Knowledge to Action:
North America and Global Linkages

David M. Lodge,
Francis J. DiSalvo Director,
Atkinson Center for a Sustainable Future
Professor, Dpt. Ecology & Evolutionary Biology

DAVID R. ATKINSON CENTER
for a Sustainable Future
Cornell University

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Great Lakes Protection Fund

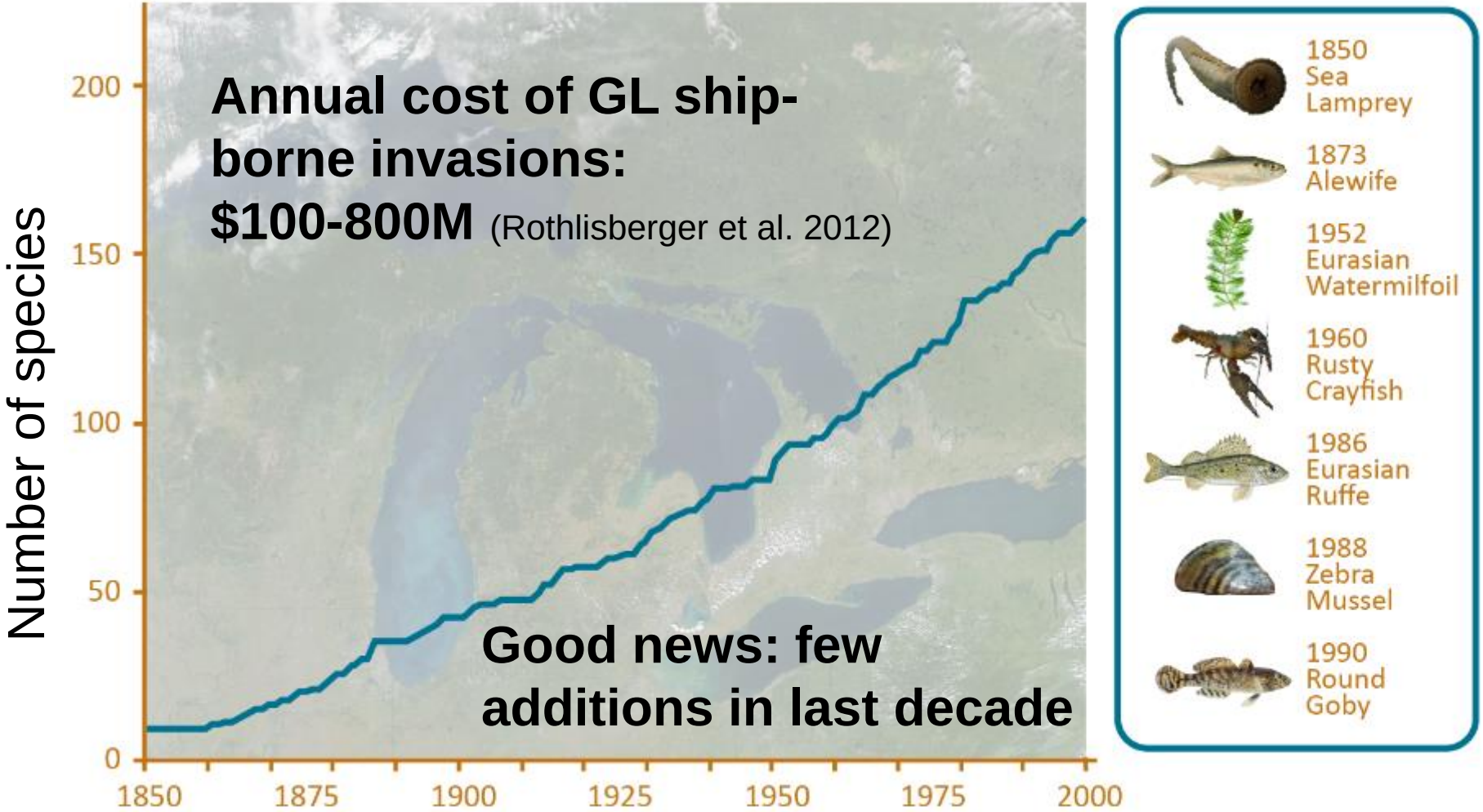
SERDP
DOD • EPA • DOE

Knowledge to Action:

Knowledge **to Action**:

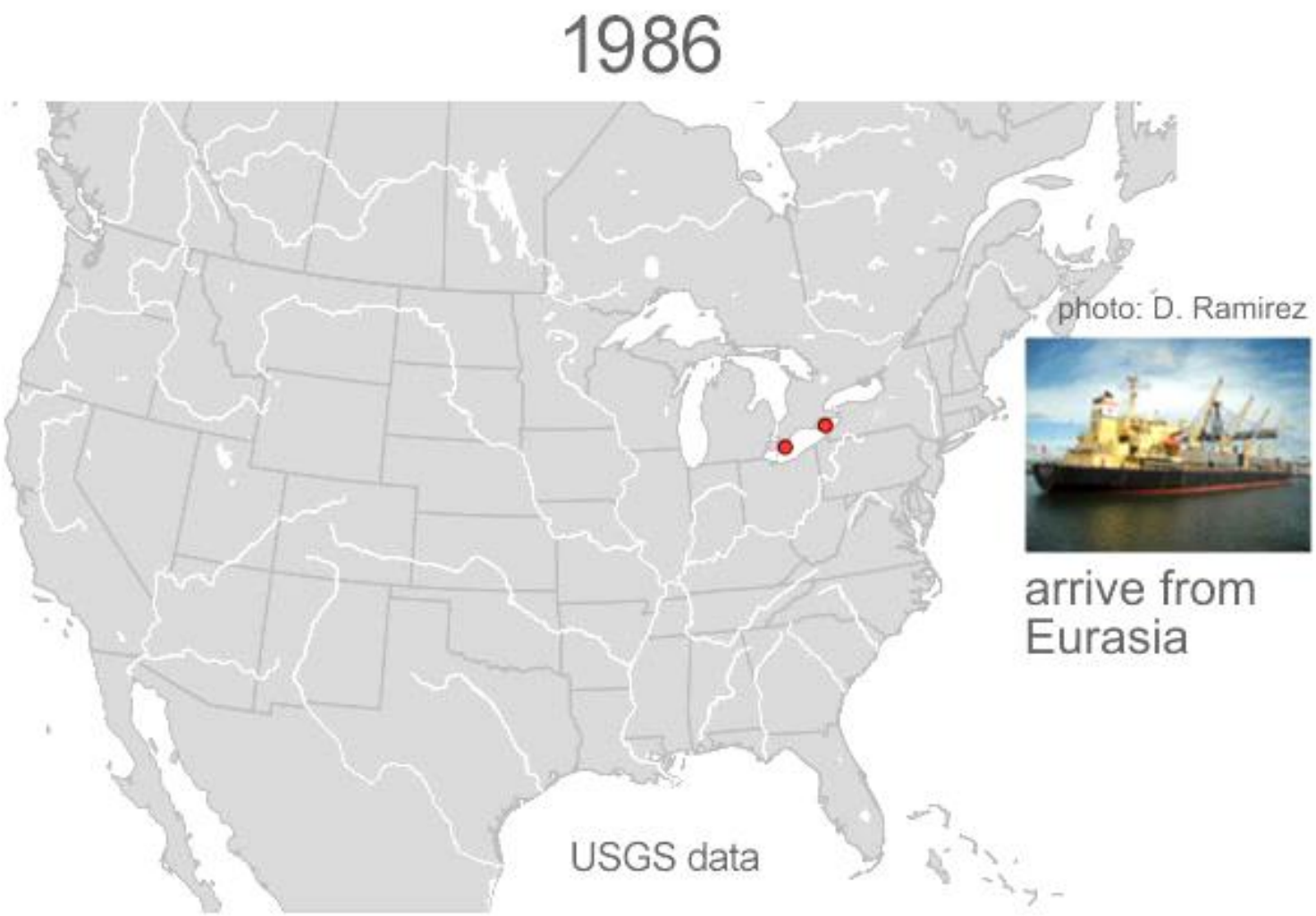
Knowledge to Action:
Co-Creation

Nonindigenous species in the Laurentian Great Lakes

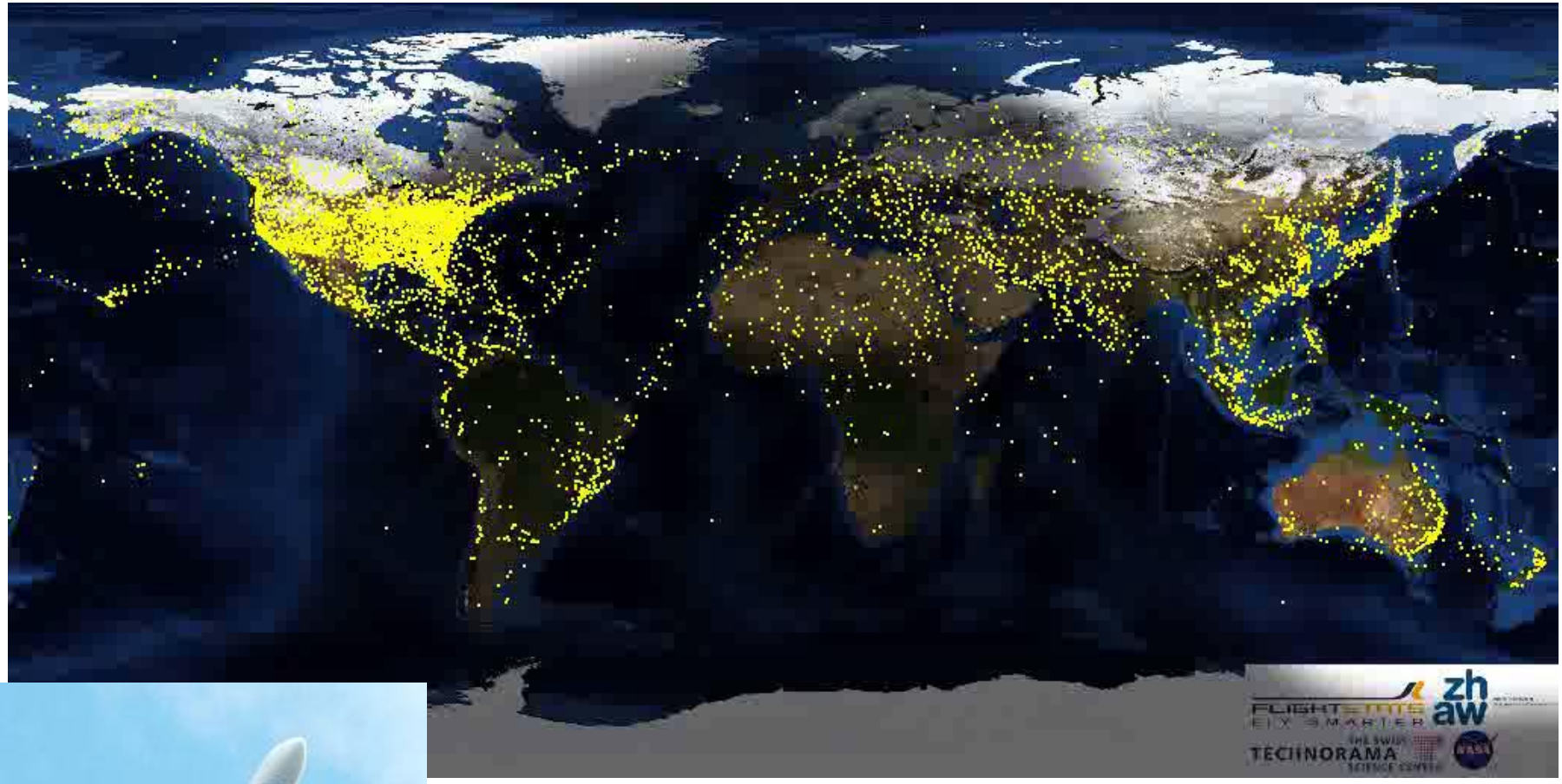


(Ricciardi, NOAA)

Dreissenid mussels

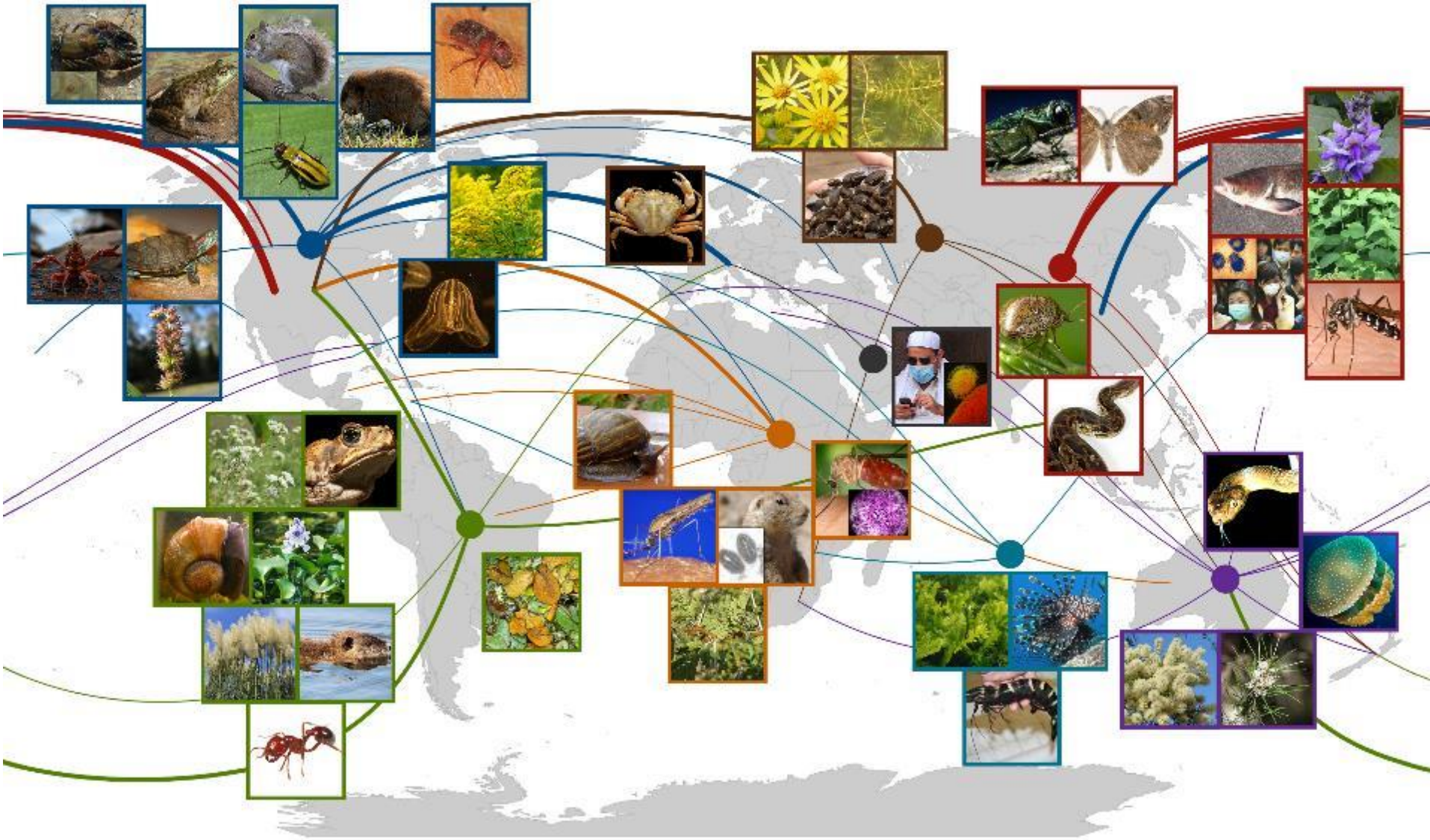


Global air traffic network



Global shipping network

More drops in the global invasion bucket . . .



Originating in: **Africa** [Anopheles gambiae (J Gathany), Giant African land snail (billy1125), Kerro thorn (J Cabrera), Monkeypox (Donelle), West Nile Virus (J Gathany; NIAID)], **Asia** [Asian Tiger Mosquito (CDC), Bighead/Silver carp (A Benson), Burmese python (P Jean), Emerald ash borer (USDA), Japanese knotweed (cankogreen), Kudzu (Brisbane), Kudzu bug (C Lam), SARS (CDC), White-spotted tussock moth (P Lilywhite)], **Australia** [Australian spotted jellyfish (N Hobgood), Brown tree snake (NPS), Melaleuca tree (T Gerust, Prickly hakea (Moon gnt0551)], **Europe/Eurasia** [Eurasian watermilfoil(D Hobern), Green crab (H Hillewaert), Ragwort (P Sellens), Zebra/Quagga mussels (B Nichols), Indian Ocean Caulerpa (NOAA), Giant tiger prawn (USDWF), Lionfish (mjwinoz)], **Middle East** [MERS (F El Bimi; NIAID)], **South America** [Apple snail (Pardee Ave), Cane toad (B Grotwicke), Giant salvinia (USDA), Nutria (Alpsdake), Pampas grass (T Jauych), Parthenium (F&K Starr), Red imported fire ant (AJ Cann), Water Hyacinth (USDA)], **North America** [American bullfrog (J Tuscynski), Bushy goldenrod (L West), Crayfish plague (D Perez; D Alderman), Eastern Grey squirrel (BirdPhotos.com), Louisiana red swamp crayfish (J Pais), Muskrat (B Mazur), Red turpentine beetle (J Berger), Red eared slider (Jim), Sandbur (H Rose), Warty comb jelly (SG Johnson), Western corn root worm (S Zukoff)]

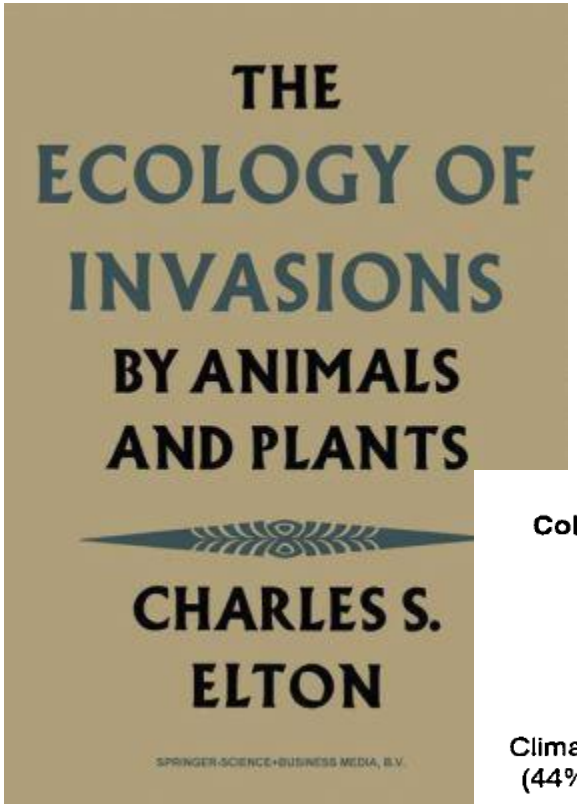
Aggregate costs of invasive species

- Annual damages ($B 2015): US $146; Canada $31; Sweden $1; EU $19; China $14; SE Asia $34
- Challenges: exponential increase, apparently irreversible
- Typical policy approach: external costs not internalized; suffer, react, adapt;
- Solutions: innovative policy, science, technology

Knowledge to Action:

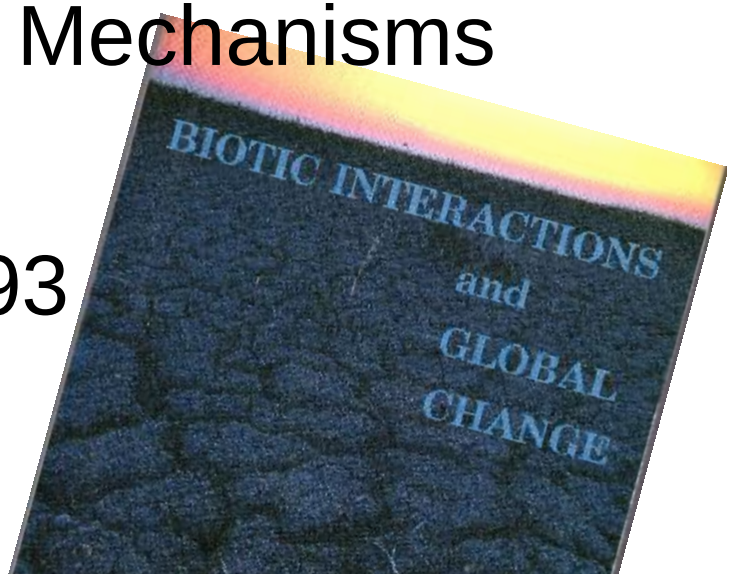
North America and Global Linkages

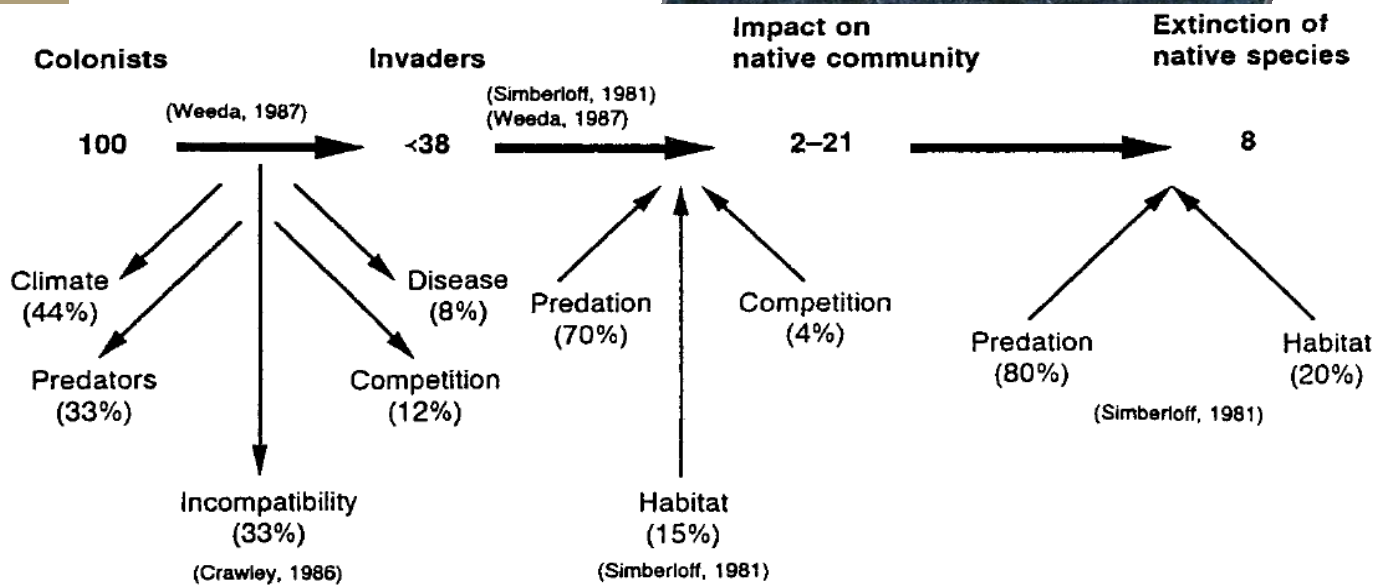
In the beginning (of the modern era of invasion biology) . . . Impacts and Mechanisms



1958

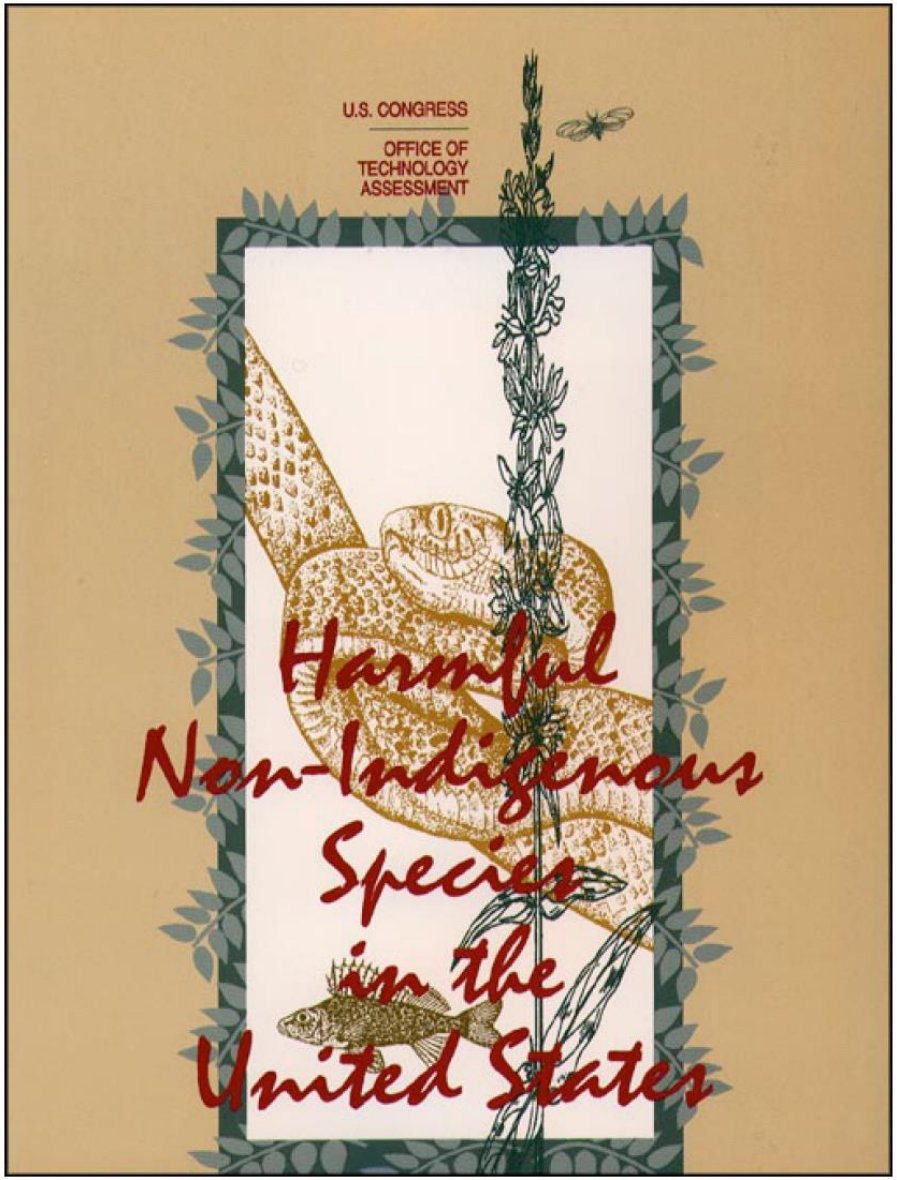
1993



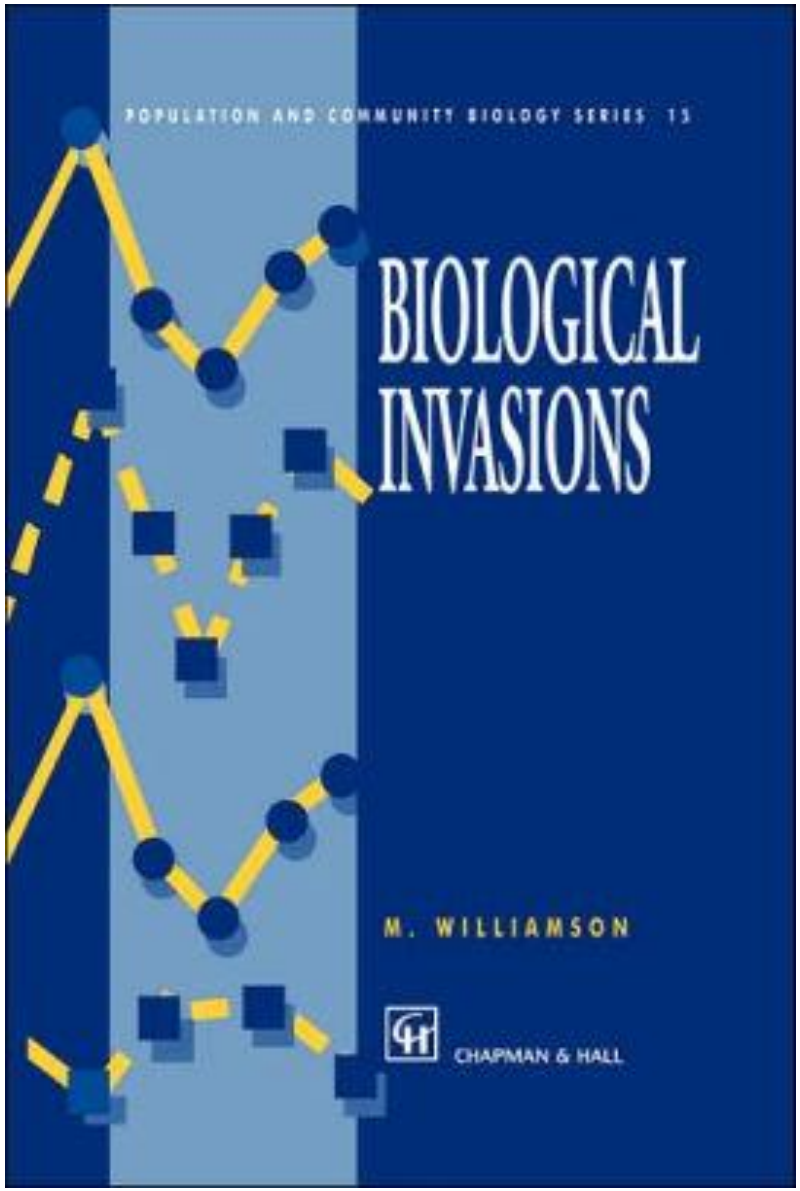


(Lodge 1993 in Kareiva et al.)

