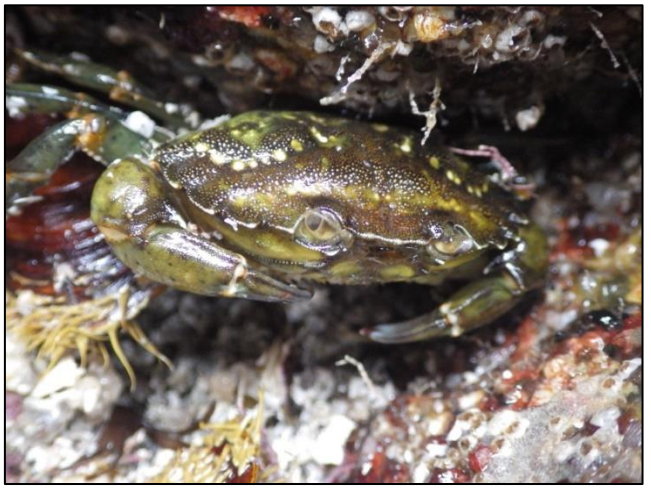
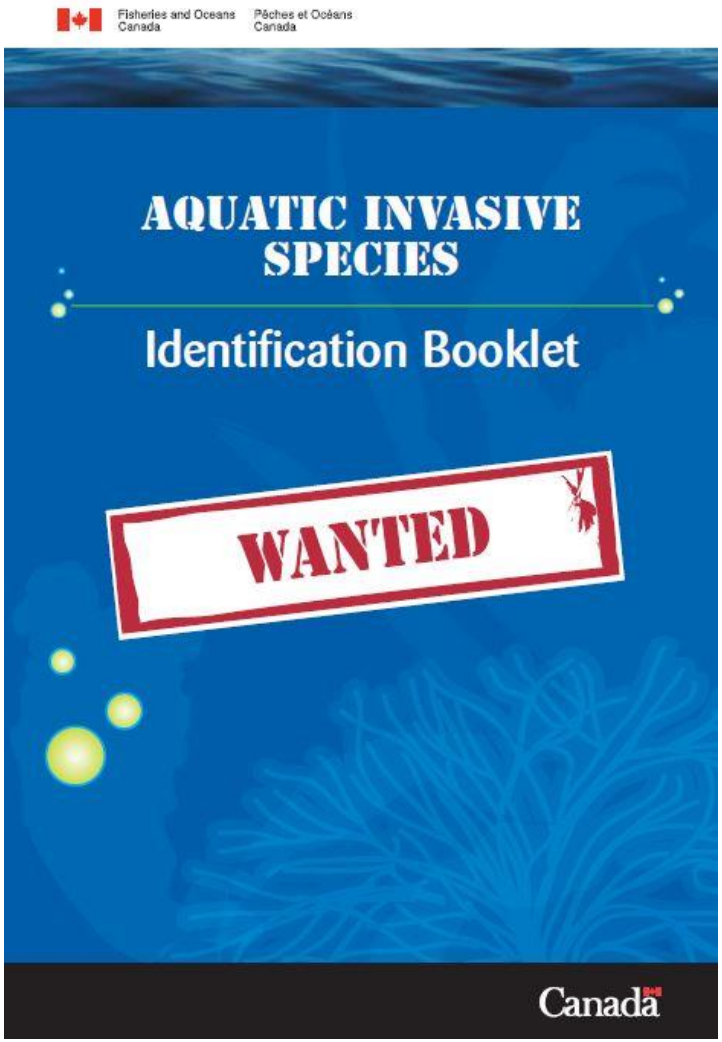
Biological Invasions in Marine Systems



Biological Invasions



http://waves-vagues.dfo-mpo.gc.ca/Library/365586.pdf

Biological Invasions Outline

Introduction:

- Basic concepts
- Brief history
- Impacts on Economy, Human Health & Ecology

Pathways in Marine Systems

- Shipping (Boring, Fouling, Ballast Water)
- Movie: Ballast Water

Biological Invasions

Introduction & establishment of species beyond their historical range

Introduction:

I. Natural range expansion

II. Human introductions

Establishment:

III. Survival

IV. Reproduction

Biological Invasions

Introduction:

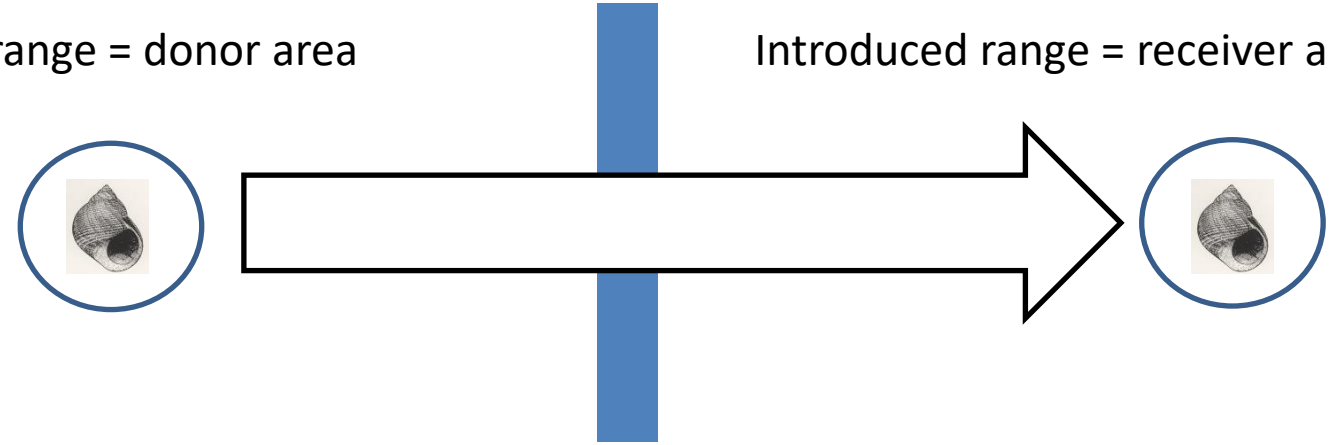
Native species

Introduced species

Barrier

Historical range = donor area

Introduced range = receiver area

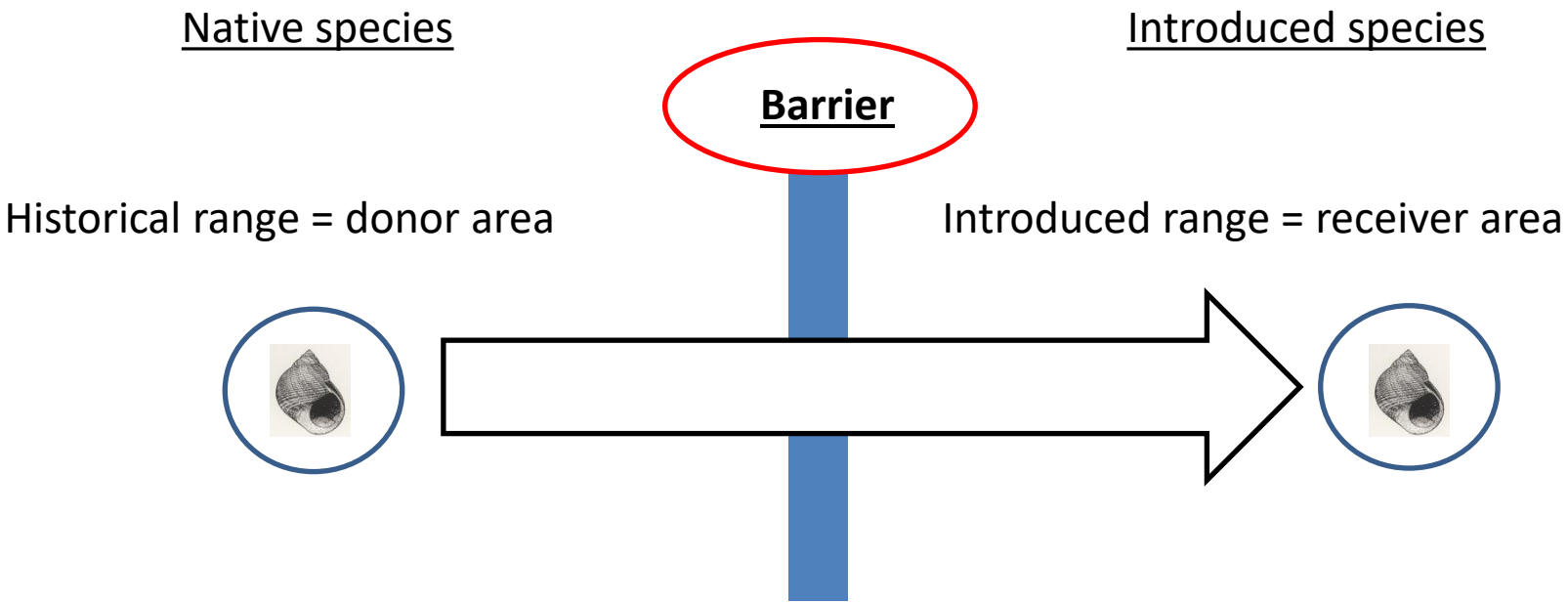


Synonyms: = indigenous

= non-native
= exotic
= alien
= non-indigenous

Biological Invasions

Introduction:



Barriers

Geographical obstacles: oceans, mountains, deserts
Gradients: temperature, salinity, pressure, chemical environment

Human Introductions

Unintentional introductions:

"hitchhikers" & "stowaways"
(e.g. rats, incl. parasites)

accidental release / escape
(e.g. domestic animals, pets,
ornamental plants)

Intentional introductions:

agriculture, aquaculture, hunting
(e.g. rabbits in Australia)

biocontrol
(e.g. myxoma virus in Australia, 1950ies,
→ Myxomatosis in rabbits)

Vectors, Invasive Hotspots & Pathways

Vector: Transport vehicle

- Ship
- Airplane
- Car

etc.

Invasive "hotspots"

- Seaports
- Airports

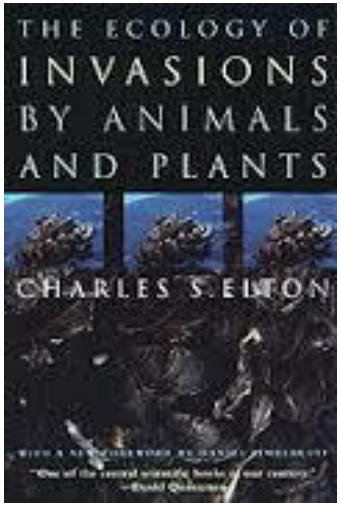
Pathways:

1. **Corridor** between donor & receiver area
2. **Medium / Carrier**

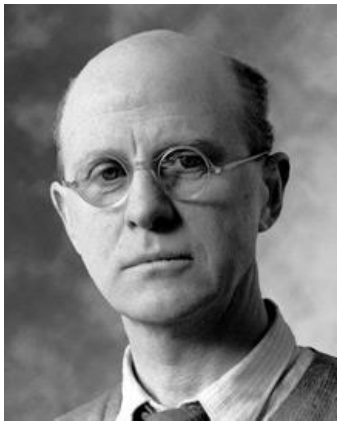
- Ballast water
- Shipp hulls
- Plant material
- Hosts

etc.

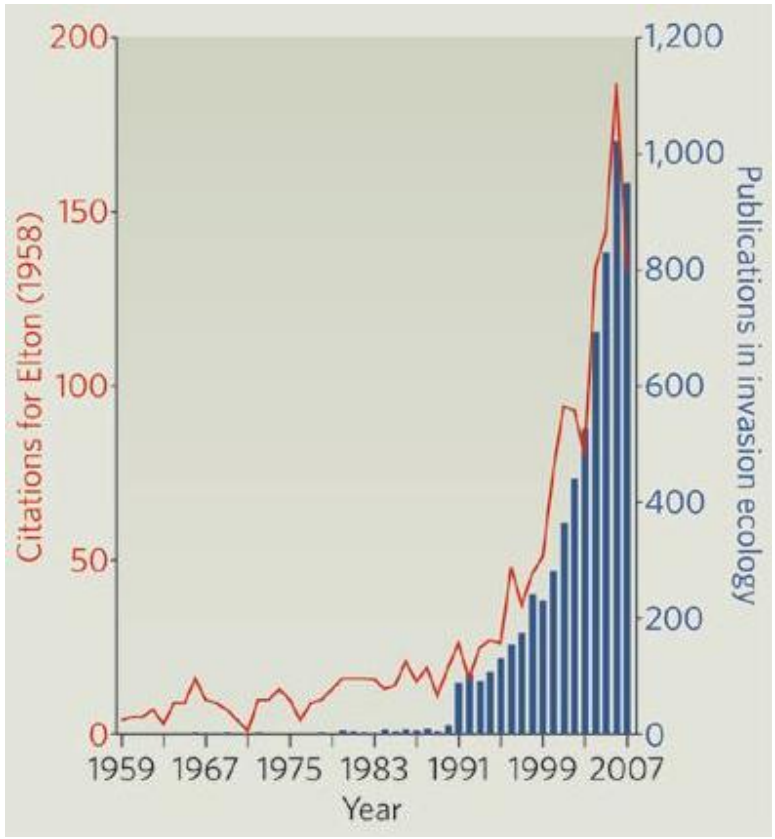
History of Biological Invasions



(1958)



Charles S. Elton
(1900-1991)



Key Questions:

Why and how are species dispersed by human activities?

What is the negative impact of species in a new environment?

How can this be prevented?

Invasions research increased in the 1980ies

Ricciardi & MacIsaac 2008, Nature 452

Definitions

Introduced species:

A species intentionally or unintentionally transported and released by humans into an environment outside its historical range.

Invasive species:

An introduced species with an ecological, economic or human health related impact.

Impacts of Invasive Species

- Economy
- Human Health
- Ecology

Impacts on Economy & Human Health

BBC NEWS

Jellyfish threaten Israeli power plant

5 July 2011 Last updated at 23:54 BST

Nomadic jellyfish
Rhopilema nomadica Galil, 1990
Red Sea → Mediterranean Sea

Venomous
Disrupting Fisheries & Tourism
Clogging Power plants: $50,000 (in 2001)

www.cabi.org

Impacts on Economy & Human Health

Pufferfish *Lagocephalus sceleratus* (Gmelin, 1789)
Red Sea → Mediterranean Sea

Disrupting Fisheries:
$10 Million damage (Turkey, in 2014)

Venomous, Tetrodotoxin
Disrupting Tourism
Deaths reported from Egypt & Israel

Nader et al. 2012

Impacts on Ecology

at the Population, Community & Ecosystem Level:

- predation of native species
- competition with native species
- facilitation of native species by ecosystem engineers
- behavioral & morphological changes in native species (phenotypic plasticity)
- genetic & evolutionary consequences → hybridization (loss of genetic diversity)
- extinction of native & endemic species

