Vector analysis and the role of hull fouling in California's invasion history

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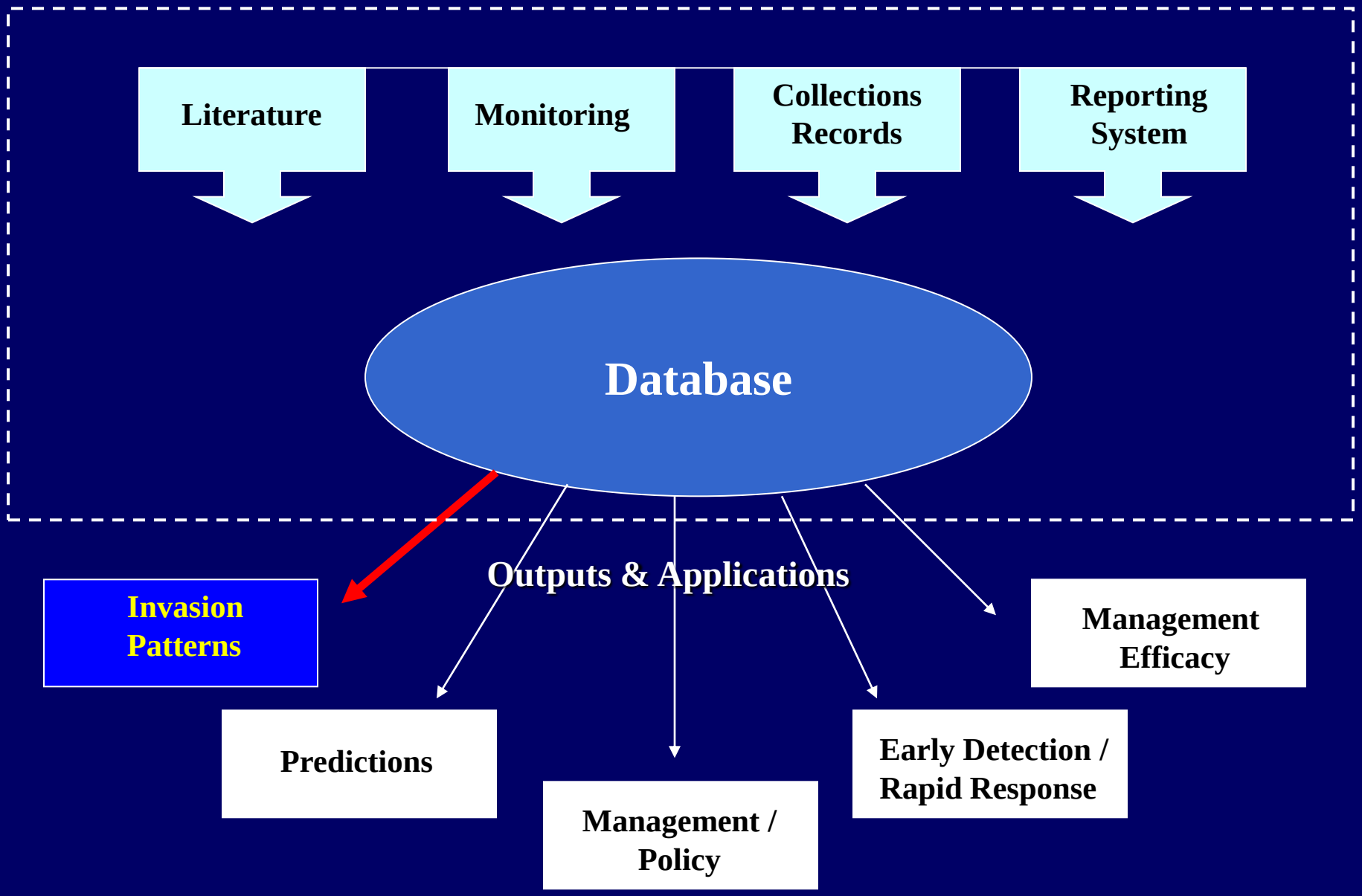
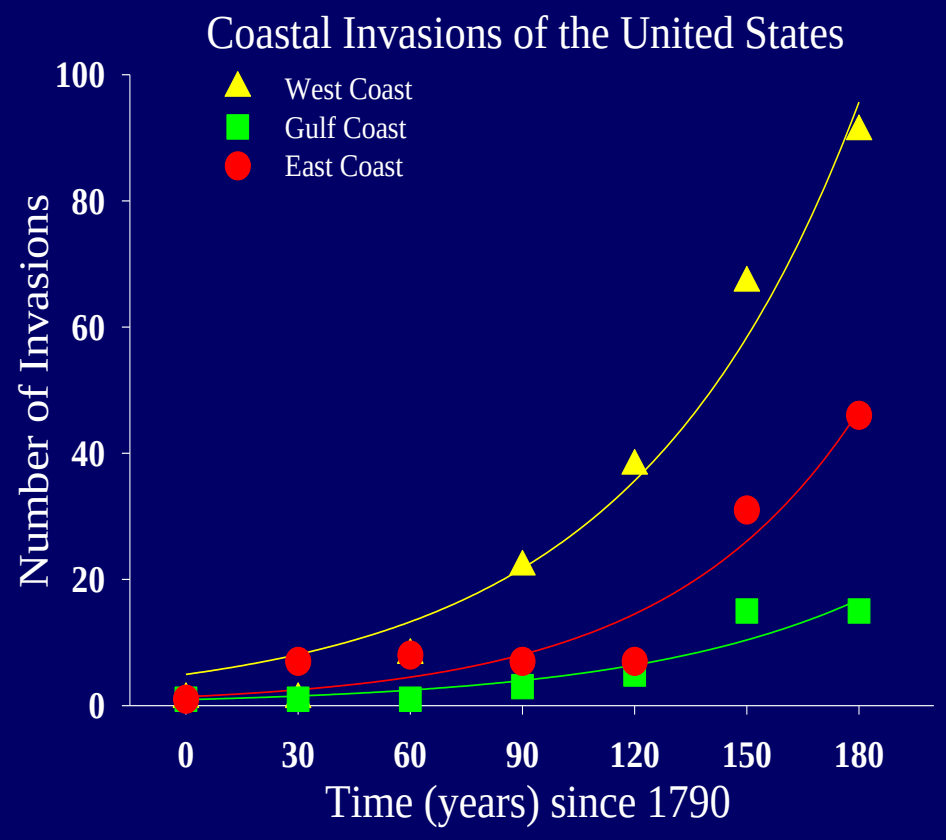
NEMESIS

(National Exotic Marine and Estuarine Species Information System)



