Colonization Pressure and the Insights of Supply-Side Invasion Ecology

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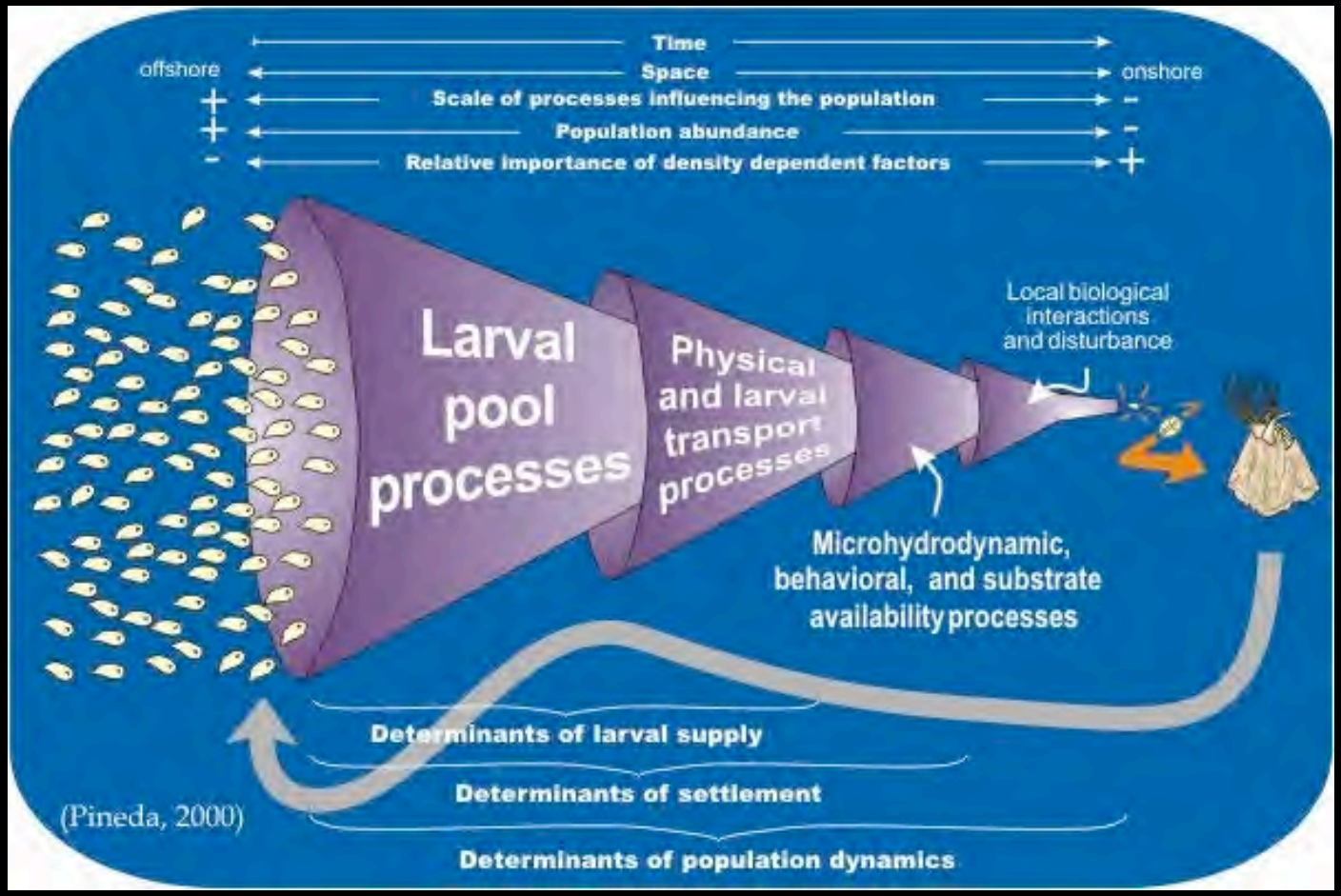
Outline

Propagule and Colonization Pressure Definitions and Evidence

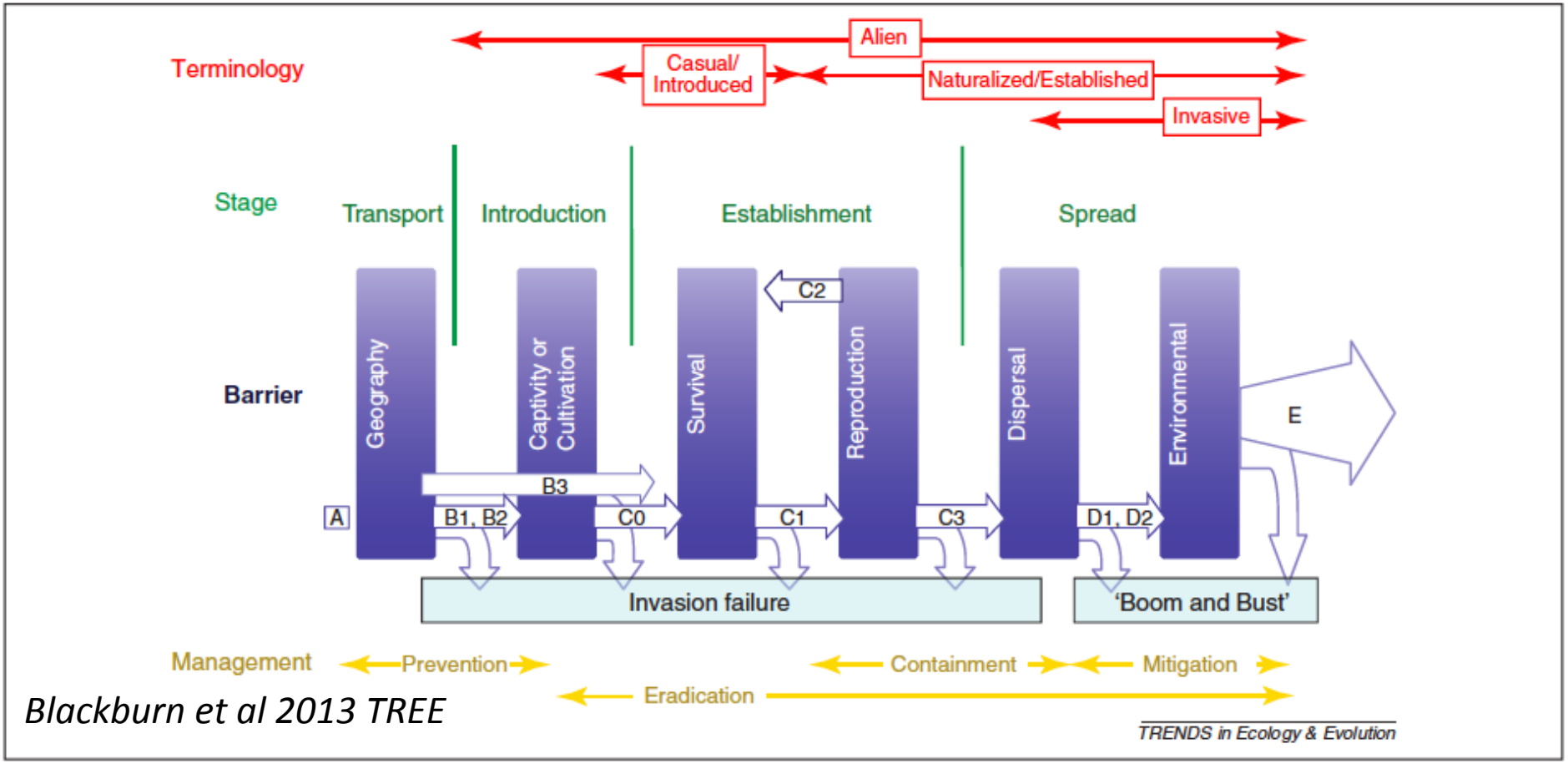
Colonization Pressure as a Null Model in Invasion Science

A Hypothesis-Driven Agenda for Invasion Pathway Science

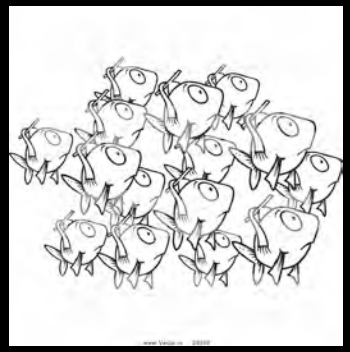
Supply-Side Ecology

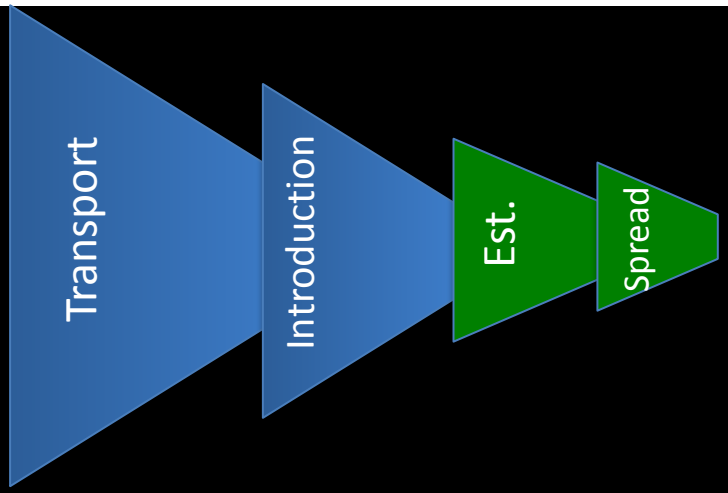


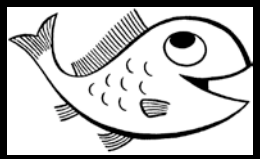
"[at some scale]…the control exerted by physical transport processes on population and community dynamics matches the effect of local processes, such as predation and competition among residents of the site." **Roughgarden 1986**



