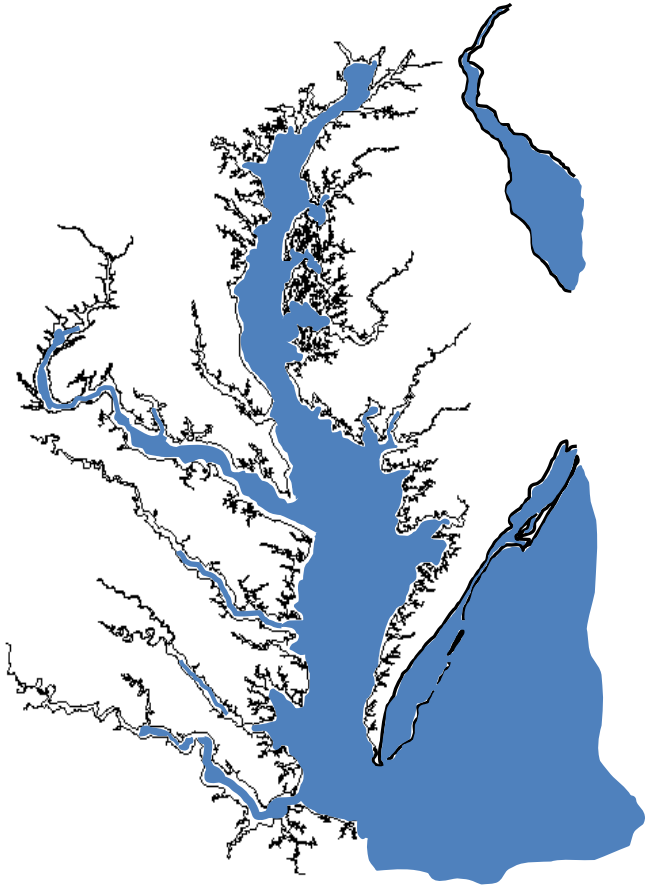
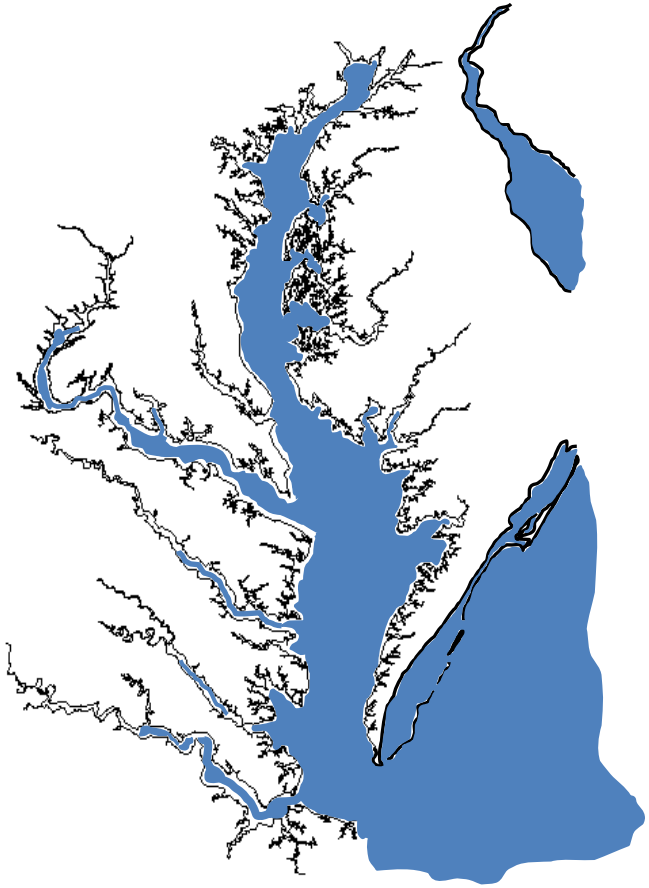
Shellfish Breeding Programs

Stan Allen
Aquaculture Genetics and Breeding Technology Center
Virginia Institute of Marine Science
College of William and Mary



Oyster Breeding Programs

Stan Allen
Aquaculture Genetics and Breeding Technology Center
Virginia Institute of Marine Science
College of William and Mary



Species	# of programs	Average (range) # of families tested per generation	Average (range) # of traits in breeding goal	Traits included in the breeding goal (in addition to growth rate)				World prod. 2005* (x 1000 tons)
				Disease resistance	Carcass quality	Age at sexual mat.	Other	
Atlantic salmon	13	280 (100-800)	5.4 (3-13)[1]	10	9	9	4	1 236
Rainbow trout	13	206 (100-400)	5.2 (2-11)	5	7	2	2	487
Coho salmon	4	133 (40-300)	2.7 (1-6)	1	1			117
Chinook salmon	2	100	1.5		1	1		24
Common carp	4	?	3.7	1	2	1	6	3 043
Channel catfish	1	200	4	1	1			380
White fish	1	70	2		1			1
Atlantic cod	3	110 (50-200)	4 (2-8)	2	1	2	1	8
Turbot	2	60	1					7
Sea bass	3	100	5	1	1		1	346
Sea bream	4	100	6	1	1		1	242
Tilapia	1	?	3	3	1		1	2 026
Oysters	5	48 (30-60)	4.3 (4-5)	2	3			4 615
Mussel	1	60	3		1			1 786
Marine shrimp	3	212 (150-300)						2 675
Abalone	2	70 (59-100)	3.5 (3-4)		2			334
Sum	62	125	3.8					

