



INFECTIOUS DISEASE (/CATEGORY/BRANCHES-OF-MEDICINE-A-M/INFECTIOUS-DISEASE)

Emerging infectious diseases and biological invasions .

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1. Background

Changes to climate, habitats and biodiversity are affecting abiotic and biotic components of ecological niches, while social and economic changes (e.g. the development of megacities and increasing movement of people and goods in a globalized world) offer multiple routes for species translocation and dissemination [1] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C1>)–3 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C3>)). Together these external drivers increasingly facilitate biological invasions, a major threat to biodiversity and ecosystems globally [4] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C4>)). Non-native species include disease-causing microorganisms and parasites, and disease vectors (e.g. arthropod vectors such as mosquitoes), which pose substantial threats to human, domesticated animal and wildlife populations. Invasions by pathogens are, in public and animal health terms, emerging infectious diseases (EIDs; such as human immunodeficiency virus (HIV) and severe acute respiratory syndrome (SARS) [5] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C5>), 6 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C6>)). In this paper, we focus on the mutual relevance of invasion science [7] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C7>)) and public health epidemiology in the context of EIDs of direct public health significance [8] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C8>)). We also highlight how invasive non-pathogenic species, and infectious diseases that do not affect humans or domesticated animals directly, may indirectly impact human health. Possible indirect effects include those affecting the health of domesticated animals, crops, natural resources of wild plant and animal origin and also the health of natural ecosystems. Epidemiology is a broad field that encompasses many areas of health research; here, we use the term 'epidemiologists' to refer to those within the subspecialty focused on epidemiology of EIDs, which may also include disease ecologists. Responses to EIDs engage a wide community of medical, veterinary and public and animal health professionals.

The World Health Organization (WHO) defines an EID as 'an infectious disease that has appeared in a population for the first time, or that may have existed previously but is rapidly increasing in incidence or geographic range' (<https://apps.who.int/iris/handle/10665/204722>) (<https://apps.who.int/iris/handle/10665/204722>)). Infectious diseases emerge via a number of mechanisms. 'Adaptive emergence' constitutes genetic change of a microorganism that results in a phenotype that is capable of invading a new ecosystem, particularly by jumping to new host species, including humans [9] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C9>)). This mechanism of emergence may permit pathogens causing animal infections to become transmissible to humans (i.e. become zoonoses) and, in some cases, to be sustained by human-to-human transmission in the absence of animal reservoir hosts [10] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C10>)–12 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C12>)). Expansion or 'geographical emergence' by changes to geographical ranges of pathogens or parasites can involve long-distance translocation, more localized spread or both. For invasion biologists, invasive species are those translocated intentionally or accidentally through a human agency (often over long distances) from the locations where they are native to an ecosystem where they were previously absent [13] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C13>), 14 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C14>)). This is analogous to the emergence of EIDs by long-distance geographical spread.

The ideas that EIDs are essentially invasive species [15] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C15>)), and that two branches of science (invasion science and EID epidemiology) are studying similar phenomena [16] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C16>)–18 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C18>)), are not new. Furthermore, management objectives and methods may be similar [19] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C19>)). Invasive arthropod vectors of parasites and pathogens, such as *Aedes* species of mosquitoes, are a case in point; they are traditionally considered part of EID studies, but are also studied by invasion biologists (e.g. [17] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C17>)), 20 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C20>)). However, despite these commonalities, functionally, the fields of invasion science and EID epidemiology work in parallel rather than together. Therefore, in this review, we explore the extent of similarities in key concepts, processes and methodological approaches, as well as useful differences that provide opportunities for synergies, which may enhance our understanding and practical management of invasions and EIDs. We call for these fields to be integrated within the One Health approach to enhance human well-being.

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2. Common ground

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2.1. Shared global context: the One Health concept

EIDs that have affected humanity in recent decades have sharpened the focus of microbiologists, epidemiologists, human and animal health practitioners, as well as environmental and biological scientists, on the intersections of human, animal and ecosystem health. Emergence of many infectious diseases is associated with the dynamics of natural communities and their abiotic environmental determinants [21 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C21>)]. Many EIDs, including invasive pathogens such as West Nile virus (WNV) in North America, are maintained by (or originate in) wild animal hosts, and their emergence may have negative effects on natural communities as well as human or production animal health [22 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C22>)]. Accordingly, the One Health concept has evolved, which postulates that human, animal and ecosystem health are interrelated and interdependent, and that reactionary or preparatory responses to threats to human well-being demand holistic, transdisciplinary approaches encompassing all three components, including medical and veterinary practitioners and collaborators in ecosystem health [23 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C23>)]. Public health organizations around the world are increasingly adopting the One Health approach to make their responses to infectious diseases more effective (e.g. <https://www.cdc.gov/onehealth/> (<https://www.cdc.gov/onehealth/>)). The One Health concept encompasses benefits to human well-being (ecosystem services, i.e. benefits produced by ecosystem functions and structures for human well-being) as well as risks (ecosystem disservices, i.e. 'nuisances' for human well-being such as pests, and biological and geophysical hazards [24 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C24>)]). Both EIDs [25 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C25>)] and biological invasions [26 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C26>)] are important causes of ecosystem disservices, although biological invasions often render services and disservices at the same time [26 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C26>)]. Both disease emergence and biological invasions are increasing, being driven by the same global changes in climate, biodiversity, socio-economics and trade/travel [27 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C27>)]. The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net (<http://www.ipbes.net>)) was launched in 2012 to assess the state of biodiversity and of the ecosystem services it provides to society [28 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C28>)], 29 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C29>)]. Integrating disservices in the IPBES conceptual framework illustrates the shared role that EIDs and biological invasions play for human well-being as components of One Health (figure 1 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577F1>)).

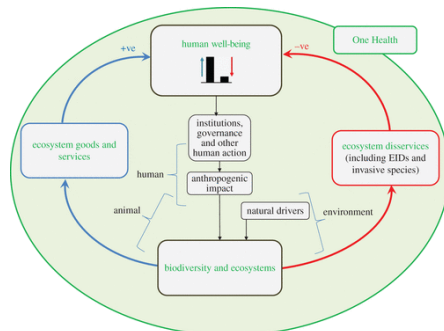


Figure 1. Biological invasions and EIDs as components of One Health. The schematic combines an adaptation of the IPBES Conceptual Framework [29 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C29>)] with a schematic of the One Health concept. The IPBES Conceptual Framework illustrates the interplay between anthropogenic and natural drivers of change in nature (biodiversity and ecosystems) (black boxes and arrows) and how this connects ecosystem services to human well-being (+ve effects, blue box and arrows). We also identify connections to ecosystem disservices, such as those caused by EIDs and invasive species (-ve effects, red box and arrows). For simplicity, positive effects of invasive species are not shown. The One Health concept (green circle) encompasses the IPBES Conceptual Framework, with its interacting human, animal and environment components.

The One Health concept recognizes that impacts of ecosystem changes on human health may act indirectly, e.g. via impacts on food and water security or by affecting biodiversity [17 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C17>)], 30 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C30>)], 31 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C31>)], and the UN Food and Agriculture Organization has adopted the One Health approach (<http://www.fao.org/asiapacific/perspectives/one-health/en/> (<http://www.fao.org/asiapacific/perspectives/one-health/en/>)). For example, several invasive trees in South Africa reduce water availability, thereby causing indirect impacts on human health (figure 2 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577F2>)). More generally, biological invasions are increasingly being framed in a context of a

transdisciplinary social–ecological system in which wider implications, including health and socio-economic impacts, are considered [32] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C32>). In South Africa, such transdisciplinary approaches have been termed ‘invasion science for society’ [33] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C33>), which echoes the One Health concept.

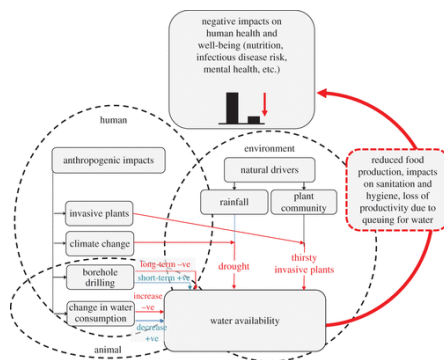


Figure 2.

An example of indirect effects of invasive species on human health. Here, the indirect impact is water availability, which in South Africa is imperilled by invasive plants that are ‘thirsty’ (i.e. take up water at rates that significantly reduce water flows), climate change-induced drought and the competing requirements of drinking water for human populations, livestock production and other agricultural enterprises. How this issue is central to the One Health concept is illustrated by the interacting human, animal and environment components of the water availability problem as indicated by dashed circles. These circles indicate the main impacts of humans (the anthropogenic impacts), animals (the consumption of water by livestock and the consequent need to drill boreholes) and the environment (rainfall and plant communities).

2.2. Common drivers and biological processes

There are many overlaps and parallels between EIDs and biological invasions. Both involve species crossing geographical barriers that historically prevented natural dispersal, processes of establishment in a new environment, and subsequent range expansion to occupy the new environment. Not all EIDs can be termed invasive species, but some EIDs spread, and many establish, internationally, and such pathogens can be readily considered as invasive species (e.g. WNV, chikungunya, SARS and Zika in the Americas; chikungunya and dengue in Europe; HIV and influenzas globally). Even if EID emergence is associated with native range expansions (e.g. the spread of Lyme disease into Canada from the USA), and as such might not be formally considered as invasive species, insights on the basis of invasion concepts are still very relevant.