Impacts on Ecology

Ecology, 65(2), 1984, pp. 370–381

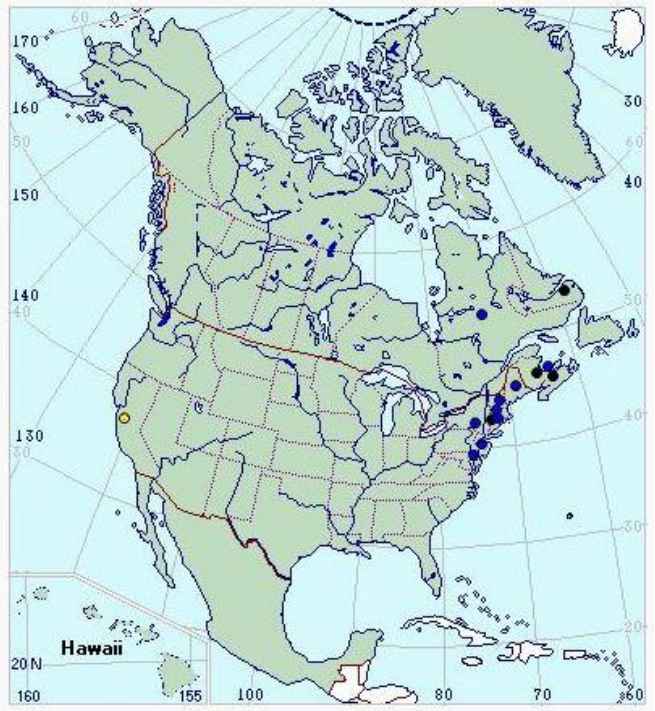
HABITAT AND COMMUNITY MODIFICATION BY AN INTRODUCED HERBIVOROUS SNAIL[1]

MARK D. BERTNESS
Section of Population Biology and Genetics, Brown University, Providence, Rhode Island 02912 USA

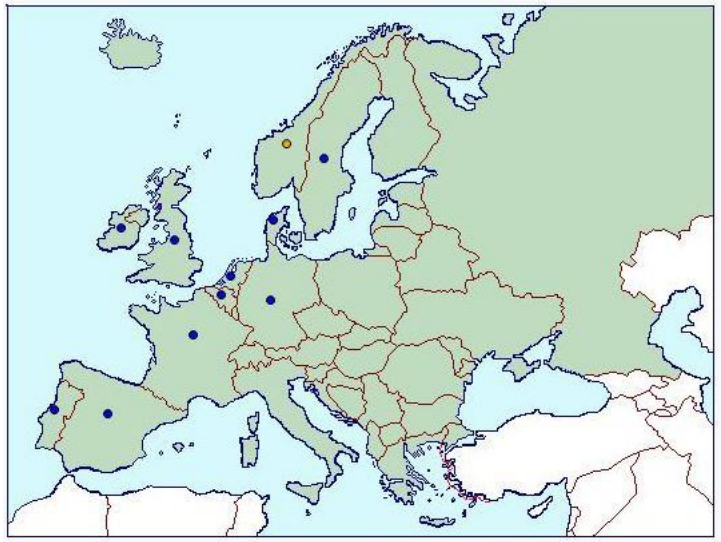
common periwinkle *Littorina littorea* (Linnaeus, 1758)