* FAO statistics 2007

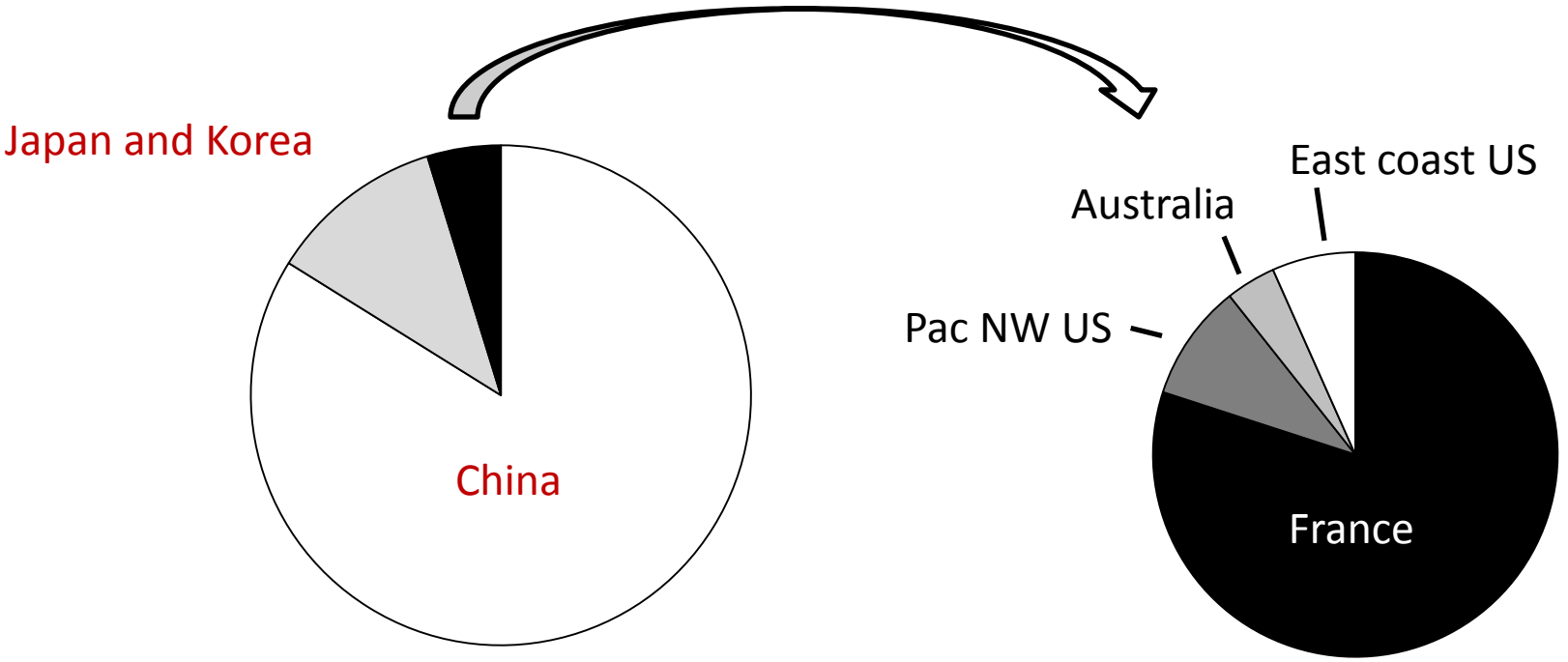
Oysters!