The concepts of ‘barriers’ and ‘stages’ are as relevant in biological invasions [13] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C13>) as they are to disease emergence by international spread of a pathogen [5] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C5>), and also to the processes mediating de novo emergence of a zoonosis from a microorganism maintained by animal reservoir hosts [34] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C34>). This topic has been reviewed before [17] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C17>), [35] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C35>). However, we focus on three key elements that permit, or prevent, EIDs and biological invasions: (i) geography, which is surmounted by dispersal; (ii) compatibility, which is determined by genetics and may be surmounted by evolution (including pre-adaptation via eco-evolutionary experience; see below); and (iii) environment, which is a barrier that may be lifted by disturbance, including environmental changes. Together, these factors mediate the biotic and abiotic qualities of the niche, the species’ fitness in that niche and determine how the niche qualities and fitness may change (table 1) (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577TB1>) and figure 3 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577F3>).

(i) Geography: The crossing of historical geographical barriers and human-mediated introductions are related to both invasive species and many EIDs. The movement of invasive species, and long-distance dispersal of EIDs or their vectors, occurs via air and surface transport of goods and people [36 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C36>)]. For infectious diseases of humans, air travel is considered the most important route because it is rapid enough for humans infected in source locations to remain infective upon arrival in their destinations (e.g. SARS [37 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C37>)]). For many invasive species, the travel time from the native to the alien region is less important due to the occurrence of long-lived life stages such as seeds and eggs, so international spread of plants and animals is often facilitated by surface transport (on land or by sea). However, surface transport is also important for EIDs whereby infected arthropods, invasive arthropod vector eggs and infected animal hosts may be transported over long distances, e.g. the historical spread of plague and the recent spread of *Aedes albopictus* eggs/immatures in tyres and house plants [38 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C38>)]–40 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C40>)]. While not a typical feature of EID introductions, deliberate transport and introduction of invasive species is common [41 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C41>)], 42 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C42>)]. Also, both EIDs and invasive species have a history of, and the potential for, being introduced via the international pet trade [43 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C43>)], 44 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C44>)], and both may be introduced deliberately as acts of bioterrorism (e.g. [45 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C45>)]). The bridging of the 'geographical' contact barrier between animals and humans (a process known as 'spillover') is essential for the de novo emergence of microorganisms as zoonoses, and the re-emergence of many zoonoses such as the spread of Nipah and Hendra viruses to humans (who are readily infected by the virus) from wildlife reservoirs [18 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C18>)]. Many zoonoses and arthropod vectors are dispersed regionally or more locally by natural means, which are not usually considered in the context of invasive species. Dispersal by migratory birds is one important mechanism whereby pathogens (e.g. influenza viruses) and some disease vectors (particularly ticks) can be dispersed over long distances (e.g. [46 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C46>)]).

Beyond the simple contingency of species being transported into a new environment, the number and size of introduction events of a given species is also important. This is termed propagule pressure in invasion science and is analogous to concepts of infection frequency (relevant for spillover and introduction to new areas) and infective dose that are important in infectious disease epidemiology [13 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C13>)], 17 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C17>)], 47 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C47>)]. If propagule pressure is low, introduced species are more likely to undergo stochastic fade-out for a range of reasons, including the probability that an infected individual meets enough naive individuals for at least one of them to acquire infection (for infectious diseases), or to mate successfully (for any species undergoing sexual reproduction).

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(ii) Compatibility: Both invasive species and EIDs must be capable of surviving in their new environment to the point of reproduction, and then of reproduction that supports stable or expanding populations. The capacity of an invading species to reproduce in the invaded environment is often measured as the intrinsic growth rate of the population (r , which is a time-based metric) in invasion science and the basic reproduction number (R_0 , which is a generation-based metric) in epidemiology. For persistence (i.e. naturalization) of invasive populations or EIDs, they must be compatible with 'environmental' conditions (including quantities such as host population size and density) to the extent that r is positive and R_0 is greater than unity [15
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C15>]. Whether or not an introduced organism becomes naturalized or invasive depends, to a great extent, on the eco-evolutionary experience of the introduced species and the recipient community. Eco-evolutionary experience describes the historical exposure of an organism to biotic interactions over evolutionary timescales [48
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C48>],49
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C49>], and emphasizes the role of traits selected for in previous environments (pre-adaptations), within both introduced and resident species, in driving the establishment success and adaptability of introduced species. In other words, eco-evolutionary experience determines the ease with which an invader can integrate into novel ecological contexts, and pre-adaptations are crucial determinants of a species' invasiveness and a community's invasibility [48
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C48>]-51
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C51>]. Continuing evolutionary change of invading species is commonplace [52
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C52>], and often involves admixture (intraspecific hybridization between previously allopatric populations) or hybridization between closely related species (e.g. [53
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C53>]). Such genetic recombination often leads to enhanced performance by invasive populations due to heterosis and hybrid vigour [54
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C54>]. However, many invasive species adapt in the absence of admixture or hybridization [54
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C54>],55
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C55>], resulting in traits that increase their performance. For example, invasive species may undergo rapid evolution in traits related to dispersal (e.g. [56
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C56>]) and much insight has been gathered on such adaptations by identifying candidate genes underlying them. Adaptive emergence of EIDs for transmissibility of animal pathogens to or among humans explicitly requires genetic change, by mutations and recombination events [10
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C10>],11
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C11>]. However, as for non-disease-causing invasive species, pathogens and disease vectors continue to evolve and adapt to new environments into which they have been introduced, enhancing R_0 within the invaded environments [57
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C57>],58
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C58>]. For pathogens of animals and humans, evolution towards increased R_0 typically involves trade-offs between traits of transmission (higher pathogen loads mean more efficient transmission when contact is made between infected and naive hosts) and virulence (higher pathogen loads mean greater morbidity/mortality and reduced contact rates between infected and naive hosts) [59
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C59>]. Such evolutionary processes are, however, highly idiosyncratic among pathogens that are transmitted by different routes [60
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C60>] and among different populations [61
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C61>]. Genetic changes may also permit invasive species and EIDs to persist long-term and not undergo 'boom and bust' which may occur for a range of reasons, including depletion of resources [62
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C62>],63
<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C63>].

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(iii)Environment: Environmental conditions determine whether a recipient location provides a suitable niche for species to establish and spread. Abiotic factors including climate (e.g. temperature, rainfall/humidity), and substrate qualities are key to whether introduced species can survive. Biotic factors, ranging from host population size, density and connectedness, and nutritional resources through 'enemies' (predators, parasites, pathogens, competitors and, for microorganisms, immunity and cross-immunity) to more complex community interactions, will determine whether introduced species can survive and reproduce [32 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C32>),64 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C64>)]. When biogeographic barriers are breached by human action, species may be introduced to ecological niches that are suitable for their survival and reproduction and which also provide an 'enemy-free' space that further permits their establishment and spread. For this reason, the realized niche of species may be much larger in their introduced ranges than their native ranges [65 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C65>)]. The same is true of EIDs when they are introduced into an immunologically naive population [15 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C15>)]. While evolutionary change in invading species may alter the compatibility of the invading species with the invaded environment, environmental change may facilitate invasions by creating new suitable niches for invading species without the need for evolutionary change. Human disturbance of natural communities, ranging from replacement of natural vegetation with agricultural systems to more subtle changes, can make them more vulnerable to invasive species [66 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C66>),67 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C67>)]. Such changes have similar effects on the process of emergence of infectious diseases in both wildlife and livestock [68 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C68>)]. Current and future global change (climate, biodiversity, landscape/land-use change, including urbanization) are likely to facilitate both disease emergence and biological invasions, while some sudden and unpredictable environmental fluctuations may inhibit invasions [69 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C69>),70 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C70>)].

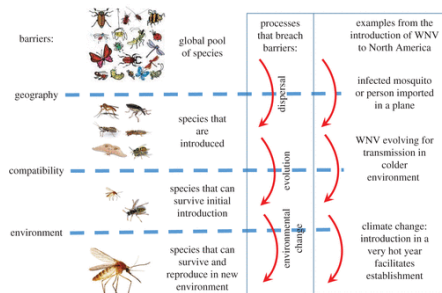


Figure 3.

A conceptual diagram of the barriers to biological invasions and EIDs and how they limit species invasions and disease emergence. Processes whereby barriers may be breached are shown in the central box, and an example of these (from the introduction of West Nile virus (WNV) to North America) is shown in the box to the right. Note the only prerequisite for biological invasions is that there is dispersal across a geographical barrier (evolution and environmental change are not required if conditions are already suitable). By contrast, an EID can arise either through evolution leading to the breakdown in a compatibility barrier or environmental change breaking an environmental barrier without there being dispersal over a geographical barrier (cf. table 1 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577TB1>)). Moreover, the order of the barriers crossed can vary. For example, in the emergence of HIV, a compatibility barrier was first crossed (non-human primate to human) before the global spread of the pandemic. The insect collage used under 'species that are introduced' in Figure 3 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577F3>) was sourced from Wikimedia Commons under the Creative Commons Share-Alike License (CC-BY-SA 3.0; see https://commons.wikimedia.org/wiki/File:Insect_collage.png) (https://commons.wikimedia.org/wiki/File:Insect_collage.png). We acknowledge the original author of the work: 'BugBoy52.40'.

