A synthesis of the marine live bait trade as a vector for species invasions

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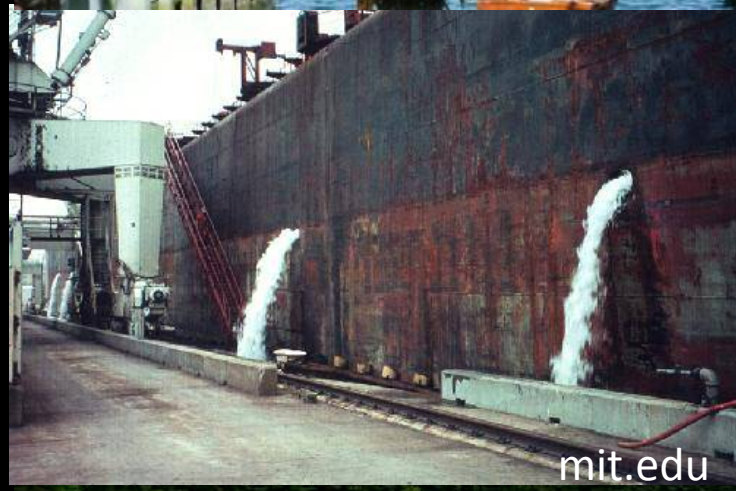
GEORGE MASON UNIVERSITY · EAST CAROLINA UNIVERSITY GREENVILLE, NC · MARE · TEMPLE UNIVERSITY · UNIVERSITY OF CALIFORNIA DAVIS · Smithsonian Environmental Research Center · Sea Grant Maryland

Vectors for aquatic introductions

Vectors differ dramatically in:

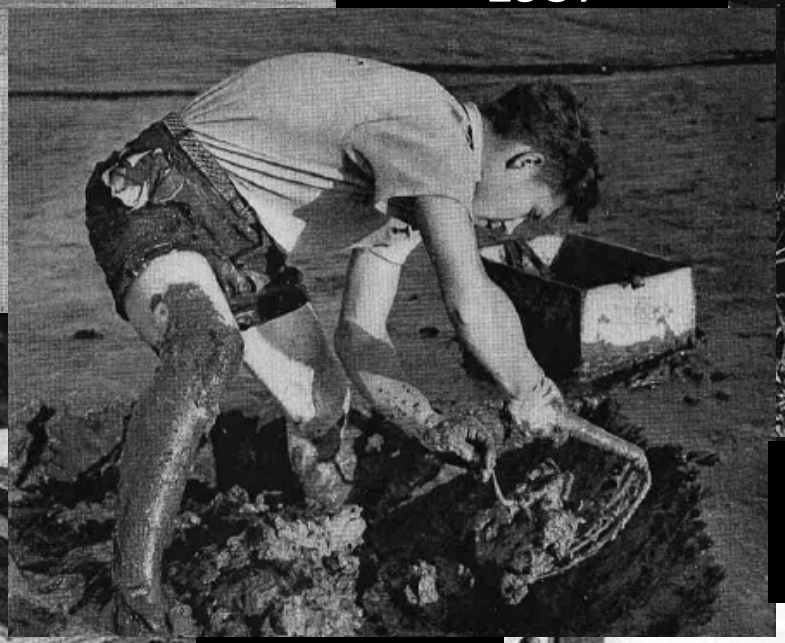
- species compositions,
- time of operation,
- volume of material moved

Differentially serve as bottlenecks for successful species transfer, some more efficiently than others