Periwinkle Introduction

Introduced



Native



Viking Ships

Periwinkle Impact

Littorina grazing & bulldozing

barnacle larvae

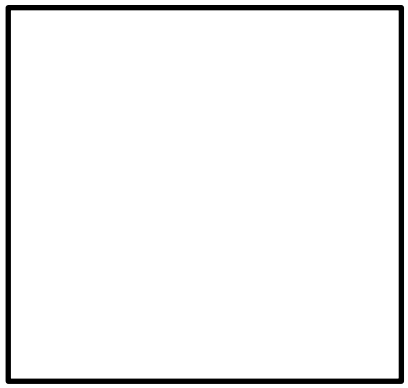
Periwinkle Removal Experiment

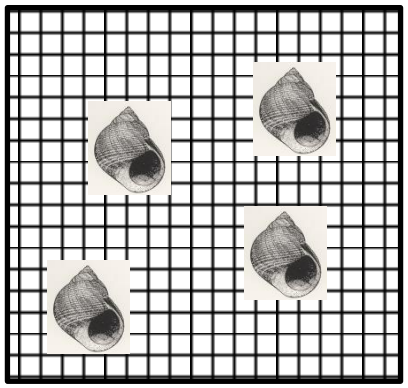
3 Treatments

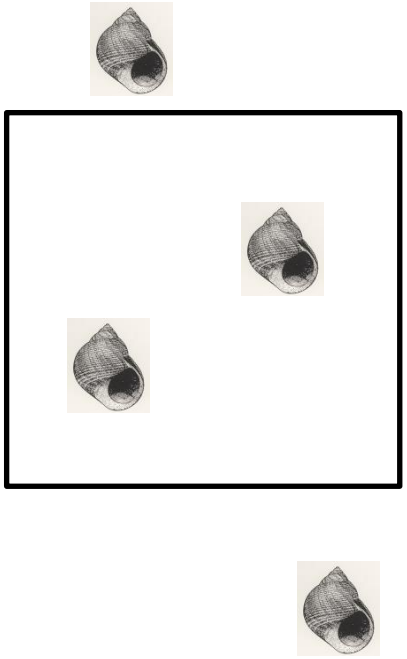
Periwinkle Removal

Caged Control

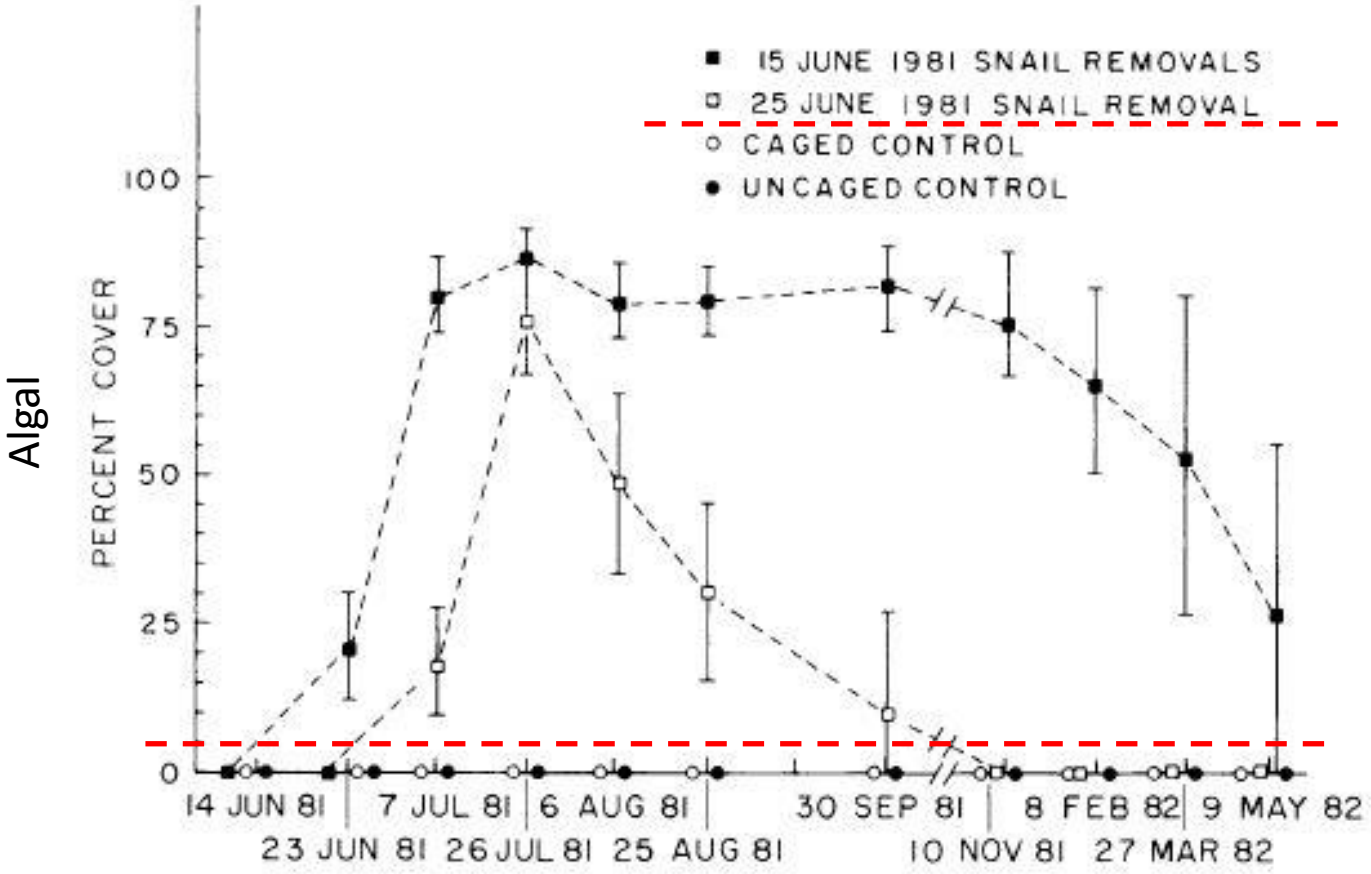
Uncaged Control







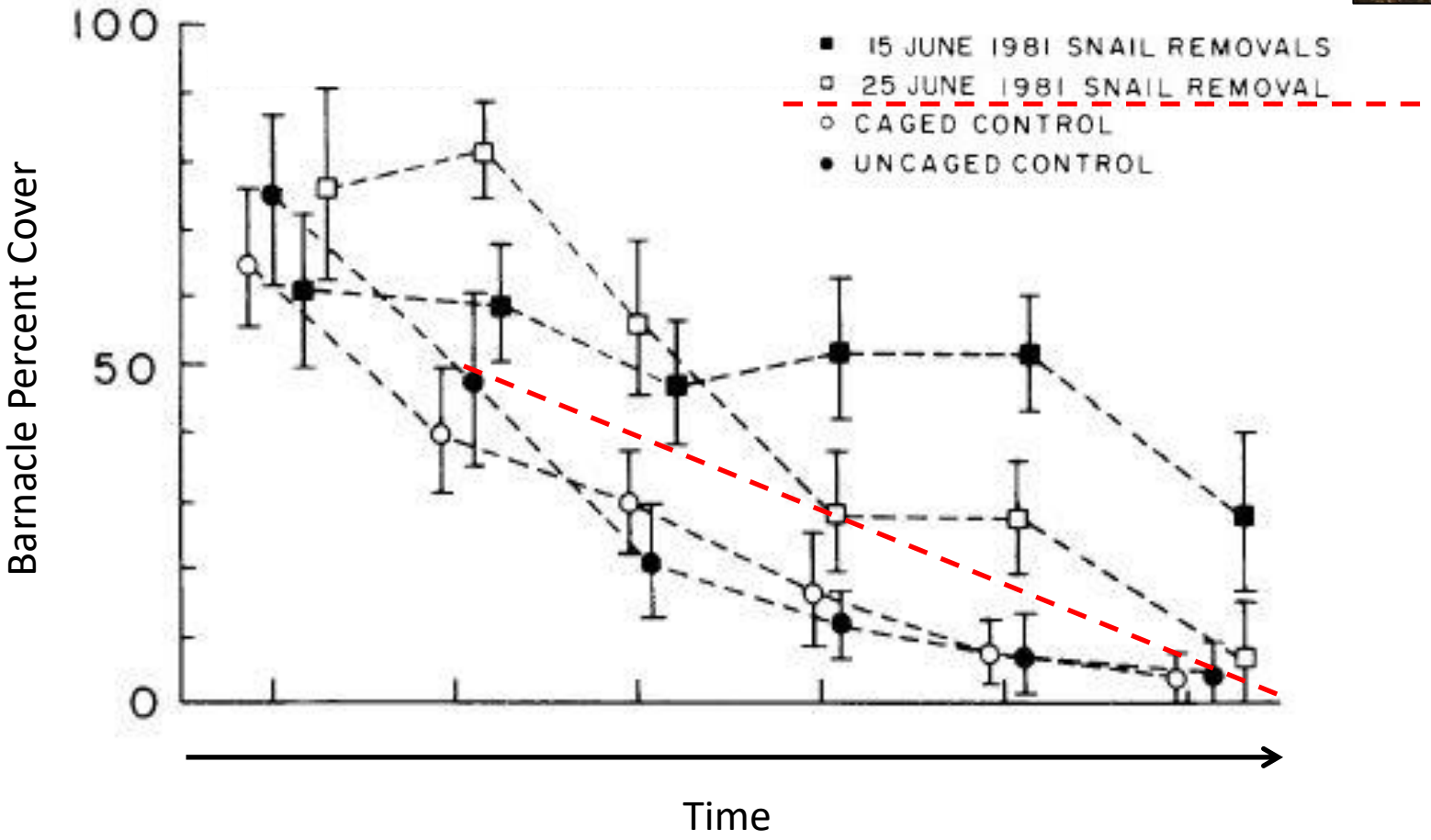
Periwinkle Removal Impact on Algae



Periwinkle removal increased percent cover of algae

→ Periwinkle grazing controls algae

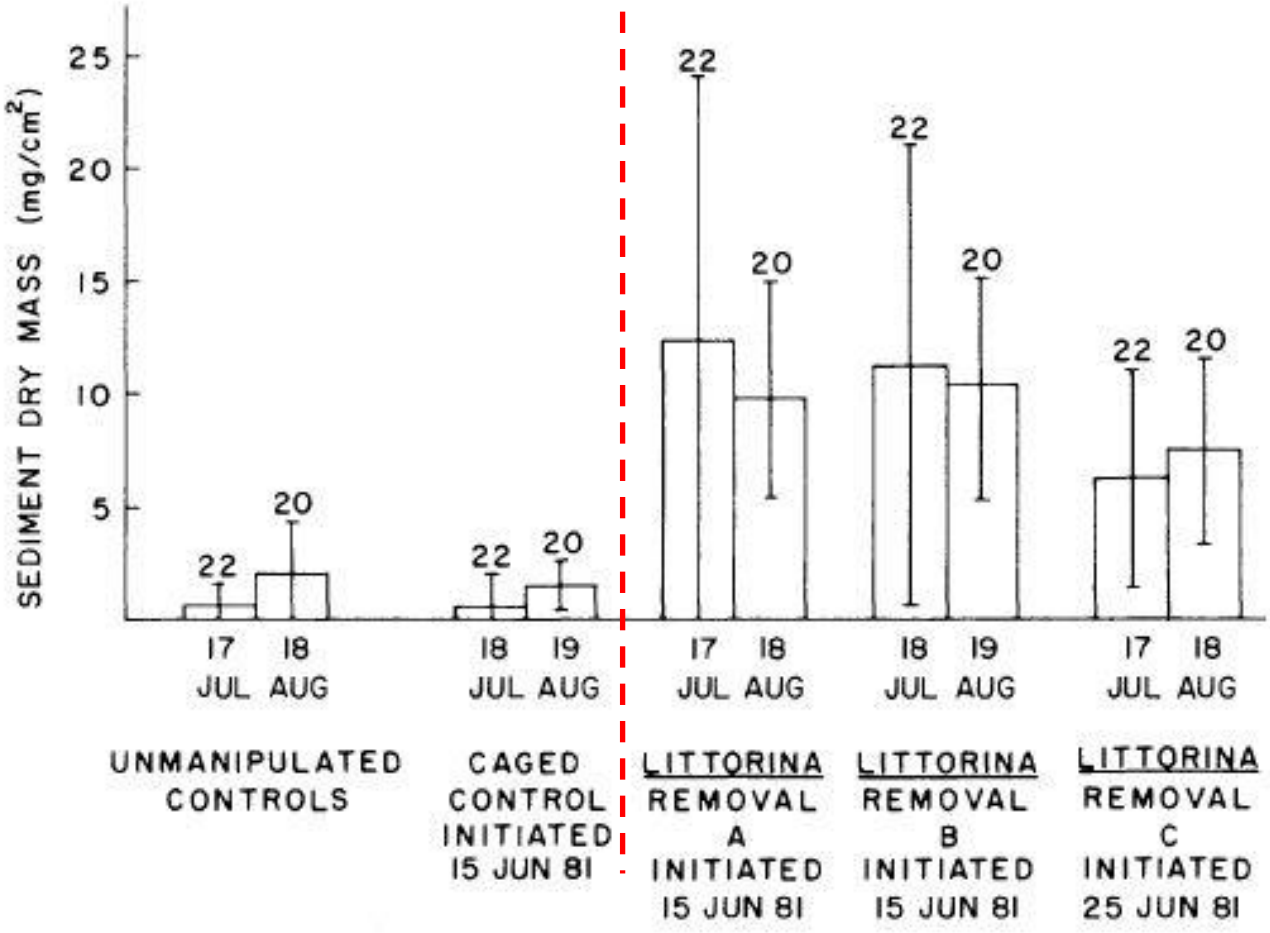
Periwinkle Impact on Barnacles