Table 1. Barriers to invasions and disease emergence, the processes whereby these may be surmounted and the phenomena and consequences that may result. EID, emerging infectious diseases.

initial barrier which when crossed can lead to the phenomenon	process	global change examples/mechanisms	EID examples
geographical	dispersal	biological invasions (i.e. inter-regional dispersal of alien species by humans)	EIDs involving international spread (e.g. HIV, SARS, WNV)

initial barrier which when crossed can lead to the phenomenon	process	global change examples/mechanisms	EID examples
compatibility	evolution	pre-adaptation via eco-evolutionary experience. Evolution of new phenotypes in the environment (e.g. herbicide resistance, reduction in body size due to size-selected harvesting, new associations)	adaptive emergence of a zoonosis (e.g. zoonotic influenza) greater capacity to survive and reproduce, allowing species to spread (e.g. WNV in North America)
environmental	disturbance	land-use change that removes competitors or predators, or opens up resources allowing range expansion of species (native or non-native) climate change that changes the geographical location of the ecological niche of species	provides new opportunities for contact between humans, animals and disease vectors; and causes biodiversity change driving disease emergence diseases and their vectors (e.g. Lyme disease vectors in Canada)

In the above section, we have separated geographical, compatibility and environmental barriers, but they are often interdependent in influencing invasion/emergence (r and R_0 depend on both compatibility and environment). Even when not mutually dependent, they act together. For example, environmental change (such as altered land use) can bridge the 'geographical' contact barrier between animal pathogens and humans, as is the case for Nipah virus [71]

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C71>).

Environmental changes also drive evolutionary changes that may alter the eco-evolutionary experience of potential invaders and potentially invaded communities. Issues of global spread of species and global environmental changes that drive disease emergence directly and indirectly (via non-disease-causing invasive species) underline the need for a One Health approach [23]

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C23>).

2.3. Similar methods

Risk analysis is a key management approach for both applied epidemiologists and invasion biologists. In this section, we focus primarily on risk assessment and return to discuss risk management later. Risk assessment is applied to help develop policies in anticipation of, and in response to, disease emergence events and biological invasions.

To support these risk assessments, both disciplines aim to identify qualities (traits or syndromes) that (i) make species 'invaders' or 'emergers' (e.g. [72]

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C72>)-74

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C74>)), (ii)

make source environments more likely to yield them (e.g. [74

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C74>)), and

(iii) render receiving environments susceptible or resistant to invaders or emerging pathogens [75

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C75>)).

Modelling is used in both invasion science and epidemiology to elucidate biological processes, predict establishment and spread, to support risk assessment and to assess effectiveness of interventions. The same 'top-down' (correlative, e.g. statistical models, ecological niche models and machine learning) and 'bottom-up' (mechanistic, e.g. dynamic simulation models, network analysis, individual-based models) methods are used for predicting the possible current and future extent of EIDs and invasive species [32

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C32>),76

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C76>)).

Disease modelling methods used by epidemiologists would, of course, be directly relevant

to modelling all types of infectious diseases, including those that affect species other than vertebrates, including plant pathogens [77

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C77>)).

Methods for monitoring invasive species, including active field surveillance and citizen science-based passive surveillance, have much in common with methods used to monitor risks from emerging zoonoses and vector-borne diseases in the environment [78

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C78>)-81

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C81>)). Similar

sampling designs are used and their implementation in target regions or sentinel sites is often determined by similar criteria, such as likely spread patterns predicted by species distribution and spread models, and occurrence of locations where impact may be greatest (e.g. [82

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C82>)). In

both disciplines, molecular approaches are used to confirm species identities and for source attribution [83

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C83>),84

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C84>)), and

both are exploring Earth observation data as proxies for potential occurrence of invaders [85

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C85>)), or risk from EIDs [86

(<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C86>)).

3. Useful differences: opportunities for synergies

3.1. Differences in scope

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From an invasion biology perspective, EIDs are idiosyncratic in two ways. First, many important EIDs affecting humans and domesticated animals are obligate parasites of vertebrates [5] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C5>), which means that consideration of the host population is paramount to predictive modelling and assessing impacts and risk. Parasitic species and microorganisms thus comprise a special subset of invasive species. For EIDs and parasitic invasive species, spread into naive populations may be rapid from the point of introduction to an epidemic, provided there is sufficient availability of naive hosts. To a first approximation, spread will not occur if the frequency of contact with naive hosts is below a threshold level. For microorganisms transmitted directly among humans, the patterns and extent of spread (equivalent to the 'invasive range') are mostly determined by characteristics of the human population and microorganism and not directly by the environment. The persistence of transmission cycles of microorganisms following spread (i.e. endemicity) depends on the details of the transmission characteristics of the microorganism and of the host population. As for non-infectious invasive species, emerging infections may boom and bust but usually due to mechanisms associated with the availability of susceptible hosts, through either reduction in the host population by a highly pathogenic EID or the development of immunity to the emerging pathogen in the host population [87] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C87>).

Second, the causal organisms of EIDs (viruses, bacteria, fungi, protozoa and helminths) and vectors (particularly insects) are, for the most part, at the 'small and fast' end of the spectrum of invasive species, i.e. they have very small size and their generation time is often (but not always) short (days to months). By contrast, generation times may be years to decades for organisms like invasive trees. Notably, few invasive plants have reached their broad-scale climatic limits in their new ranges even centuries after introduction (e.g. [88] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C88>))–90 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C90>)). Given the ease of accidental long-distance movement by human agency, microorganisms are likely to be common as invasive species of natural systems globally, although data on the occurrence of such events are very limited. Furthermore, due to their extremely short generation times, compared to many invasive plant species for example, they have greater capacity to adapt genetically to new environments. Despite this, and compared to their focus in EID epidemiology, microorganisms remain understudied in invasion biology due to a range of factors including difficulties with isolation or culturing, poorly known biogeography and therefore their native versus non-native status, and difficulties in detecting and ascribing impacts to the causative agent (e.g. [91] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C91>)).

The first difference described above could be thought of as a limit on the scope of direct synergies in models used and the number of 'invasive EIDs' that may lend themselves to direct collaborations between invasion biologists and epidemiologists. However, clearly some invasive species are parasites or pathogens, and for these, the expertise of EID epidemiologists would enrich invasion biology. Furthermore, this apparent idiosyncrasy does not mean that invasion biologists cannot profit from modelling approaches developed in EID epidemiology. The second difference is of interest because the larger size (which makes their detection and enumeration easier) and longer generation times of many invasive species have meant that the demographic processes and community ecology of invasions have been more readily studied. Epidemiologists tend to use relatively simple criteria-led approaches or species distribution models to assess whether, and to what extent, invasion by pathogens and vectors may occur now and in the future (e.g. [92] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C92>))). The approach to understanding the processes of introduction–naturalization–invasion used by invasion biologists has made it easier to describe and understand individual invasion processes [32] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C32>)). This approach could be used to enhance risk assessment for EIDs, particularly those that are vector-borne and those that are zoonoses associated with wildlife, as all of the factors involved in these processes may determine the speed, trajectory and impact of EIDs as well as invasive species.

Factors that make species more successful invaders have been studied in invasion science since the 1980s (including using approaches of comparing native with invasive species, and invasive alien with alien-but-not-invasive species [93] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C93>))), but only more recently by epidemiologists interested in emerging diseases [72] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C72>)), 94 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C94>)), 95 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C95>)). Consequently, the elucidation of traits of invasiveness and invasibility and the recognition that these traits of invaders and invaded communities interact to permit or prevent invasions [96] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C96>)) is generally much richer than for EIDs. Studies in invasion science have led to concepts of traits that permit invaders to be more successful in certain environments (e.g. 'urban winner' species [97] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C97>))), and ordination-type methods for classifying communities in terms of their invasibility (e.g. 'periodic tables of niches' [98] (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C98>))). All of these could be a focus for direct knowledge transfer from invasion science to those assessing risk of zoonotic EIDs and arthropod vectors, and for conceptual exploration of

their application to assessing risk of all EIDs. Ultimately, this may significantly enhance our understanding of the different components of the emergence/invasion systems allowing more effective prevention and control strategies.

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3.2. Differences in risk management methods

As invasion biologists and epidemiologists have practical objectives of reducing impacts of the species that are their focus (by prevention, eradication, containment, control or impact reduction), sharing of tools, methods and activities that facilitate these objectives may have considerable value. This subject is worthy of a review in its own right—the following are simply examples.