1993


U.S. CONGRESS
OFFICE OF TECHNOLOGY ASSESSMENT
Harmful Non-Indigenous Species in the United States

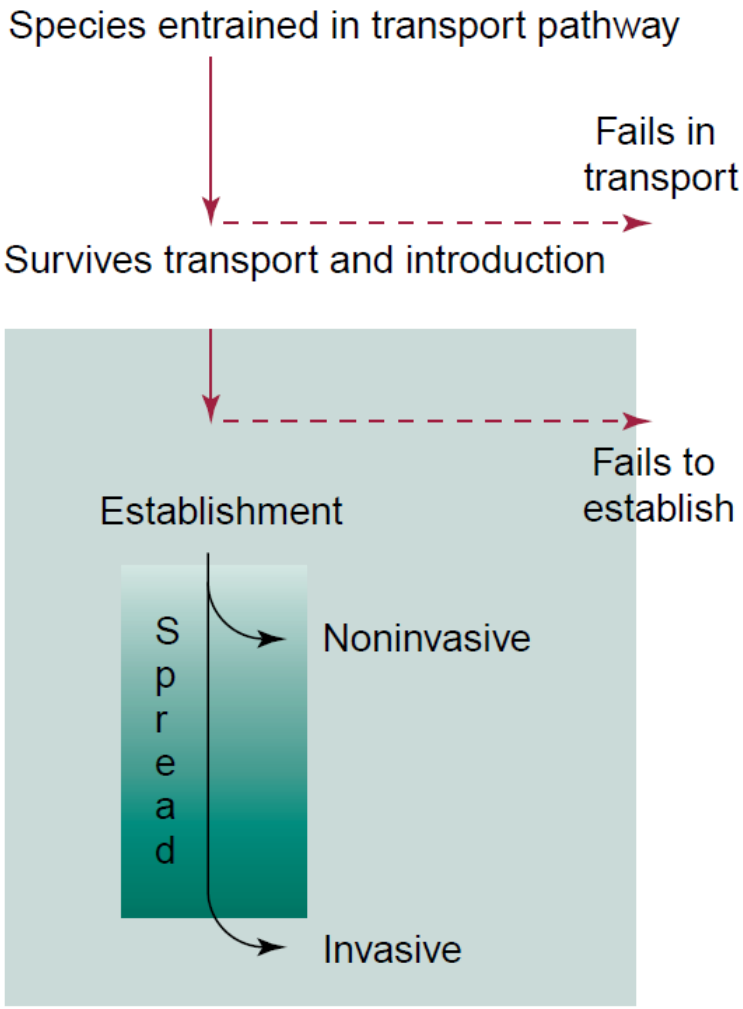
1996


POPULATION AND COMMUNITY BIOLOGY SERIES 15
BIOLOGICAL INVASIONS
M. WILLIAMSON
CHAPMAN & HALL

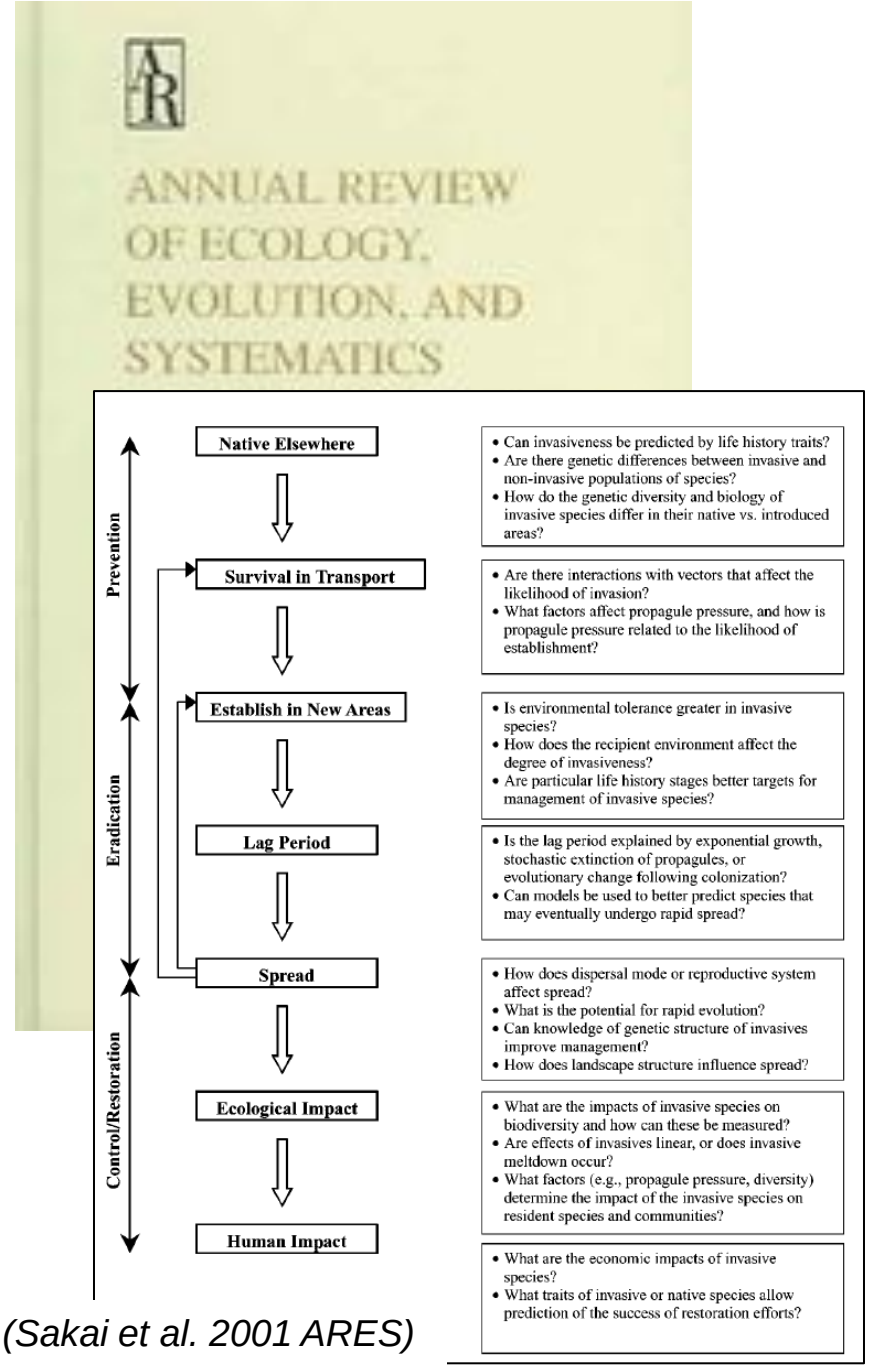
Shifting funding imperatives: NSF's 1997 "Broader Impacts"

1997 - March 28: New merit review criteria are approved by the National Science Board for proposals to NSF. Representing the first change in 16 years, the new criteria balance intellectual merit with concerns for broader impacts

2001



(Kolar & Lodge 2001)
TRENDS in Ecology & Evolution



(Sakai et al. 2001 ARES)

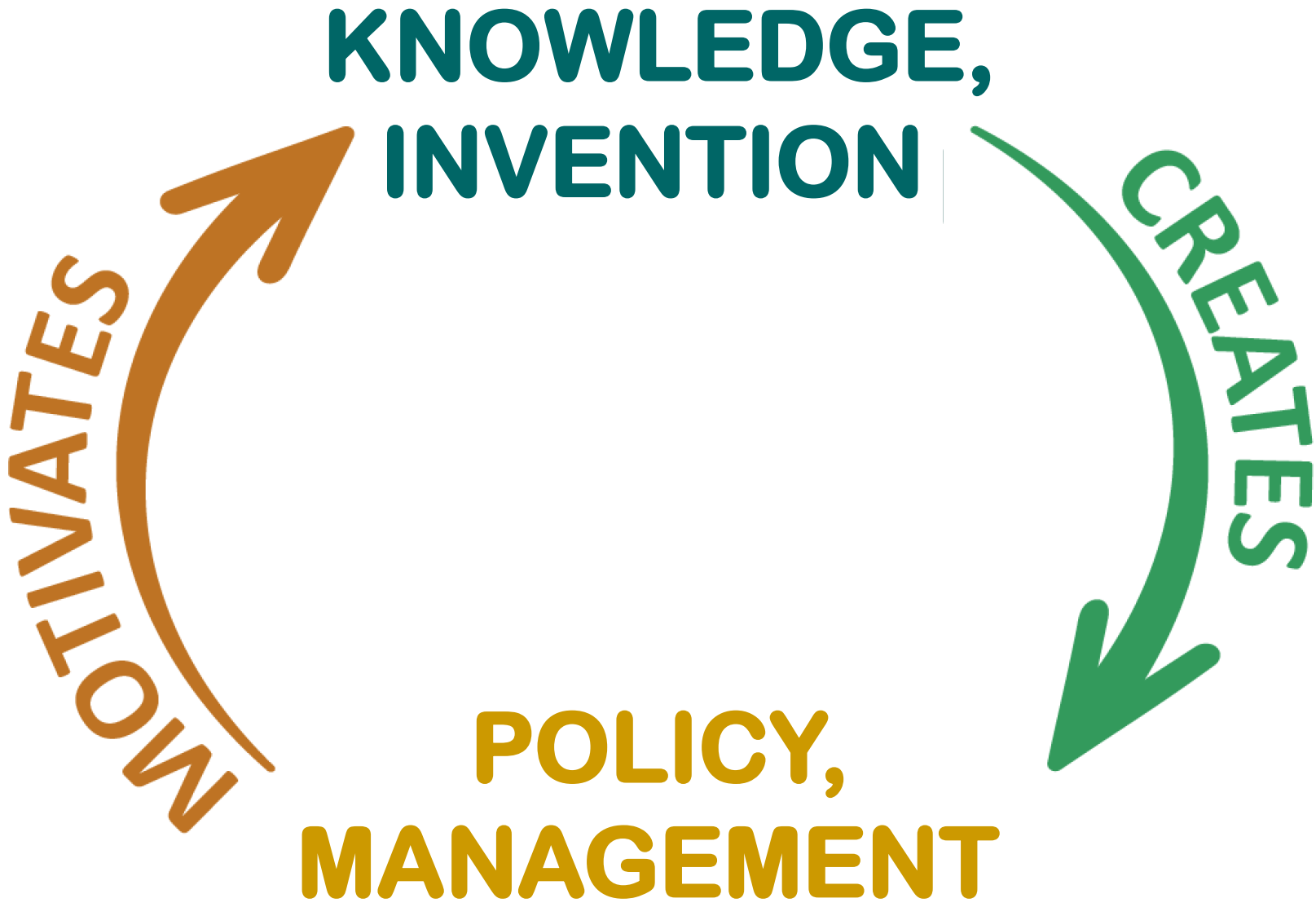
Knowledge **to Action**:
North America and Global Linkages