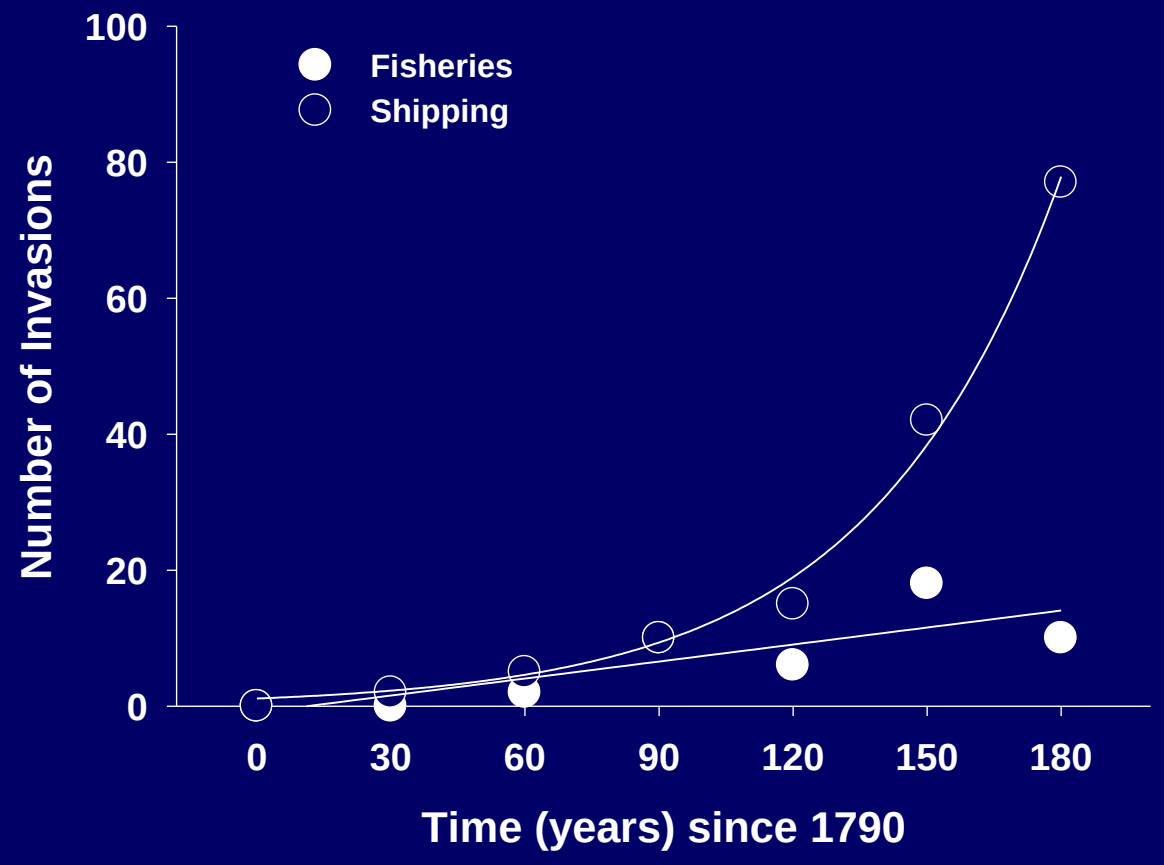
Increasing Discovery Rate



Ruiz et al 2000

Fofonoff et al. 2003

Discovery Rate of Coastal Invasions by Vector

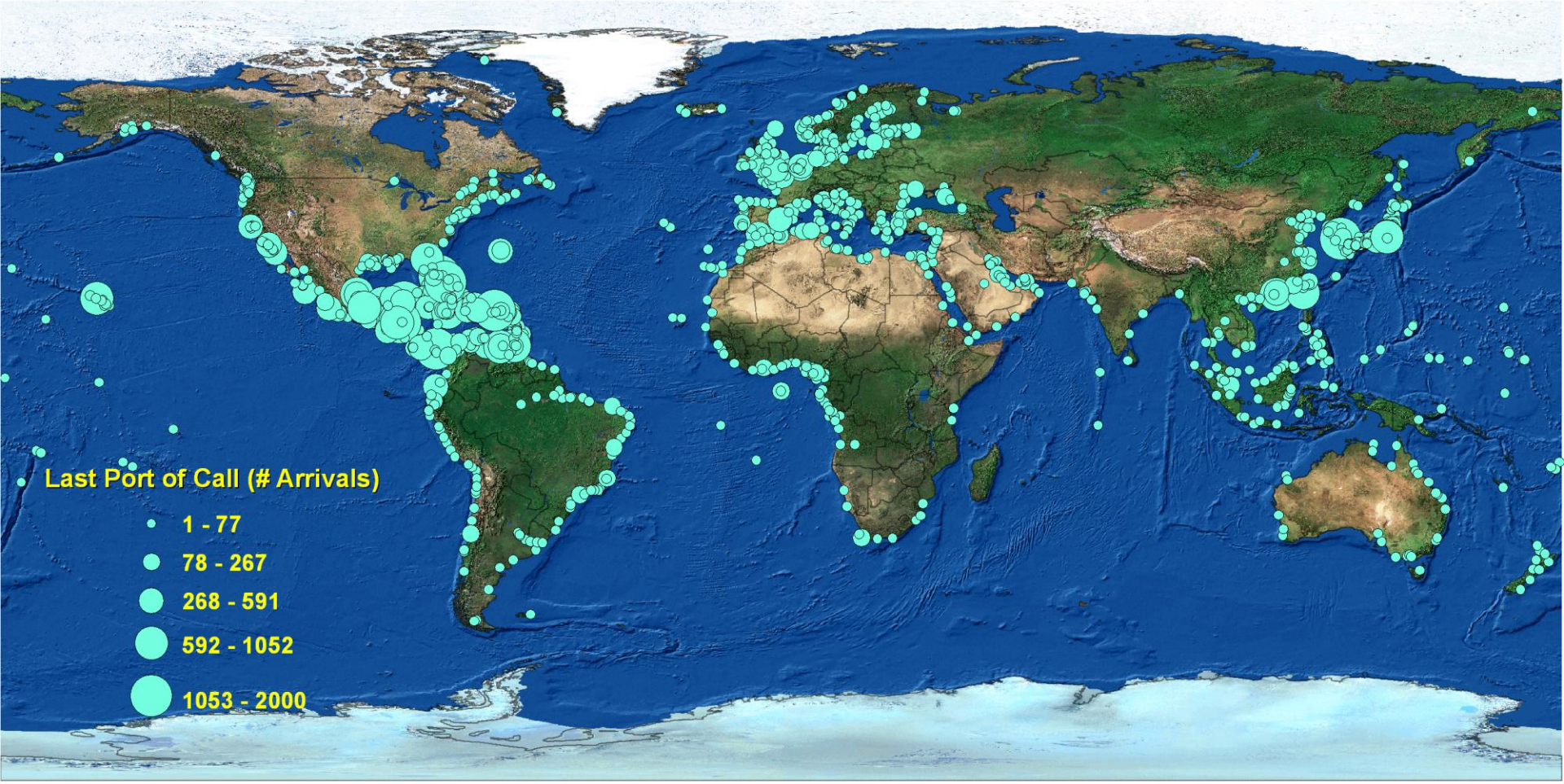


Ruiz et al 2000

Trade by Ships

- Global Scale
- Ships carry >90% world trade
- > 85,000 ships in world fleet
- > 5.4 billion tonnes cargo / year
- Underpins global economic development
- Modern society is shipping dependant
- Continuing to increase

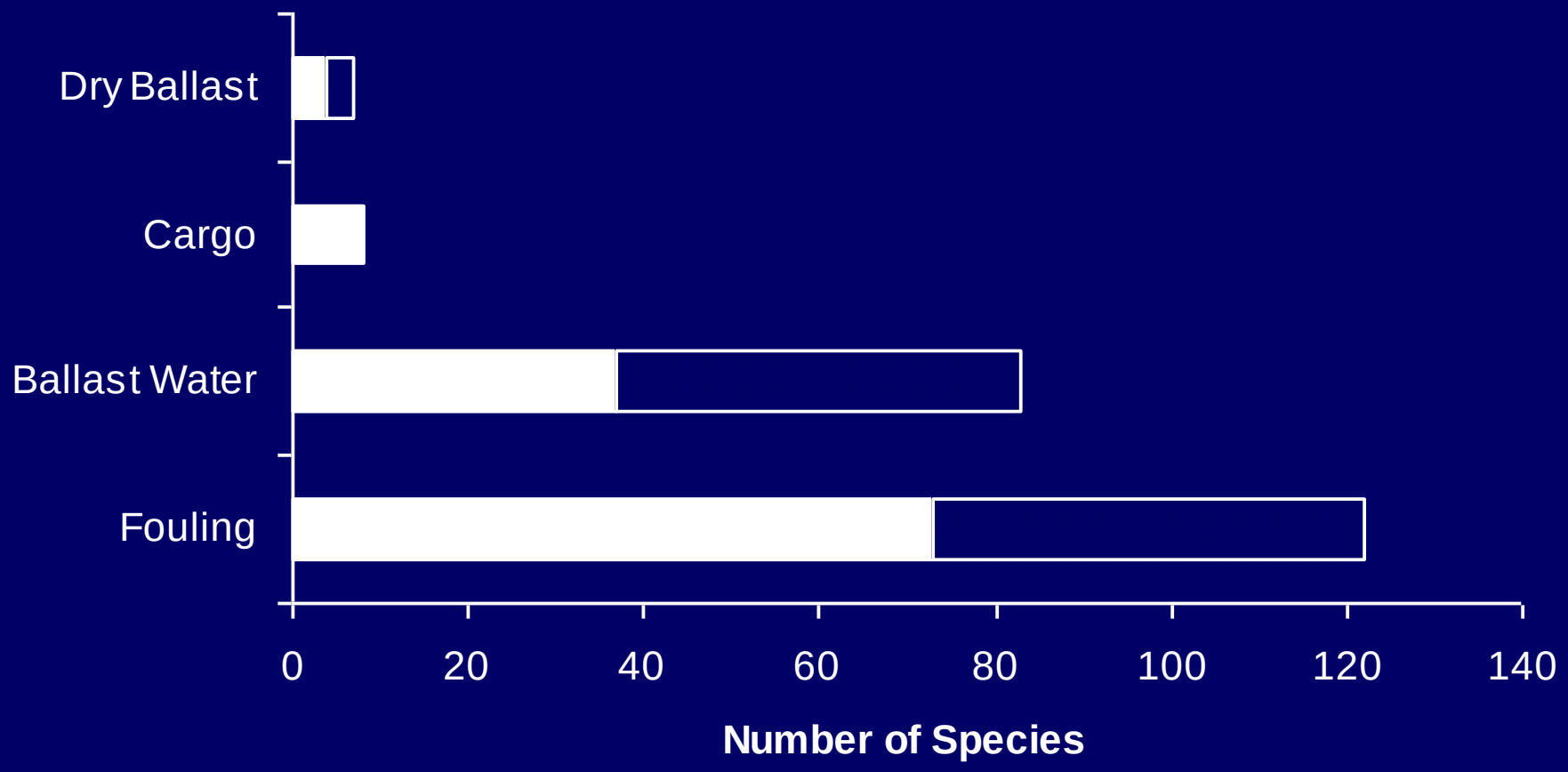
Last Ports of Call to US Ports and Places (Jan 2004 – Dec 2005)



Miller et al. 2007

Ships as Vectors: Ballast Water or Hull Fouling?