While risk assessment of an anticipatory nature is very similar in the fields of infectious disease epidemiology and biological invasions, there are differences when risk management is conducted in the face of invasions or EIDs. In invasion science, risk management addresses the consequences of inaction by estimating the 'invasion debt', primarily of existing introduced species [99 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C99>)]. This approach could be readily adapted to risk management practices for EIDs. Those responsible for managing invasions use a range of tools, such as eradographs, to visualize the impacts of interventions to control geographical spread [100 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C100>)] and identification of management-specific switch points in control programmes that determine if and when management objectives should be changed [101 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C101>)].

Field surveillance/monitoring is conducted for both EIDs (particularly when these are zoonoses or vector-borne) and invasive species [102 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C102>)], [103 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C103>)], and it may be practical and economical to develop combined field surveillance programmes. For example in Canada, south-to-north invasion of tick and fly vectors and of vector-borne pathogens of human and livestock health significance is occurring or a threat [102 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C102>)], [103 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C103>)]. While the vectors and vector-borne diseases of livestock may not have human health importance, surveillance may use methods and/or locations similar enough for collaborations in field surveillance to be logical. Molecular methods are mainstream in identifying microbial pathogens in infectious disease surveillance programmes, but these methods are almost entirely used for identifying pathogens and comparisons to identify disease clusters or to attribute sources [104 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C104>)]. More detailed molecular analytical approaches are used in invasion science to understand invasion dynamics, such as underlying propagule pressure [105 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C105>)], landscape-scale dispersal patterns and rates [106 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C106>)], or to reconstruct invasion history and pathways [83 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C83>)], [107 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C107>)]. These approaches may assist risk assessment and policies for management [108 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C108>)], while analysis of environmental DNA using meta DNA barcoding can assist in detecting any species (non-infectious invasive and EIDs) during transport, thereby aiding in preventing introductions from occurring [109 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C109>)]. While molecular approaches are often used to identify the provenance of source populations of invading populations and EIDs [84 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C84>)], they can also provide information relevant to biological control of invasive populations, for example, identifying the native regions where the prospects of identifying co-evolved biological control agents are more likely [110 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C110>)]. All of these more detailed approaches could be more widely implemented in the field of EID surveillance.

Passive citizen science methods of collecting information on species distributions are used both in public health and in ecology. In ecology, the object is monitoring of biogeography and global biodiversity information (e.g. eButterfly—<http://www.e-butterfly.org/>) (http://www.e-butterfly.org/) and iSpot—<https://www.ispotnature.org/> (<https://www.ispotnature.org/>)). However, in public health, these methods have been developed to the point where data are systematically collected and analysed in national surveillance programmes to provide early warning of emerging vector-borne diseases allowing rapid responses [111 (<https://royalsocietypublishing.org/doi/10.1098/rsos.181577#RSOS181577C111>)]. Because most invasion science does not (directly) address human health issues, funding is probably much more difficult to mobilize for work on invasions than for EIDs. This means that cheaper means must be sought to detect new introduced species than can be implemented for EIDs. Nonetheless, the experience of public health epidemiologists in this area may benefit the field of invasion science, and epidemiologists may benefit from incorporating more cost-efficient methods developed in invasion biology.

In public health epidemiology, the need for rapid, specific and sensitive methods to detect clusters of disease cases as the first sign of an outbreak has led to a revolution in molecular and bioinformatics methods (particularly whole-genome sequencing and analysis) for

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Source:

Google Uyarı - Infectious disease (https://www.google.com.tr/alerts/feeds/13289712346447876356/2633815497114439932)

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 INVASIONS
 AND ECOSYSTEMS
 COMPONENTS
 HEALTH THE
 COMBINES
 ADAPTATION
 CONCEPTUAL
 FRAMEWORK
 TAB="PANE-
 PCW"

CLASSIFICATION).
FIGURE 2

q

GENERALY,
INVASIONS
INCREASINGLY
FRAMED IN A
CONTEXT OF
TRANSDISCIPLINARY
SOCIAL
ECOLOGICAL
SYSTEMS
WHICH
IMPLICATIONS,
HEALTH AND
ECONOMIC
IMPACTS,
CONSIDERED
AS DATA
TABS-PANE-
REFERENCES" ID="RSOS181577C32R
LINK="327A">

TRANSDISCIPLINARY
HUMAN-ENVIRONMENT
SCIENCE
SOCIETY' [<A
TABS-PANE-
REFERENCES" ID="RSOS181577C33R
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ECHOS THE
ONE HEALTH
CONCEPT.
ID="RSOS181577E2"
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<FIGURE CAPTION
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FIGURE 2

XMLNS-PXJF="JAVA:COM.ATYPON.FRONTEND.SERVICES.IMPL.PASSPORTXSLJAVAEXTENTIONS">AN

EXAMINE THE
EFFECTS OF
SPATIAL
HUMAN
HEALTH
IMPACTS
AVAILABILITY,
WHICH IN
APOLLIS
IMPERILED
BY INVASIVE
TAXA
THIS STUDY
(I.E. TAKE UP
RATES THAT
SIGNIFICANTLY
WATER
FLOW(S)
CHANGE
DROUGHT
COMPETING
REQUIREMENTS
OF THE INORGANIC
WATER FOR
POPULATIONS,
PRODUCTION
AND OTHER
AGRICULTURAL
ENTERPRISES.
ISSUES TO
CONCENTRATED
HEALTH
ILL BY THE
INTERACTING
ENVIRONMENT
COMPONENTS
WATER
AVAILABILITY
INCREASED
BY DASHED
CIRCLES.
CIRCLES
IMPACTS OF
HUMANS
ANTHROPOGENIC
ANIMALS,
CONSUMPTION
OF WATER
LIVESTOCK
AND THE
CONSEQUENT
NEED TO
BORROW (LES)
ENVIRONMENT
AND PLANT

Q

INFECTION
LOCATIONS
INTERVA
INTRO
ARRIVAL IN
DESTINATIONS
E.G. CAPS
TAB-PANE-

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C37"
CLASS05181377C37R
LINK=1757A>).

TO
SPECIES
TIME FROM
THE NATIVE
TO THE
REGION IS
IMPORTANT
OCCURRENCE
LOVE ONE

STAGES
SUCH AS
SEEDS AND
INTERNATIONAL
PIPING AND
ANIMALS IS
EACH OTHER
BY STRAIGHT
TRANSPORT
(ONLY AND OR

HOWEVER
TRANSPORT
IMPORTANT
WORLDWIDE
WECTED
ARTHROPODS,
ARTHROPOD
VECTORS
EGGS AND
IMMATURE
HOSTS MAY

TRANSPORTED
OVER LONG
DISTANCES,
HISTORICAL
RATHER THAN
SPREAD OF
ALCOHOLS</>

EGG MATURES
AND LARVAE
AND LARVAE
DATA
TAB-PANE-

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C38"
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FEATURE OF
INTRODUCTIONS,
DELIBERATE
TRANSPORT
INTRODUCTION
OF INVASIVE
COMMON IN A
TAB-PANE-

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EDS AND
INVASIVE
STATES
HISTORY OF,
POTENTIAL
FOR BEING
INTRODUCED
INTERNATIONAL
PET TRADE
TAB-PANE-

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C43"
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CLASS05181377C45R
LINK=1757A>

BRIDGING OF
'GEOGRAPHICAL'

Q

CONTACT BETWEEN ANIMALS AND HUMANS (A PROCESS 'SPILLOVER') ESSENTIAL FOR THE EMERGENCE OF MICROORGANISMS

ZOOZOSES EMERGENCE OF MANY STRAINS THE SPREAD OF NIPAH AND VIRUSES TO HUMANS (WE CAN BE INFECTED BY THEM)

WILDLIFE RESERVOIRS TAB-PANE- REFERENCES" ID="RSOS181577C18" CLASS="L3" LINK="76-7A-1").

ZOOZOSES ARTIBOD VECTORS DISPERSED REGIONALLY OR MORE LOCAL BY MEANS WHICH ARE USUALLY CONSIDERED CONTENT OF INVASIVE SPECIES DISPERSAL

MIGRATORY BIODIVERSITY MECHANISM PATHOGENS INFLUENZA AND SOME DISEASES (VECTORS CAN BE DISPERSED DISTANCES)

TAB-PANE- REFERENCES" ID="RSOS181577C46" CLASS="L3" LINK="76-7A-1").

BEYOND CONTINGENCY OF SPECIES REPORTED ENVIRONMENT, AND STUB OF INTRODUCTION EVENTS OF A SPECIES IS IMPORTANT.

TERMINED PROPAGULE IN SCIENCE ANALOGOUS CONCEPTS INFECTION FREQUENCY (RELEVANT SPILLOVER INTRODUCTION TO NEW AREA STAND DISEASE THAT IMPORTANT INFECTIOUS EPIDEMIOLOGY

TAB-PANE- REFERENCES" ID="RSOS181577C13" CLASS="L3" LINK="76-7A-1").

TAB-PANE- REFERENCES" ID="RSOS181577C17" CLASS="L3" LINK="76-7A-1").

TAB-PANE- REFERENCES" ID="RSOS181577C47" CLASS="L3" LINK="76-7A-1").