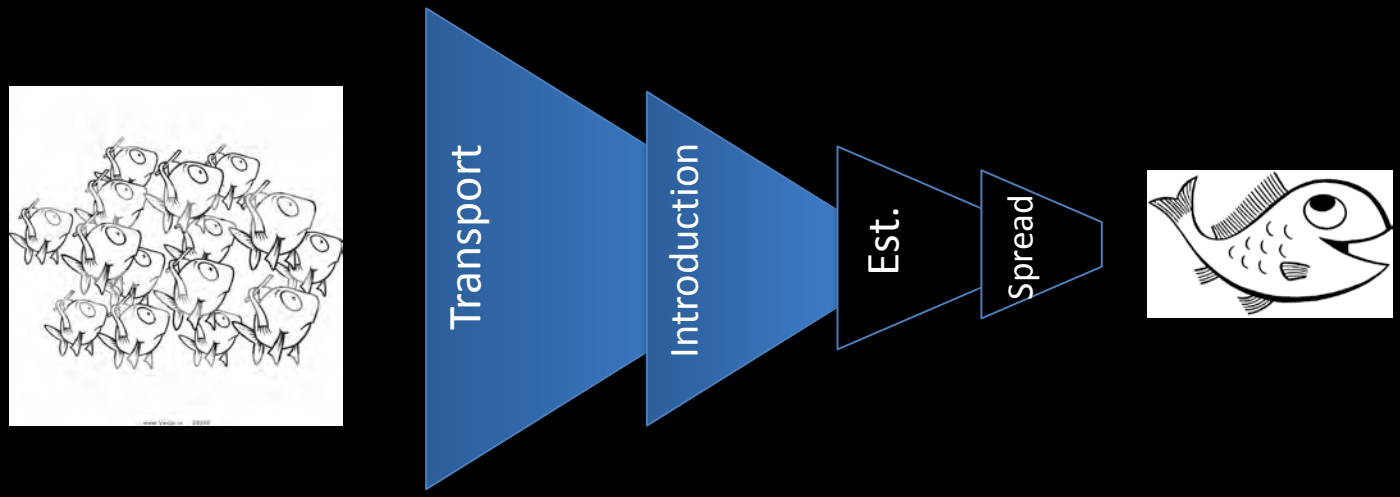
Blackburn et al 2013 TREE







Supply-Side Invasion Ecology



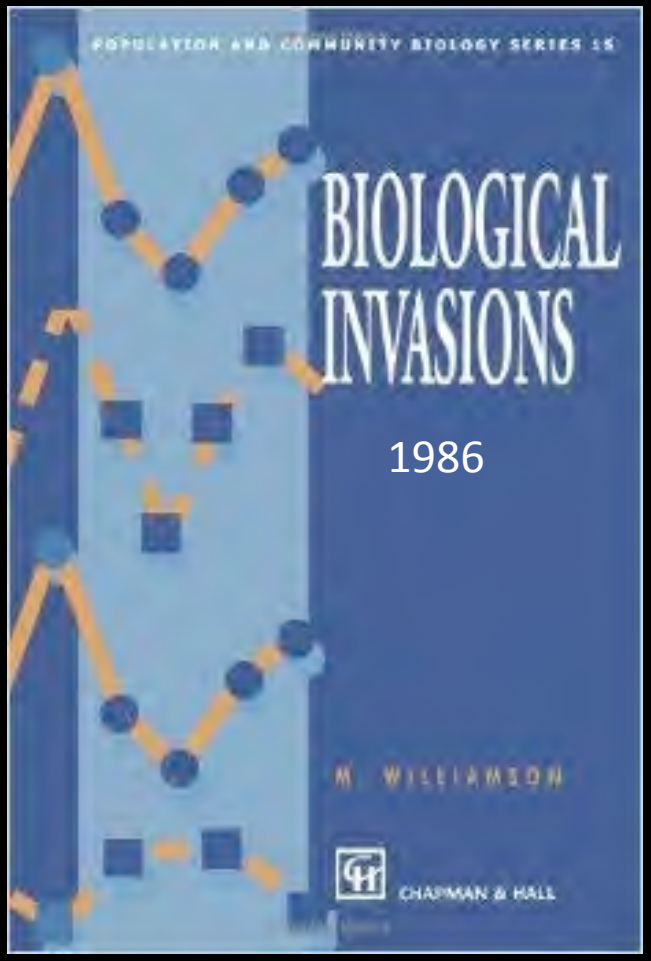
[at some scale]…the control exerted by transport and introduction processes on establishment and spread dynamics matches the effect of local processes, such as predation and competition among residents of the site

How many and which species will establish non-native populations?
And where are we likely to find many established non-native species?

Answer:

You get more non-native species where, and during what time frame, you transport and introduce more non-native species

The focus on the early stages of the invasion process was not a part of SCOPE or Elton's book, but the notion is by no means new to the field



Propagule Pressure
Colonization Pressure

Table 1.1 The conceptual framework.
CFP indicates conceptual framework point

A Arrival and establishment

CFP 0 Most arrivals at present are from human importations, but natural arrivals are also of interest

CFP 1 Most invasions fail, only a limited number of taxa succeed (tens rule)

CFP 2 Invasion (or propagule) pressure is an important variable. So invasions are often to accessible habitats by transportable species

CFP 3 All communities are invasible, perhaps some more than others

CFP 4 The *a priori* obvious is often irrelevant to invasion success. Among factors to consider: *r* (intrinsic rate of natural increase), abundance in native habitat, taxonomic isolation, climatic and habitat matching, vacant niche

B Spread

CFP 5 Spread can be at any speed in any direction, in analysed cases usually either as predicted by estimates of *r* (the intrinsic rate of natural increase) and *D* (the diffusion coefficient), or faster

C Equilibrium and effects

CFP 6 Most invaders have minor consequences (tens rule)

CFP 7 Major consequences have as
- effects: depressed populations to individual extinctions to ecosystem restructuring
- mechanisms: enemies (vertical food-chain processes), competition, amensalism, swamping (horizontal food-chain processes)

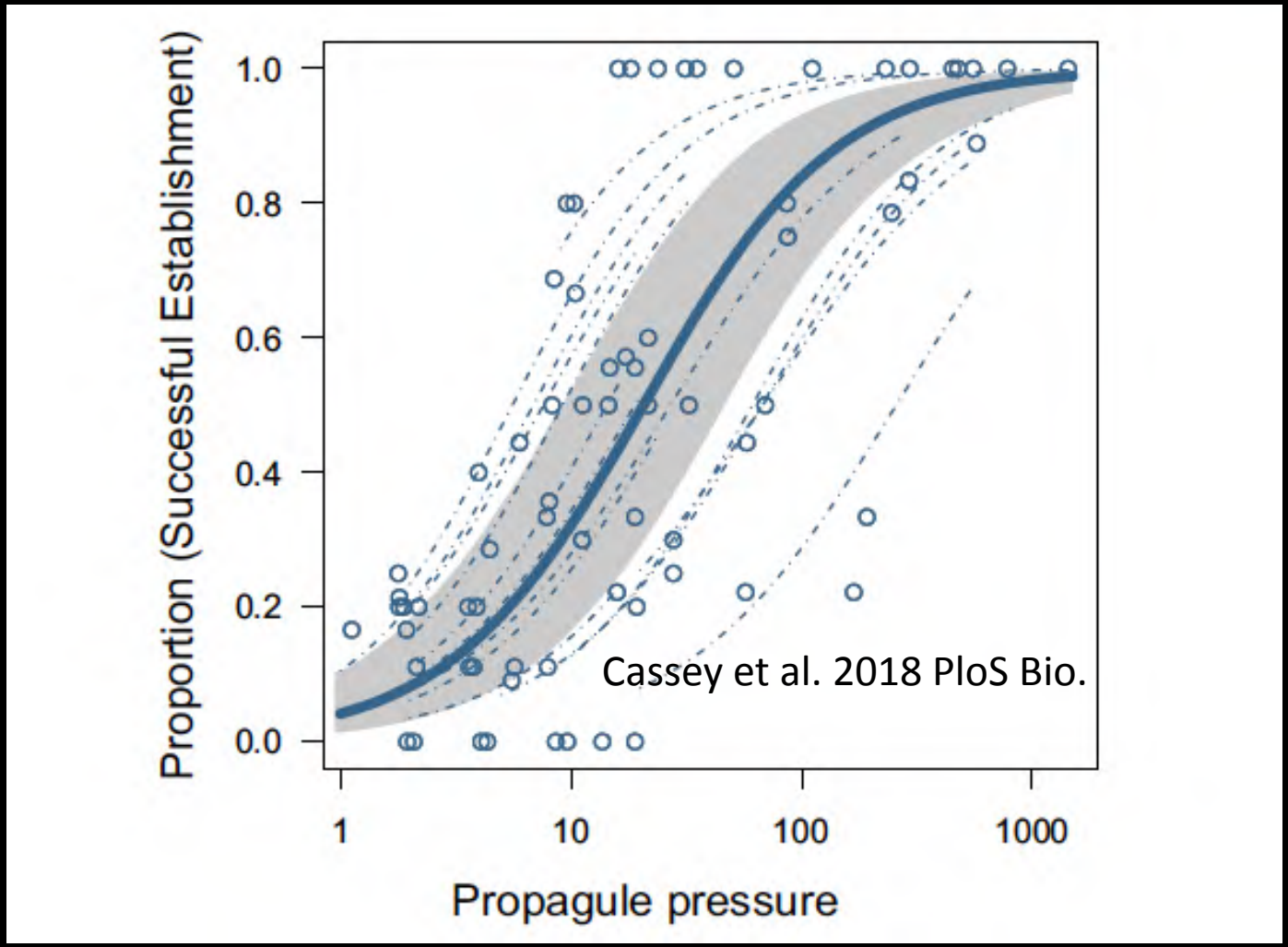
CFP 8 Genetic factors may determine whether a species can invade; genetic factors affect events at the initial invasion; evolution may occur after invasion

D Implications

CFP 9 Invasions are informative about the structure of communitie and the strength of interactions, and vice-versa

CFP 10 Invasion studies are relevant to considering the risks of introducing new species or genotypes, the release of genetically engineered organisms and the success and consequences of biological control

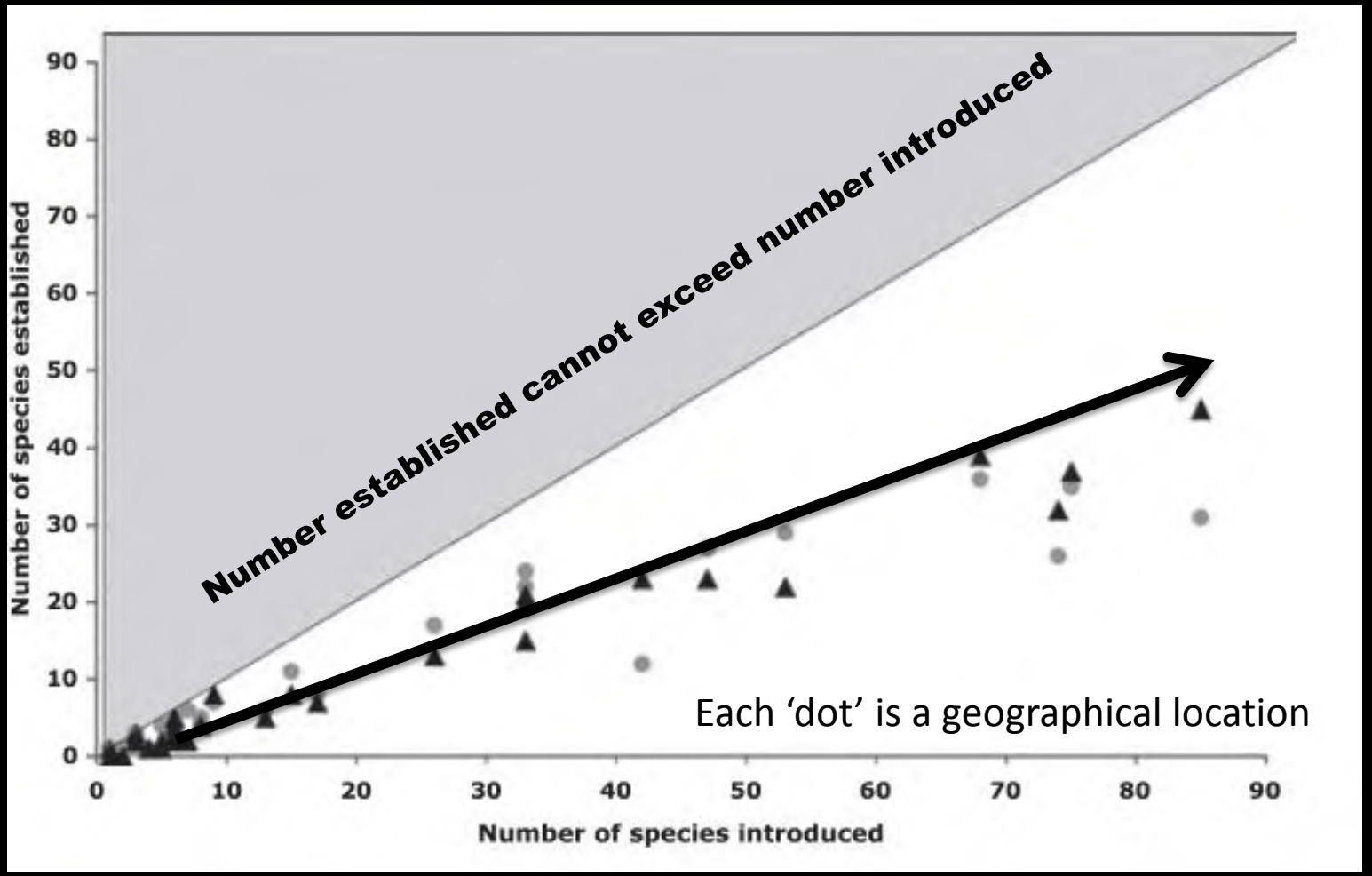
Propagule Pressure



Mechanisms: environmental and demographic stochasticity, genetic diversity, individual differences (age, stage, sex ratio), Allee Effects

Colonization Pressure

The more species that are introduced (released) the more that establish viable non-native populations



Lockwood et al. 2009 Div. and Dist.

E = IS

Number of non-native species in one location (*E*) is a product of the number of species introduced (*I*) and the fraction of those that successfully established (*S*).

Lonsdale 1999 Ecology

S is the stuff of intrinsic ecology with propagule pressure added in….