History of the Maine marine baitworm trade

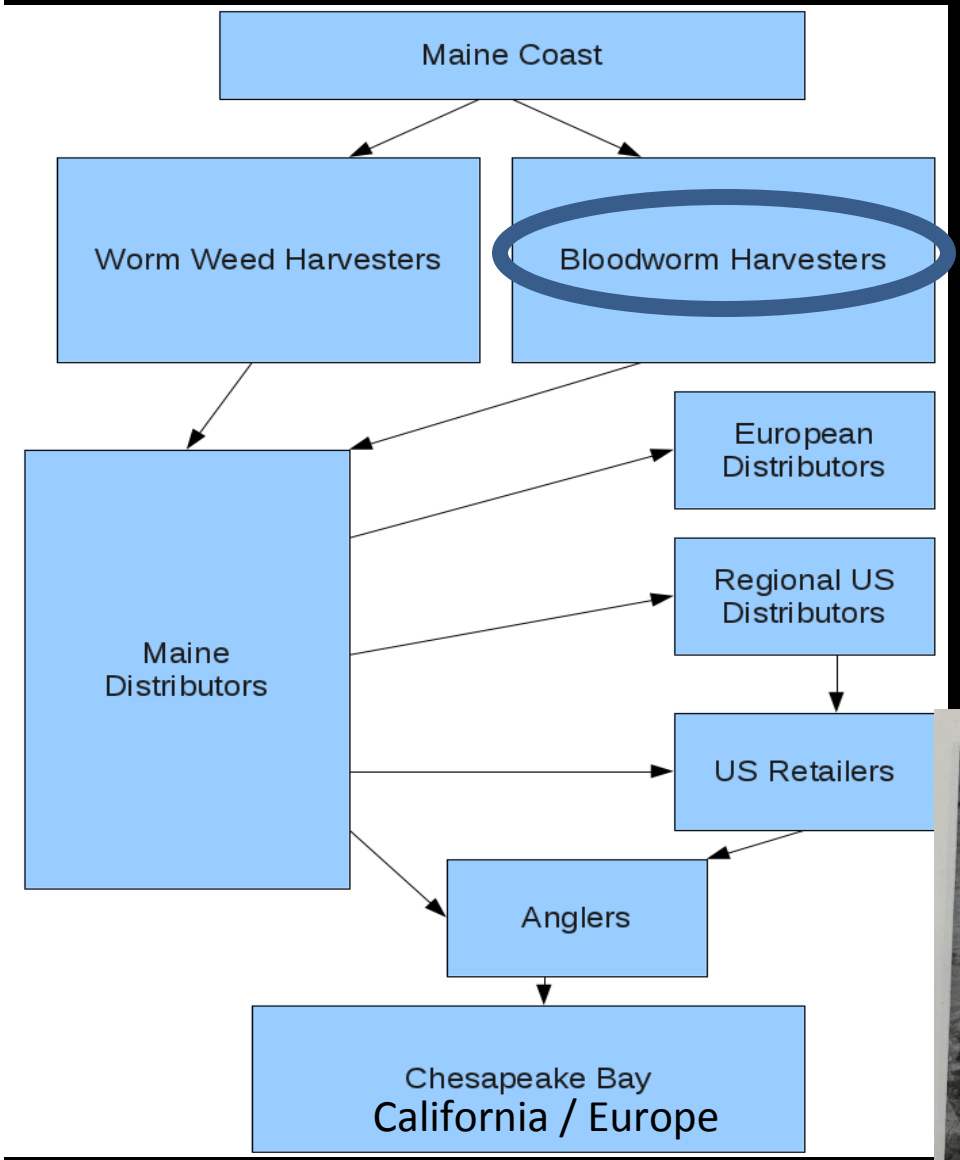
1920s
1930s
1937



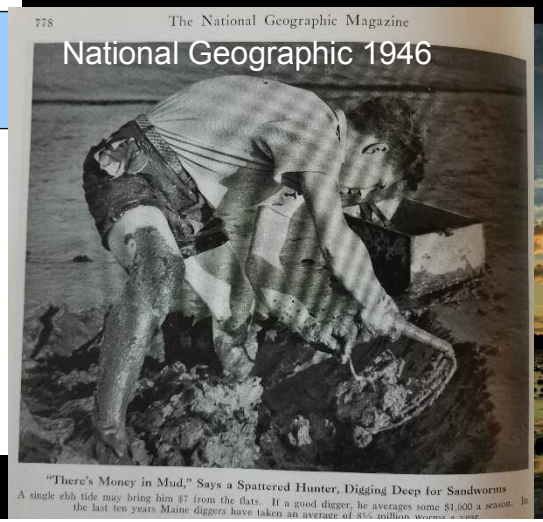
Pre 1940, >12.5 million
1955-1985 >1 billion

National Geographic 1946

Maine marine baitworm trade



- Top 10 most valuable fishing industries in Maine, USA
- Since 1946, operates year round
- Worms (*Glycera dibranchiata*) harvested at low tide with modified rake
- Sold to dealers at ~ $0.25 / worm
- ~800 independent harvesters
- Collect 100 -1000 worms per tide