#1

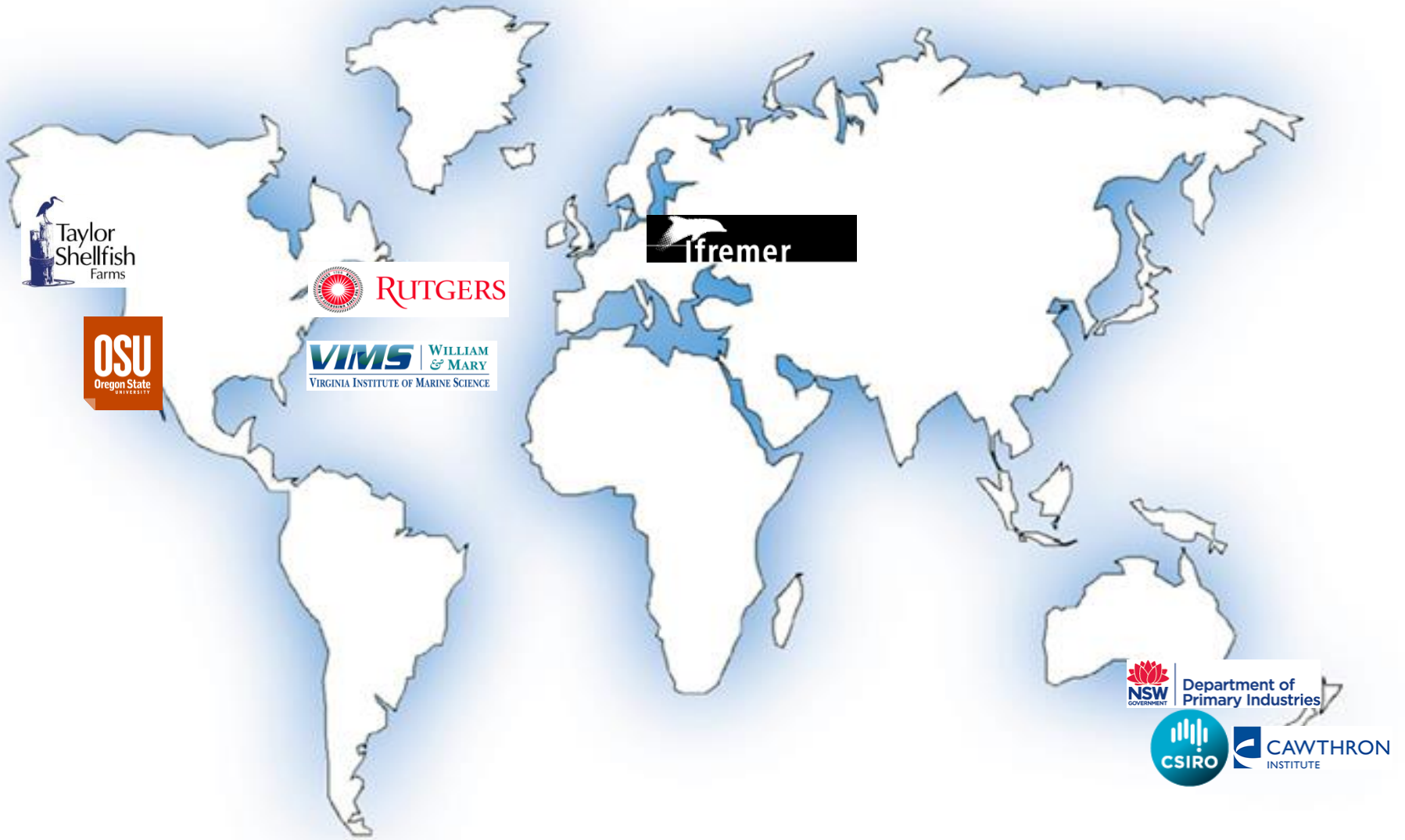
4.6M mt

From Rye et al., 2010

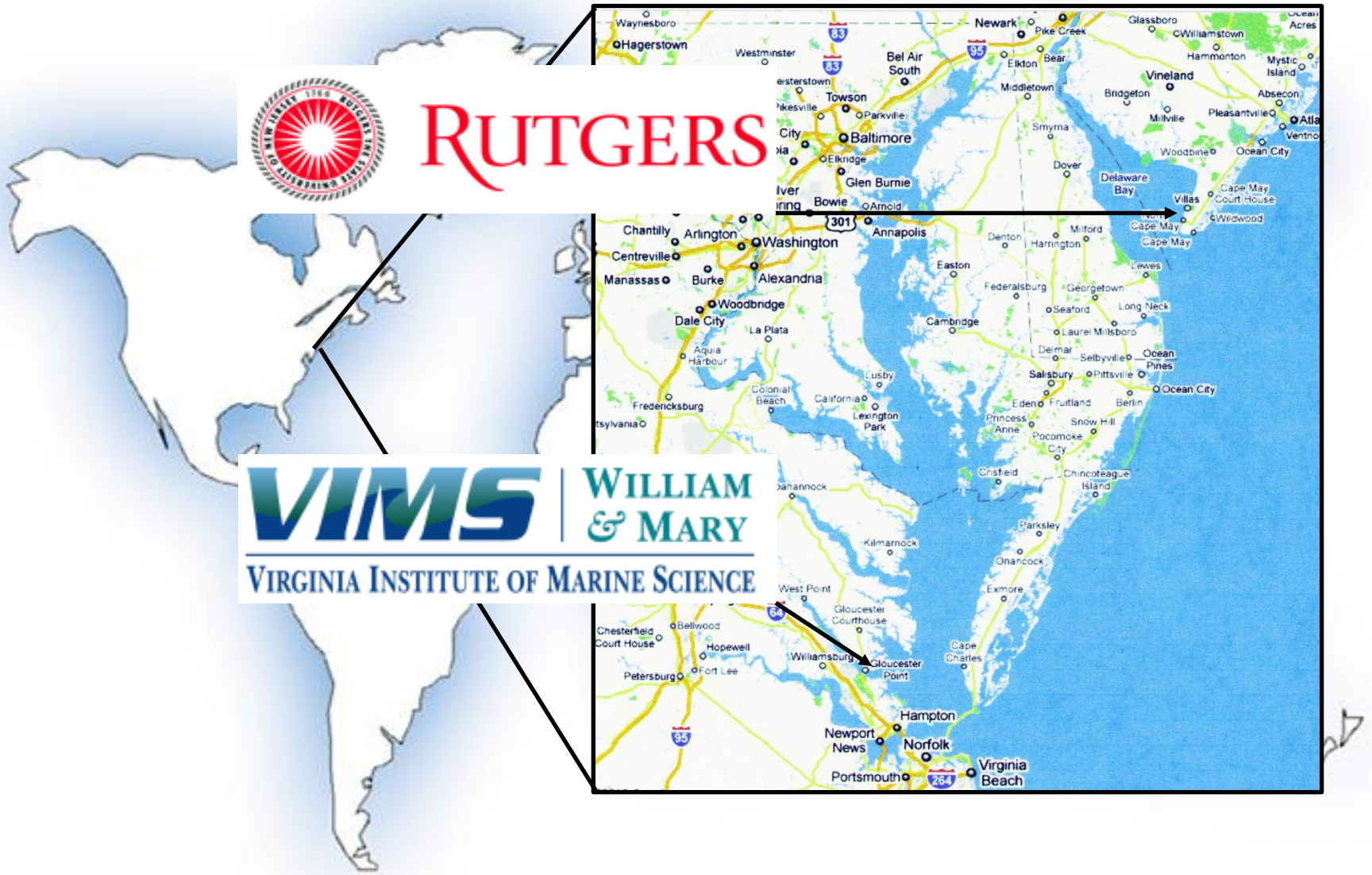
Product from natural catch vs hatchery seed