Periwinkle removal increased percent cover of barnacles

→ Periwinkle bulldozing affects barnacles

Periwinkle Impact on Sediments



Periwinkle removal increased sediment dry mass

→ Periwinkle activity affects sediments

Snail Impact on Cordgrass (*Spartina*)

Snail removal increased cordgrass biomass

→ Snails control cordgrass

Impact on Ecology

Ecology, 65(2), 1984, pp. 370–381

HABITAT AND COMMUNITY MODIFICATION BY AN INTRODUCED HERBIVOROUS SNAIL[1]

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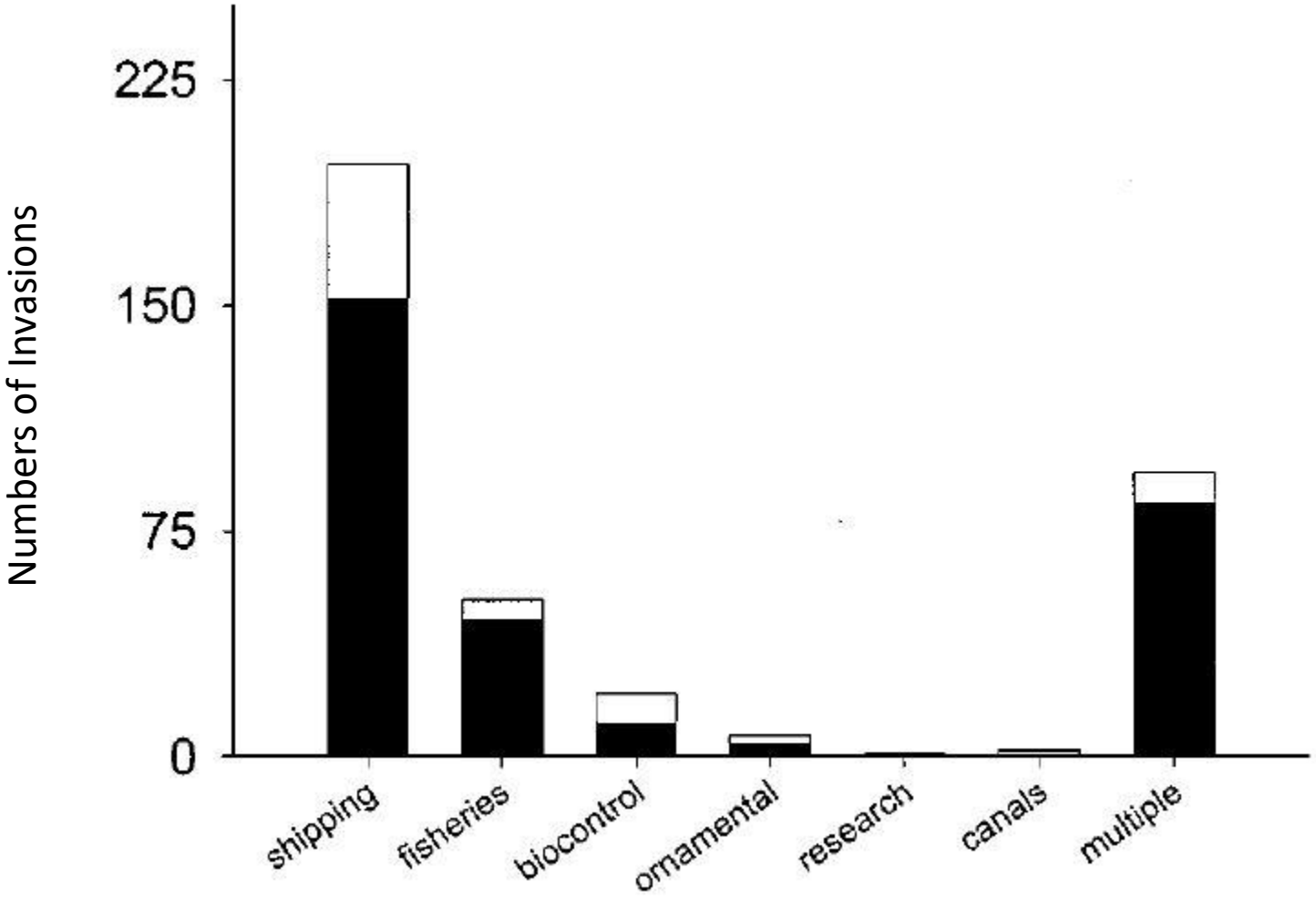
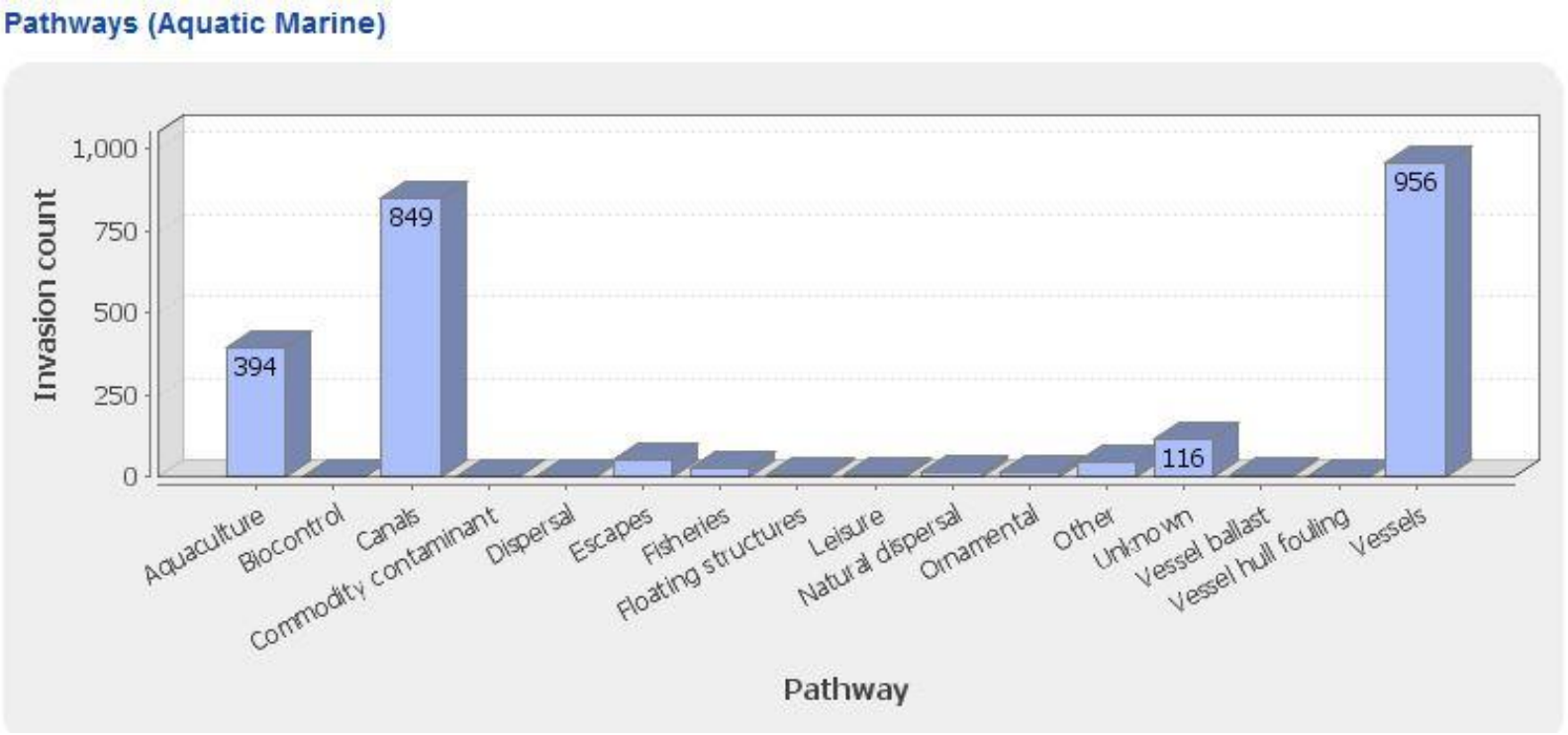
Pathways in Marine Systems: Shipping