Vector(s) for coastal species introduced to North America by shipping (n=171)

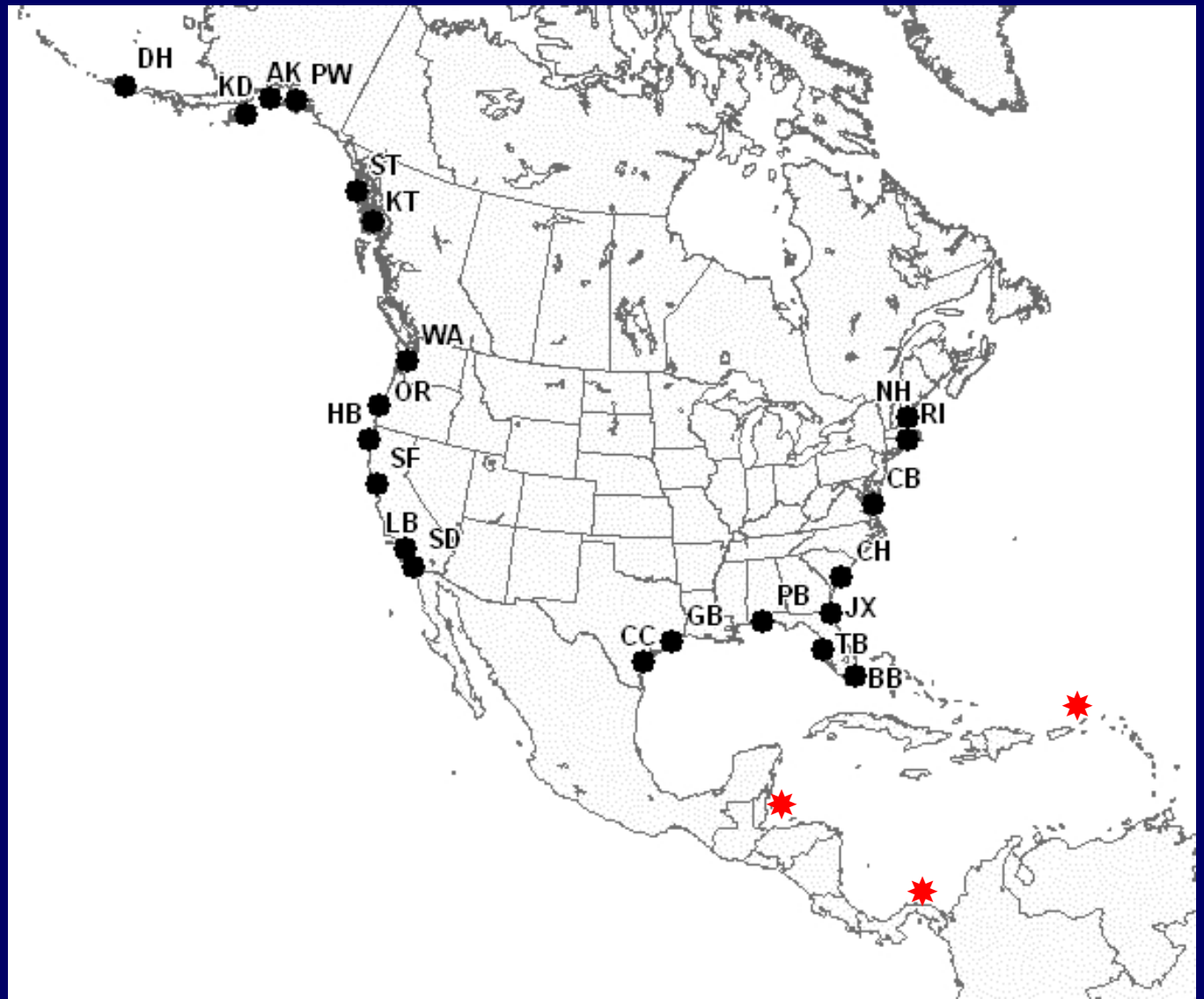


Fofonoff et al 2003

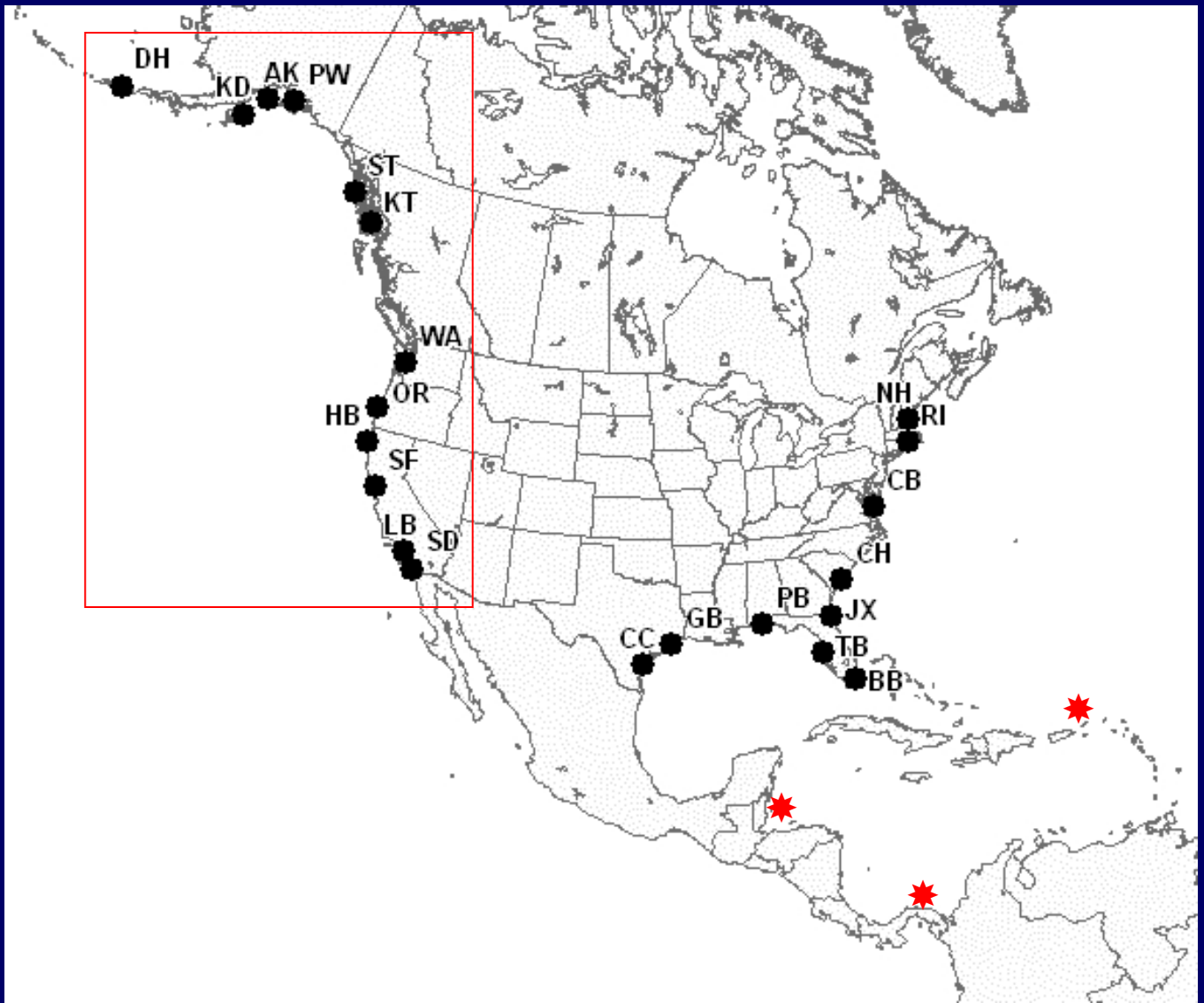
Overview

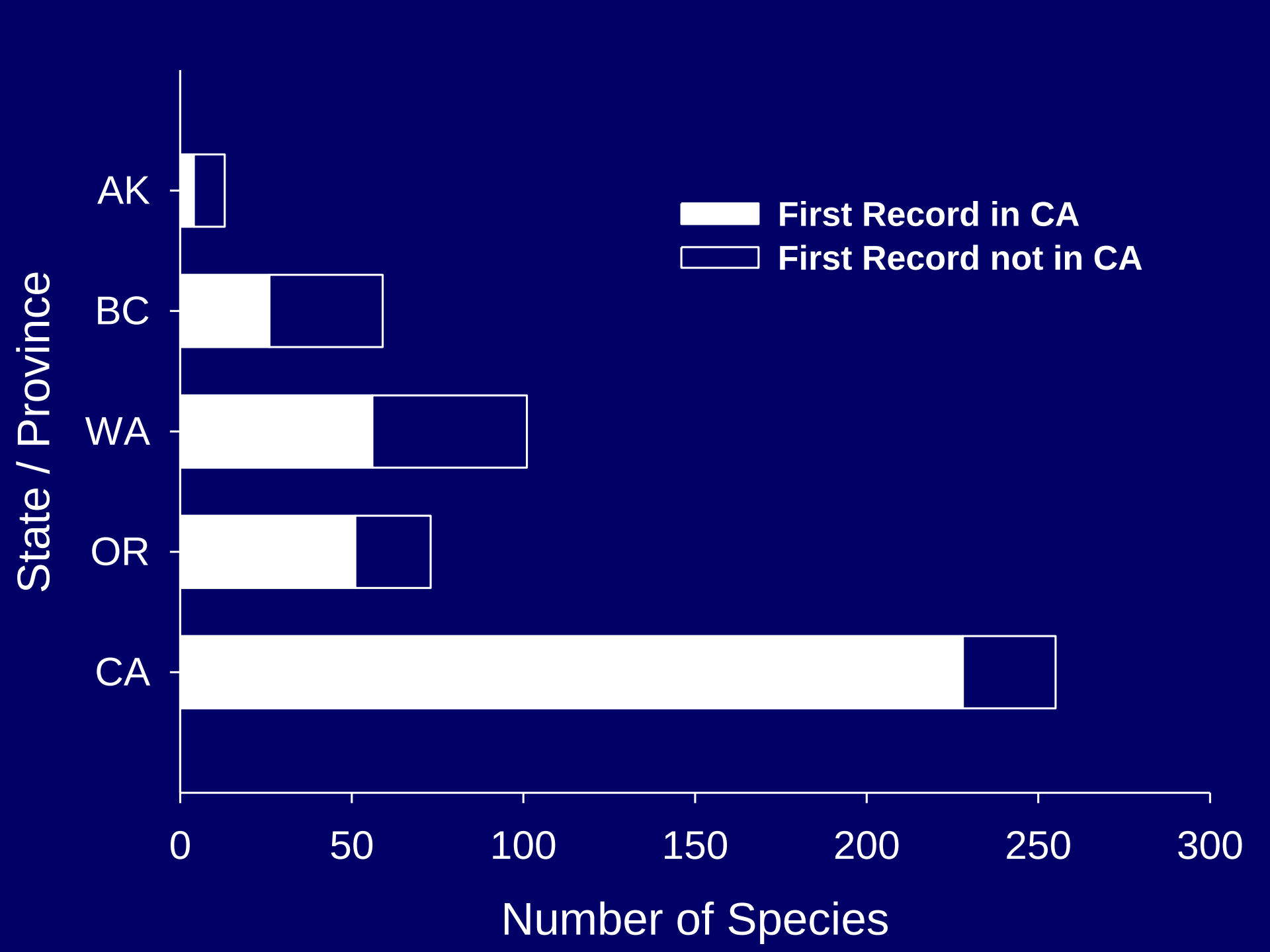
- Historical role of California & SF Bay as a beachhead for invasions in western North America