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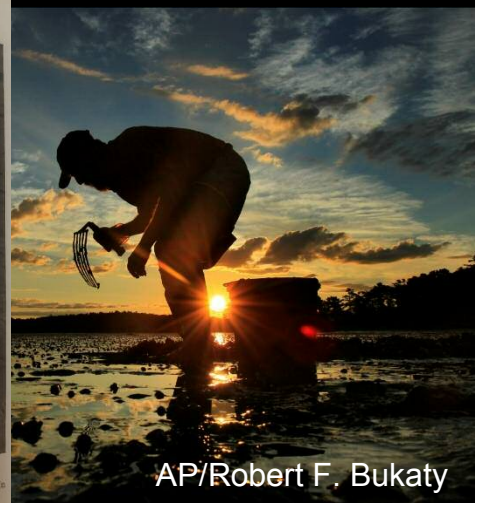
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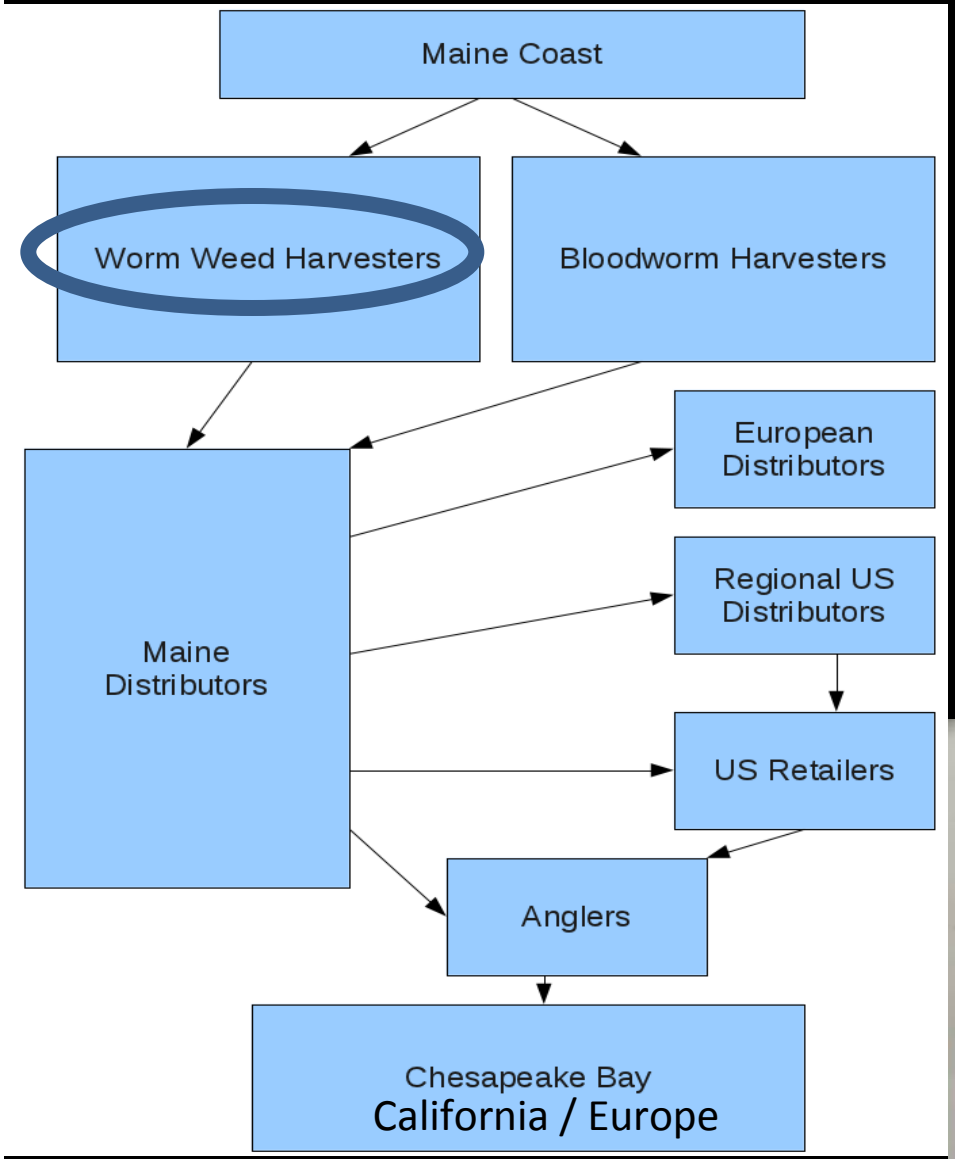
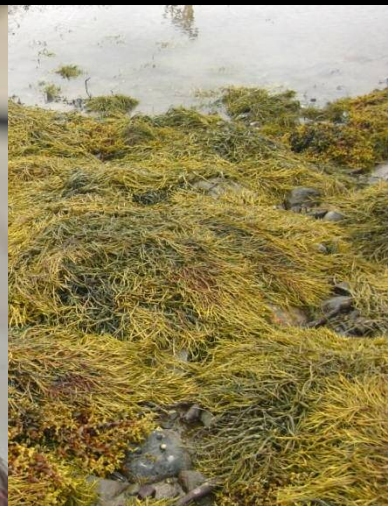
Maine marine baitworm trade



- Wormweed (*Ascophyllum nodosum* ecad *scorpioides*) from tidal marshes
- Various processing methods
- Ideal packing material: "Restorative properties"; "Rockweed is vital to keeping the worms energetic and alive" (Nat Geo 1946)
- Consumers receive bags of worms and algae; 40% discard (Lau 1995)
- >9 metric t/yr imported into San Francisco, CA (Cohen et al. 2001)



Research focus

1) Biological characterization

(Taxonomic, functional, and genetic diversity)