PROPAGULE PRESSURE IS INTRODUCED SPECIES ARE MORE LIKELY TO FADE-OUT

^

Q

FOR A
 RANGE OF
 REASONS
 INCLUDING
 PROBABILITY
 THAT AN
 INDIVIDUAL
 MEETS
 ENOUGH
 INDIVIDUALS
 LEAST ONE
 OF WHICH
 ACQUIRES
 INFECTION
 INFECTIOUS
 DISEASES
 SUCCESSFULLY
 (EQUATION
 UNDERGOING
 REPRODUCTION).

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 <BOLD>COMPATIBILITY</BOLD>:

INVASIVE
 SPECIES MUST
 BE CAPABLE
 SURVIVING IN
 ENVIRONMENT
 POINT OF
 REPRODUCTION,
 AND OFTEN
 REPRODUCTION
 SUPPORTS
 STABLE OR
 POPULATIONS.
 THE
 CAPACITY OF
 SPECIES TO
 REPRODUCE
 INVASED
 ENVIRONMENT
 MEASURED
 INTRINSIC
 RATE OF THE
 POPULATION
 WHICH IS A
 TIME-SPECIFIC
 METRIC IN
 INVASION
 AND THE
 REPRODUCTION
 NUMBER
 <SUB>
 GENERATION-
 BASED IN
 EPIDEMIOLOGY.
 PERSISTENCE
 NATURALIZATION)
 POPULATIONS
 OF THE
 THEY MUST
 COMPATIBLE
 WITH
 'ENVIRONMENTAL'
 INCLUDING
 QUANTITIES
 SUCH AS
 POPULATION
 DENSITY AND
 THE EXTENT
 TO WHICH
 AS POSITIVE
 <SUB>
 THE GREATER
 THE DATA
 TAB= PANE-
 REFERENCES"
 DOI="RSOS181577C15R"
 CLASS="LA">
 WHETHER
 INTRODUCED
 ORGANISM
 BECOMES
 OR INVASIVE
 DEPENDS AT
 EXTENT ON
 THE ECOSYSTEM
 EVOLUTIONARY
 EXPERIENCE
 INTRODUCED
 SPECIES AND
 RECIPIENT
 COMMUNITY.
 EVOLUTIONARY
 EXPERIENCE
 DESCRIBES
 HISTORICAL
 EXPOSURE
 ORGANISM
 INTERACTIONS
 EVOLUTIONARY
 EXPERIENCE
 TAB= PANE-
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 CLASS="LA">
 THE DATA
 TAB= PANE-

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 CLASSIFICATION
 LINK (73-7A>1),
 EMPLOYERS
 THE BASIS OF
 THE TRAITS
 SELECTED
 PREVIOUS
 ENVIRONMENTS
 ADAPTATIONS),
 INTRODUCED
 RESIDENT
 SPECIES IN
 ESTABLISHMENT
 SUCCESS
 ADAPTABILITY
 INTRODUCED
 SPECIES IN
 WORDS.
 EVOLUTIONARY
 EXPERIENCE
 DETERMINES
 WHETHER
 AN INVADER
 INTEGRATE
 INTO LOCAL
 ECOSYSTEMS,
 CONFER,
 ADAPTATIONS
 CRITICAL
 DETERMINANTS
 SPECIES'
 INVASIVENESS
 COMMUNITIES
 INVASION
 TAB - PANE -
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C48"
 CLASSIFICATION
 LINK (73-7A>1),
 TAB - PANE -
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 CLASSIFICATION
 LINK (73-7A>1),
 EVOLUTIONARY
 CHANGES
 SPLITTING
 COMMONPLACE
 TAB - PANE -
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C52"
 CLASSIFICATION
 LINK (73-7A>1),
 AND OVER
 (ADAPTIVE
 HYBRIDIZATION
 BETWEEN
 POPULATIONS)
 HYBRIDIZATION
 CLOSELY
 RELATED
 (E.G. LER
 DATA -
 TAB - PANE -
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C53"
 CLASSIFICATION
 LINK (73-7A>1),
 GENETIC
 RECOMBINATION
 LEADS TO
 ENHANCED
 PERFORMANCE
 POPULATIONS
 DUE TO
 HYBRIDIZATION
 VIGOROUS
 TAB - PANE -
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C54"
 CLASSIFICATION
 LINK (73-7A>1),
 HOWEVER,
 INVASIVE
 ADEPT IN
 ABSENCE OF
 ADMIXTURE
 HYBRIDIZATION
 TAB - PANE -
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C54"
 CLASSIFICATION
 LINK (73-7A>1),
 TAB - PANE -
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C55"
 CLASSIFICATION
 LINK (73-7A>1),
 RESULTING
 IN TRAITS
 INCREASE
 PERFORMANCE.
 EXAMPLE,
 INVASIVE
 SPECIES MAY
 UNDERGO
 RAPID
 EVOLUTION
 RELATED TO
 DISPERSAL

(F, G, K, A
 TAB<PANE-
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 INSIGHT HAS
 GATHERED
 ADAPTATIONS
 IDENTIFYING
 CANDIDATE
 UNDERSTANDING
 ADAPTIVE
 EMERGENGE
 OF PATHOGENS
 TRANSMISSIBILITY
 PATHOGENS
 HOSTS
 HUMANS
 EXPLICITLY
 REQUIRES
 CHANGE BY
 MUTATIONS
 RECOMBINATION
 EVENTS<A
 TAB<PANE-
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 AS FOR NON-
 DISSEMINATE
 PATHOGENS
 DISEASE
 CONTROL
 TO EVOLVE
 AND ADAPT
 ENVIRONMENTS
 INTO WHICH
 THEY HAVE
 INTRODUCED,
 ENHANCING

 WITHIN THE
 ENVIRONMENTS
 TAB<PANE-
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 TAB<PANE-
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 ID=RSOS181577C58R
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 PATHOGENS
 OF ANIMALS
 HUMANS
 EVOLUTION
 INCREASED

 INVOLVES
 TRADE-OFFS
 BETWEEN
 TRANSMISSION
 EFFICIENCY
 LOADS OF
 TRANSMISSION
 CONTACT IS
 BETWEEN
 INFECTION
 HOSTS AND
 VIRULENCE
 HIGHER
 LOADS OF
 MORBIDITY/MORTALITY
 REDUCED
 CONTACT
 BETWEEN
 INFECTION
 HOSTS<A
 DATA<A
 TAB<PANE-
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 LINK=59].
 EVOLUTIONARY
 PROCESSES
 HOWEVER,
 IDIOSYNCRATIC
 PATHOGENS
 TRANSMITTED
 DIFFERENT
 ROUTES<A
 TAB<PANE-
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C60"
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 LINK=60].
 POPULATIONS

Q

IKA HANA
 TAB-PANE-
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 CHANGES
 MASSIVE
 INVASIVE
 SPECIES AND
 LONG-TERM
 INTERACT
 BOHM AND
 BILLOWEICH
 MAJOR CUR
 RANGE OF
 REASONS
 DEPLETION
 RESOURCES
 TAB-PANE-
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 A DATA
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 ENVIRONMENT:
 ENVIRONMENTAL
 CONDITIONS
 WHETHER A
 RECIPIENT
 PROVIDES A
 SUITABLE
 SITE FOR
 ESTABLISH
 AND
 SPREAD
 FACTORS
 INFLUENCING
 CLIMATE
 TEMPERATURE
 RAINFALL/HUMIDITY),
 SUBSTRATE
 ARE KEYS TO
 WHETHER
 INTRODUCED
 SPECIES CAN
 SURVIVE.
 FACTORS
 EXERCISING
 FROM HOST
 POPULATION
 DENSITY AND
 CONNECTEDNESS,
 NUTRITIONAL
 RESOURCES
 PRESENCE
 (PREDATORS,
 PARASITES,
 COMPETITORS
 AND FOR
 MICROORGANISMS,
 AND CROSS-
 SPECIES
 COMMUNITY
 INTERACTIONS,
 DETERMINE
 WHETHER
 INTRODUCED
 SPECIES CAN
 SURVIVE AND
 REPRODUCE
 TAB-PANE-
 REFERENCES" //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C32"
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 LINK="#27A">].
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 LINK="#47A">].
 WHEN
 BIOGEOGRAPHIC
 BARRIERS
 BREACHED
 BY
 SPECIES MAY
 INTRODUCED
 ECOLOGICAL
 NICHE THAT
 ARE
 SUITABLE
 SURVIVAL
 AND
 REPRODUCTION
 AND ALSO
 PROVIDE AN
 FREE SPACE
 FOR
 ESTABLISHMENT
 SPREAD
 FOR THIS
 REASON,
 REALIZED
 NICHE OF
 SPECIES MAY

Q

SPECIES MAY BE INTRODUCED IN LARGER RANGES THAN THEIR NATURAL RANGES. [DATA](#)

TAB: PANE-REFERENCES" <https://royalsocietypublishing.org/doi/10.1098/rsos.181577> [CLASSIC ARTICLE INLINE-FIGURE](#)

LINK: >65].

END WHEN INTRODUCED INTO A NEW ENVIRONMENT IMMUNOLOGICALLY POPULATIONS MAY BE REPLACED BY INVASIVE SPECIES. [DATA](#)

TAB: PANE-REFERENCES" <https://royalsocietypublishing.org/doi/10.1098/rsos.181577> [CLASSIC ARTICLE INLINE-FIGURE](#)

LINK: >66].