- Current state of knowledge about vectors for California invasions
- Potential importance of hull fouling for initial introduction and subsequent spread

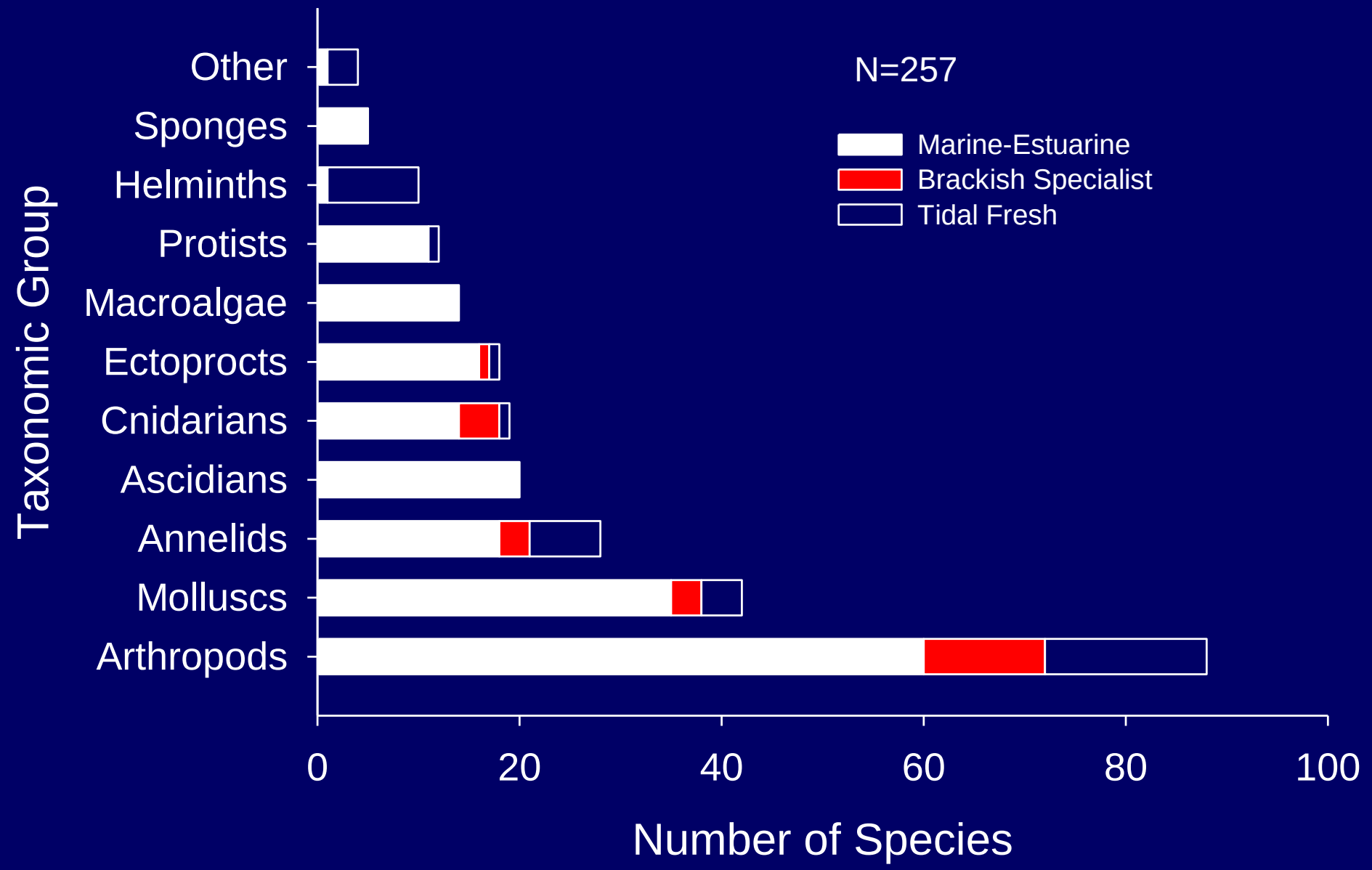
Standardized Surveys: Sessile Invertebrate Community