2) Prevention via osmotic shock

3) Social science: surveys and economic analysis

Wormweed transfers entire communities of live invertebrates

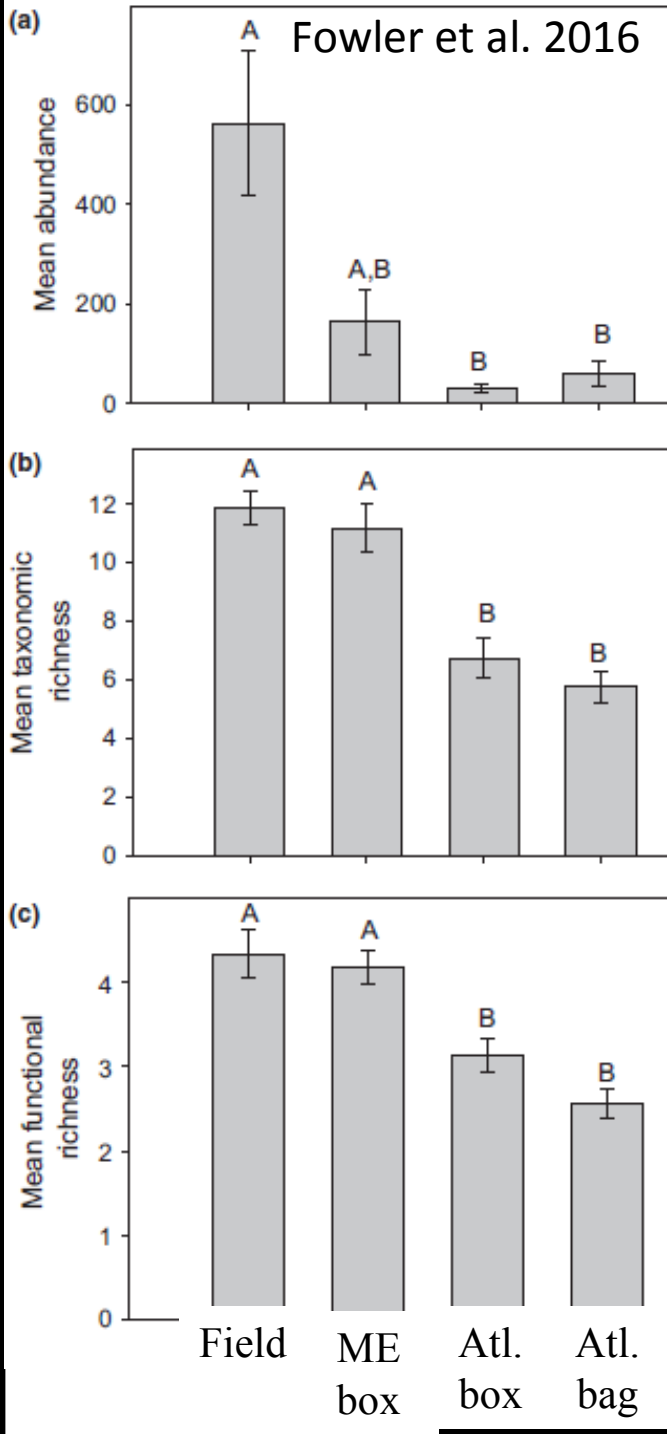
>110 taxa of marine macro- and micro-organisms in baitboxes and wormweed (Haska et al. 2011; Cohen 2012; Blakeslee et al. 2016; Fowler et al. 2016)

Stepwise reduction in all measures from field to recipient region

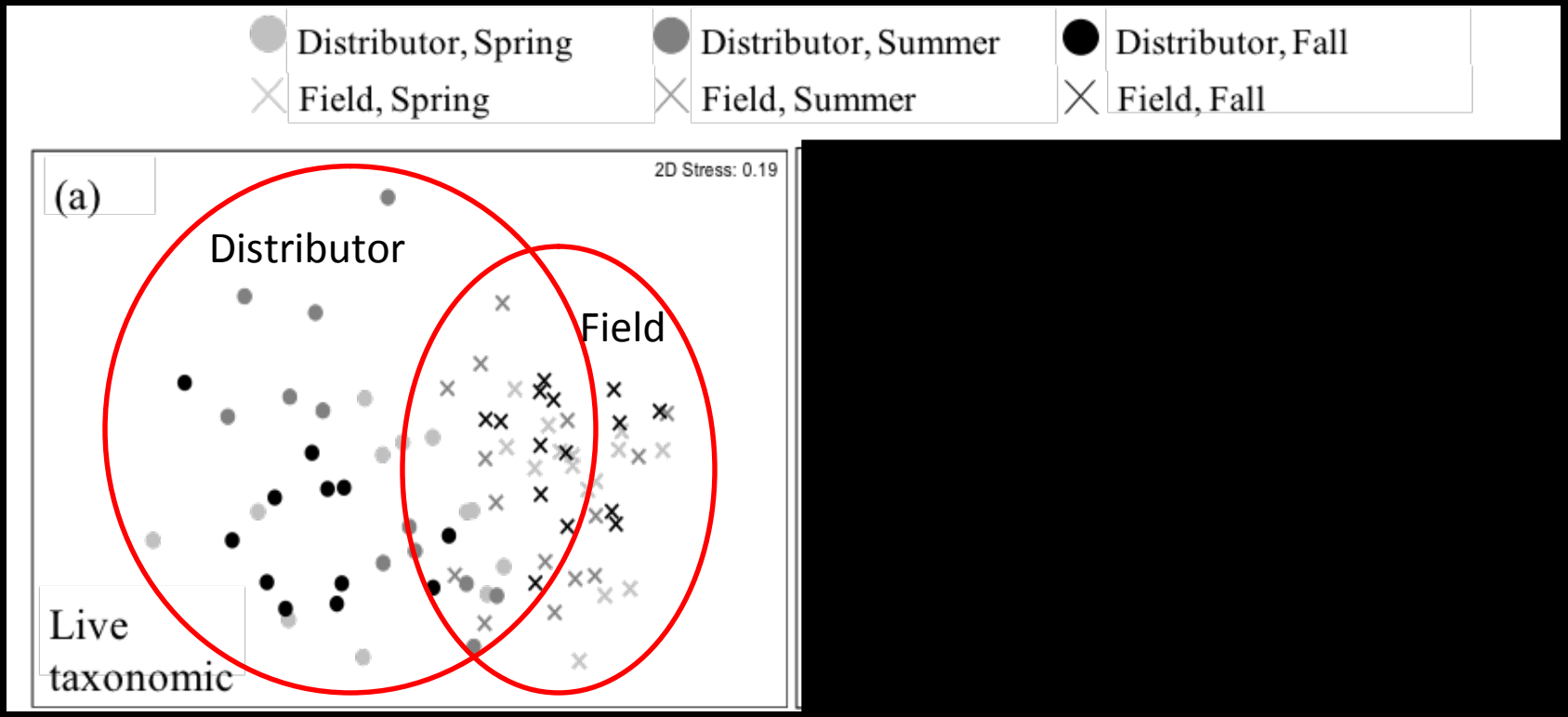
58 taxa live in boxes and bags in summer in Mid-Atlantic, USA alone