Policy (often a prerequisite to action)—examples:

Lacey Act (1950)--Injurious Wildlife provisions

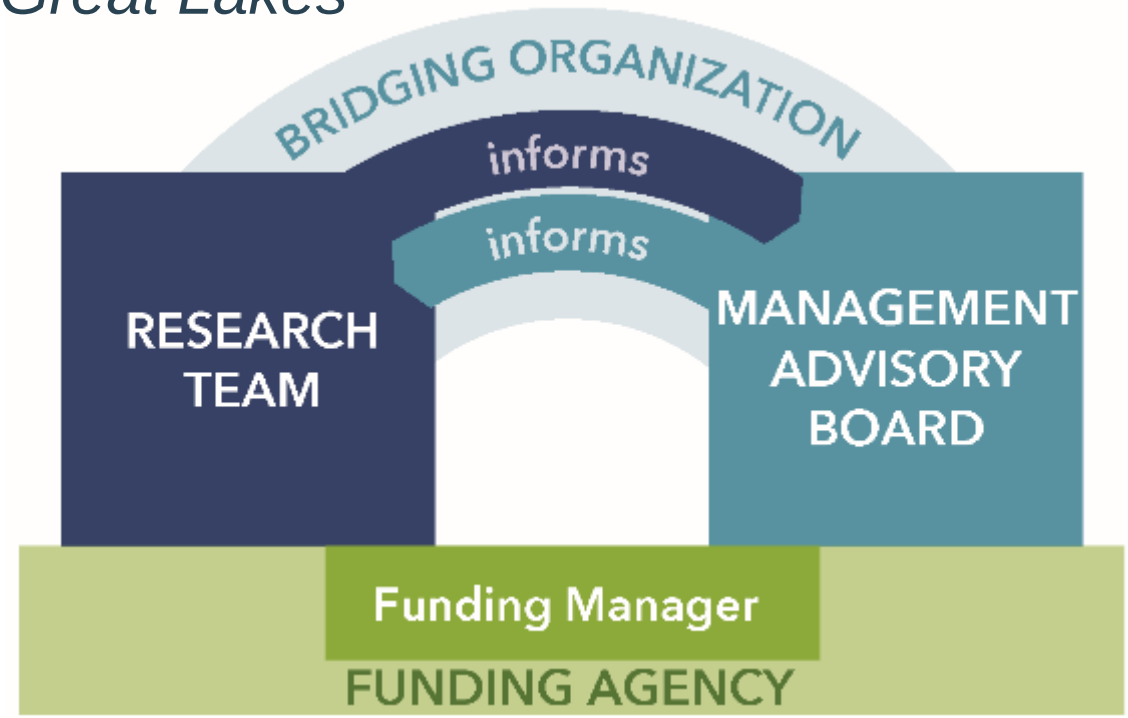
Non-indigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA)

Executive Order 13112 (1999), amended by Ex. Order 13751 (2016)


KNOWLEDGE,
INVENTION
CREATES
POLICY,
MANAGEMENT
MOTIVATES

Knowledge to Action: Co-Creation

Forecasting spread and bioeconomic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes



Knowledge to Action: Co-Creation

- 8 state agencies
- 5 US agencies
- Binational orgs
- Non-profits
- DFO Canada
- Ontario

INVASION PROCESS	RESEARCH advances	informing	POLICY goals	and	MANAGEMENT examples
Introduction	Assess risks of pathways • commerce in living organisms (e.g. pets, horticulture) • transportation vectors carrying many unknown species (e.g. planes, trucks, ships and boats) Quantify effectiveness/costs of alternative mgmt		Prevent arrival, release or escape		Pre-import approval for specific species; lists of allowed, prohibited, watch species Fumigating wood packing material; shipboard ballast water treatment Prioritize prevention by benfit:cost
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Arrow width reflects the declining number of species reaching each stage of invasion

(Lodge et al. 2016 ARER)

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(Lodge et al. 2016 ARER)

Prevent invasions: Trait-based Risk Assessment

Royal Plec
Panaque nigrolineatus

Oscar
Astronotus ocellatus

Silver Arowana
Osteoglossum bicirrhosum

Red Bellied Piranha
Pygocentrus nattereri

Zebra Tilapia
Tilapia buttikoferi

Arctic Grayling
Thymallus arcticus

Siamese Fighting Fish
Betta splendens

Red Shiner
Cyprinella lutrensis

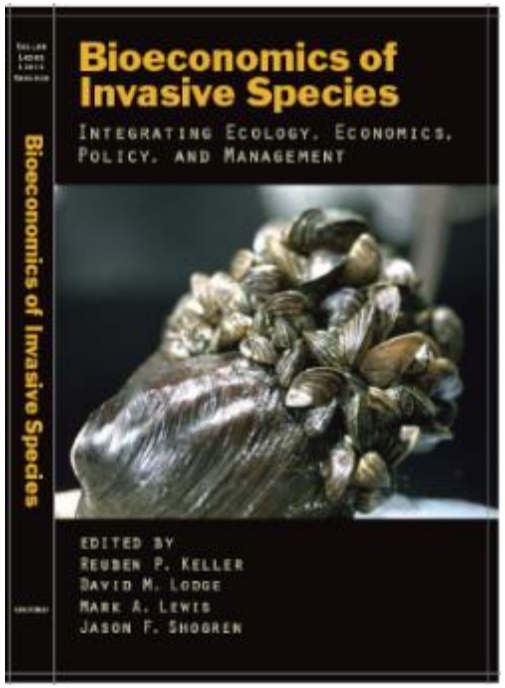
Westslope Cutthroat Trout
Oncorhynchus clarkii

Florida Gar
Lepisosteus platyrhincus

(Howeth et al. 2016)

Species profiling: benefits > costs

Australian Weed Risk Assessment (actual policy)
(Keller, Lodge Finnoff 2007)



Crayfish risk assessment
(Zeng et al. 2015)

USA reptile risk assessment
(Springborn, Romagosa, Keller 2011)

USA mollusc risk assessment
(Keller et al. 2007)

Great Lakes aquatic plant risk assessment
(Gantz et al. 2015)

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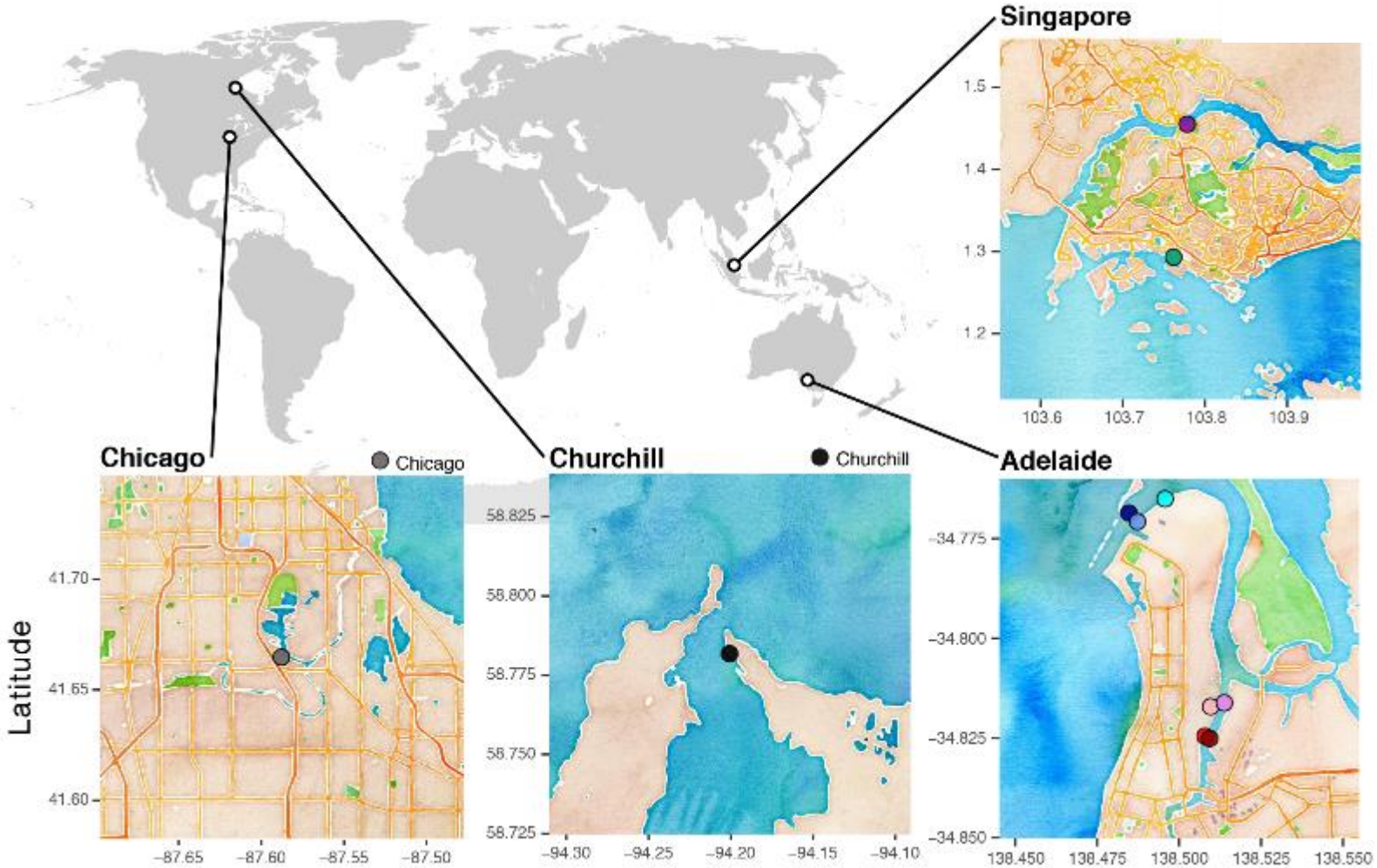
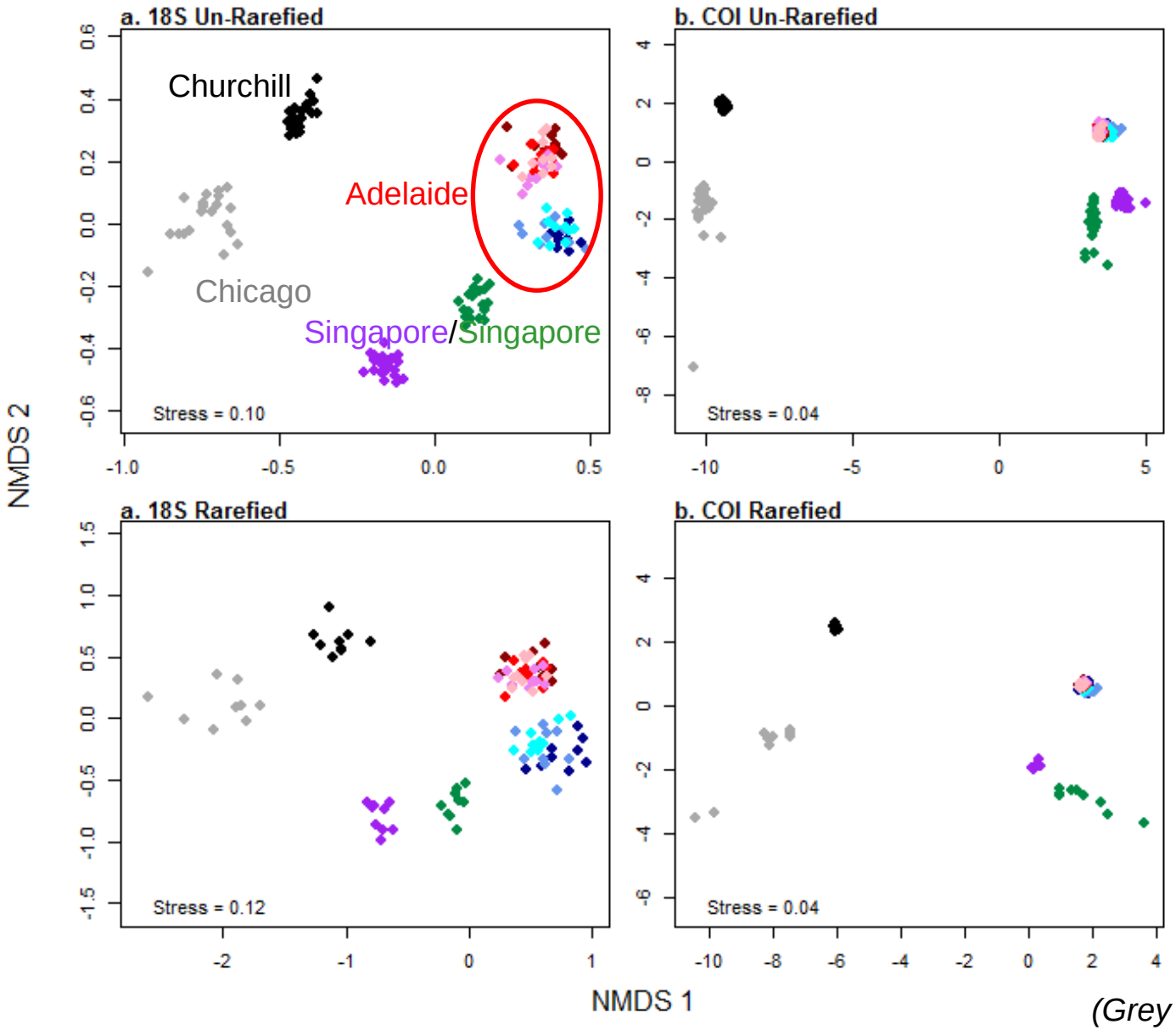
(Lodge et al. 2016 ARER)