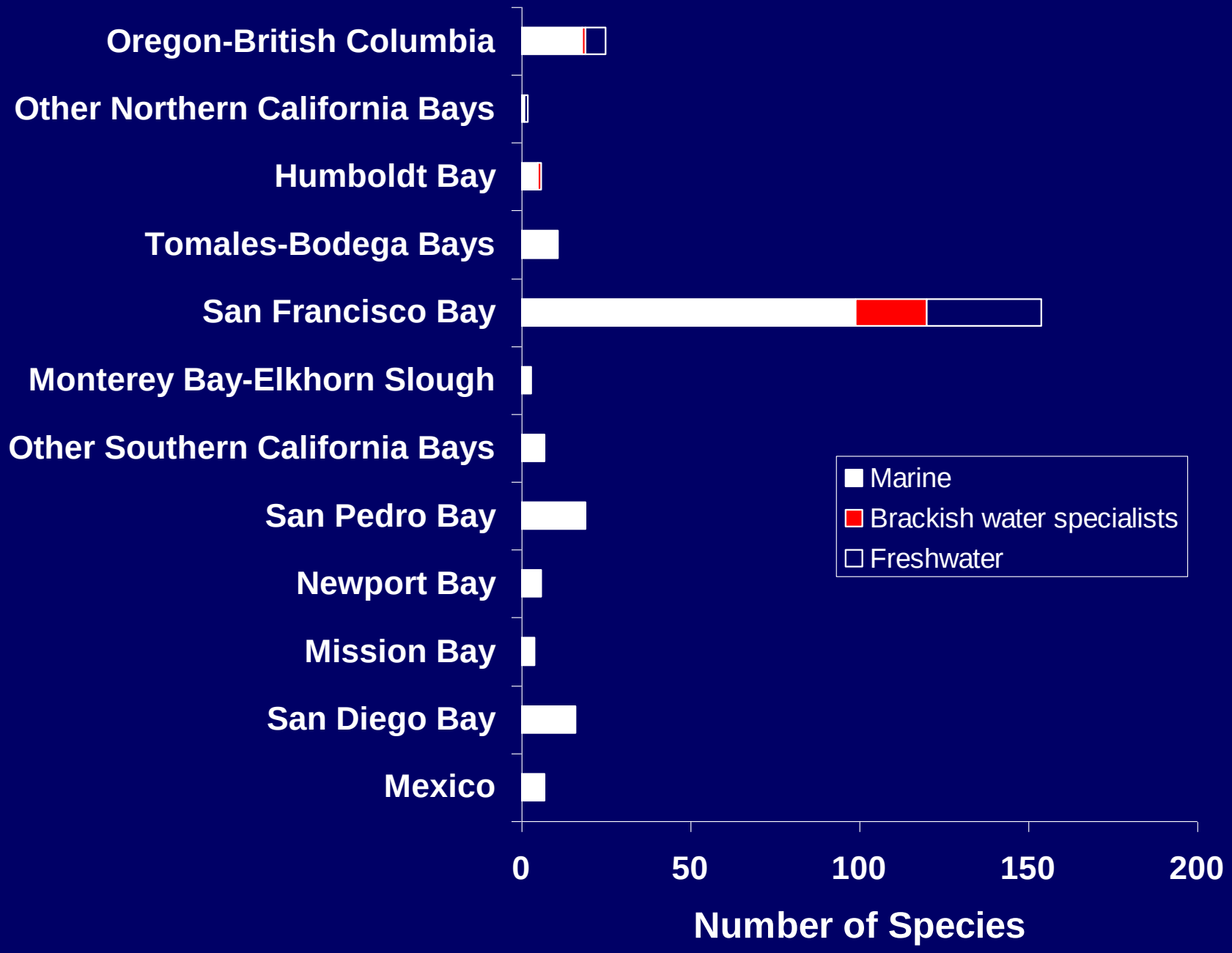


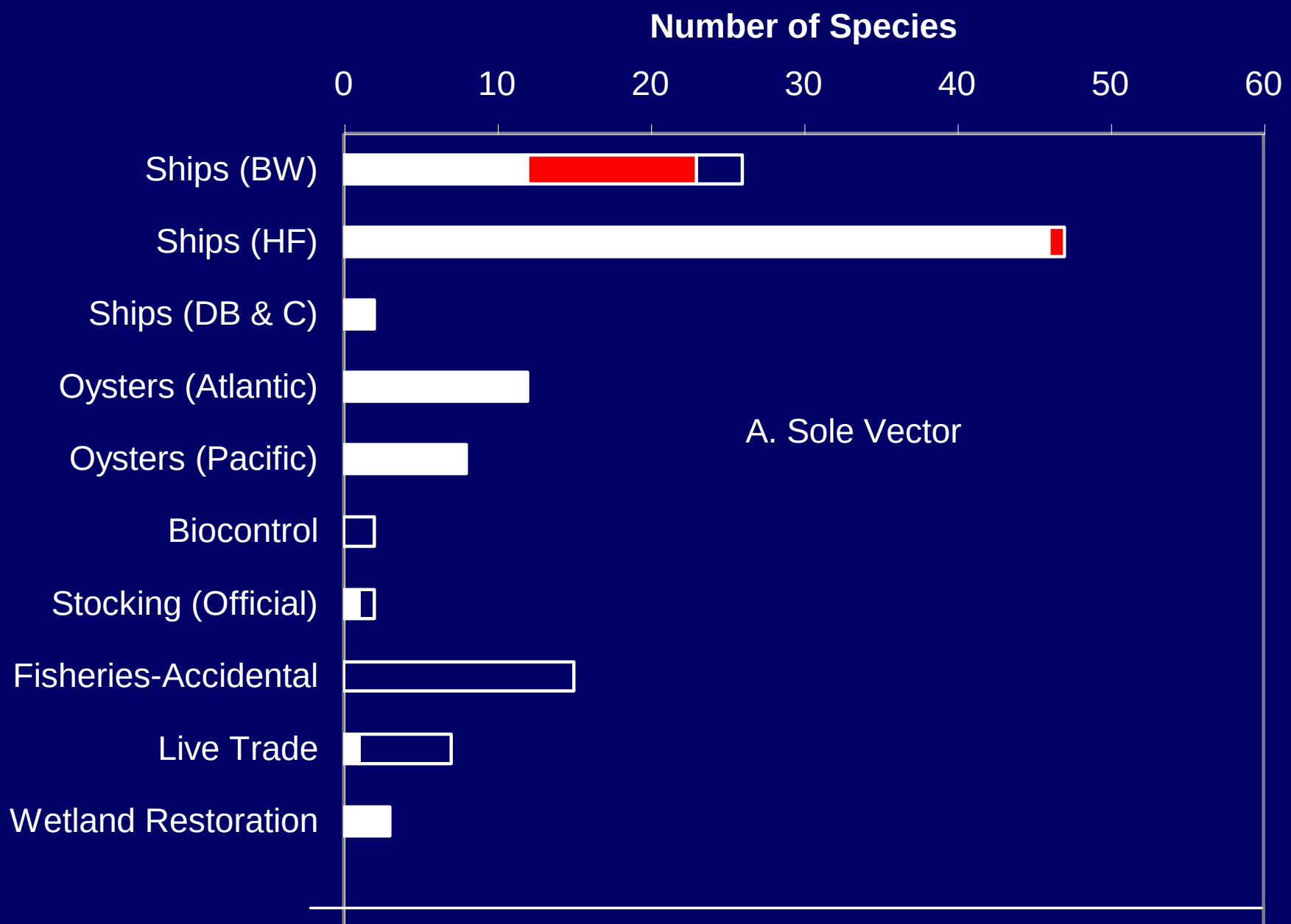
Standardized Surveys: Sessile Invertebrate Community