Dominated by crustaceans and gastropods

Estimated 1.2 billion live macro-inverts transferred since 1946



Seasonal changes in abundance and diversity of species (i.e., seasonal niches) can drive overall patterns of vector propagule pressure



PERMANOVA stage x season

$F_{2,75}$ = 2.4, P = 0.001

vector stage = global R = 0.619;

season = global R = 0.178

(Fowler et al., in review)

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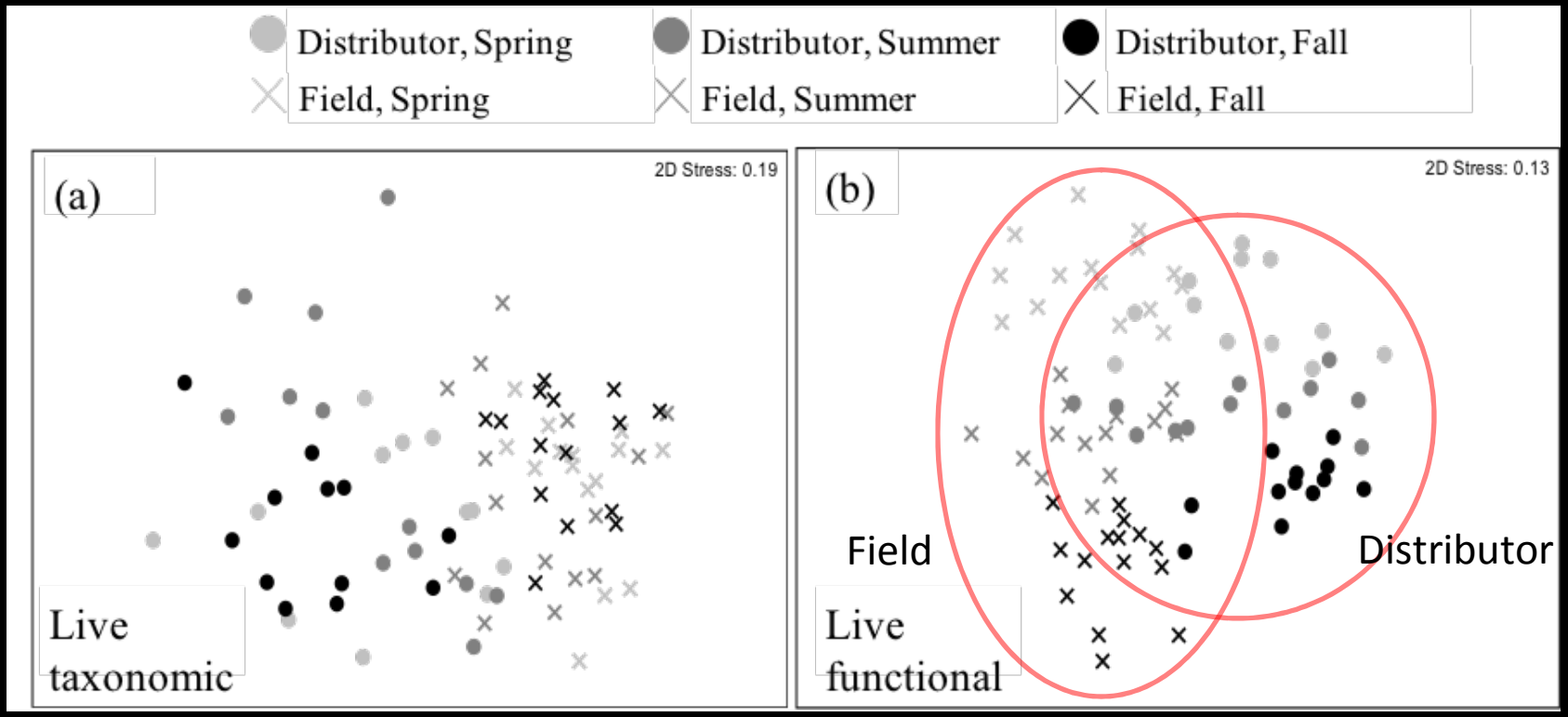