BUT you can't understand E unless you also know I

Chiron et al. 2009 Proc. Roy. Soc.

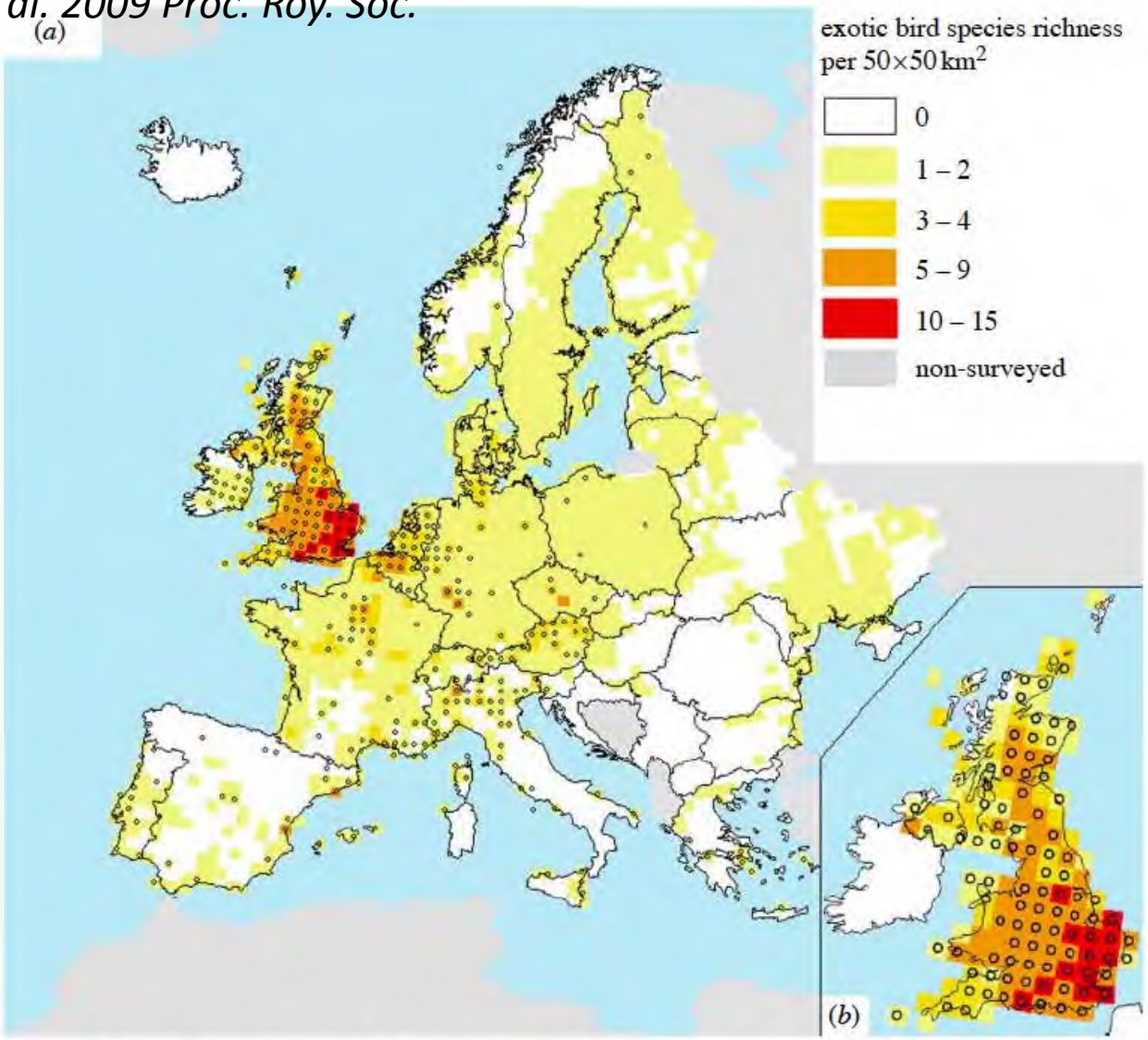
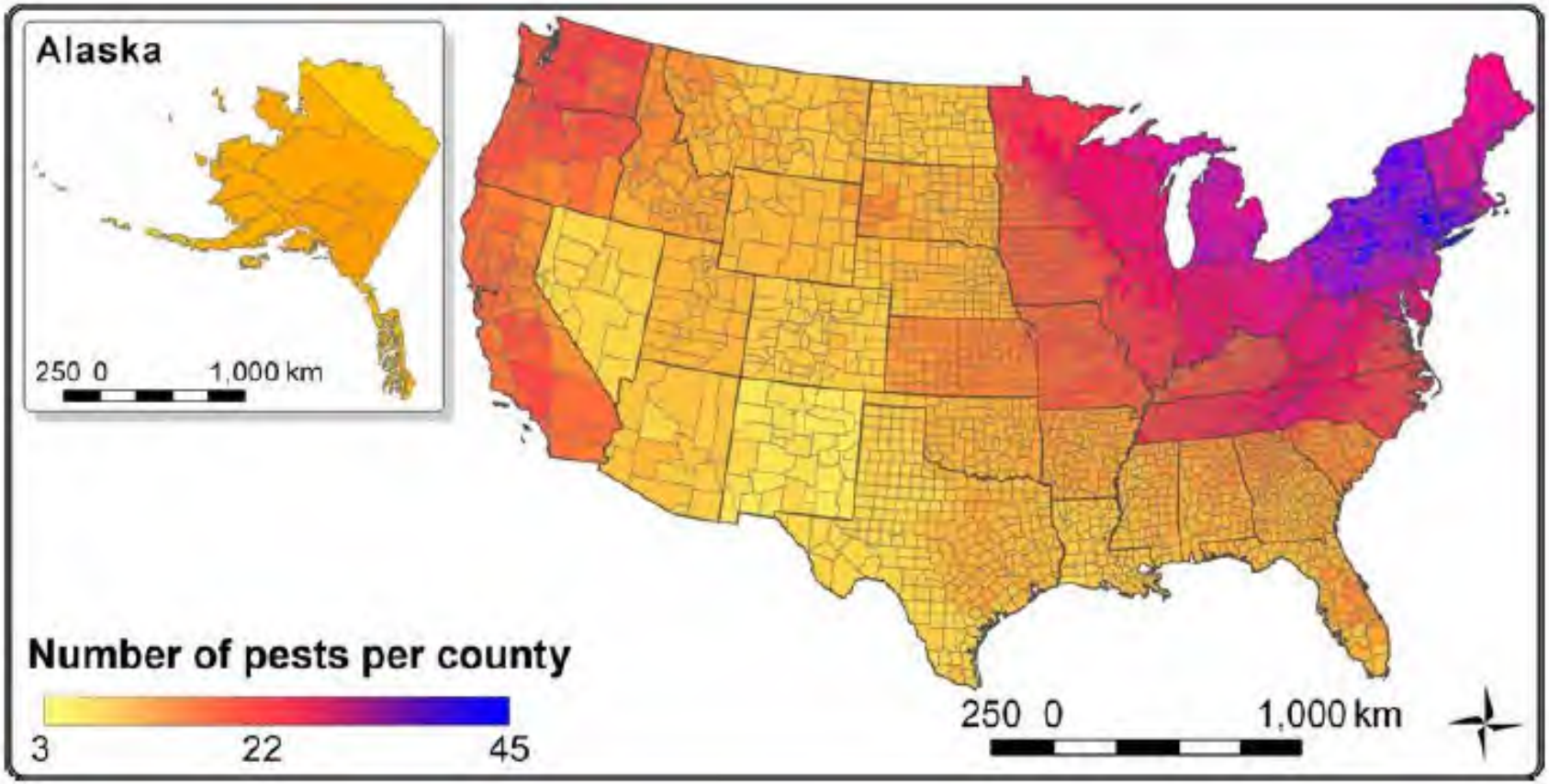


Figure 1. Distribution of exotic bird richness in (*a*) the whole of Europe and (*b*) the UK at a 50×50 km² grid square resolution. Verified introductions included in the analyses are marked with open circles.

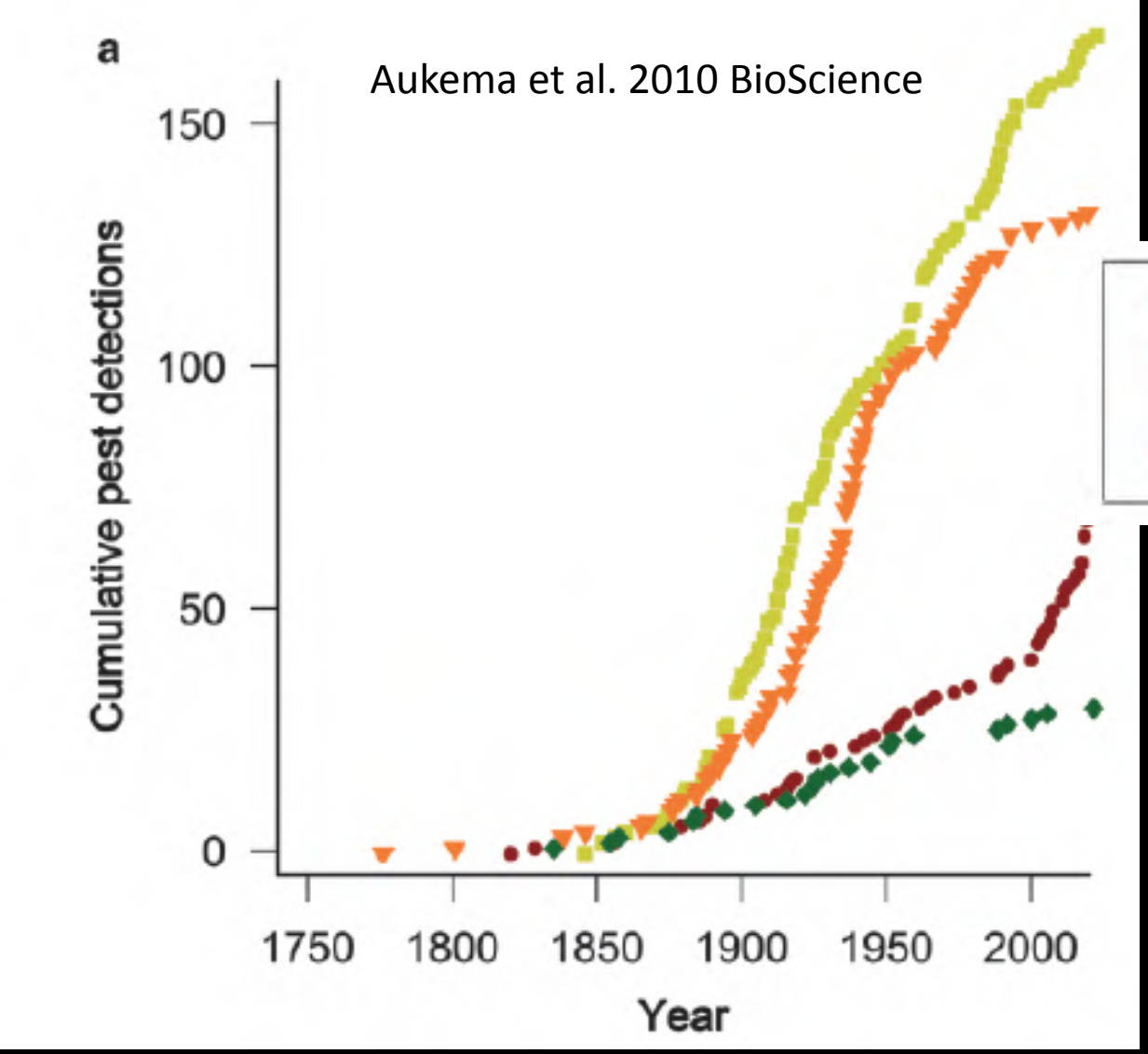
By far the best fit with observed numbers of birds per area was the number introduced



Number of forest pests per US county is best explained by proxies of propagule and colonization pressure.