Asian carps: imminent threat to Great Lakes . . .

Sampling eDNA in Ports



Multivariate clustering of OTUs



(Grey et al. in review)


eDNA
DETECTION
CREATES
OPPORTUNITY
TO MANAGE
MOTIVATES

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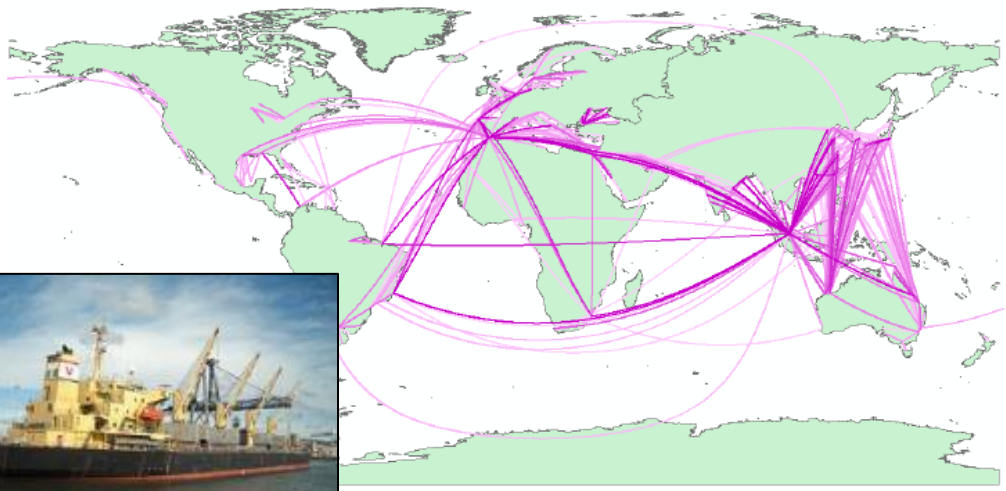
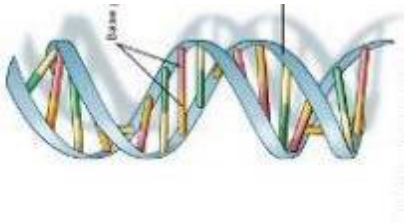
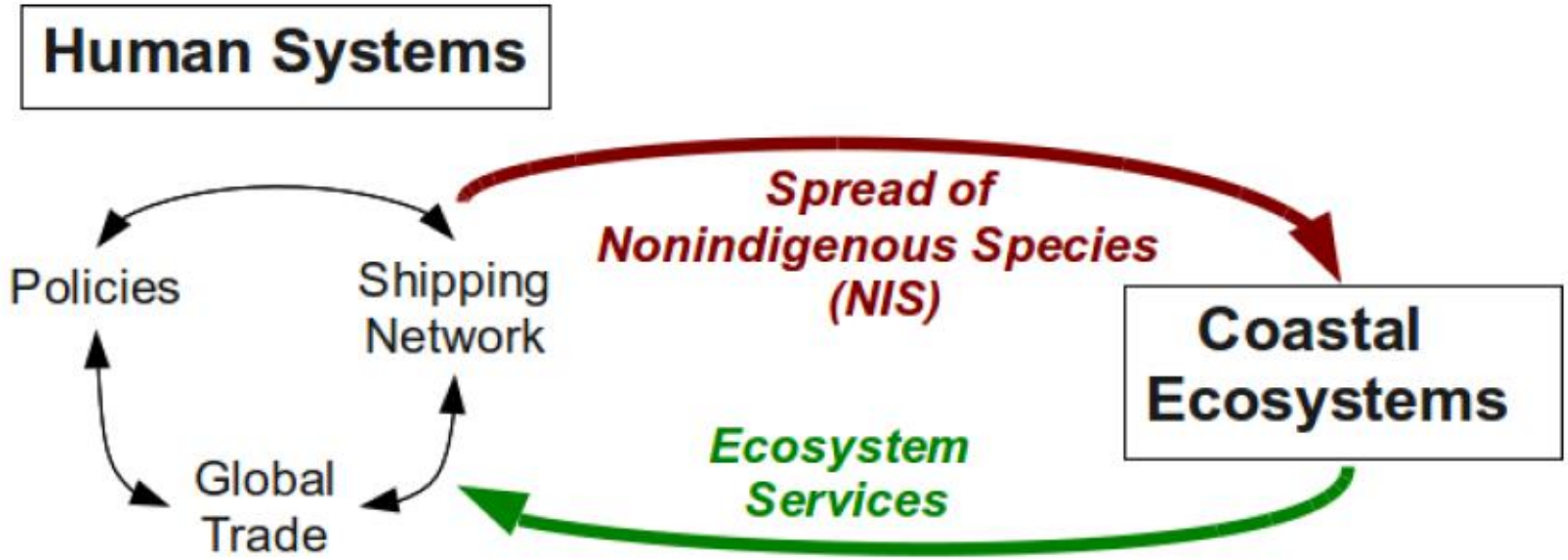
(Lodge et al. 2016 ARER)