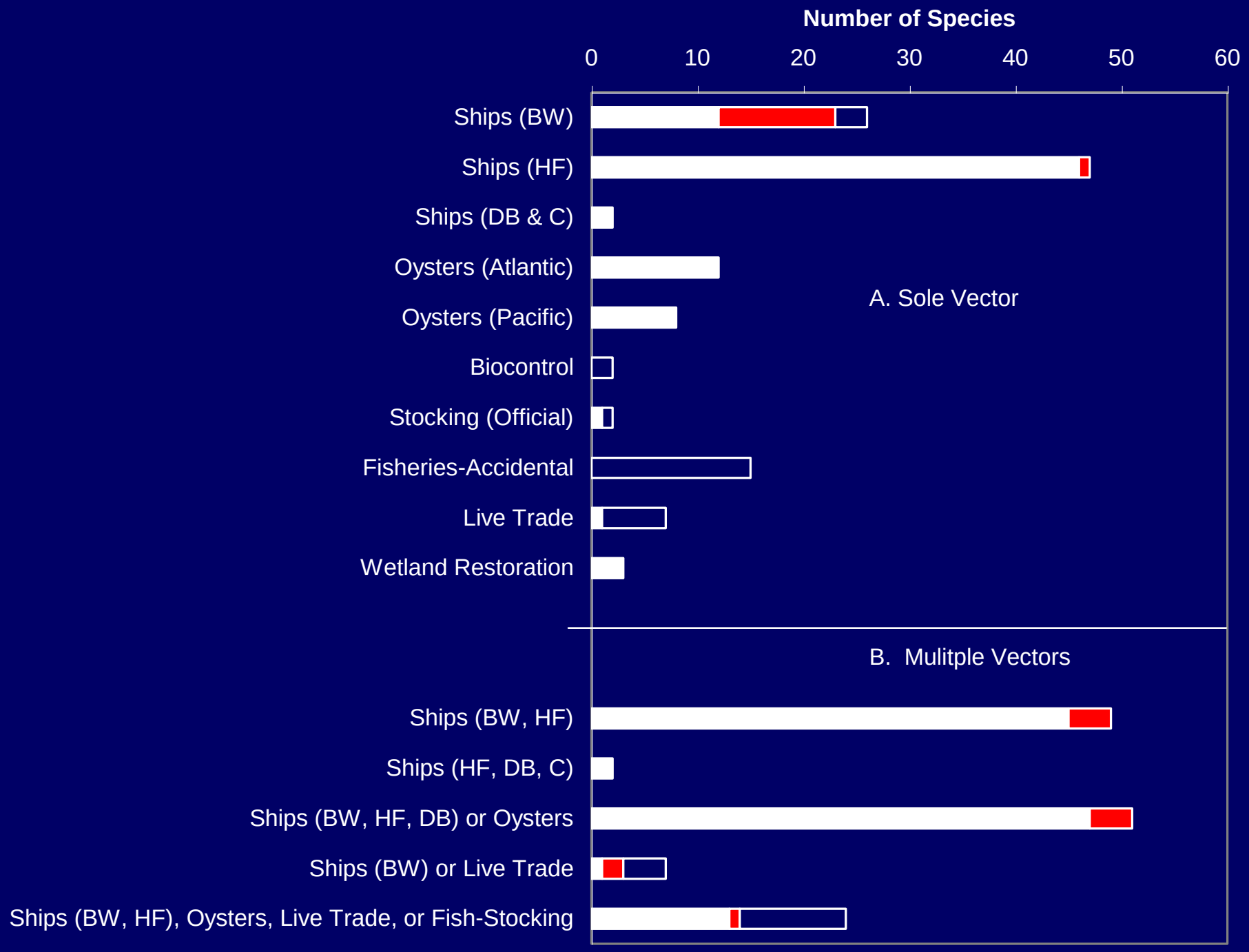

First Record in CA
First Record not in CA
State / Province
AK
BC
WA
OR
CA
0
50
100
150
200
250
300
Number of Species


N=257
Marine-Estuarine
Brackish Specialist
Tidal Fresh
Taxonomic Group
Other
Sponges
Helminths
Protists
Macroalgae
Ectoprocts
Cnidarians
Ascidians
Annelids
Molluscs
Arthropods
0
20
40
60
80
100
Number of Species


Oregon-British Columbia
Other Northern California Bays
Humboldt Bay
Tomales-Bodega Bays
San Francisco Bay
Monterey Bay-Elkhorn Slough
Other Southern California Bays
San Pedro Bay
Newport Bay
Mission Bay
San Diego Bay
Mexico
Marine
Brackish water specialists
Freshwater
0
50
100
150
200
Number of Species


Number of Species
0
10
20
30
40
50
60
Ships (BW)
Ships (HF)
Ships (DB & C)
Oysters (Atlantic)
Oysters (Pacific)
Biocontrol
Stocking (Official)
Fisheries-Accidental
Live Trade
Wetland Restoration
A. Sole Vector

Multiple Vectors are Possible for Many Species


Number of Species
0
10
20
30
40
50
60
Ships (BW)
Ships (HF)
Ships (DB & C)
Oysters (Atlantic)
Oysters (Pacific)
Biocontrol
Stocking (Official)
Fisheries-Accidental
Live Trade
Wetland Restoration
A. Sole Vector
B. Mulitple Vectors
Ships (BW, HF)
Ships (HF, DB, C)
Ships (BW, HF, DB) or Oysters
Ships (BW) or Live Trade
Ships (BW, HF), Oysters, Live Trade, or Fish-Stocking

