more phenotypically plastic than non-invasive or native ones	Antigenic variation is a similar strategy as the phenotypic variation of invasive species to cope with different environmental conditions. Phenotypic plasticity in pathogens facilitate hosts shifts and rapid adaptation to new and unpredictable host environments	Davidson et al. (2011), Palmer et al. (2016), De Fine Licht (2018)
Polyploidy	Polyploid organisms, particularly plants, are predicted to have an increased invasion likelihood, since polyploidy can lead to higher fitness during the establishment phase and/or increased potential for subsequent adaptation	To be tested	Beest et al. (2012)
Resource-enemy release	The non-native species is released from its natural enemies and can spend more energy in its reproduction, and invasion increases with the availability of resources	Selection for pathogen virulence and horizontal transmission is highest at the onset of an epidemic but decreases thereafter, as the epidemic depletes the pool of susceptible hosts	Blumenthal (2006), Bolker et al. (2010), Berngruber et al. (2013)
Shifting defense hypothesis	After having been released from natural specialist enemies, non-native species will allocate more energy to cheap (energy inexpensive) defenses against generalist enemies and less energy to expensive defenses against specialist enemies; the energy gained in this way will be invested in growth and/or reproduction, which makes the non-native species more competitive	Specialist pathogens would become generalist after host switch	Doorduin and Vrieling (2011), Woodcock et al. (2017)
Specialist-generalist	Non-native species are more invasive in a new region if the local predators are specialists and local mutualists are generalists	Generalist parasites use generalist cell receptors	Callaway et al. (2004), Baranowski et al. (2001)

Sampling	A large number of different non-native species is more likely to become invasive than a small number due to interspecific competition. Also, the species identity of the locals is more important than the richness in terms of the invasion of an area	Exposure to many pathogens, increase the chances to get infected by someone	Crawley et al. (1999), Alizon et al. (2013)

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