Example oyster breeding programs

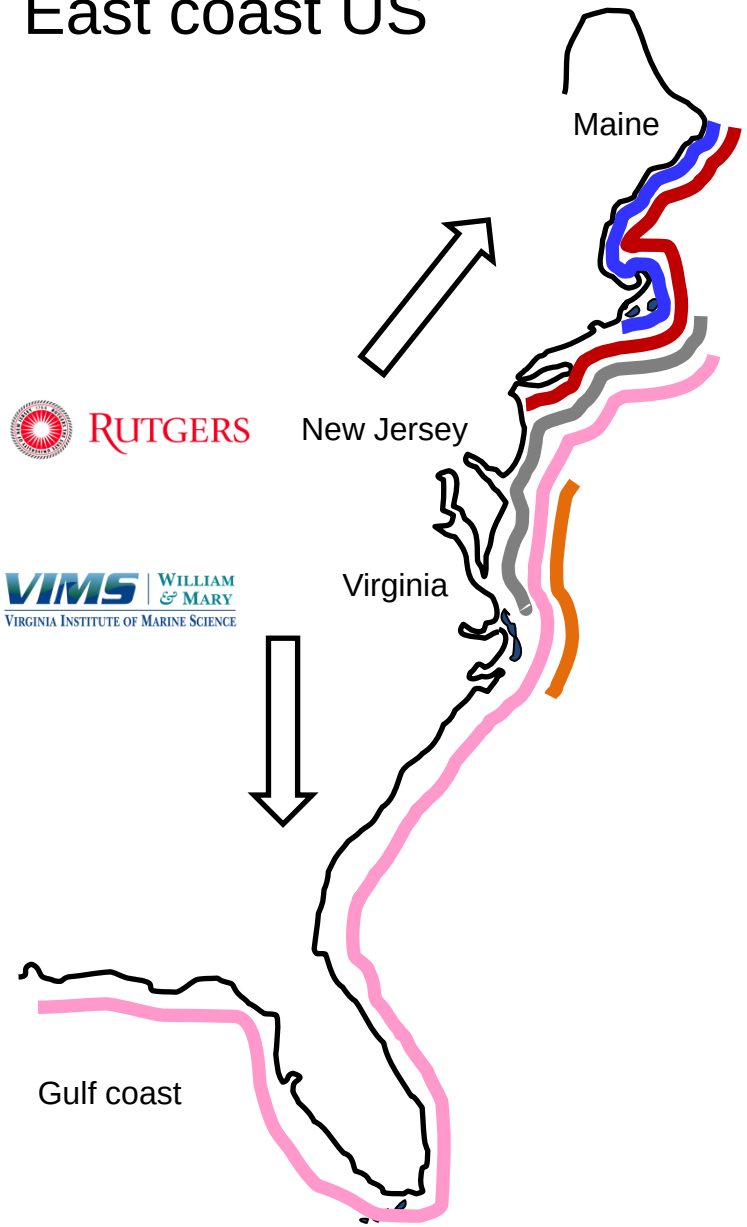


Example oyster breeding programs



East coast US

Crassostrea virginica

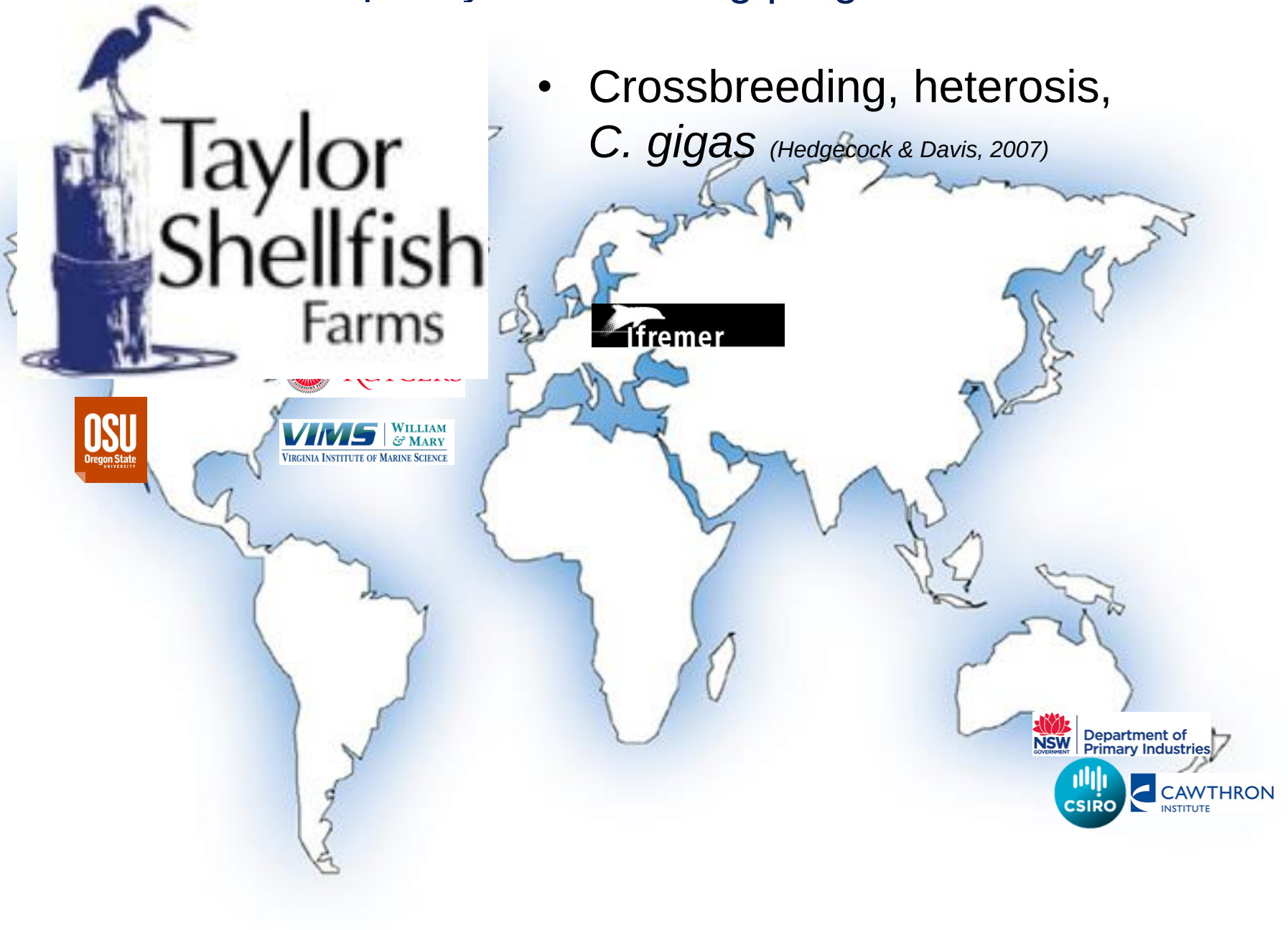


Regional Challenges to Selective Breeding

- Cold Water Physiology
- Juvenile Oyster Disease
- MSX Disease
- Dermo Disease
- Wide salinity variation