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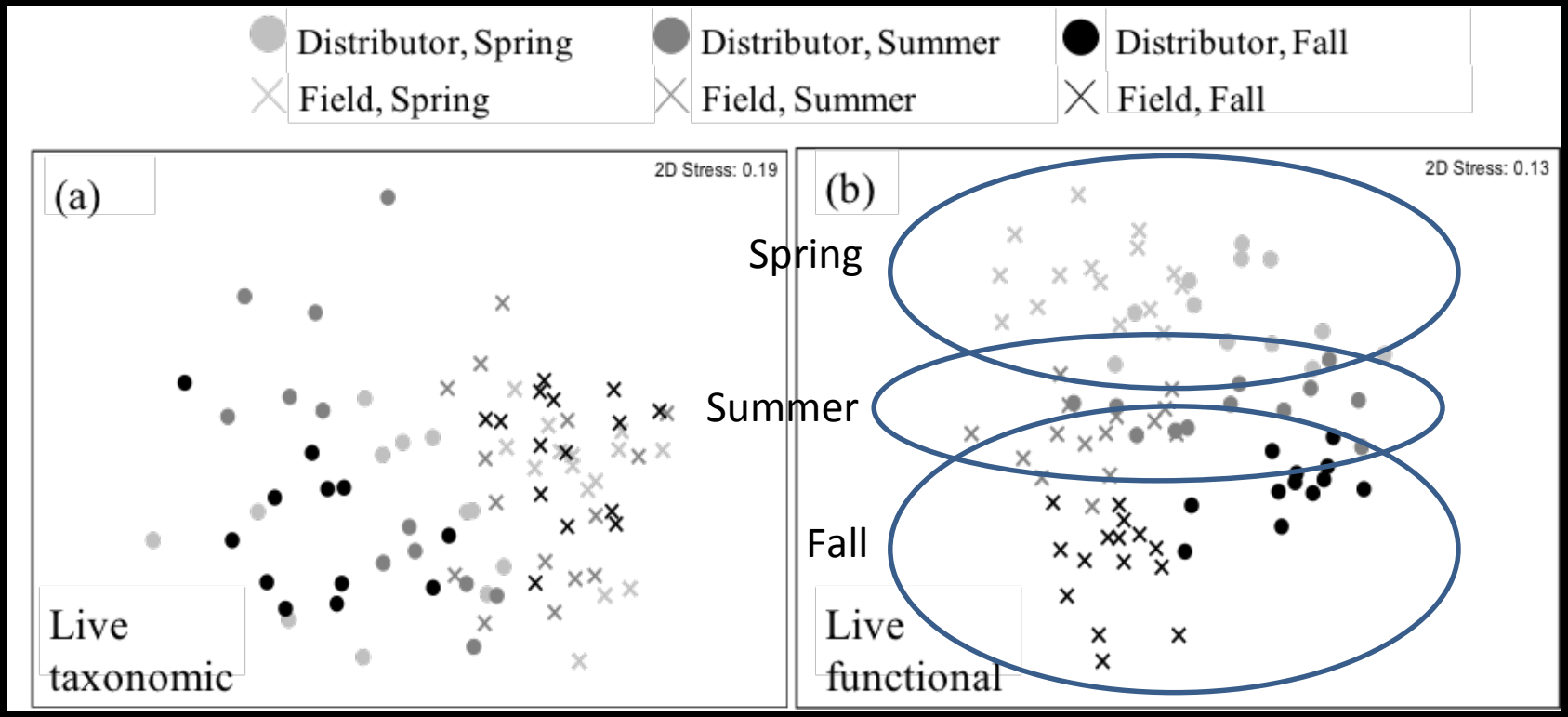

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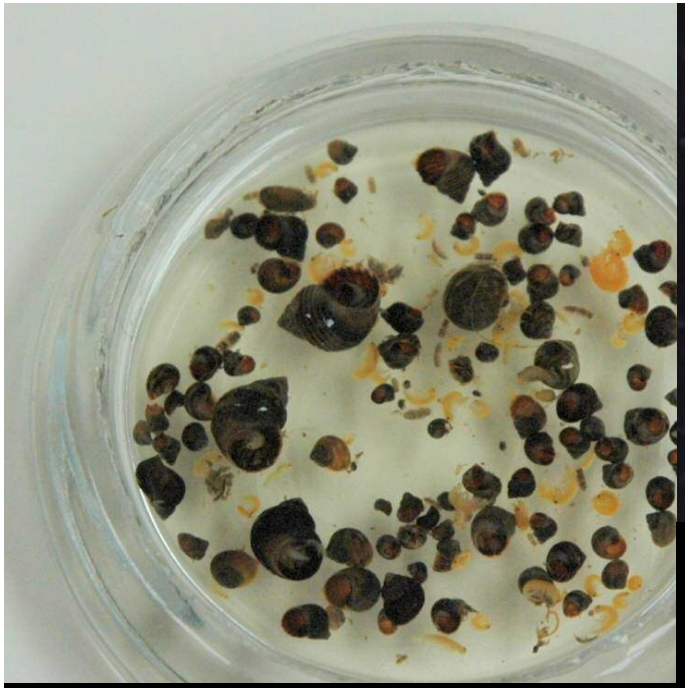
Related to interplay of water temperature, reproduction, and larval recruitment dynamics of particular taxa (Fowler et al., in review)