EVOLUTIONARY CHANGES IN SPECIES MAY BE FACILITATED BY CREATING NEW NICHES OR BY INTRODUCING SPECIES FROM OTHER REGIONS. [DATA](#)

TAB: PANE-REFERENCES" <https://royalsocietypublishing.org/doi/10.1098/rsos.181577> [CLASSIC ARTICLE INLINE-FIGURE](#)

LINK: >67].

CHANGES IN CLIMATE AND LAND-USE PATTERNS CAN FACILITATE THE INTRODUCTION OF INVASIVE SPECIES. [DATA](#)

TAB: PANE-REFERENCES" <https://royalsocietypublishing.org/doi/10.1098/rsos.181577> [CLASSIC ARTICLE INLINE-FIGURE](#)

LINK: >68].

AND CLIMATE CHANGE CAN FACILITATE THE INTRODUCTION OF INVASIVE SPECIES. [DATA](#)

TAB: PANE-REFERENCES" <https://royalsocietypublishing.org/doi/10.1098/rsos.181577> [CLASSIC ARTICLE INLINE-FIGURE](#)

LINK: >69].

AND CLIMATE CHANGE CAN FACILITATE THE INTRODUCTION OF INVASIVE SPECIES. [DATA](#)

TAB: PANE-REFERENCES" <https://royalsocietypublishing.org/doi/10.1098/rsos.181577> [CLASSIC ARTICLE INLINE-FIGURE](#)

LINK: >70].