Example oyster breeding programs

- Crossbreeding, heterosis, *C. gigas* *(Hedgecock & Davis, 2007)*

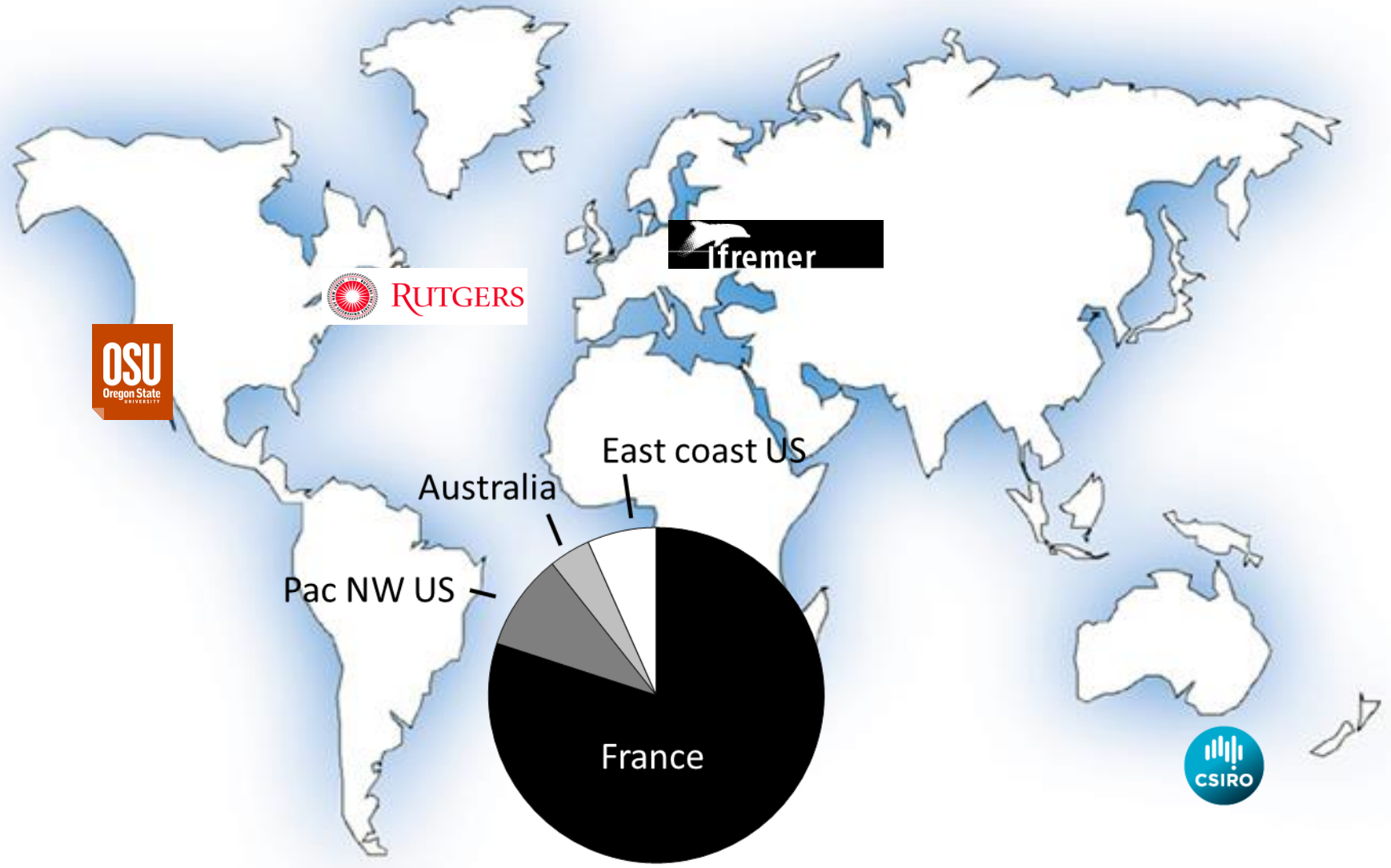