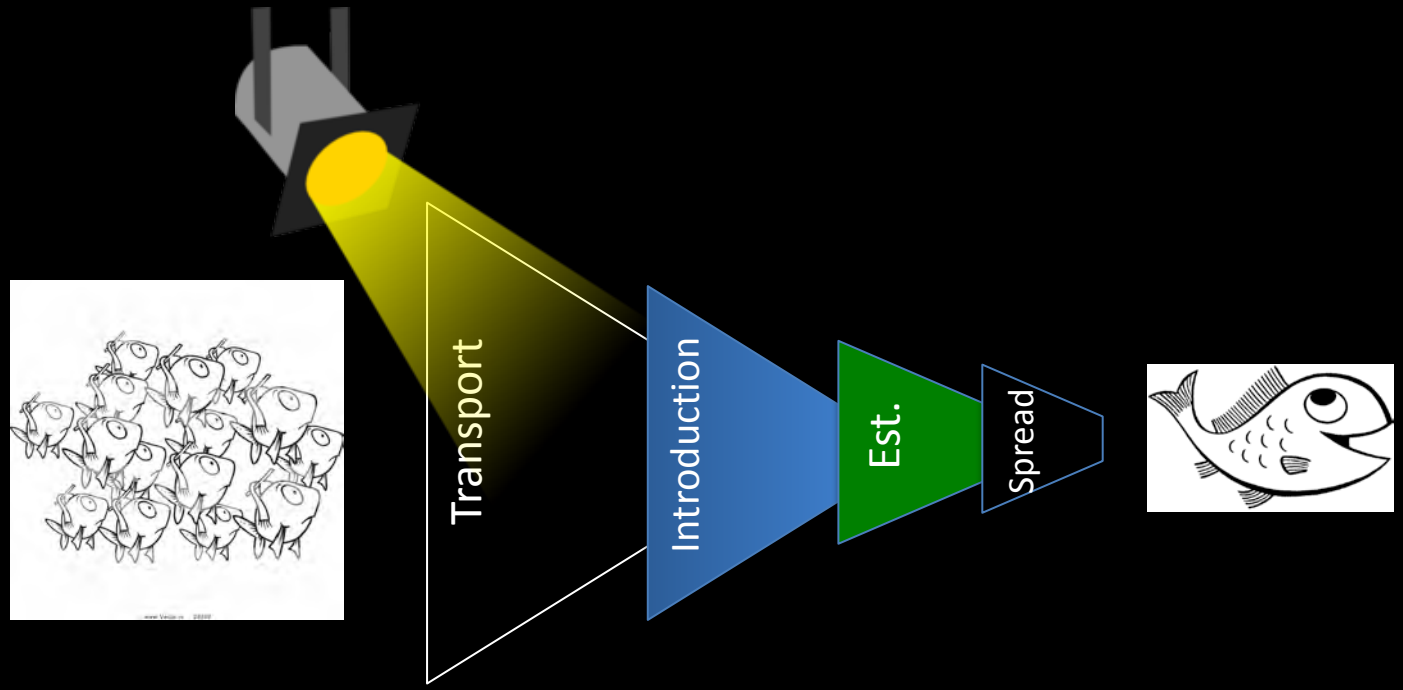
Leibhold et al. 2013 Div. and Distr.

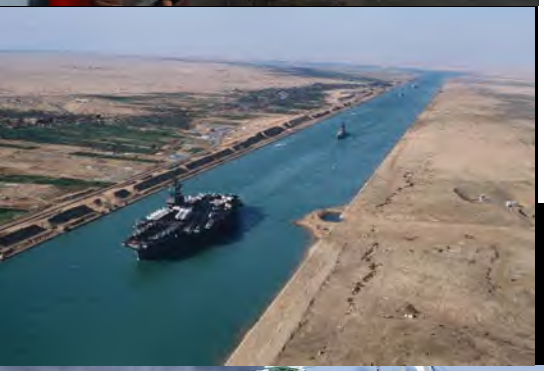
Aukema et al. 2010 BioScience



We also regularly see an association between increases in trade, or changes in trade partners, and increasing numbers of non-native species through time.

If Colonization Pressure likely explains spatial and temporal patterns in number of non-native species, there is high value in documenting patterns in drivers.



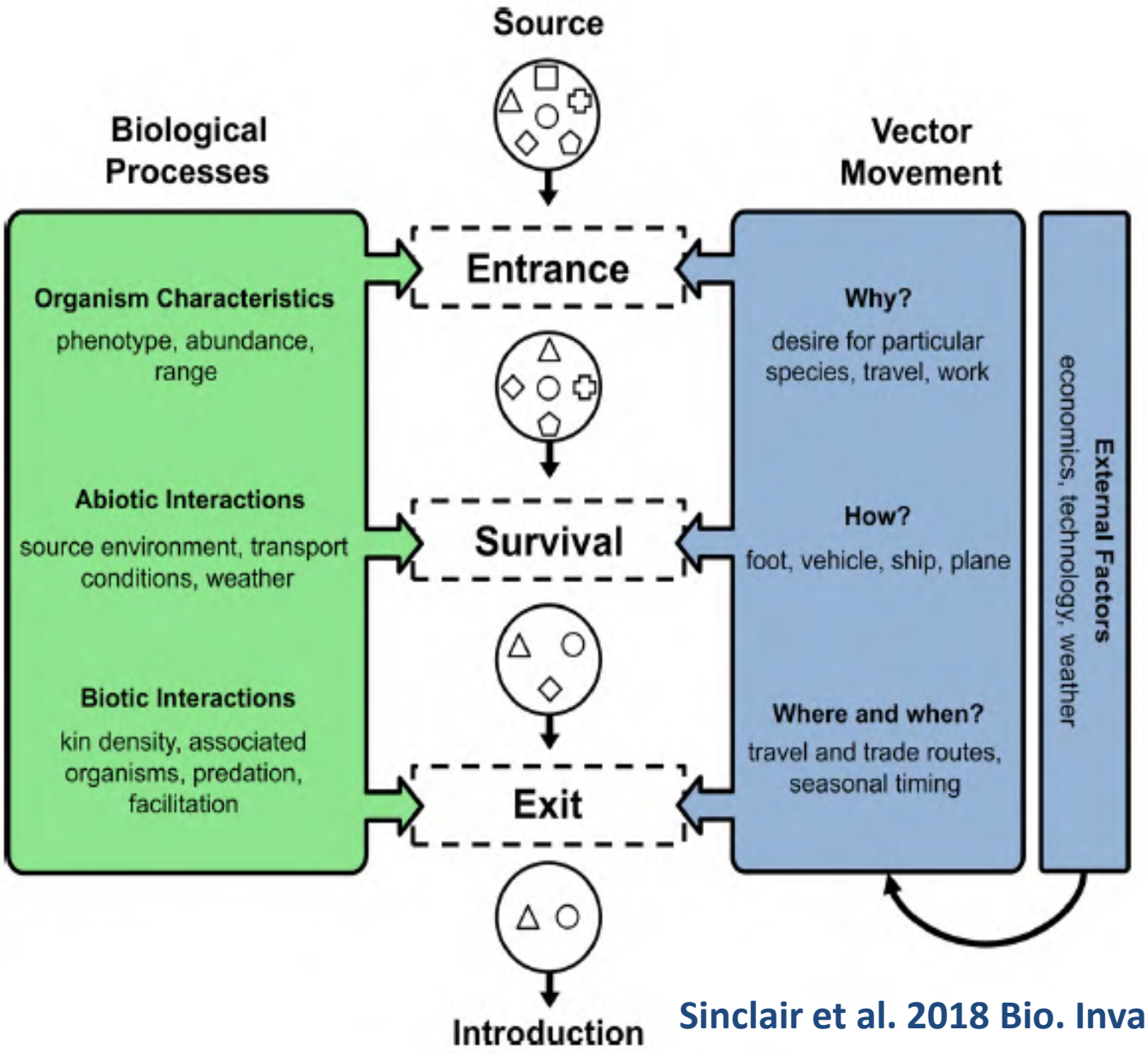


INITIAL INTRODUCTION INTO REGION	PATHWAY	DEFINITION	EXAMPLES	REGULATION
INTENTIONAL	Commodity → Release	Intentional introduction as a commodity for release	Biocontrol agents, game animals, plants for erosion control	Responsibility: APPLICANT Permits required National regulation
INTENTIONAL	Commodity → Escape	Intentional introduction as a commodity but escapes unintentionally	Feral crops and livestock, pets, garden plants, live baits	Responsibility: IMPORTER Screening risk analysis National regulation
INTENTIONAL	Commodity → Contaminant	Unintentional introduction with a specific commodity	Parasites, pests, and commensals of traded plants and animals	Responsibility: EXPORTER Quarantine procedures International regulation
UNINTENTIONAL	Vector → Stowaway	Unintentional introduction attached to or within a transport vector	Hull fouling, ballast water/soil/sediment organisms	Responsibility: CARRIER Quarantine procedures International regulation
UNINTENTIONAL	Dispersal → Corridor	Unintentional introduction via human infrastructures linking previously unconnected regions	Lessepsian migrants, Ponto-Caspian aliens in the Baltic	Responsibility: DEVELOPER Environmental impact laws International regulation
UNINTENTIONAL	Dispersal → Unaided	Unintentional introduction through natural dispersal of alien species across political borders	Potentially all alien taxa capable of dispersal	Responsibility: POLLUTER 'Polluter Pays' International regulation

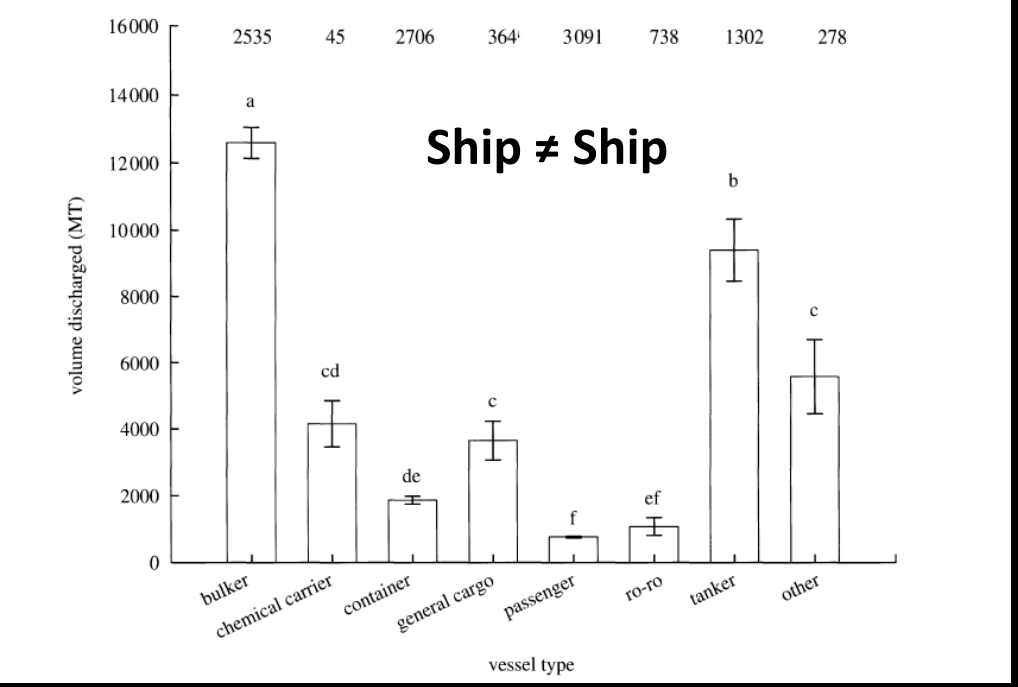
Fig. 2. A simplified framework to categorize pathways of initial introduction of alien species into a new region. Alien species may, as a direct or indirect result of human activity, arrive and enter into a new region through three broad mechanisms: the importation of a commodity, the arrival of a transport vector and/or natural spread from a neighbouring region where the species is itself alien. Five pathways are associated with human activity either as commodities (release and escape), contaminants of commodities, stowaways on modes of transport and opportunists exploiting corridors resulting from transport infrastructures. The sixth category highlights alien species that may arrive unaided in a region as a result of natural spread (rather than human transport) following a primary human-mediated introduction in a neighbouring region. For each pathway a brief description is presented with examples. The different regulatory approaches for each pathway are also illustrated. While a case is often made regarding differences between intentional vs. unintentional introductions, the scheme highlights a gradient of human intention that reflects the difficulty in distinguishing between ignorant and premeditated action.