Odostomia (Boonea) bisuturalis

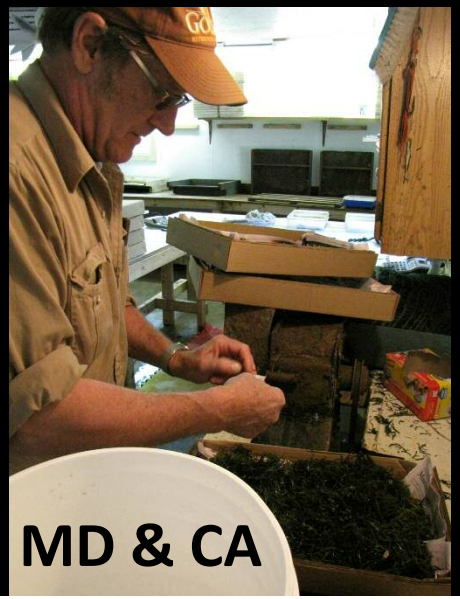
Carcinus maenas

Mya arenaria

Jaera albifrons

Mites – Halacaridae & Bdellidae

How can we lessen the abundance and diversity of hitchhikers in wormweed without negatively affecting the industry?



MD & CA

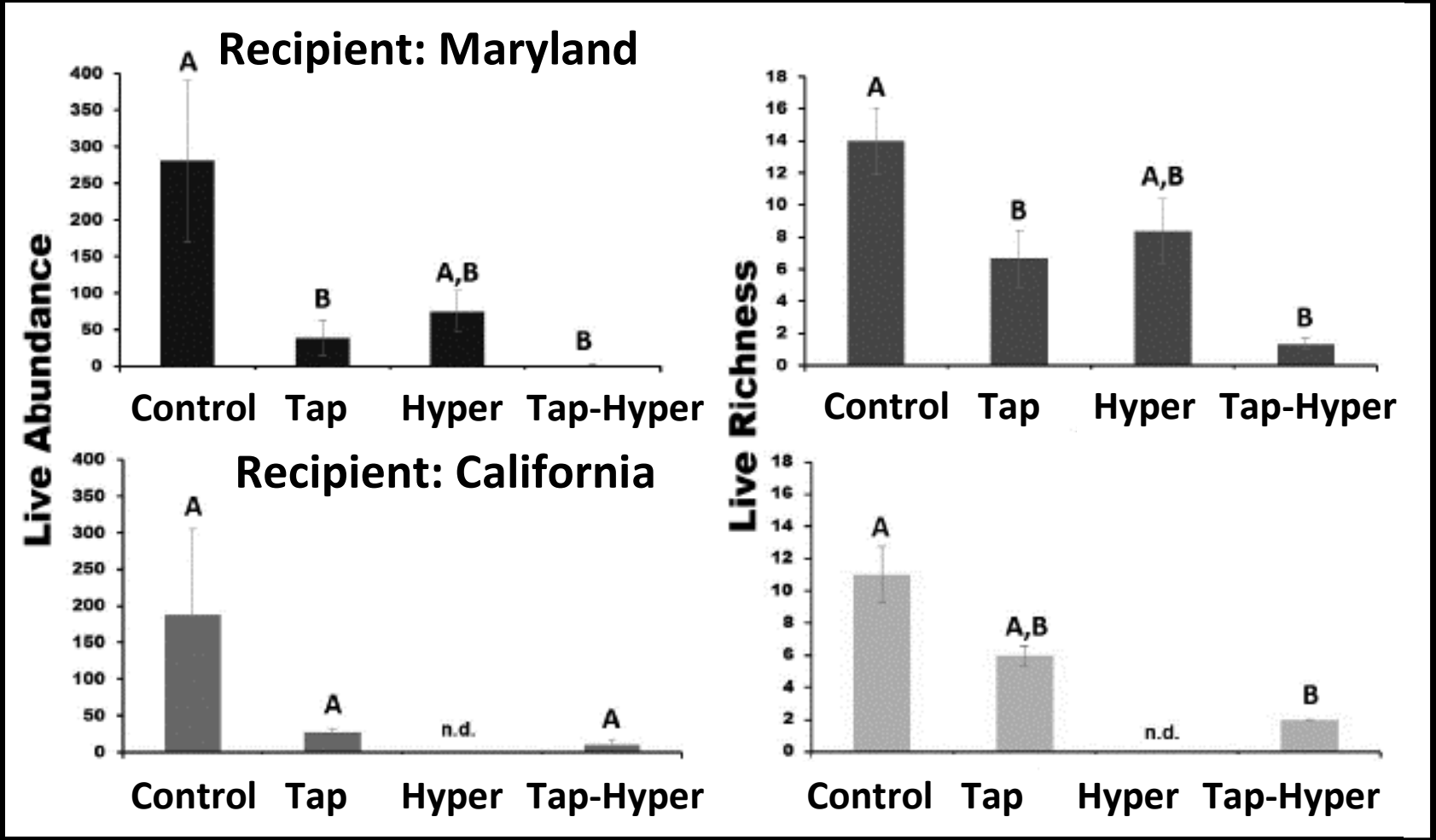
Treatments (40F):