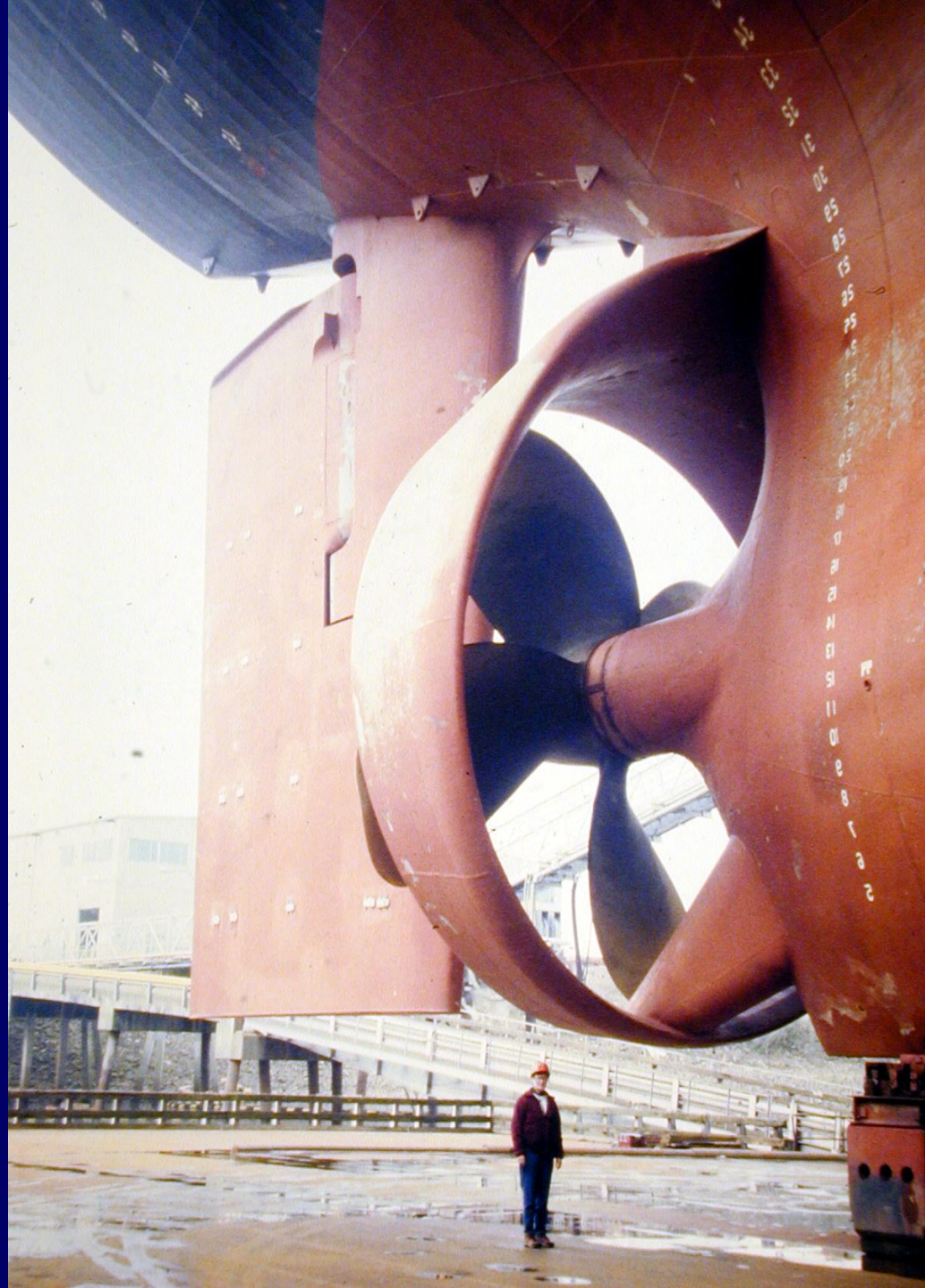
Hull Fouling

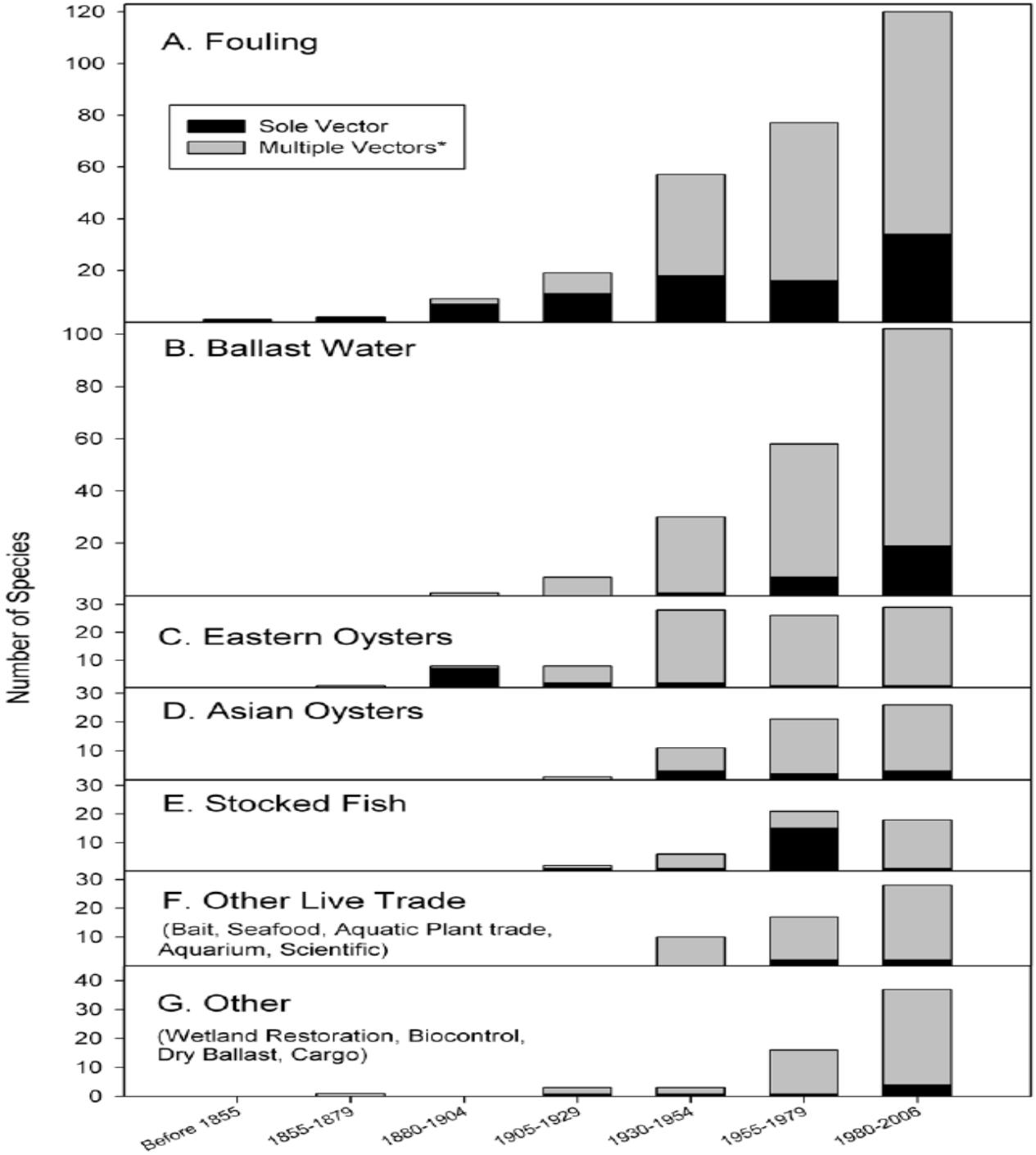
- Important Historically

Hull Fouling

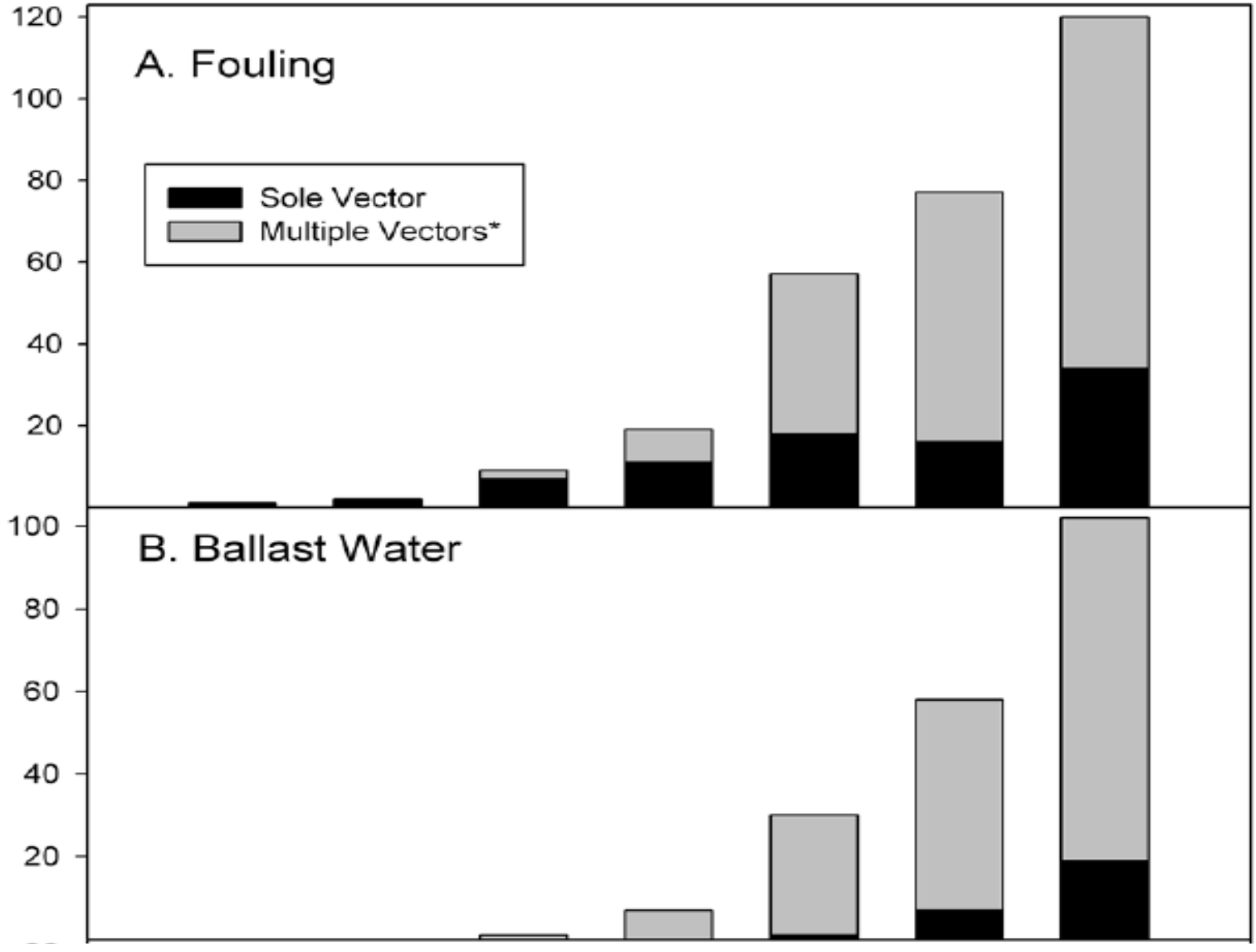
How Important Today?