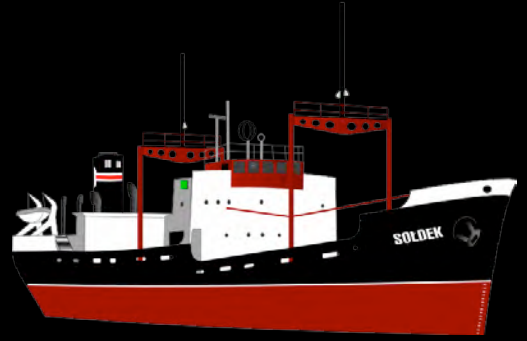
Hulme et al. 2008 J. Applied Ecology

Hypothesis Driven Pathway Science

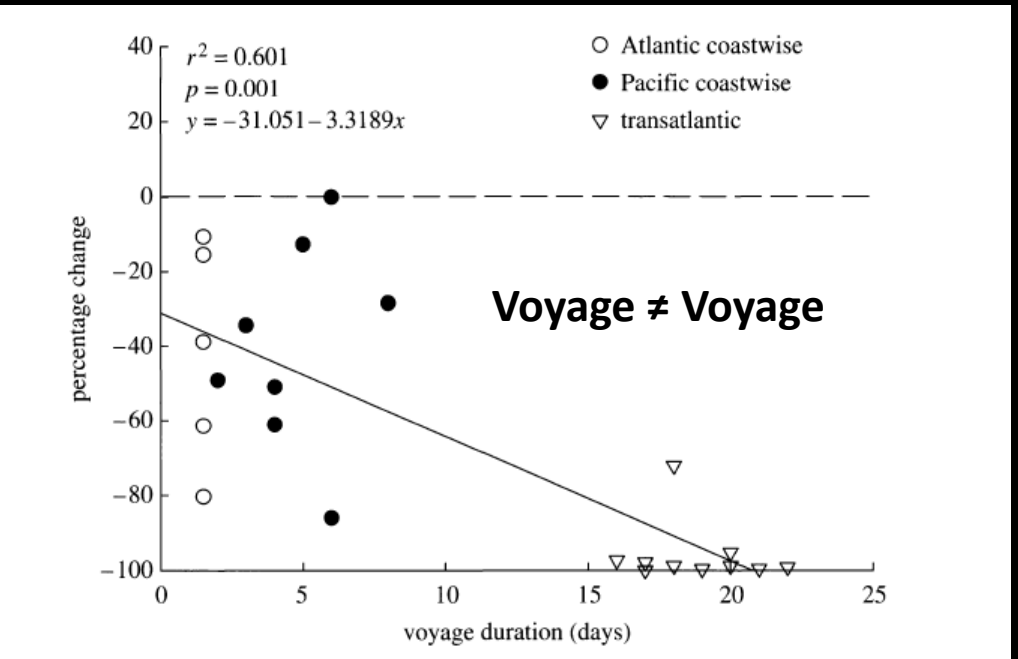


Sinclair et al. 2018 Bio. Invasions





Not all ships bring the same probability of introducing a non-native species in their ballast.



Not all ports have an equal probability of being invaded because of these differences.

Verling et al. 2005. Proc. Roy. Soc.

Same applies to many other vectors….although not as well documented

Table 1. Number of containers inspected, number of insect interceptions, points of origin and valid species or single gênera interceptions reported for cargo arriving in maritime transport, air transport, and land transport across US–Mexico border and between fiscal year 1997 and 2001.

Transport type	Cargo type	Number of containers inspected	Number of insect interceptions	Number of points of origin	Number of insect taxonomic designations	Number of species
Maritime	Empty container	606	0	0	0	0
	Nonagricultural	883	0	0	0	0
	Nonrefrigerated containers	6459	125	35	70	46
	Refrigerated containers	2578	208	22	80	49
Air	Agricultural	4150	142	28	46	19
	Nonagricultural	1266	2	2	2	1
US–Mexico border	Low-risk agriculture	4902	5	1 (Mexico)	4	3
	Empty container	2407	0	0	0	0
	Nonagricultural	1019	0	0	0	0
	Agricultural	5093	77	1 (Mexico)	25	13

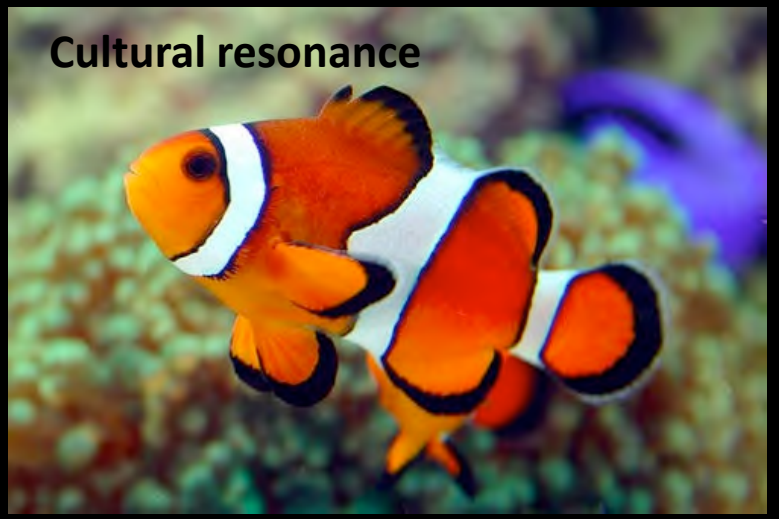
Work et al. 2005 Biol. Invas.

Phenotypic plasticity

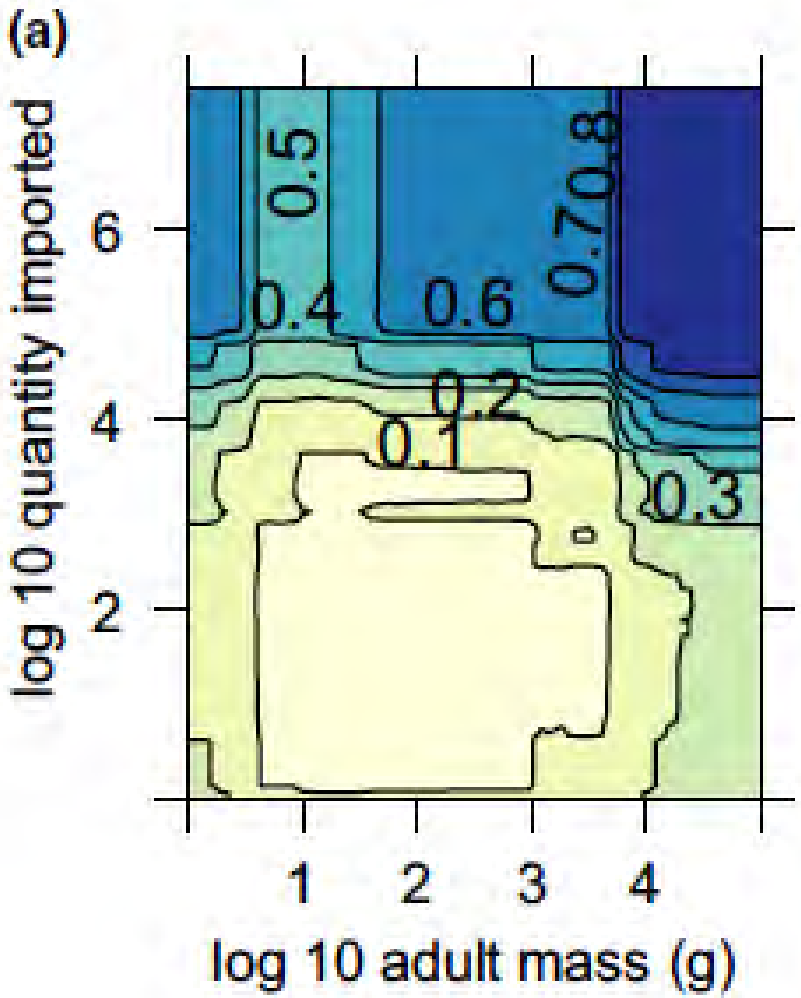
Ease of care + coloration

Purposeful Transport?

Cultural resonance

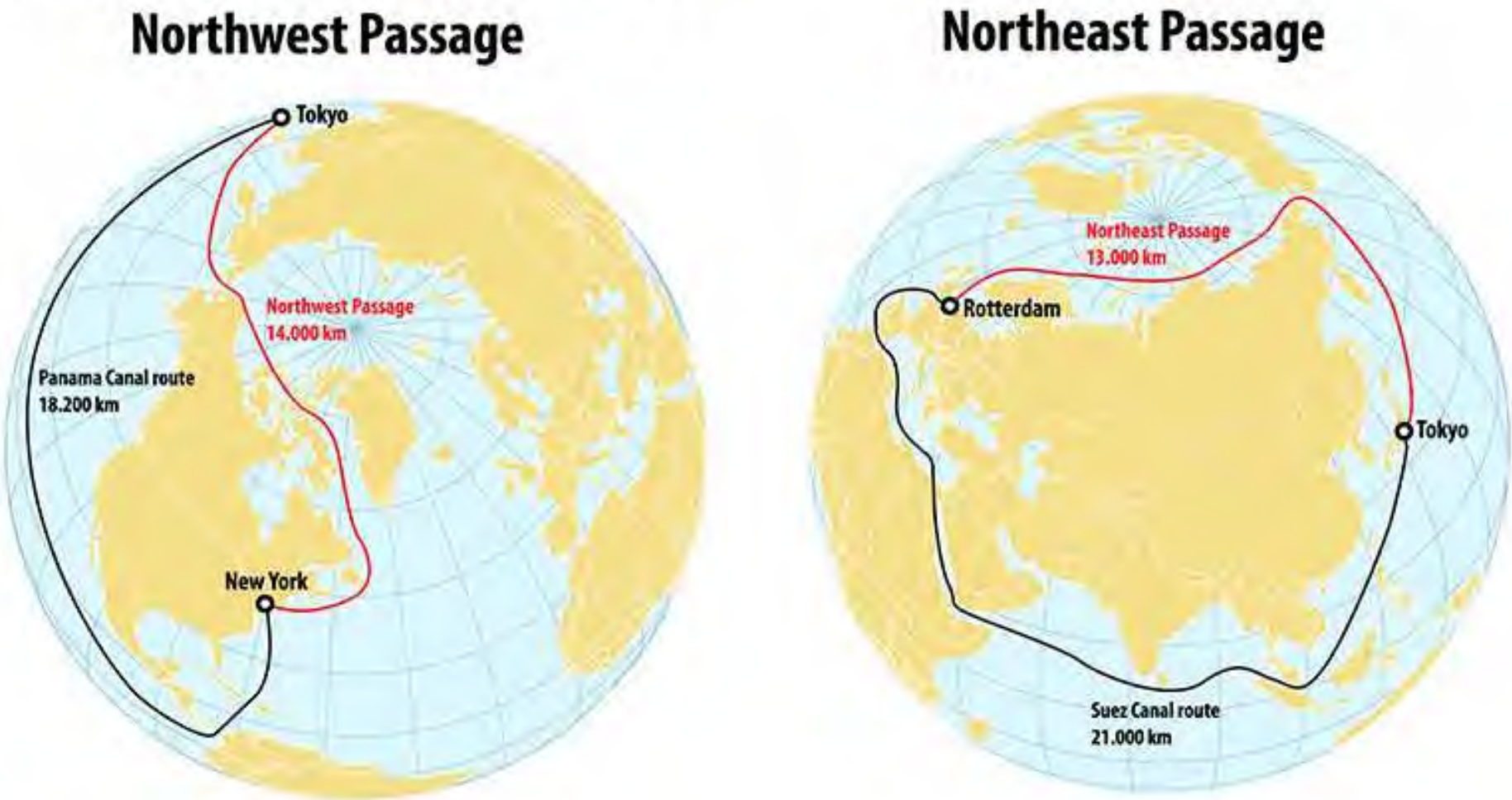


Why do some species enter into the exotic pet market, and when they do, how many are sold per year and where?