Coastal Invasions in North America



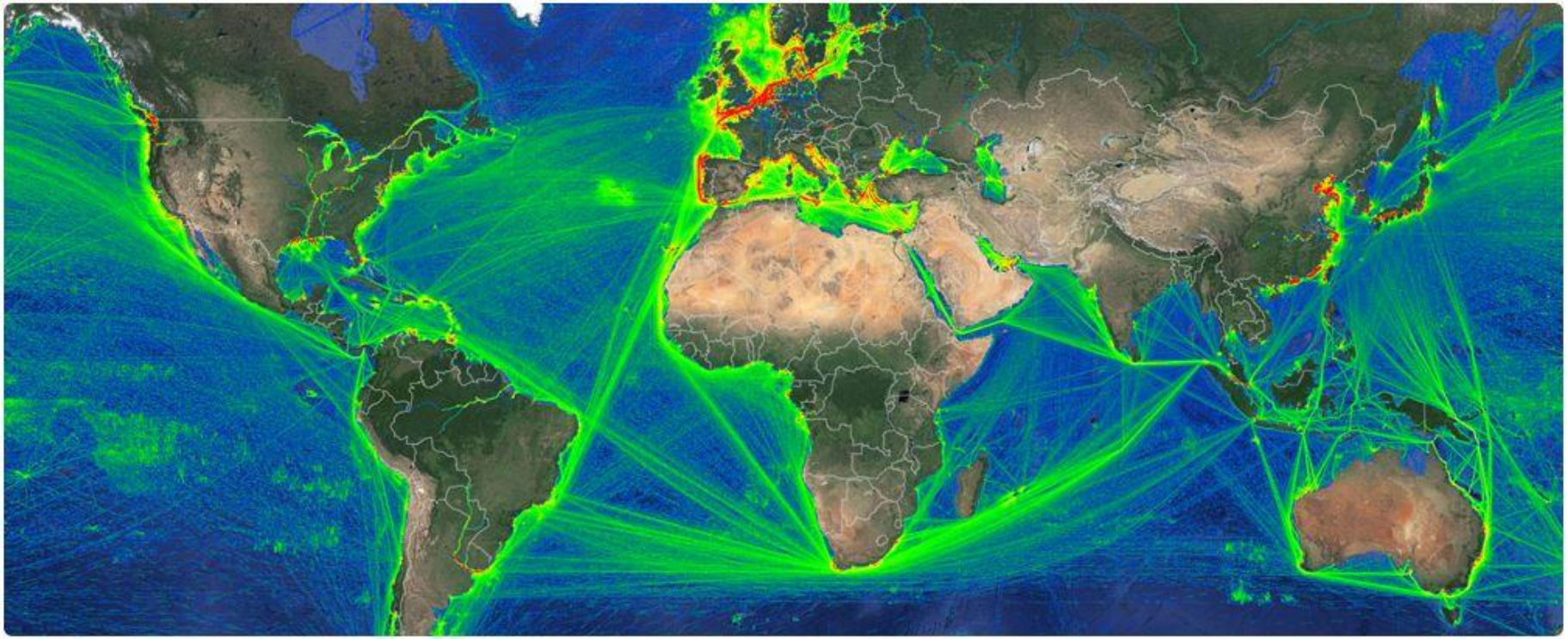
Ruiz et al., Annu. Rev. Ecol. Syst. 2000. 31:481–531

Coastal Invasions in Europe



http://www.europe-aliens.org/default.do

Global Shipping

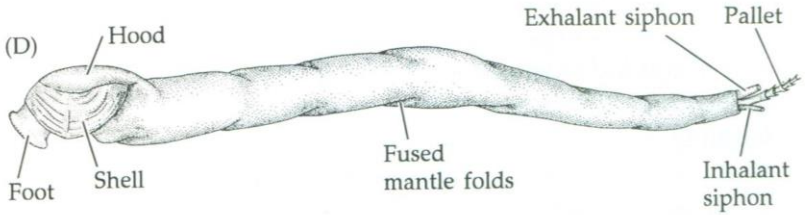


Transoceanic & coastal shipping

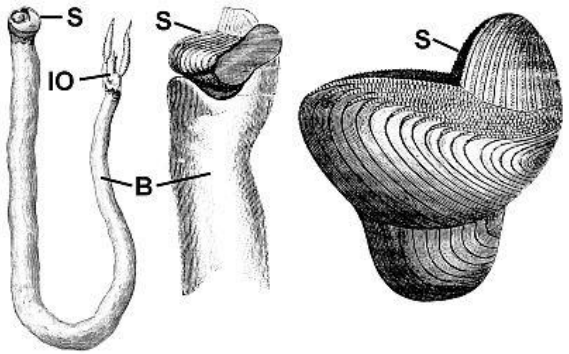
https://www.marinetraffic.com

Historic Case: Ship Hull Boring

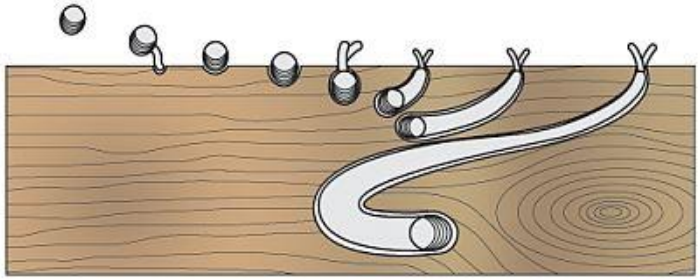
Atlantic shipworm *Teredo navalis* (a clam)



Brusca & Brusca 2003



Popular Science Monthly, August 1878



Teredo settling & growth

Columbus VS *Teredo*

1504: "… rotten, worm-eaten … more riddled with holes than a honeycomb…

With three pumps, pots and kettles,
and with all hands working, they could
not keep down the water which came
into the ship, and there was no other remedy
for the havoc which the ***worm*** had wrought…

my ship was sinking under me…"