- Control (no water)
- Tap water (12 hr)
- Hyper salinity (12 hr)
- Tap + Hyper (12 + 12 hr)

(Blakeslee et al., 2016)

Results: Osmotic Shock treatments

All worms in excellent condition in both MD and CA



Simplest treatment, tap water, statistically as effective as more complicated treatments in reducing associated biota

(Blakeslee et al., 2016)

Sharing results with stakeholders

Fall 2016 survey of ME bloodworm distributors

Without laws/incentive, not receptive to soaking wormweed

Add labor costs,

Change facility requirements,

Require dependable source of fresh water

Current request from Europe: naked in trays

Water, worms, ice packs

Too time consuming to remove bloodworms when packed in wormweed

<u>Is it more cost effective to use wormweed or "naked in trays" methods to ship bloodworms?</u>

(Wieland et al. 2018)

Economics of the marine live bait trade

Costs of prevention (change to vector) vs. cost of failed prevention for 3 taxa transported via the live marine bait trade to the US west coast

Littorina saxatilis & *L. littorea*

Carcinus maenas

Michael Marmach

Ascophyllum nodosum

<u>Total damages and costs per year on west coast (US$)</u>

Littorina saxatilis & *L. littorea*	*Carcinus maenas*	*Ascophyllum nodosum*
$24,600 (control only) (Cohen et al. 2012)	$992K – 46 million (Lovell et al. 2007; de Rivera et al. 2007, 2010; Grosholz et al. 2011; Mach and Chan 2014; St. Hilaire et al. 2016)	$5,000 (control only) (Miller et al. 2004)

Monetary value of damages not readily apparent for snails and alga

	Six 125 trays					Six 125 boxes			
		Number	Unit Cost	Total Cost			Number	Unit Cost	Total Cost
Naked in Trays	Worms	750	0.35	262.5		Worms	750	0.35	262.5

- Cost of worms is largest cost factor for either method
- Monetary cost of prevention is small, as long as demand stays constant

Would fishermen buy naked-in-trays bloodworms?
Mid-Atlantic, USA fishermen surveys (N=886; N= 610 use bloodworms)

Fishing with bloodworms

- 89% purchase worms from bait and tackle stores
- 86% have worms left after fishing
- 33% discard in water
- 84% unaware of bloodworm vector
- 60% are aware of non-native issues
- 16% have seen invasive information

Paolisso and Trombley (2015)

Would fishermen buy naked-in-trays bloodworms?

Mid-Atlantic, USA fishermen surveys (N=886; N= 610 use bloodworms)

Environmentalism

- 80% very concerned about quality of fishing environment
- 93% are very or somewhat concerned about non-natives
- 94% are very or somewhat concerned about packing materials
- 61% would discard worms/wormweed first in garbage
- 98% would definitely use or use info given at a bait store

97% would definitely use or use info given on labels

<u>Appears to be scope for leveraging fishing concerns with regard to bloodworm packing materials</u>

Paolisso and Trombley (2015)

Moving forward

- Currently no regulations on this vector in the US
- ME distributors can ship bloodworms naked; US states could require consumers and retailers to use wormweed-free shipping
- Eliminating wormweed use in ME would decrease hitchhikers and would not impose a change in cost to the consumer

  - may restrict demand for worms, lower prices or reduce quantities traded

  •Need info on practicality and consumer buy-in of wormweed removal / treatment

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AP Photo/Robert F. Bukaty

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MARE

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The Marine Laboratory of the University of Maine

Smithsonian Environmental Research Center

Supporting Table S2. The five ecological traits used to determine functional groups used in this study that are considered the most relevant to competition in benthic communities (modified from Wahl 2009).

Body Size	Growth form	Trophic Type	Modularity	Motility
S	B	A	C	A
(<1mm)	(bushy)	(autotroph)	(colonial)	(attached)
M	E	D	S	B
(1 mm - <10 mm)	(encrusting)	(deposit feeder)	(solitary)	(burrowing)
L	F	G		C
(10 mm - <100 mm)	(filamentous)	(grazers)		(crawling)
X	M	P		D
(100 mm - 1000 mm)	(massive)	(predator)		(drifting)
XX		S		S
(>1000 mm)		(suspension feeder)		(swimming)