Example oyster breeding programs

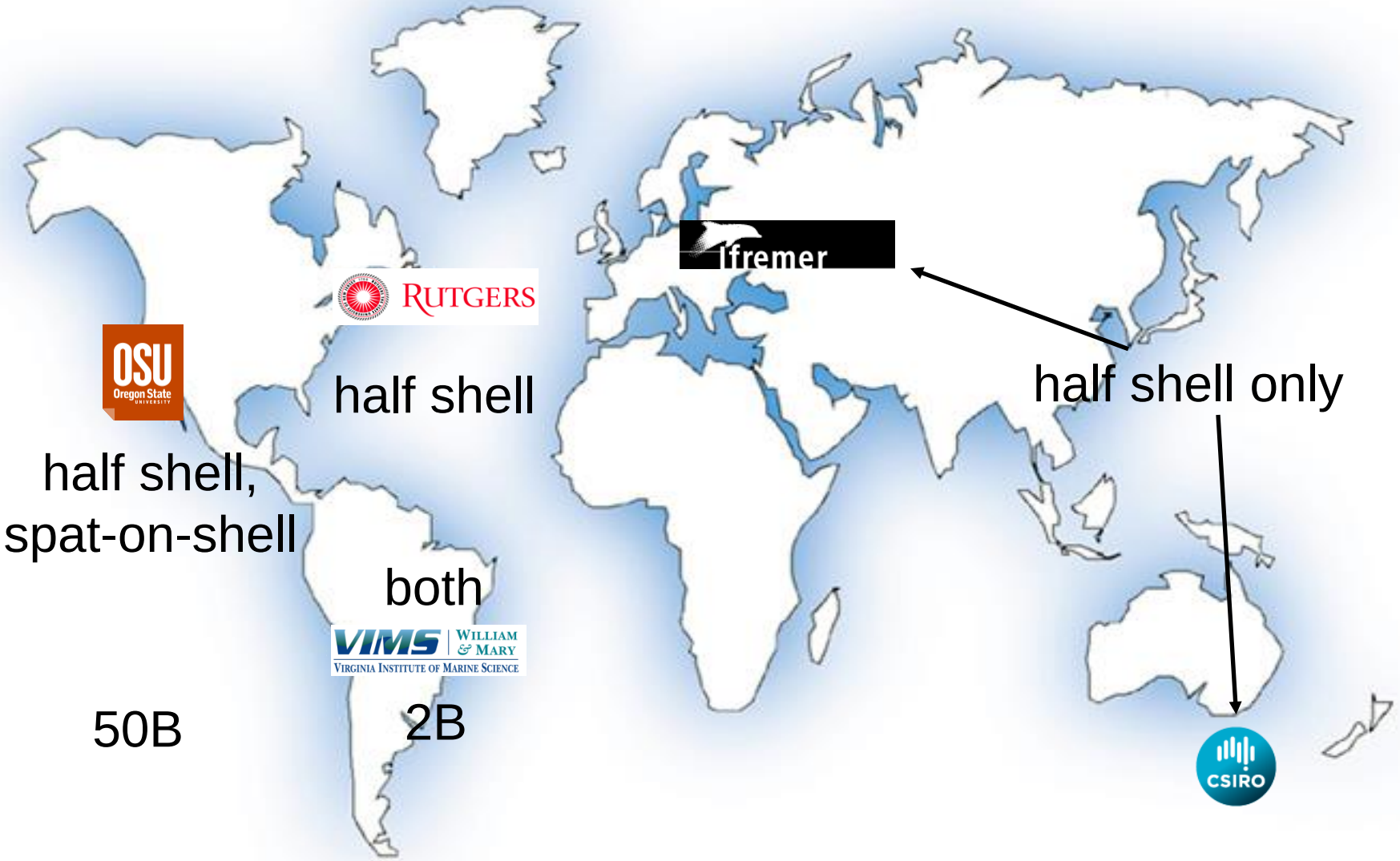
- MX, QX resistance, Sydney rock
- OsHV-1 resistance, *C. gigas*