Teredo Damage in San Francisco Bay

1913 *Teredo* invaded San Francisco Bay
1919-1921: $ 3.1 billion damage
→ “Stepping stone invasion”

Ship Hull Fouling

Vol. 11: 179–191, 2010
doi: 10.3354/ab00302

AQUATIC BIOLOGY
Aquat Biol

Published online December 21

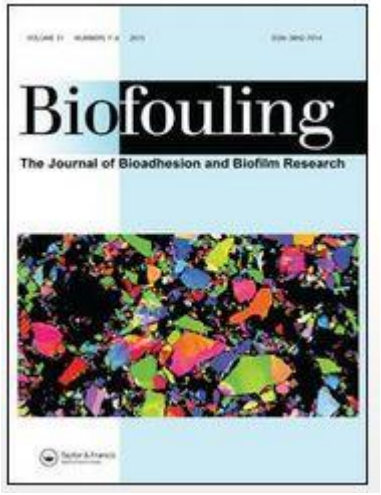
Recreational boats as potential vectors of marine organisms at an invasion hotspot

Ian C. Davidson[1,*], Chela J. Zabin[2], Andrew L. Chang[2], Christopher W. Brown[2], Mark D. Sytsma[1], Gregory M. Ruiz[3]

Hull Fouling

<u>Sessile & mobile species:</u>

Polychaetes, crustaceans, barnacles, mussels, tunicates, hydroids, bryozoans, sponges, algae…



http://www.tandfonline.com/toc/gbif20/current

Global Shipping & Ballast Water

80 % of the world's commodities transported by large ships

ca. 35,000 large ships world wide

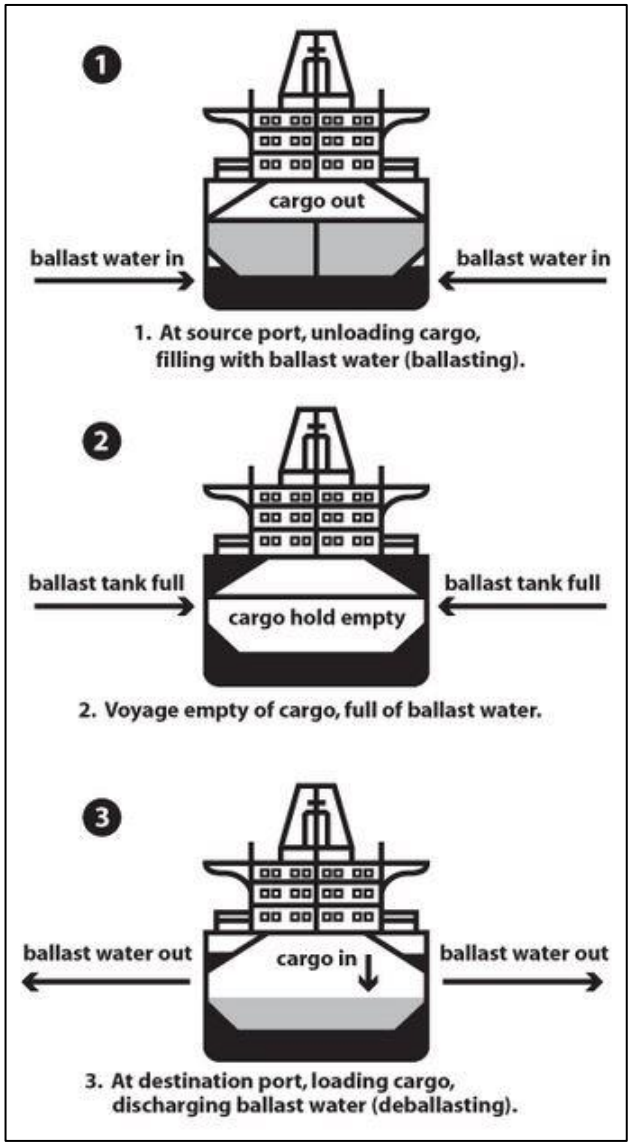
Ballast Water

Purpose: ship balance & stability, submerged propeller & rudder

Ballast water collected in ports / bays (rich in larvae & food)

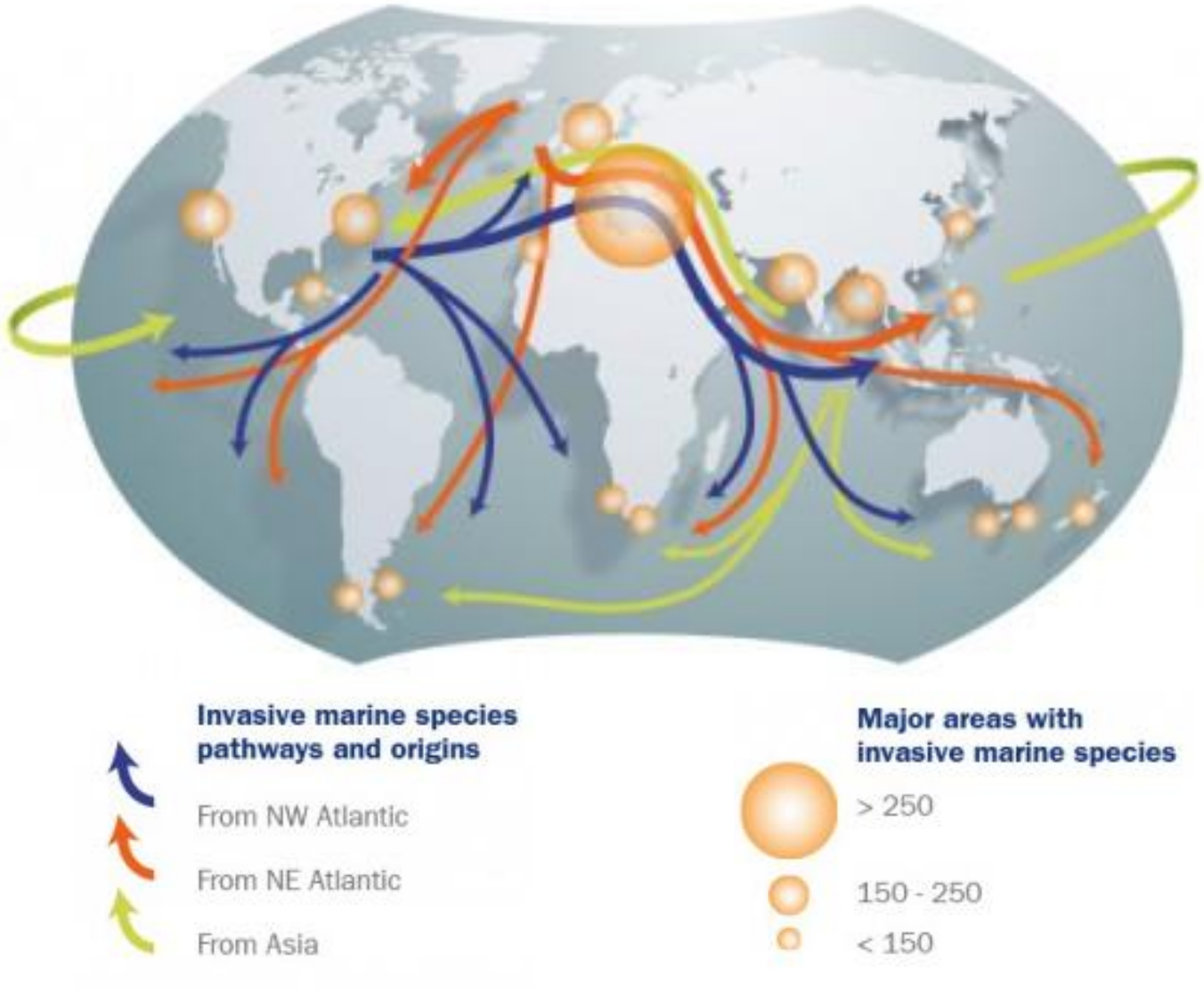
Annually ballast water discharge in ports / bays
79 million tons BW (US)
43.7 million tons (Canada)