Forecasting spread in global shipping

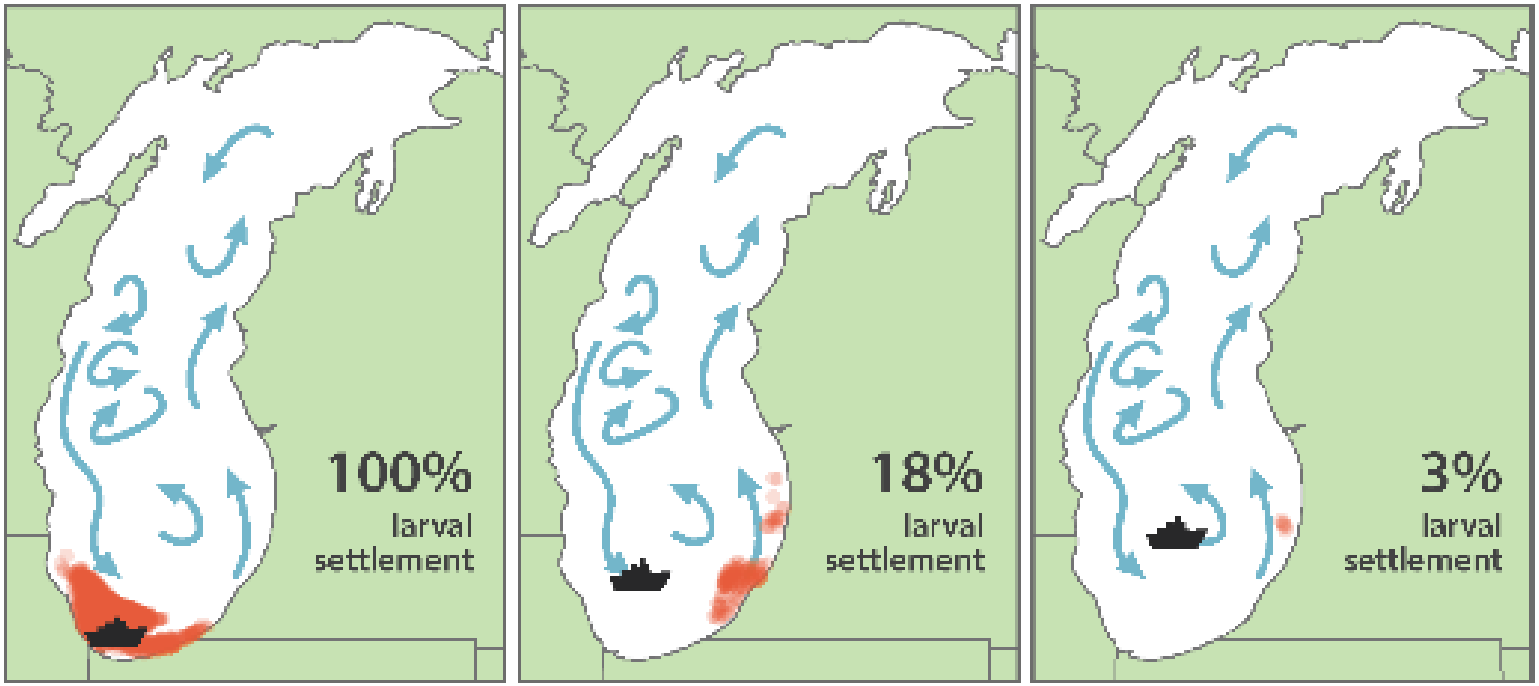


US NSF Coastal SEES program, 5 yr, biologists, computer scientists, economists, policy analyst at four universities





Forecasting Spread & Larval Settlement: Location of Deballasting

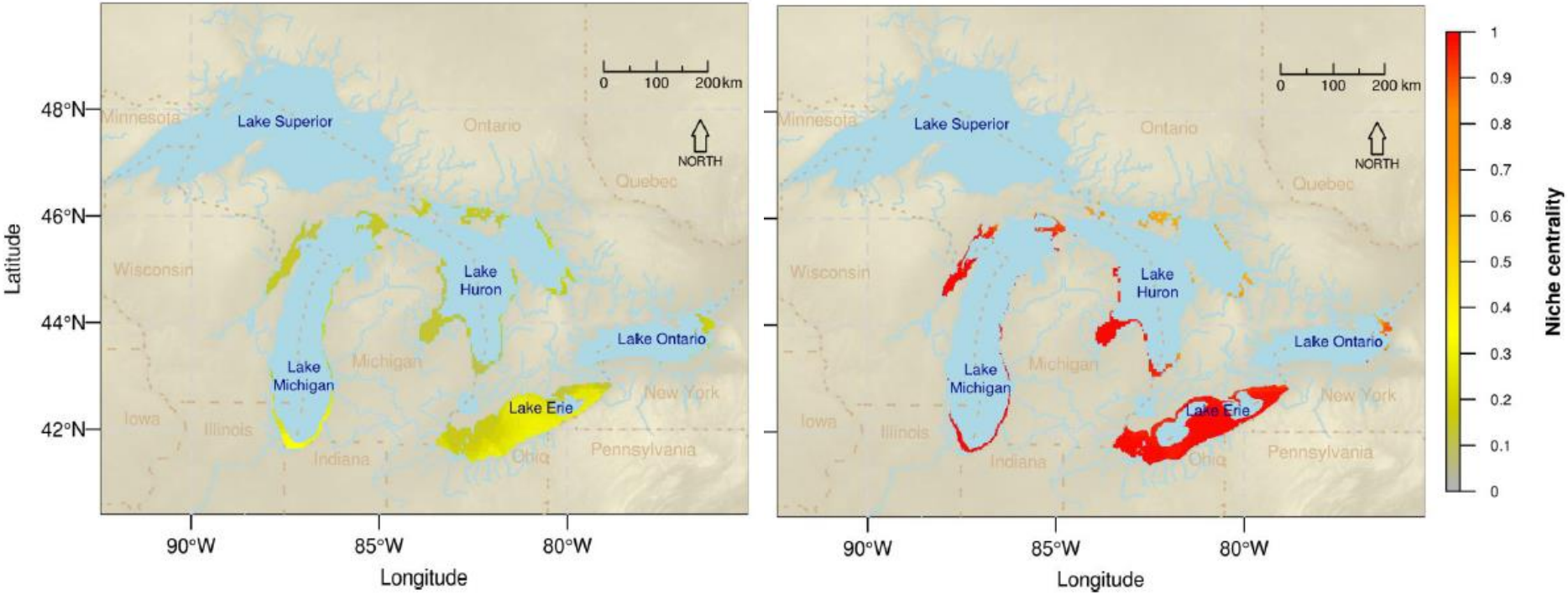


(Beletsky et al. 2017 JGLR)

Improved Species Distribution Modeling: Range-Bagging and Accounting for Habitat

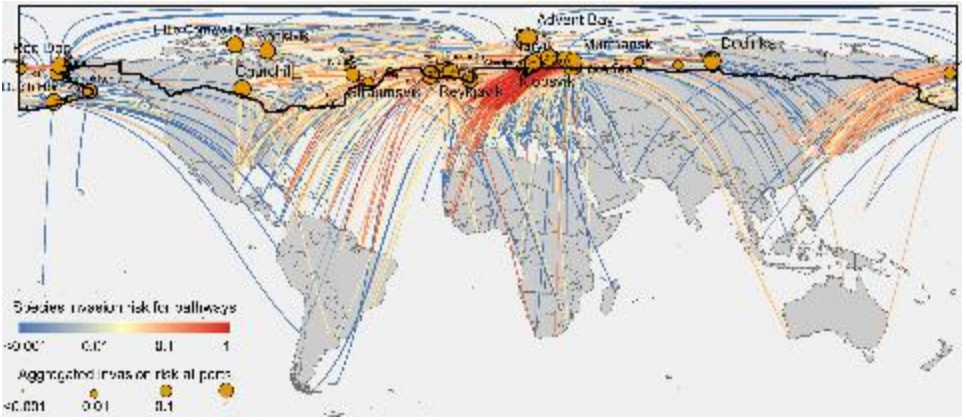
Golden Mussel

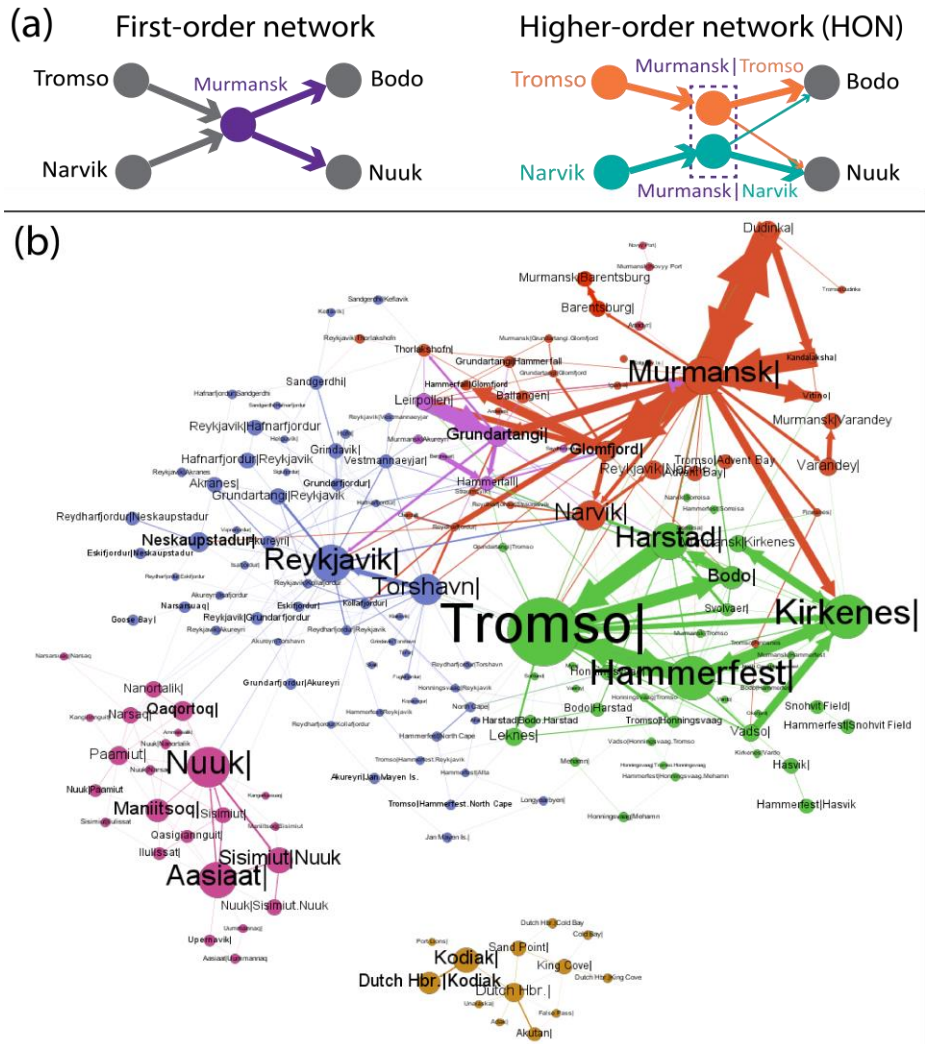
N Snakehead



(Drake 2015 J R Soc Interface; Kramer et al. 2016 Ecosphere)

Voyage-specific Risk Assessments for Arctic Shipping





(Xu, Chawla et al. in review)