Principal oyster breeding programs

Programs and “links to production”



Principal oyster breeding programs

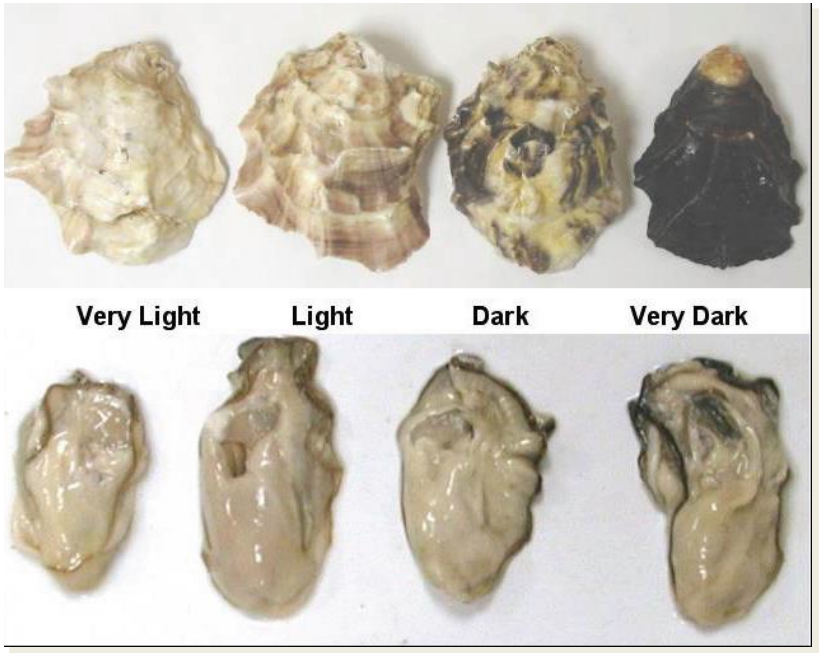


Molluscan Broodstock Program

Started: 1996

Funding: Special project – USDA →
USDA + grant support →
Grant support + donations from industry

Traits: Yield (growth x survival) – “generalist”
Color



Molluscan Broodstock Program

Started: 1996

Funding: Special project – USDA →
USDA + grant support →
Grant support + donations from industry

Traits: Yield (growth x survival) – "generalist"
Color

Type of industry supported: Eyed larvae (spat-on-shell) and half shell

eyed larvae

spat-on-shell

Molluscan Broodstock Program

Started: 1996

Funding: Special project – USDA →
USDA + grant support →
Grant support + donations from industry

Traits: Yield (growth x survival) – "generalist"
Color

Type of industry supported: Eyed larvae (spat-on-shell) and half shell

Testing system: Commercial sites tended by industry

~50 families, up to 2x/ year

cooperating commercial farms

Photos: C. Langdon

Geographic range:
California to Alaska

Molluscan Broodstock Program

Started: 1996

Funding: Special project – USDA →
USDA + grant support →
Grant support + donations from industry