→ Ports are invasive hot spots



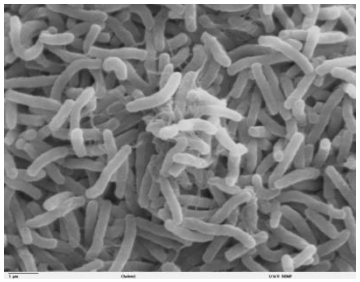
Ruiz et al. 2000, Gollasch 2007, DFO 2017

Global Ballast Water Transport



http://www.safetyatdockwise.com/ballast-water-.html

Ballast Water Species

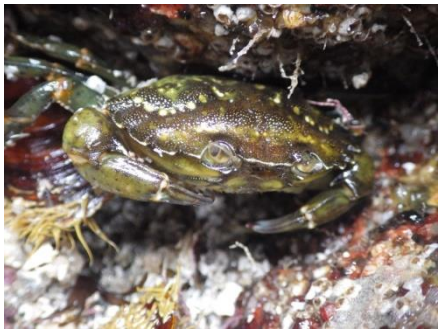


Vibrio cholerae

Neogobius melanostomus

Dreissena polymorpha

Cercopagis pengoi



Carcinus maenus

Asterias amurensis

Eriocheir sinensis

Undaria pinnatifida

Mnemiopsis leidyi

Ten of the Most Unwanted

Marine plants, animals and microbes are being carried around the world attached to the hulls of ships and in ships' ballast water. When discharged into new environments, they may become invaders and seriously disrupt the native ecology and economy. Introduced pathogens may cause diseases and death in humans.

Cholera
Vibrio cholerae (various strains)

Native to: Various strains with broad ranges.
Introduced to: South America, Gulf of Mexico and other areas.
Impacts: Some cholera epidemics appear to be directly associated with ballast water. One example is an epidemic that began simultaneously at three separate ports in Peru in 1991, sweeping across South America, affecting more than a million people and killing more than ten thousand by 1994. This strain had previously been reported only in Bangladesh.

North American Comb Jelly
Mnemiopsis leidyi

Native to: Eastern Seaboard of the Americas
Introduced to: Black, Azov and Caspian Seas
Impacts: Reproduces rapidly (self fertilising hermaphrodite) under favourable conditions. Feeds voraciously on zooplankton. Depletes zooplankton stocks: altering food web and ecosystem function. Contributed significantly to collapse of Black and Azov Sea fisheries in 1990s, with massive economic and social impact. Now threatens similar impact in Caspian Sea.

Cladoceran Water Flea
Cercopagis pengoi

Native to: Black and Caspian Seas
Introduced to: Baltic Sea
Impacts: Reproduces to form very large populations that dominate the zooplankton community and clog fishing nets and trawls, with associated economic impacts.

North Pacific Seastar
Asterias amurensis

Native to: Northern Pacific
Introduced to: Southern Australia
Impacts: Reproduces in large numbers, reaching 'plague' proportions rapidly in invaded environments. Feeds on shellfish, including commercially valuable scallop, oyster and clam species.

Mitten Crab
Eriocheir sinensis

Native to: Northern Asia
Introduced to: Western Europe, Baltic Sea and West Coast North America
Impacts: Undergoes mass migrations for reproductive purposes. Burrows into river banks and dykes causing erosion and siltation. Preys on native fish and invertebrate species, causing local extinctions during population outbreaks. Interferes with fishing activities.

Zebra Mussel
Dreissena polymorpha

Native to: Eastern Europe (Black Sea)
Introduced to: Western and northern Europe, including Ireland and Baltic Sea; eastern half of North America
Impacts: Fouls all available hard surfaces in mass numbers. Displaces native aquatic life. Alters habitat, ecosystem and food web. Causes severe fouling problems on infrastructure and vessels. Blocks water intake pipes, sluices and irrigation ditches. Economic costs to USA alone of around US$750 million to $1 billion between 1989 and 2000.

Toxic Algae (Red/Brown/Green Tides)
Various species

Native to: Various species with broad ranges.
Introduced to: Several species have been transferred to new areas in ships' ballast water.
Impacts: May form Harmful Algae Blooms. Depending on the species, can cause massive kills of marine life through oxygen depletion, release of toxins and/or mucus. Can foul beaches and impact on tourism and recreation. Some species may contaminate filter-feeding shellfish and cause fisheries to be closed. Consumption of contaminated shellfish by humans may cause severe illness and death.

Asian Kelp
Undaria pinnatifida

Native to: Northern Asia
Introduced to: Southern Australia, New Zealand, West Coast of USA, Europe and Argentina
Impacts: Grows and spreads rapidly, both vegetatively and through dispersal of spores. Displaces native algae and marine life. Alters habitat, ecosystem and food web. May affect commercial shellfish stocks through space competition and alteration of habitat.

Round Goby
Neogobius melanostomus

Native to: Black, Azov and Caspian Seas
Introduced to: Baltic Sea and North America
Impacts: Highly adaptable and invasive. Increases in numbers and spreads quickly. Competes for food and habitat with native fishes including commercially important species, and preys on their eggs and young. Spawns multiple times per season and survives in poor water quality.

European Green Crab
Carcinus maenas

Native to: European Atlantic Coast
Introduced to: Southern Australia, South Africa, USA and Japan
Impacts: Highly adaptable and invasive. Resistant to predation due to hard shell. Competes with and displaces native crabs and becomes a dominant species in invaded areas. Consumes and depletes wide range of prey species. Alters inter-tidal rocky shore ecosystem.

Further Information:
Global Ballast Water Management Programme
International Maritime Organization, London, UK
Fax +44 (0)20 7587 3261
Web http://globallast.imo.org

The species presented here are for illustrative purposes only. Their introduced ranges may be greater than depicted. There are numerous other examples of serious marine bio-invasions around the world.

Global Ballast Water Management Programme · GEF · undp · IMO

http://globallast.imo.org/

Ballast Water History

Prior to 1870:
dry ballast use

1870–1880ies:
Ballast water use

1903:
Asian diatom *Odontella (Biddulphia) sinensis*
Asia → North Sea

1912:
Chinese mitten crab *Eriocheir sinensis*
Asia → Germany

- Competition
- Erosion & clogging
- Cumulative damage: 112.546.000 CAD

O. sinensis

E. sinensis

Ballast Water History

1962-1984:
Tens of ballast water invasions reported annually

1975:
First ballast water sampling (Medcof 1975)

1980ies:
First ballast water transport experiments
(e.g. salinity, temperature, light tolerance, starvation etc.)

1985:
First review linking 57 invasive species to ballast water in N America
(Carlton 1985)

2000:
ca. 150 invasive species / 180 invasions linked to ballast water in N America

2017:
ca. 950 invasions linked to ballast water in Europe

Ballast Water History

Since 2006

http://www.aquaticinvasions.net/

Ballast Water Regulation & Management

International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM)

Adoption: 13 February 2004; Entry into force: 8 September 2017

INTERNATIONAL MARITIME ORGANIZATION

Ballast water control:

Ballast water log books & external log book examinations mandatory

Ballast water management:

1. Ballast water exchange at sea
2. Ballast water processing on board

→ Push to make next generation BW processing mandatory

http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships'-Ballast-Water-and-Sediments-(BWM).aspx

Invaders from the Sea (BBC, IMO)

Movie: https://youtu.be/u5JkRtMTEdI