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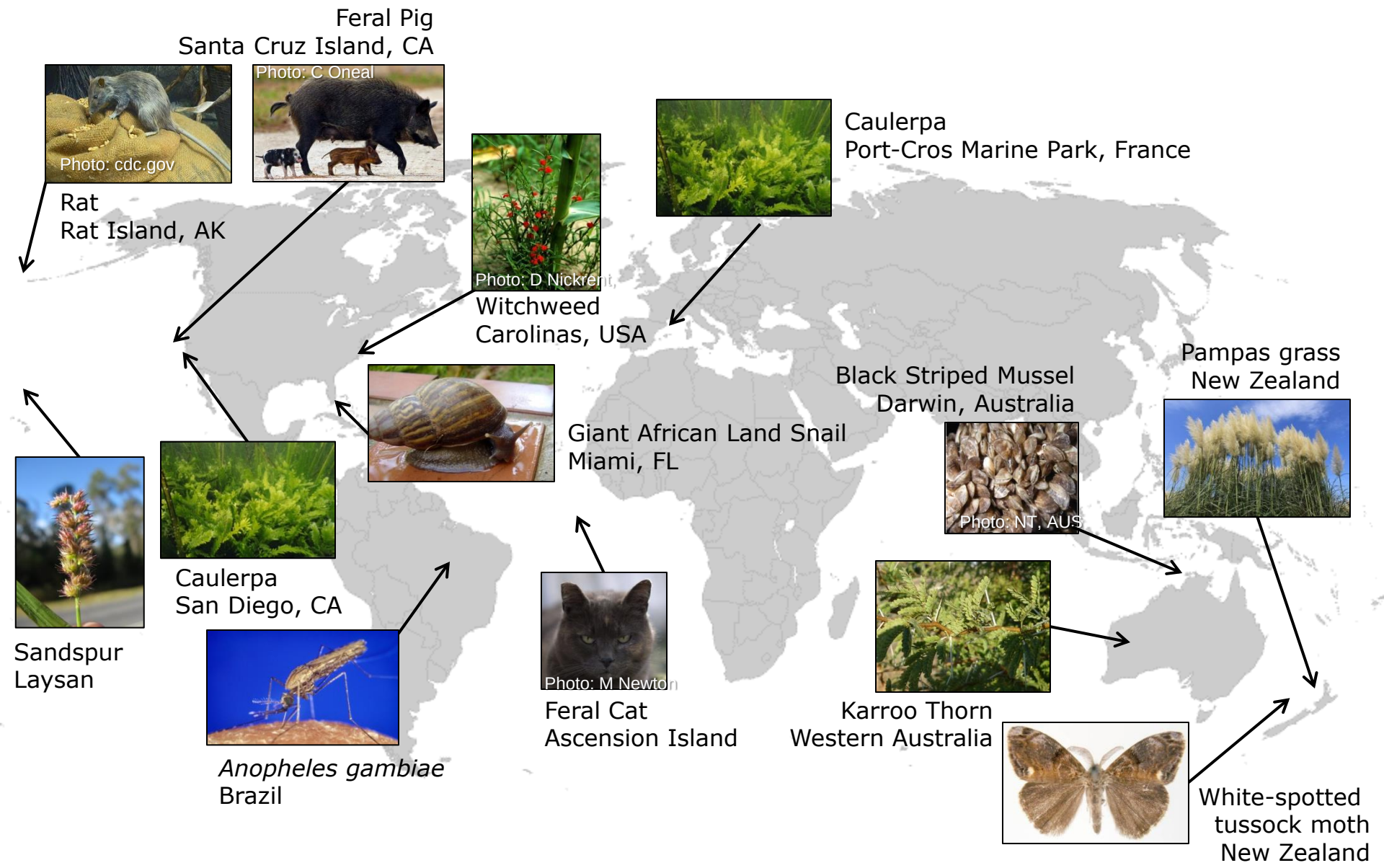
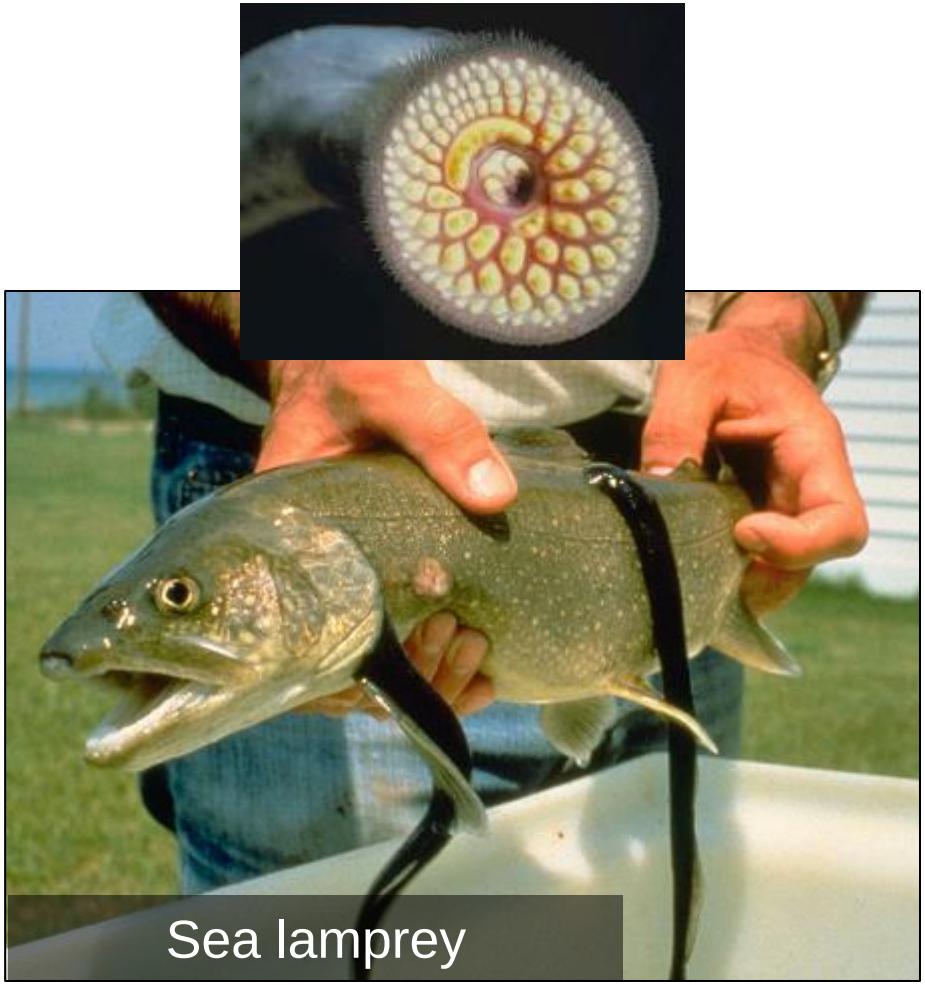
(Lodge et al. 2016 ARER)

Eradication (not just for islands)

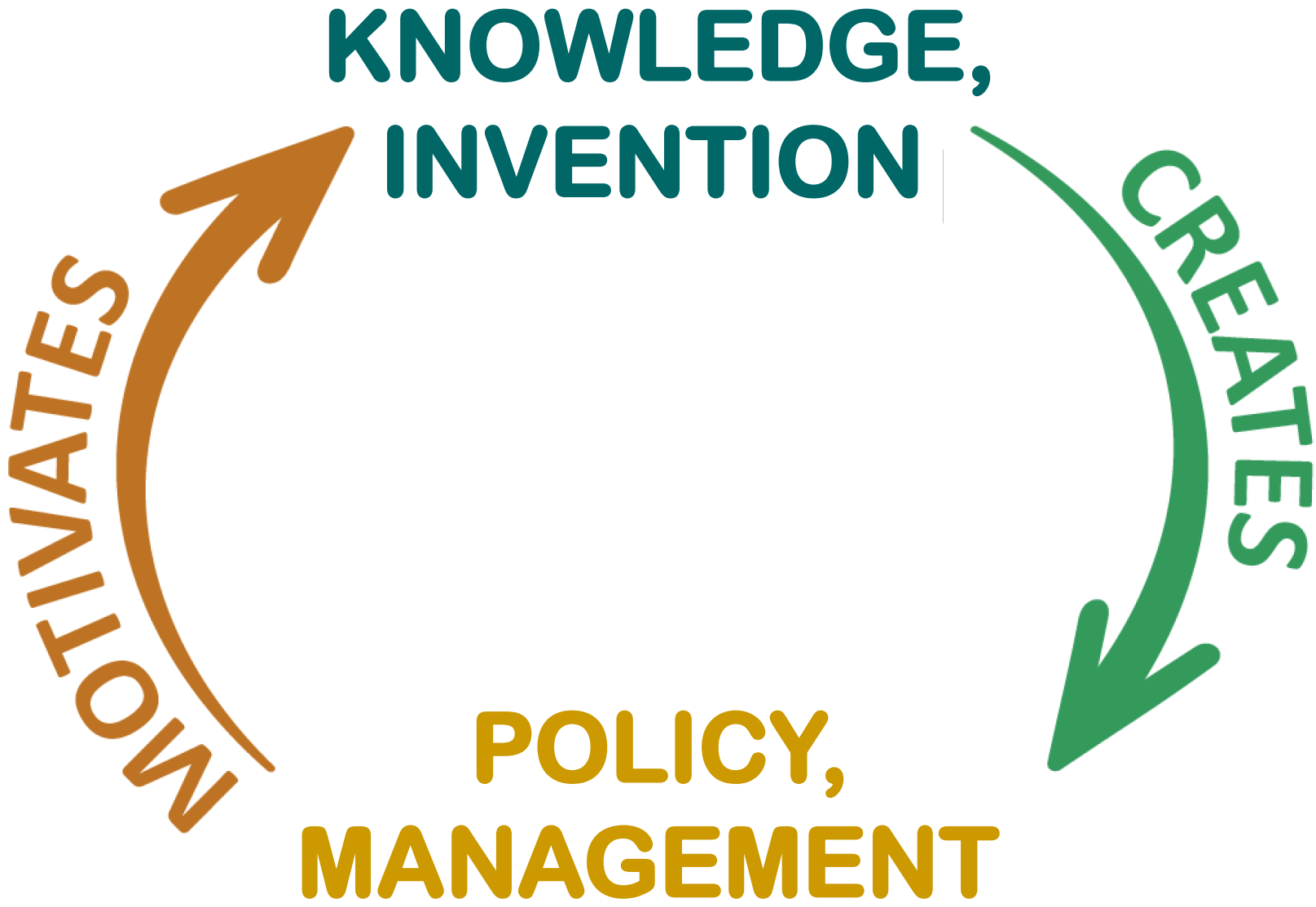


Control



Sea lamprey

Johnson grass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