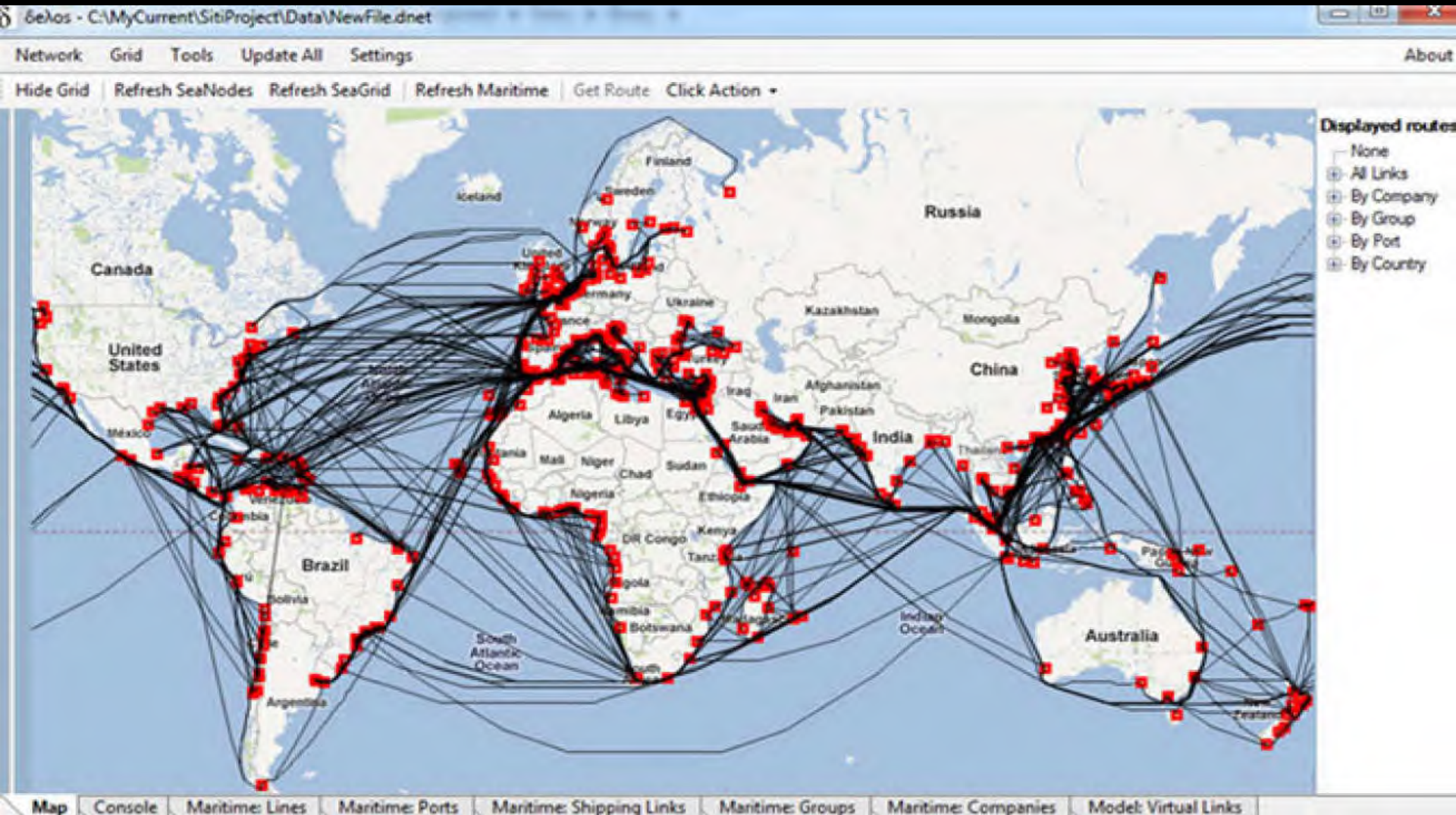
Stringham and Lockwood 2018.
J. Applied Ecol.

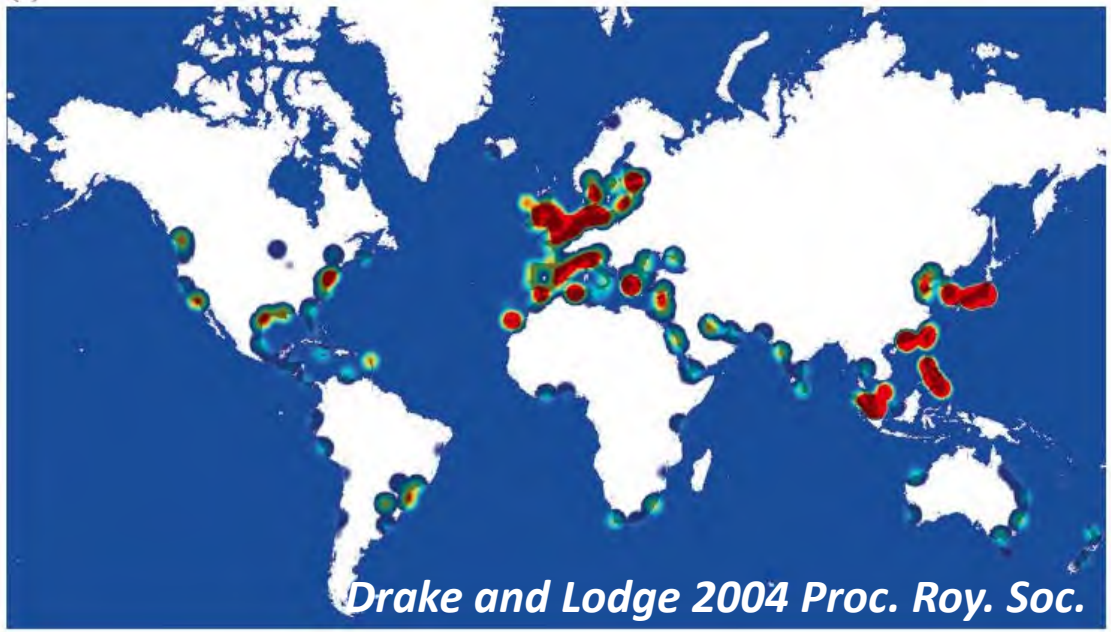
New Arctic Shipping Routes



We can use this approach to pathway science to anticipate locations likely to experience high invasions rates, and the species likely to show up.

Network Approaches

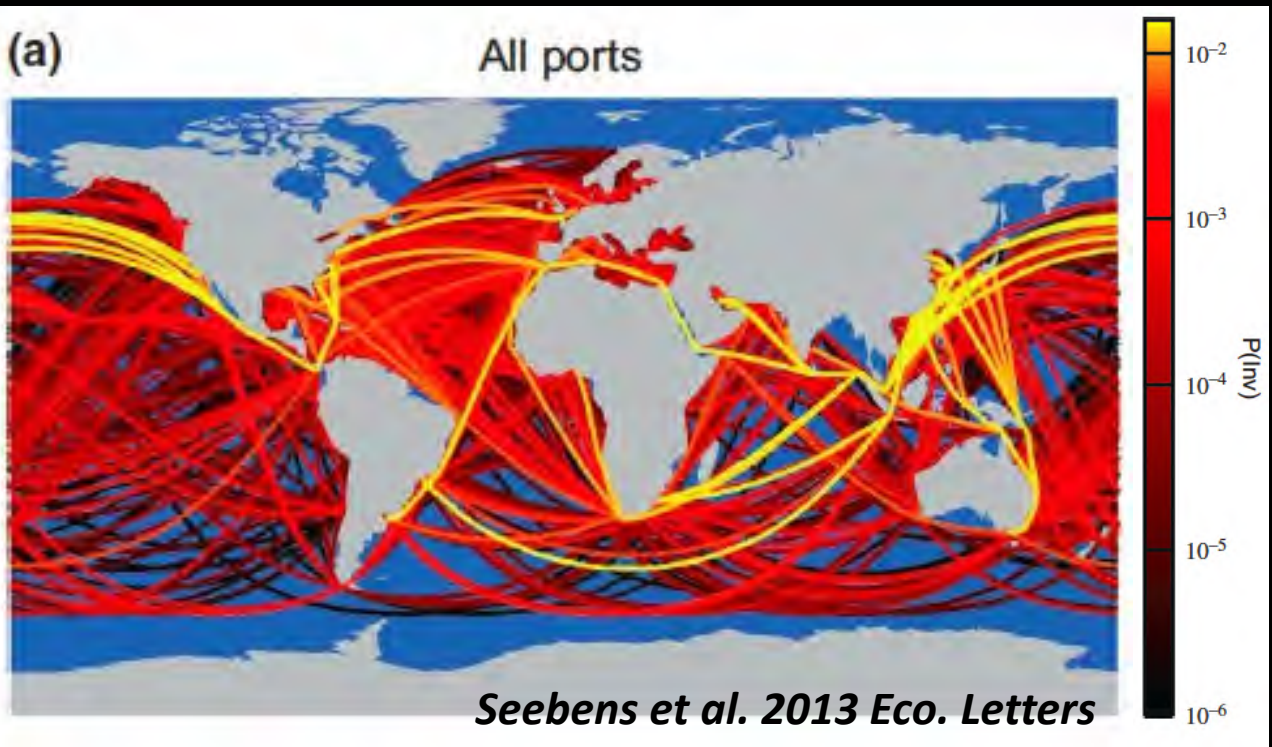




Drake and Lodge 2004 Proc. Roy. Soc.

‘Hot’ ports

Number of ships visiting ports per year, scaled by a probability of per-ship-call initiating an invasion