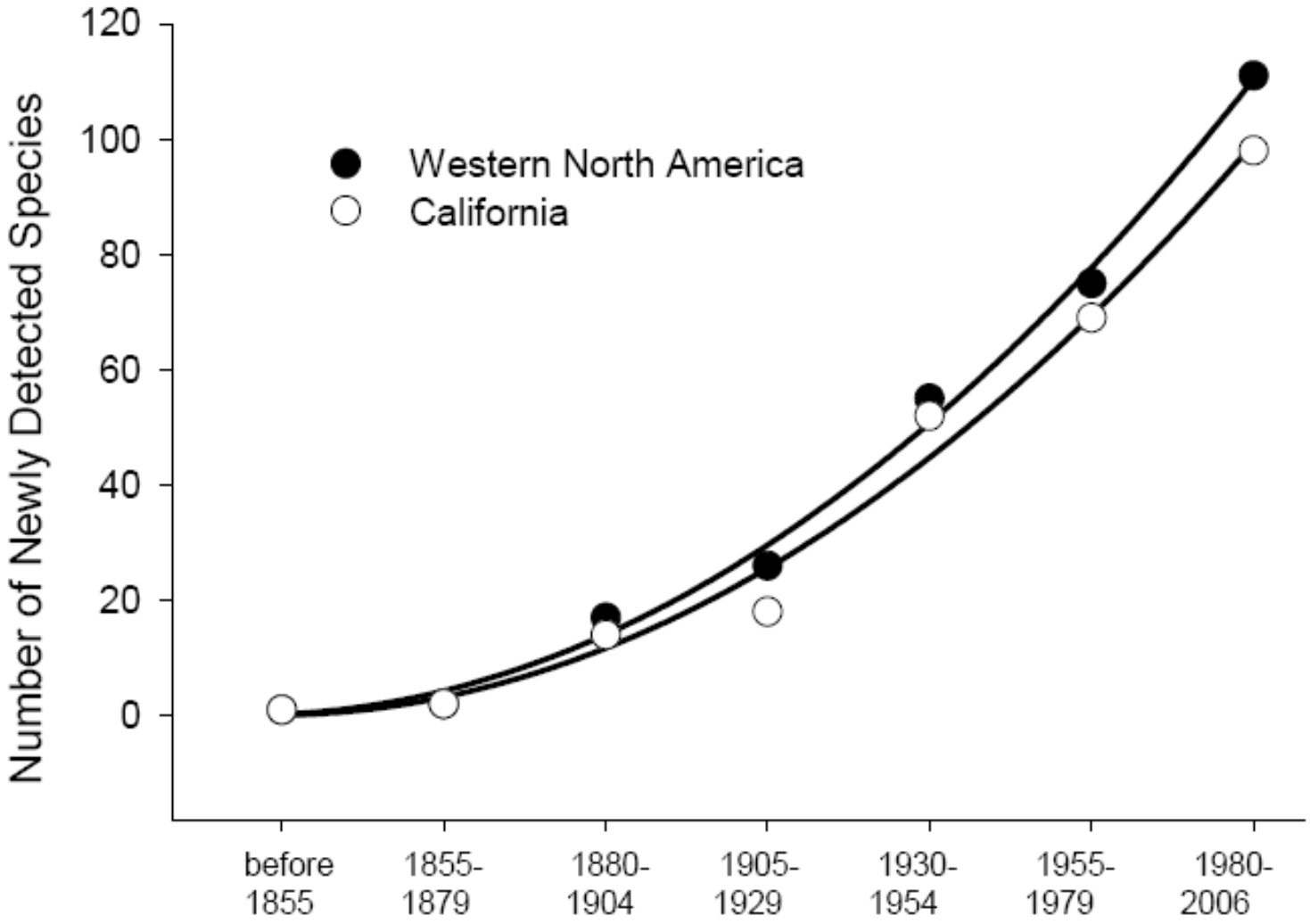
- bigger ships
- travel farther, faster
- better husbandry
- WSA = ~335M sq meters/yr from overseas vessels



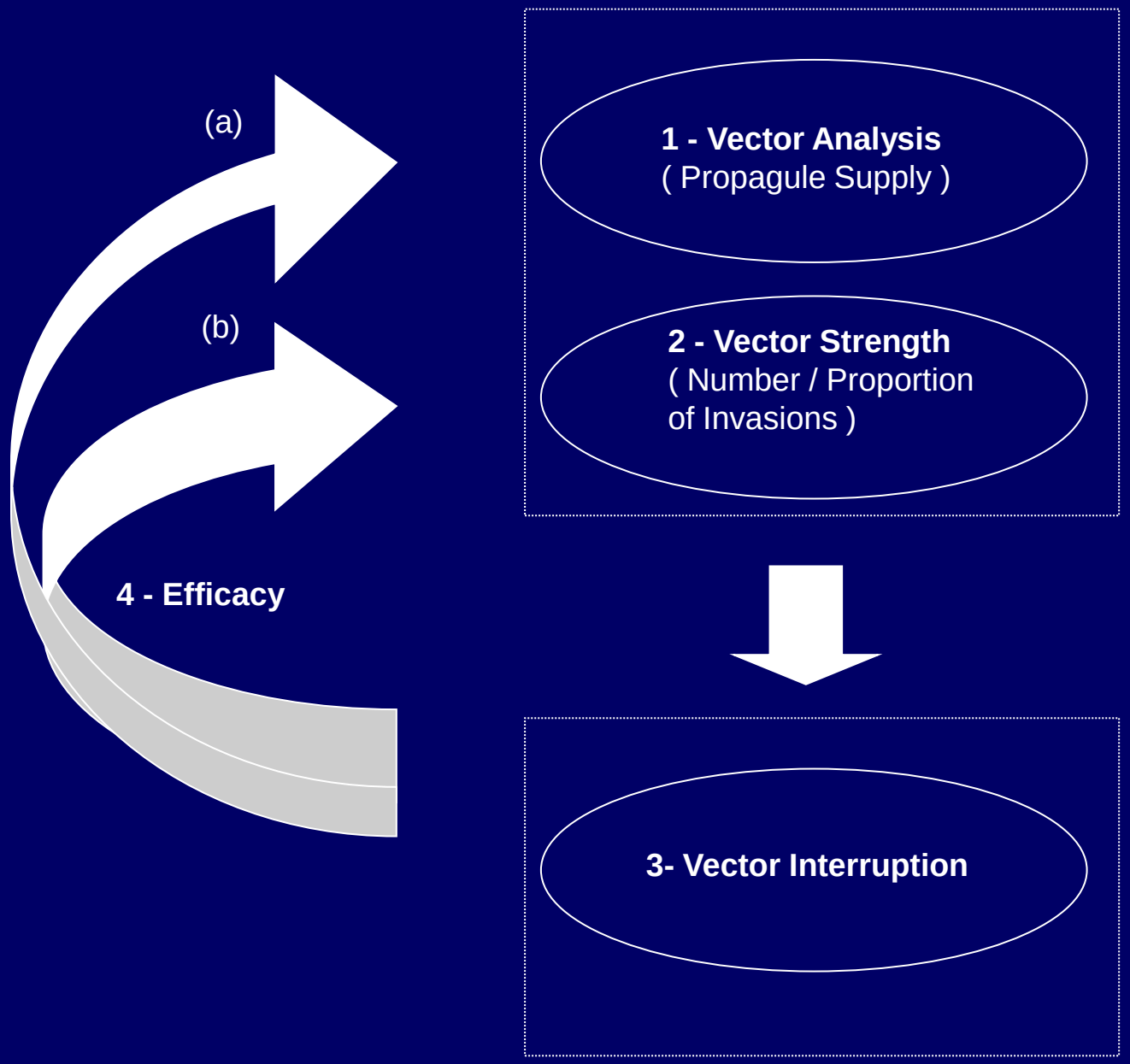

A. Fouling
Sole Vector
Multiple Vectors*
B. Ballast Water
C. Eastern Oysters
D. Asian Oysters
E. Stocked Fish
F. Other Live Trade
(Bait, Seafood, Aquatic Plant trade, Aquarium, Scientific)
G. Other
(Wetland Restoration, Biocontrol, Dry Ballast, Cargo)
Number of Species
Before 1855
1855-1879
1880-1904
1905-1929
1930-1954
1955-1979
1980-2006

Relative Importance of BW vs HF?




Number of Newly Detected Species
120
100
80
60
40
20
0
Western North America
California
before 1855
1855-1879
1880-1904
1905-1929
1930-1954
1955-1979
1980-2006

COMPONENTS OF VECTOR MANAGEMENT



Collaborators

- Gail Ashton, SERC
- Chris Brown, SERC
- Jim Carlton, Williams College
- Paul Fofonoff, SERC
- Steve Foss, Cal DFG
- Tuck Hines, SERC
- Kristen Larson, SERC
- Linda McCann, SERC
- Sharon Shiba, Cal DFG
- Brian Steves, SERC

Sponsors:

- Cal Dept Fish & Game
- National Sea Grant
- Prince William Sound RCAC
- Smithsonian Institution
- US Coast Guard
- US Fish and Wildlife Service