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 CONCEPTUAL
 DIAGRAM OF
 BARRIERS
 BIOLOGICAL
 AND PHYSICAL
 AND HOW
 THEY AFFECT
 SPECIES
 INVASIONS
 DISEASE
 EMERGENCE.
 BARRIERS
 BARRIERS
 ARE SHOWN
 IN THE
 CENTRAL
 EXAMPLE OF
 INTRODUCTION
 OF WEST
 NILE VIRUS
 INTO
 AMERICA AS
 THE BOX TO
 THE RIGHT
 NOTE THE
 PREREQUISITE
 BIOLOGICAL
 INVASIONS IS
 THAT THERE
 DISPERSAL
 GEOGRAPHICAL
 (EVOLUTION
 AND
 ENVIRONMENTAL
 CHANGES ARE
 NOT
 REQUIRED IF
 CONDITIONS
 ALREADY
 SUITABLE).
 CONTRAST
 AN IN CAN
 THROUGH
 LEADING TO
 BREAKDOWN
 COMPATIBILITY
 ENVIRONMENTAL
 BREAKING
 ENVIRONMENTAL
 WITHOUT
 BEING
 DISPERSAL
 GEOGRAPHICAL
 BARRIER (C.
 CLASS "PEE
 SHOWABLE EVENT"
 ID="RSOS181577TB1"
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 MOREOVER
 THE ORDER
 BARRIERS
 CAN VARY.
 EXAMPLE, IN
 EMERGENCE
 COMPATIBILITY
 WAS FIRST
 (CROSSED
 BY HUMAN)
 BEFORE THE
 SPREAD OF
 PANDEMIC
 COLLAGE
 USED UNDER
 THAT ARE
 INTRODUCED
 IN FIGURE <A
 TAB="PANE-
 FIGURES"
 HREF="7C7C7FB"//ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577F3"
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 SQUARED
 WIKIMEDIA
 UNDER THE
 COMMONS
 SHARE-
 LICENSE (CC-
 BY-SA 4.0).
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 WE
 ACKNOWLEDGE
 ORIGINAL
 AUTHOR OF

```

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INVASIONS
EMERGENCE,
PROCESSES
THESE MAY
SURMOUNTED
PHENOMENA
CONSEQUENCES
RESULTS,
INFECTIOUS
DISEASES
</SPAN>
</CAPTION>
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ALIGN="LEFT;"
ROWSPAN="1">INITIAL
WHICH WHEN
CAN LEAD TO
PHENOMENON</TH>
ALIGN="LEFT;"
ROWSPAN="1">PROCESS</TH>
ALIGN="LEFT;"
ROWSPAN="1">GLOBAL
EXAMPLES/MECHANISMS</TH>
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EXAMPLES</TH>
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COLSPAN="1">DISPERSAL</TD>
COLSPAN="1">BIOLOGICAL
REGIONAL
DISPERSAL
SPECIES BY
HUMANS)
COLSPAN="1">EIDS
INTERNATIONAL
SPREAD (E.G.
WILDS)
READABILITY="9">
COLSPAN="1">COMPATIBILITY</TD>
COLSPAN="1">EVOLUTION</TD>
COLSPAN="1">PRE-
ADAPTATION
EVOLUTIONARY
EVOLUTION
PHENOTYPES
ENVIRONMENT
RESISTANCE
INTRODUCED
DUE TO SIZE
HARVESTING,
ASSOCIATIONS)
COLSPAN="1">ADAPTIVE
EMERGENCE
ZOOZOOZIS
ZOOZOOZIS
INFECTION)
<BREAK><GREATER
CAPACITY AND
REPRODUCTION,
FOLLOWING
SPREADS (E.G.
MAY IN
AMERICA)
</TD></TR>
READABILITY="10">
COLSPAN="1">ENVIRONMENTAL</TD>
COLSPAN="1">DISTURBANCE</TD>

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q

COLSPAN="1">LAND-
 USE CHANGE
 REMOVES
 COMPETITORS
 PREDATORS,
 OR OPENS
 RESOURCES
 ALLOWING
 EXPANSION
 OF SPECIES
 NATIVE (OR
 NON-NATIVE)
 <BREAK/>CLIMATE
 CHANGE
 CHANGES
 GEOGRAPHICAL
 LOCATION OF
 ECOLOGICAL
 SPECIES</TD>
 COLSPAN="1">PROVIDES
 OPPORTUNITIES
 CONTACT
 BETWEEN
 ANIMALS
 AND
 DISEASE,
 AND <BREAK/>CAUSES
 BIODIVERSITY
 DECREASE
 EMERGENCE<BREAK/>DISEASES
 VECTORS
 (E.G., WEE
 VESICLE IN
 CANADA)
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 INSTANCES/"
 XML:NS:BSTG="HTTP://WWW.ATYPON.COM/BACKSTAGE-
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 SECTION-WE
 SEPARATED
 GEOGRAPHICAL,
 COMPATIBILITY,
 ENVIRONMENTAL
 BARRIERS,
 ARE OPEN
 INTERDEPENDENT
 INFLUENCING
 INVASION/EMERGENCE
 (<I>R</I>) AND
 <SUB>/SUB>
 DEPEND ON
 COMPATIBILITY
 ENVIRONMENT).
 EVEN WHEN
 MUTUALLY
 DEPENDENT,
 TOGETHER.
 EXAMPLE
 ENVIRONMENTAL
 CHANGES
 ALTERS
 LAND USE
 CAN BRIDGE
 'GEOGRAPHICAL'
 CONTACT
 BETWEEN
 PATHOGENS
 HUMANS, AS
 IS THE CASE
 WITH
 DATA
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 ENVIRONMENTAL
 ALSO DRIVE
 EVOLUTIONARY
 THAN MAY
 ALTER THE
 EVOLUTIONARY
 EXPERIENCE
 POTENTIAL
 INVADERS
 AND
 POTENTIALLY
 COMMUNITIES.
 ISSUES OF
 SPREAD OF
 SPECIES AND
 ENVIRONMENTAL
 THAT DRIVE
 EMERGENCE
 DIRECTLY
 INDIRECTLY
 VIA NON-
 DISEASE
 PATHWAYS
 SPECIES
 UNDERLINE
 FOR A ONE
 APPROACH
 TABSPANE-
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MANAGEMENT
APPLIED
EPIDEMIOLOGISTS
INVASION
BIOLOGISTS.
SECTION:WE
FOCUS:Y
PRIMARY
ASSESSMENT
AND RETURN
TO DISCUSS
MANAGEMENT
ASSESSMENT
APPLIED
POLICIES IN
ANTICIPATION
OF DISEASE
EMERGENCY
BIOLOGICAL
INVASIONS
TO SUPPORT
ASSESSMENTS,
DISCIPLINES
IDENTIFY
QUALITATIVE
SYMPTOMS)
THAT
‘INVASERS’
‘EMERGERS’
(THE
DATA
TAB: PANE-
REFERENCES"//ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C72"
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LINK="74-7A">),
TO MAKE
ENVIRONMENTS
WORLD-
THEY
TAB: PANE-
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RENDER
ENVIRONMENTS
SUSCEPTIBLE
RESISTANT
TO INVADERS
EMERGING
PATHOGENS
TAB: PANE-
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MODELING
IS BEING
INVASION
SCIENCE
EPIDEMIOLOGY
ELUCIDATE
BIOLOGICAL
PROCESSES,
ESTABLISHMENT
AND TO
SUPPORT
RISK
ASSESSMENT
EFFECTIVENESS
INTERVENTIONS.
THE SAME
TO DO
(CORRELATIVE,
STATISTICAL
ECOLOGICAL
MODELS AND
LEARNING)
AND
‘BOTTOM UP’
(MECHANISTIC,
DYNAMIC
NETWORK
INDIVIDUAL-
BASED
MODELS
ARE USED
FOR
PREDICTING
POSSIBLE
CURRENT

Q

q

AND THE LIFE
 CYCLES AND
 SPREAD OF
 TAB. PANE-
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 LINK >32-7A>].
 TAB. PANE-
 REFERENCES"
 DE-RSOS181377C76R
 LINK >76-7A>].
 MODELS OF
 METHODS
 EPIDEMIOLOGISTS
 COURSE OF
 RELEVANT
 MODELING
 ALL TYPES
 INFECTIOUS
 INCLUDING
 THOSE THAT
 SPECIES
 OTHER THAN
 VERTEBRATES,
 INCLUDING
 PATHOGENS
 TAB. PANE-
 REFERENCES"
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 LINK >77-7A>].
 METHODS
 MONITORING
 SPECIFIC
 INCLUDING
 ACTIVE
 SURVEILLANCE
 AND CITIZEN
 SCIENCE
 PASSIVE
 SURVEILLANCE,
 IN COMMON
 WITH
 METHODS
 MONITORING
 REMOVED FROM
 ZOOLOGICAL
 AND
 VECTOR-
 DISEASES IN
 ENVIRONMENT
 TAB. PANE-
 REFERENCES"
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 TAB. PANE-
 REFERENCES"
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 SAMPLING
 DESIGN AND
 IMPLEMENTATION
 REGARDING
 SELECTION OF
 SITES IS
 DETERMINED
 BY SIMILAR
 CRITERIA,
 SUCH AS
 SPREAD
 PREDICTED
 BY SPECIES
 DISTRIBUTION
 AND
 MODELS
 OCCURRENCE
 LOCATIONS
 IMPACT MAY
 BE THE
 GREATEST
 DATA
 TAB. PANE-
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 DISCIPLINES
 APPROACHES
 ARE USED TO
 IDENTIFY
 AND
 ATTRIBUTION
 TAB. PANE-
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 REFERENCES"
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 AND BOTH
 EXPERIMENTAL
 OBSERVATION
 DATA AS

q

PROXIES
 POTENTIAL
 OF INVASION
 OF INDIAN
 TAB SPANE-
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 FROM THIS
 TAB SPANE-
 REFERENCES"
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 TO SECTION
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 USEFUL
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 SYNERGIES</H3>
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 PERSPECTIVE,
 IDIOSYNCRATIC
 WAYS, FIRST,
 IMPORTANT
 AFFECTING
 HUMANS
 DOMESTICATED
 ANIMALS
 OBLIGATE
 PARASITES
 VERTEBRATES
 TAB SPANE-
 REFERENCES"
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 LINA="15/A3",
 MEANS THAT
 CONSIDERATION
 POPULATION
 PARAMOUNT
 PREDICTIVE
 MODELLING
 ASSASSIN
 AND RISK
 SPECIES AND
 MICROORGANISMS
 COMPRISE A
 SPECTRUM OF
 POSSIBLE
 FOR ENDS
 PARASITIC
 INVASIVE
 SPECIES
 SPREAD INTO
 POPULATIONS
 RARE FROM
 THE POINT
 OF
 INTRODUCTION
 EPIDEMIC
 PROVIDED
 SUFFICIENT
 AVAILABILITY
 HOSTS AND A
 FIRST
 APPROXIMATION,
 WILL NOT
 OCCUR IF
 FREQUENCY
 OF CONTACT
 WITH NAIVE
 BECOMES A
 THRESHOLD
 MICROORGANISMS
 TRANSMITTED
 DIRECTLY
 HUMANS,
 PATTERNS
 AND EXTENT
 OF SPREAD
 (EQUIVALENT
 INVASIVE
 RANGE) ARE
 DETERMINED
 BY
 CHARACTERISTICS
 HUMANS
 POPULATION
 MICROORGANISM
 AND NOT BY
 DIRECTLY
 ENVIRONMENT.
 PERSISTENCE
 TRANSMISSION
 MICROORGANISMS
 SPREAD (I.E.

Q

ENDEMICALLY
 THE DETAILS
 TRANSMISSION
 CHARACTERISTICS
 MICROORGANISM
 AND HOST
 POPULATION.
 INFECTIONS
 INVASIVE
 EMERGING
 INFECTIONS
 AND BOOM
 AND BUST
 USUALLY
 MECHANISMS
 ASSOCIATED
 AVAILABILITY
 SUSCEPTIBLE
 THROUGH
 REDUCTION
 POPULATION
 BY A HIGH
 PATHOGENIC
 DEVELOPMENT
 OF IMMUNITY
 EMERGING
 PATHOGEN IN
 POPULATION
 A DATA
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 OF CANISMS,
 OF CANISMS,
 VIRUSES,
 BACTERIA,
 PROTOZOA
 HELMINTHS)
 (VECTORS EARLY
 ARE FOR
 THE MOSTIE
 SMALL ISLANDS
 FAST-TRAVEL
 SPECTRUM
 OF INVASIVE
 SPECIES HAVE
 VERY SMALL
 SIZE AND
 GENERATION
 TIME IS
 OFTEN (BUT
 ALWAYS)
 SHORT (DAYS
 TO MONTHS).
 CONTRAST
 GENERATION
 BE YEARS TO
 DECADES
 ORGANISMS
 INVASIVE
 NOTABLY,
 INVASIVE
 HAVE
 REACHED
 BROAD-
 SCALE
 CLIMATIC
 THEIR NEW
 RANGES
 CENTRIES
 ACCESSION
 INTERCATION
 (DATA
 TAB SCANE-
 REFERENCES:
 CLASSOS181377C88R
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 TAB SCANE-
 REFERENCES:
 CLASSOS181377C90R
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 CASE OF
 ACCIDENTAL
 DISJUNCT
 MOVEMENT
 BY HUMAN
 MICROORGANISMS
 ARE LIKELY
 COMMON AS
 SPREADS OF
 SYSTEMS,
 GLOBALLY
 DATA ON THE
 OCCURRENCE
 EVENTS ARE
 LIMITED
 FURTHERMORE,
 EXTREMELY
 GENERATION
 TIMES,
 COMPARED

Q

COMPARED
 INVASIVE
 SPECIES FOR
 EXAMPLE
 THEY HAVE
 CAPABILITY TO
 GENETICALLY
 ENVIRONMENTS.
 DESPITE
 COMPARED
 TO OTHER
 ECOSYSTEMS
 MICROORGANISMS
 UNRESEARCHED
 UNRESEARCHED
 BIOLOGICAL
 RANGE OF
 INCLUDING
 DIFFICULTIES
 ISOLATION
 CULTURING,
 BIOGEOGRAPHY
 THEREFORE
 NATIVE
 NONNATIVE
 DIFFICULTIES
 DETECTING
 ASCRIBING
 IMPACTS TO
 CAUSATIVE
 AGENTS (E.G.
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 XML NS:STG="HTTP://WWW.ATYPON.COM/BACKSTAGE-
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 DIFFERENCE
 DESCRIBED
 COULD BE
 THOUGHT OF
 AS A LIMIT
 SOURCE OF
 SYMBIOSIS
 IN NATURE
 USED AND
 THE NUMBER
 OF SPECIES
 MAY VARY
 THEMSELVES
 COLLABORATIONS
 BETWEEN
 BIOLOGISTS
 AND
 EPIDEMIOLOGISTS.
 CLEARLY,
 IN SOME
 SPECIES ARE
 PARASITES
 PATHOGENS,
 AND FOR
 THESE USE
 OF THE
 EPIDEMIOLOGISTS
 WHICH
 INVASION
 FURTHERMORE,
 APPARENTLY
 DOES NOT ASY
 MEAN THAT
 BIOLOGISTS
 PROFIT
 MOVING
 APPROACHES
 DEVELOPED
 EPIDEMIOLOGY.
 DIFFERENCE
 INTEREST
 BECAUSE
 SIZE WHICH
 MAKES
 DETECTION
 AND
 EMERGENCE
 LONGER
 GENERATION
 TIME OF
 INVASIVE
 HAVE MEANT
 DEMOGRAPHIC
 PROCESSES
 COMMUNITY
 EPIDEMIOLOGISTS
 HAVE BEEN
 MORE
 RELIED
 EPIDEMIOLOGISTS
 RELATIVELY
 SIMPLY
 CRITERIA-
 APPROACHES
 DISTRIBUTION
 MODELS TO
 WHETHER,
 AND TO

q

AND HOW
EXTENT
INVASION BY
PATHOGENS
VECTORS
MOVING ACROSS
THE EARTH
(5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C92"
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APPROACH
UNDERSTANDING
PROCESSES
INTRODUCTION-
NATURALIZATION-
INVASION
EASIER TO
DESCRIBE
UNDERSTAND
INDIVIDUAL
PROCESSES
TABSPANE-

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C32"
CLASSOS181577C32R
LINK=332-7A>)).

APPROACH
USED TO
EVALUATE
ASSESSMENT
FOR EARLY
THOSE THAT
WILL BE
ASSOCIATED
WILD LIFE AS
FACTORS
INVOLVED IN
PROCESSES
DETERMINE
TRAJECTORY
AND IMPACT
SPECIES

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XMLNS:W3="HTTP://WWW.W3.ORG/2001/XMLSCHEMA-
XMLNS:BSTG="HTTP://WWW.ATYPON.COM/BACKSTAGE-

SUCCESSFUL
HAVE BEEN
SINCE THE
(INCLUDING
APPROACHES
COMPARING
NATIVE WITH
SPECIES
INVASIVE
ALIEN BUT!
INVASIVE
SPECIES RA
DATA

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C93"
CLASSOS181577C93R
LINK=303-7A>)),

RECENTLY
EPIDEMIOLOGISTS
IN EMERGING
DISEASES

REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C72"
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REFERENCES: //ROYAL.SOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C95"
CLASSOS181577C95R
LINK=365-7A>)),

CONSEQUENTLY,
ELUCIDATION
OF TRAIT
INVASIVENESS
INVASIBILITY
RECOGNITION
TRAIT OF
INVASERS
AND

Q

INVADED
 INTERACT TO
 PERMIT OR
 INVASIONS
 TABLE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C96"
 CLASSIFICATION
 LINK=96]
 GENERALLY
 MILITARY
 TRAINER
 THEM FOR
 STUDIES IN
 INVASIVE
 HAVE LED TO
 CONCEPTS
 THAT PERMIT
 INVADERS TO
 SUCCESSFUL
 ENVIRONMENTS
 (EVEN IN
 SPECIES)-A
 TABLE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C97"
 CLASSIFICATION
 LINK=97]),
 ORDINATION-
 METHODS
 CLASSIFYING
 IN TERMS OF
 INVASIBILITY
 PERIODIC
 TABLES OF
 DATA (A
 TABLE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C98"
 CLASSIFICATION
 LINK=98]).
 ALL OF
 COULD BE A
 FOCUS FOR
 KNOWLEDGE
 TRANSFER
 INFROM
 SCIENCE TO
 ASSESSING
 ZOOLOGIC
 AND FOR
 CONCEPTUAL
 EXPANSION
 APPLICATION
 ASSESSING
 RISK OF ALL
 ULTIMATELY,
 SIGNIFICANTLY
 ENHANCE
 UNDERSTANDING
 DIFFERENT
 COMPONENTS
 EMERGENCY/INVASION
 ALLOWING
 EFFECTIVE
 PREVENTION
 AND
 STRATEGIES.
 CLASS ARTICLE
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 DIFFERENCES
 MANAGEMENT
 METHODS</H4>
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 BIOLOGISTS
 EPIDEMIOLOGISTS
 PRACTICAL
 OBJECTIVES
 OF
 IDENTIFYING
 THE SPECIES
 THEIR FOCUS
 PREVENTION,
 ERADICATION,
 CONTROL OR,
 REPAIRING
 SHARING OF
 METHODS
 ACTIVITIES
 FACILITATE
 OBJECTIVES
 CONSIDERABLE
 VALUE THIS
 VOLUME OR
 A REVIEW IN
 RIGHT NOW
 ARE SIMPLY
 EXAMPLES.
 XMLNS:MML="HTTP://WWW.NISO.ORG/SCHEMAS/ALV1.0/"
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TICK AND
VECTORS
VECTOR-BORNE
PATHOGENS
OF HUMAN
LIVESTOCK
SIGNIFICANCE
OCCURRING
OR A DISEASE
TABS-PANE-
REFERENCES"
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LINK="102/A">],
TABS-PANE-
REFERENCES"
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WILDLIFE
VECTORS
DISEASES OF
LIVESTOCK
HAVE HUMAN
IMPORTANCE
SURVEILLANCE
METHODS
LONGITUDINAL
ENVELOPE FOR
CORRELATIONS
SURVEILLANCE
MOLECULAR
METHODS
MAINSTREAM
IDENTIFYING
PATHOGENS
INEFFECTIVE
SURVEILLANCE
PROGRAMMES,
METHODS
ARE ALMOST
INEFFECTIVE
IDENTIFYING
PATHOGENS
COMPARISONS
TO IDENTIFY
CLUSTERS
OF HOST
SPECIES
TABS-PANE-
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MOLECULAR
ANALYSES
APPROACHES
INVASION
DYNAMICS
UNDERLYING
PROPAGATING
PRESSURE
TABS-PANE-
REFERENCES"
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DISPERAL
AND RATES
TABS-PANE-
REFERENCES"
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LINK="106/A">],
RECONSTRUCT
INVASION
HISTORY
PATHWAYS
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REFERENCES"
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LINK="83/A">],
TABS-PANE-
REFERENCES"
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LINK="107/A">].
APPROACHES
MAY ASSIST
ASSESSMENT
POLICIES
FOR
MANAGEMENT
TABS-PANE-
REFERENCES"
ID="RSOS181577C108R"
LINK="108/A">],
ANALYSIS OF
ENVIRONMENTAL
METADATA
BARCODING

Q

CAN ASSIST
 DETECTING
 ANY (SPECIES
 INFECTIOUS
 AND FIDUS)
 TRANSPORT,
 AIRBORN
 PREVENTING
 INTRODUCTIONS
 OCCURRING
 TAB SCANE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C109"
 CLASSOS181377C109R
 LINK="1092/A">].
 MOVILLAR
 ARE OFTEN
 IDENTIFY
 PROVENANCE
 POPULATIONS
 OF INVADERS
 AND AIDS (A
 DATA
 TAB SCANE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C84"
 CLASSOS181377C84R
 LINK="847/A">].
 THEY CAN
 PROVIDE
 INFORMATION
 RELEVANT
 BIOLOGICAL
 CONTROL OF
 POPULATIONS,
 EXAMPLE
 IDENTIFYING
 THE NATIVE
 WILDLIFE
 PROSPECTS
 IDENTIFYING
 INVOLVED
 BIOLOGICAL
 AGENTS ARE
 MORE LIKELY
 TAB SCANE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C110"
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 THESE MORE
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 APPROACHES
 COULD
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 METHODS OF
 INFORMATION
 ON SPECIES
 DISTRIBUTIONS
 BULLETIN
 HEALTH AND
 IN ECOLOGY
 THE OBJECT
 MONITORING
 BIOGEOGRAPHY
 BIODIVERSITY
 INFORMATION
 EBUTTERFLY
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 BUTTERFLY.ORG/
 AND IS A
 HREF="HTTPS://WWW.ISPOTNATURE.ORG/"
 HOWEVER EXTLINK">HTTPS://WWW.ISPOTNATURE.ORG/).
 PUBLIC IN
 THESE
 METHODS
 HAVE BEEN
 DEVELOPED
 POINT
 WHERE DATA
 SYSTEMATICALLY
 COLLECTED
 ANALYSED IN
 NATIONAL
 SURVEILLANCE
 TO PROVIDE
 WARNING OF
 EMERGING
 VECTOR-
 BORN
 DISEASES
 ALLOWING
 RESEARCHERS
 RESEARCH
 TAB SCANE-
 REFERENCES" //ROYALSOCIETYPUBLISHING.ORG/DOI/10.1098/RSOS.181577#RSOS181577C111"
 CLASSOS181377C111R
 LINK="111/A">].
 BECAUSE
 INVASION
 DOES NOT



(DIFFICULTY)
 HUMAN
 HEALTH
 ELIMINATING IS
 MORE DIFFICULT
 MOBILIZE
 FOR WORK
 INVASIONS
 THAN FOR
 MEANS THAT
 MEANS MUST
 TO DETECT
 INTRODUCED
 SPECIES
 THAT CAN
 IMPLEMENTED
 NONETHELESS,
 EXPERIENCE
 OF PUBLIC
 EPIDEMIOLOGISTS
 MAY BENEFIT
 OF INVASION
 SCIENCE
 EPIDEMIOLOGISTS
 MAY BENEFIT
 INCORPORATING
 INEFFICIENT
 METHODS
 INVASION
 BIOLOGY.
 XML:SI="HTTP://WWW.NISO.ORG/SCHEMAS/ALN1.0/".
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 XML:SI="STG="HTTP://WWW.ATYPON.COM/BACKSTAGE-
 PUBLIC
 EPIDEMIOLOGY,
 FORECAST,
 SPECIFIC,
 AND
 MEANS TO
 DETECT
 CLUSTERS
 OF DISEASE
 SIGNIFICANT
 HAS LED TO
 REVOLUTION
 MOLECULAR
 BIOINFORMATICS
 METHODS
 (PARTICULARLY
 GENOME
 SEQUENCING
 ANALYSIS)
 FOR)

< PREVIOUS POST
 Kerala infectious disease &
 unidentified fever 2019; 59
 fatalities (/kerala-binfectious-
 diseaseb-amp-unidentified-fever-
 2019-59-fatalities)

NEXT POST >
 Hundreds converge on Maine
 capital for vaccination bill hearing
 (/hundreds-converge-on-maine-
 capital-for-vaccination-bill-
 hearing)

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1072912069519950/)