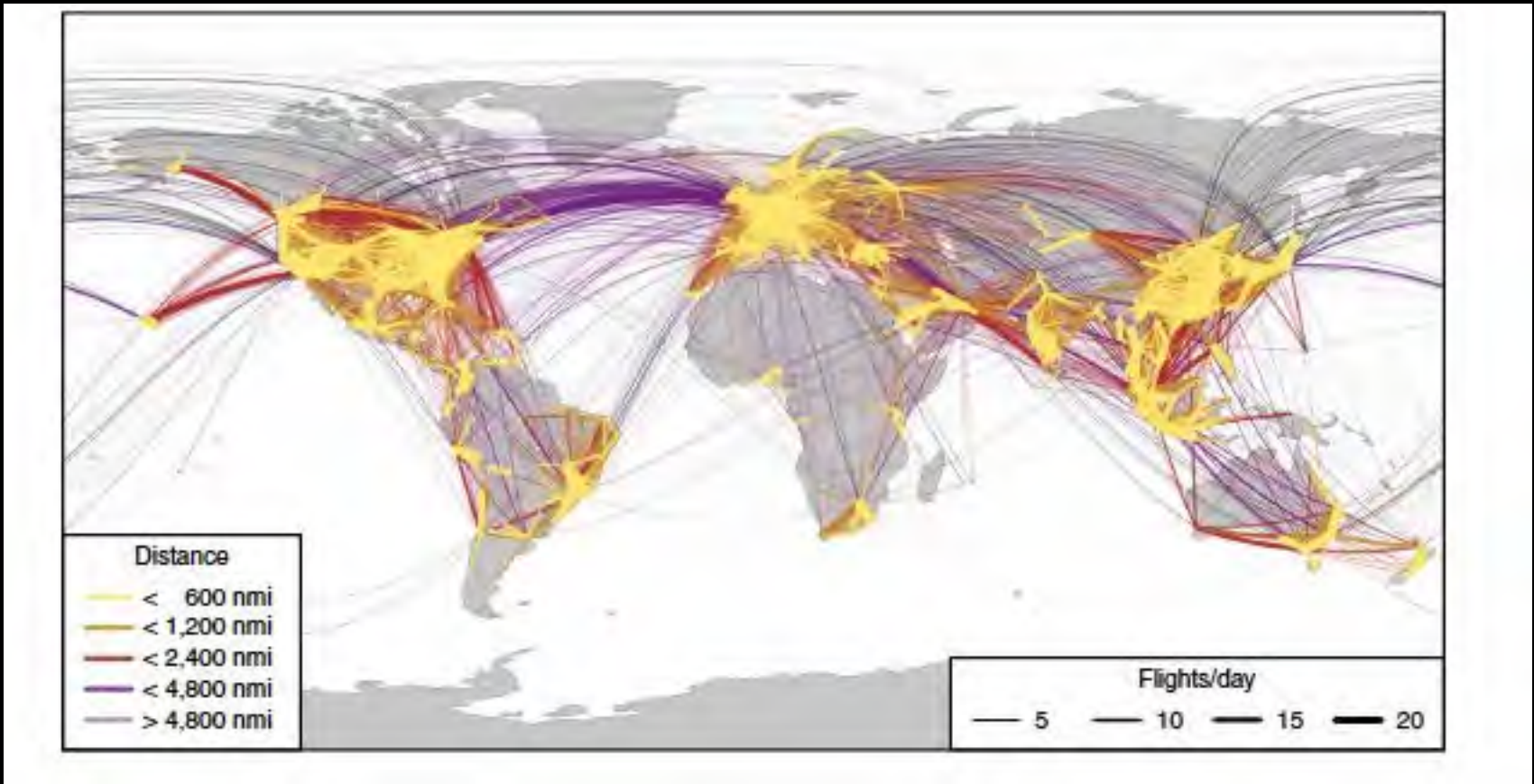
Seebens et al. 2013 Eco. Letters

‘Hot’ routes

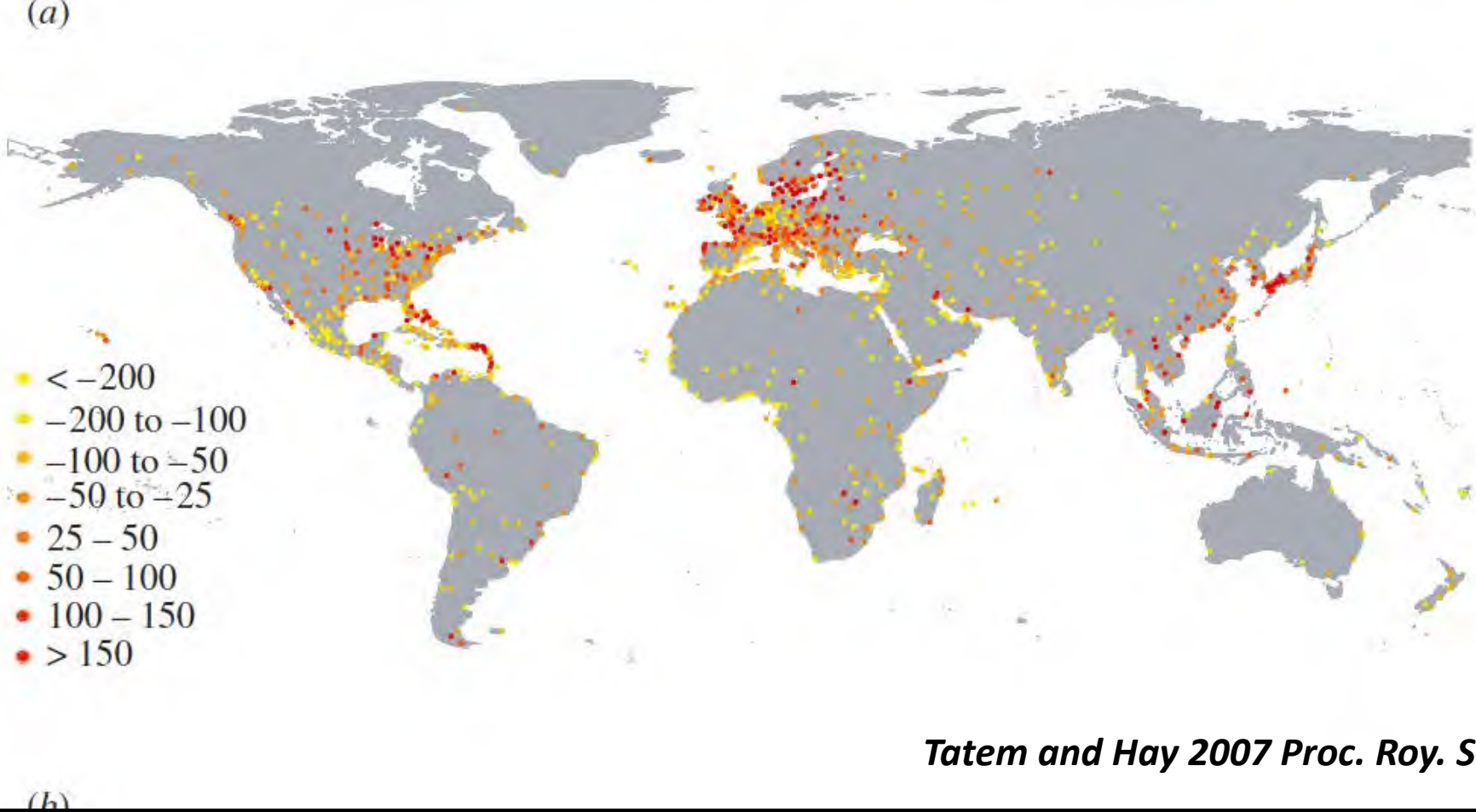
Invasion probability along every shipping connection between two ports in the network

What About Other Networks That Transport Non-Native Species?

Global airline network 2015



Schafer et al. 2019 Nature Ener

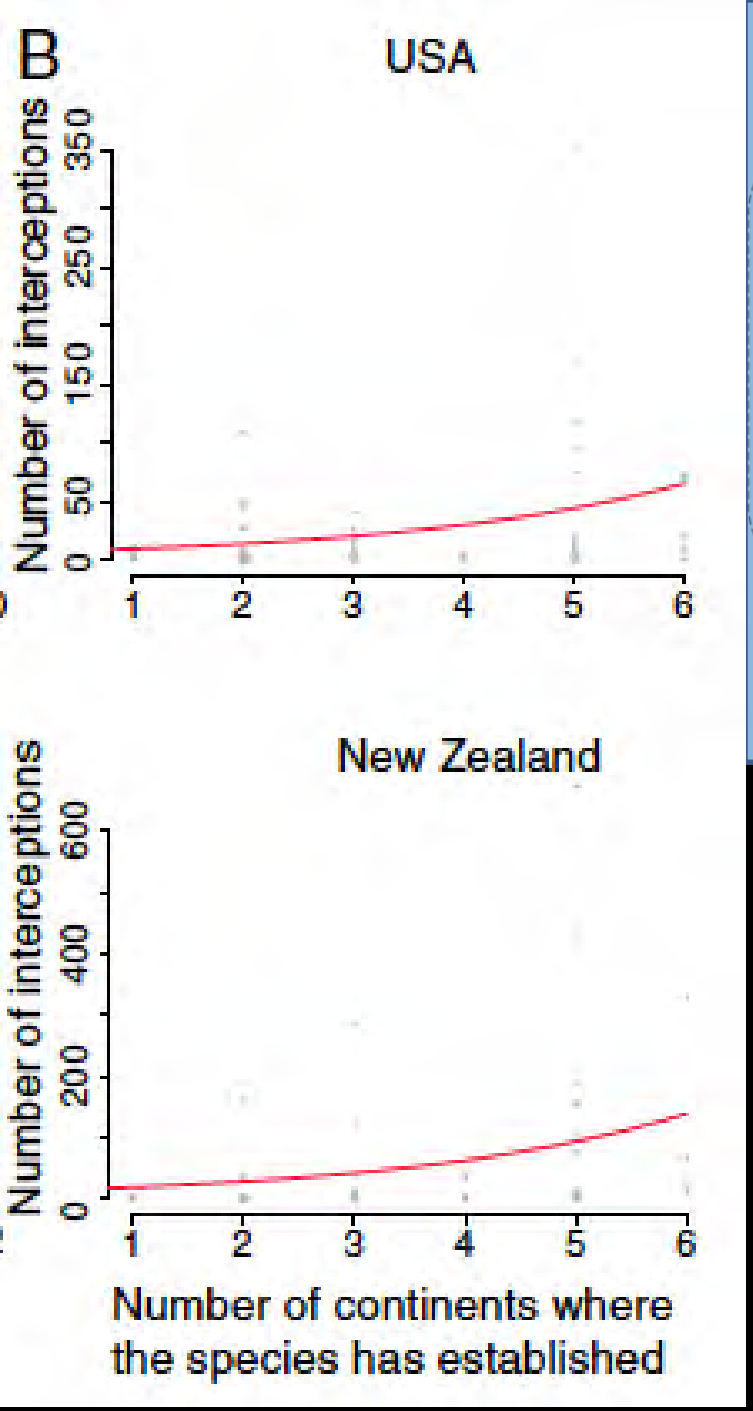


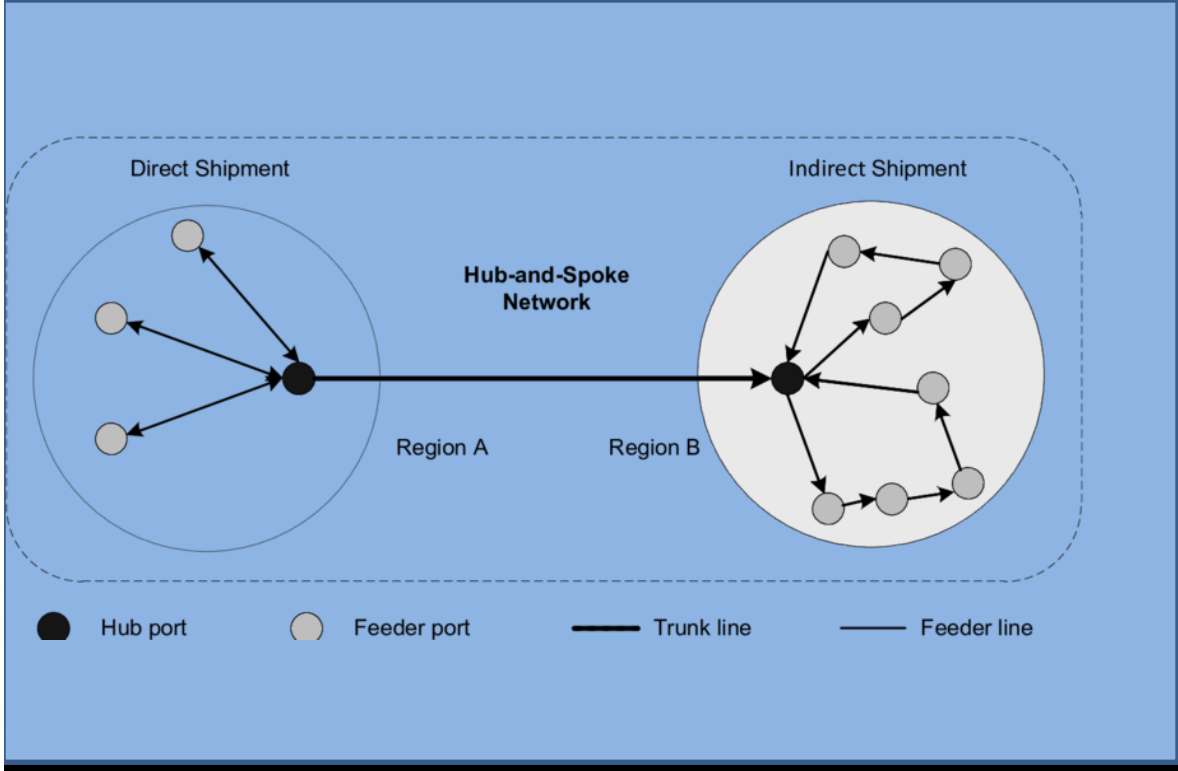
Tatem and Hay 2007 Proc. Roy. Soc.

Red to orange plots airports with a high traffic volume where the incoming flights are from regions that are climatically similar = HIGH INVASION RISK

Yellow plots airports with opposite pattern (high traffic volume from regions not climatically similar) = LOWER INVASION RISK

Don't know the species on those flights or the directionality of trade but we could predict that.

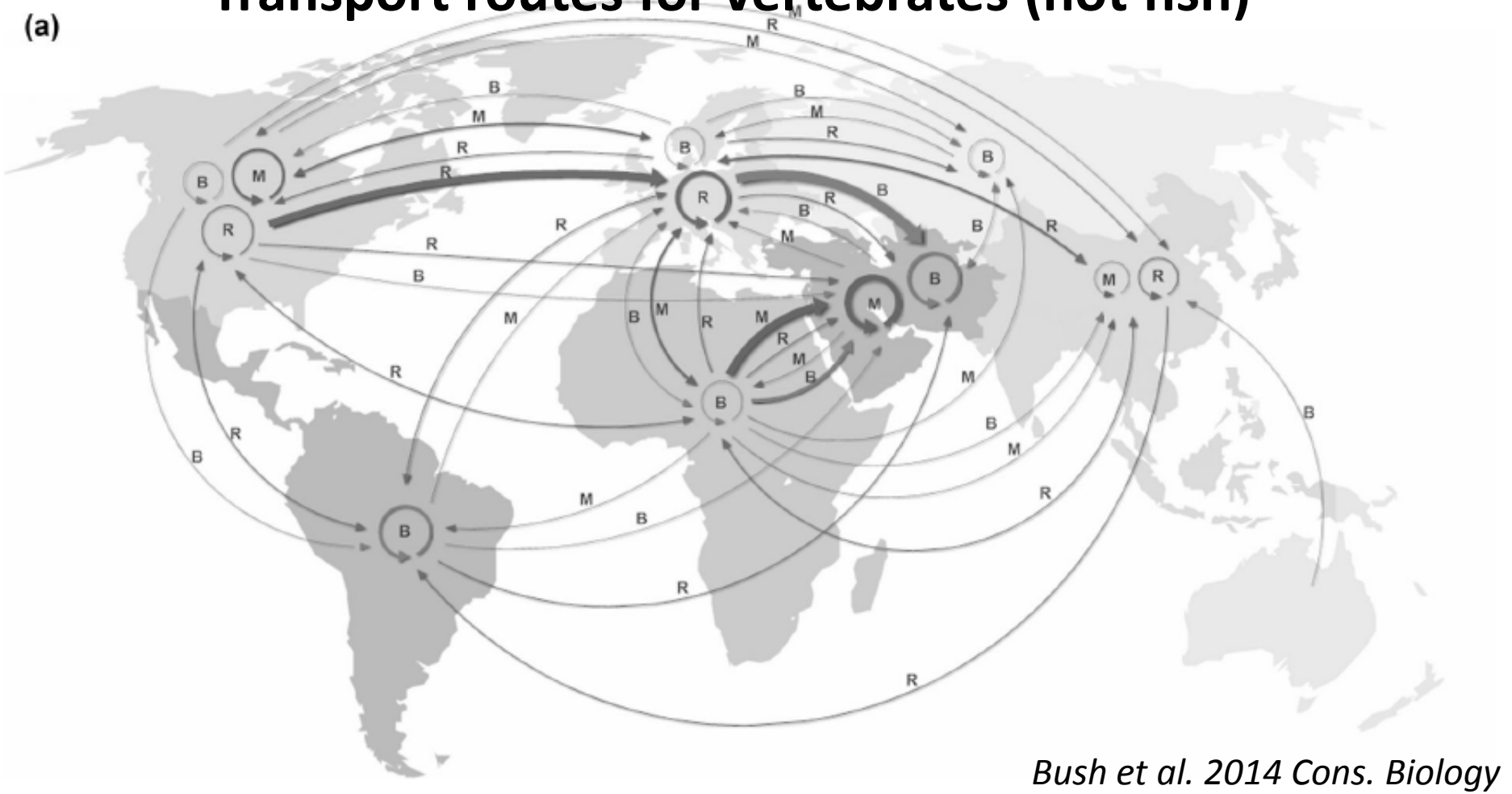




Stepping Stone or Hub-and-Spoke Networks

Bertelsmeier et al. 2018 PNAS

Transport routes for vertebrates (not fish)

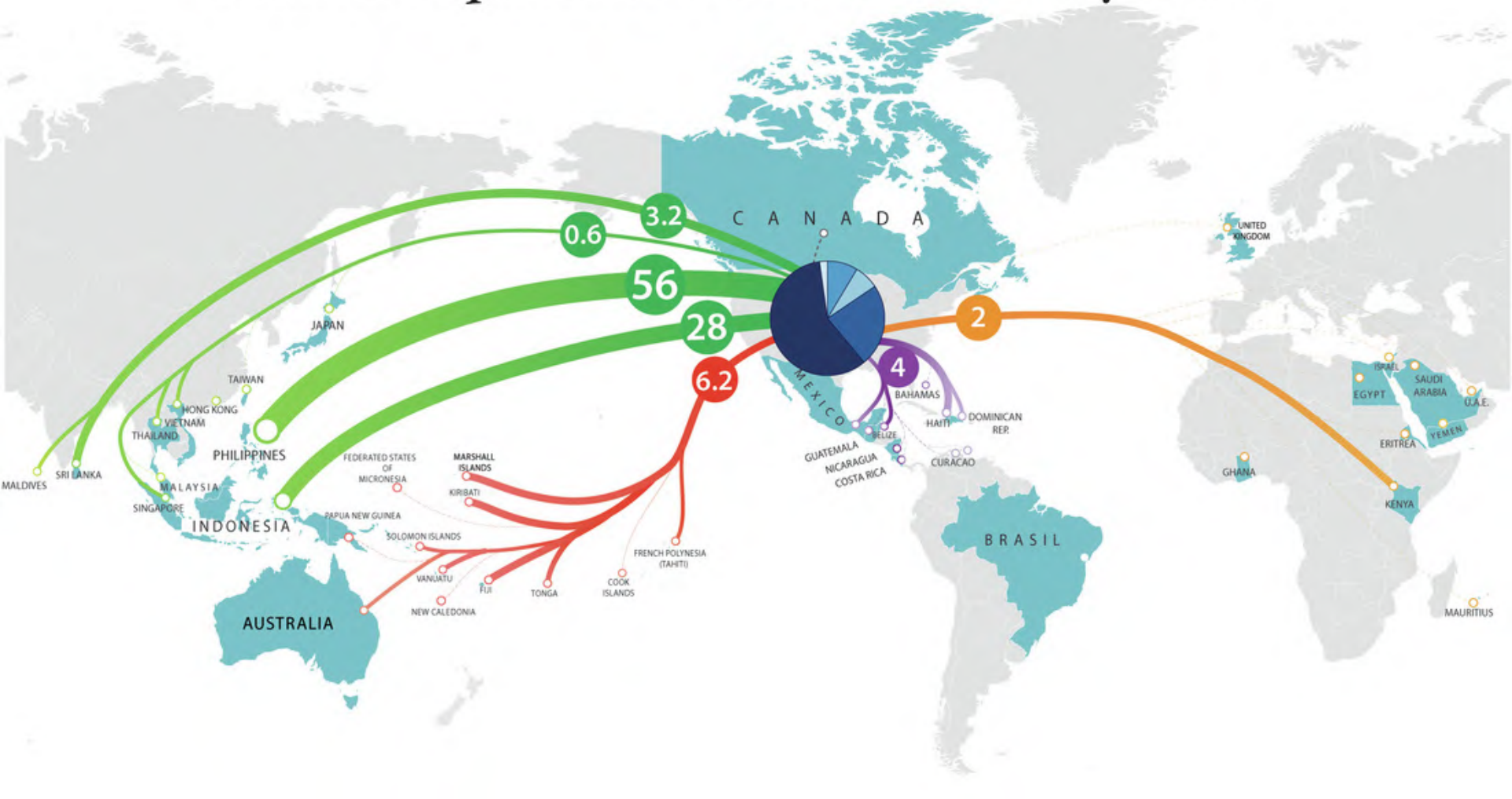


Bush et al. 2014 Cons. Biology

Networks in the wildlife trade

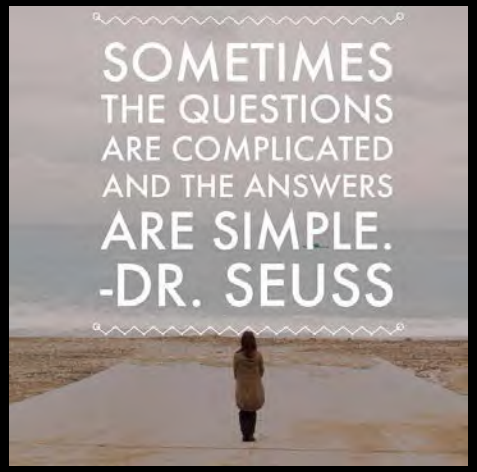
These have been built and analyzed in the context of native species conservation but not in the context of biological invasions

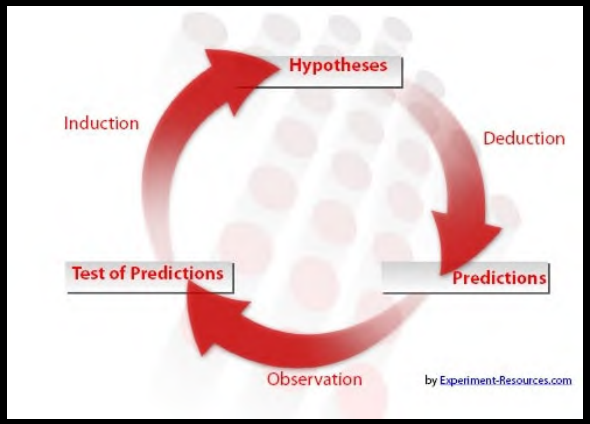
Mairne Aquairum Fishes Biodiveristy Flow

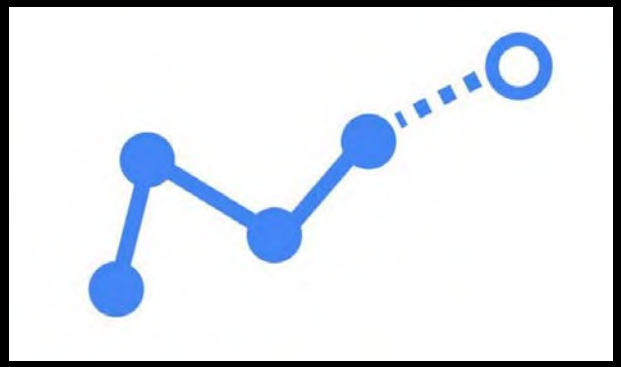


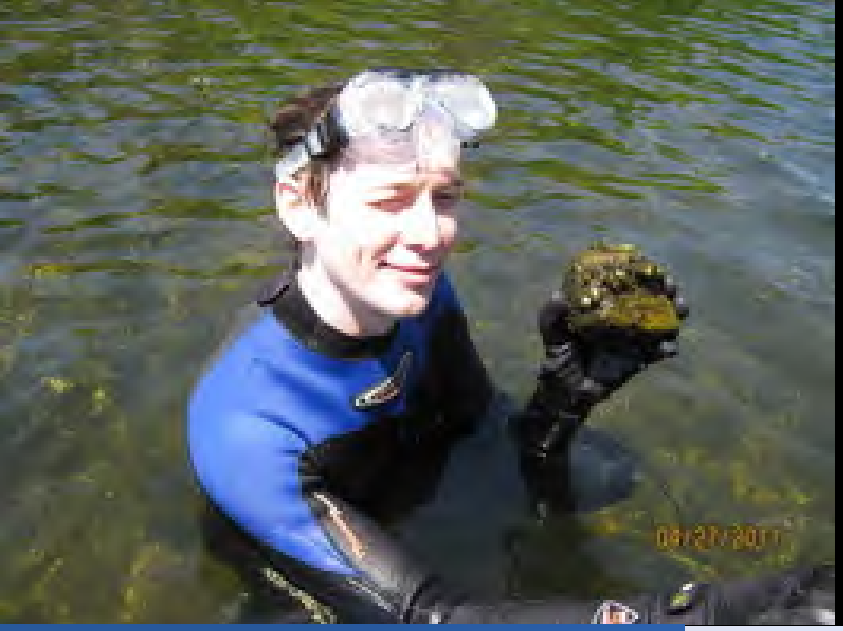
www.aquariumtradedata.org

A recognition of colonization pressure….









Thank you