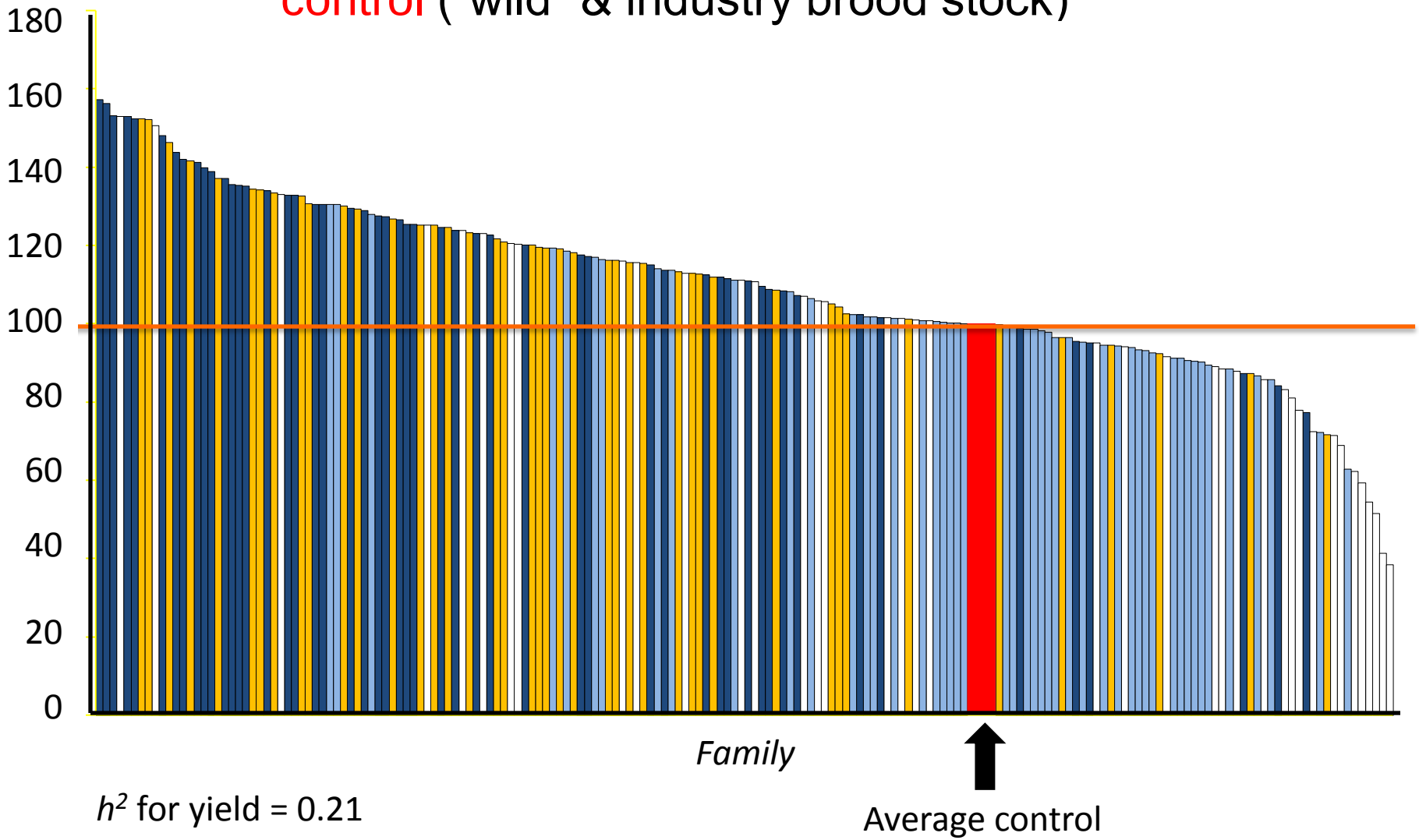
Traits: Yield (growth x survival) – "generalist"
Color

Type of industry supported: Eyed larvae (spat-on-shell) and half shell

Testing system: Commercial sites tended by industry

Example results: Improved yield

Percent improvement (3 generations) vs control ("wild" & industry brood stock)



h^2 for yield = 0.21

From C. Langdon

Molluscan Broodstock Program

Started: 1996

Funding: Special project – USDA →
USDA + grant support →
Grant support + donations from industry

Traits: Yield (growth x survival) – "generalist"
Color

Type of industry supported: Eyed larvae (spat-on-shell) and half shell

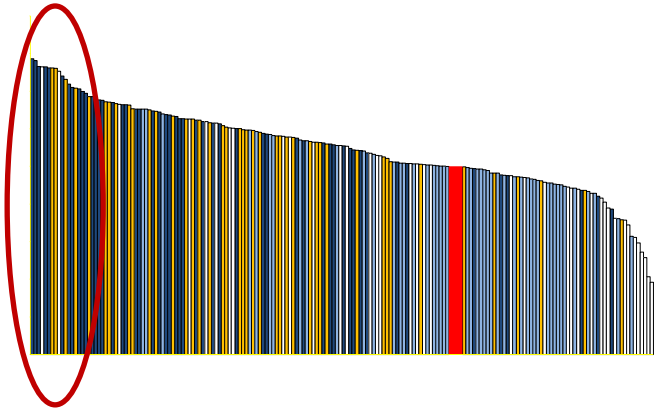
Testing system: Commercial sites tended by industry

Example results: Improved yield

Distribution: Families → "Pods"

MBP distribution of selectively bred “lines”

Pod A
Pod B
Pod C
Pod D

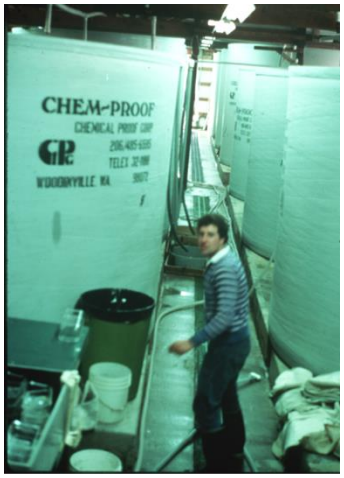


MBP

industry

Pods

A x B
B x C
etc.



Molluscan Broodstock Program

Started: 1996

Funding: Special project – USDA →
USDA + grant support →
Grant support + donations from industry

Traits: Yield (growth x survival) – "generalist"
Color

Type of industry supported: Eyed larvae (spat-on-shell) and half shell

Testing system: Commercial sites tended by industry

Example results: Improved yield

Distribution: Families → "Pods"

IP diploids / tetraploids: Not exploited / No

ASI, CSIRO partnership

ASI
Thoroughbred Oysters

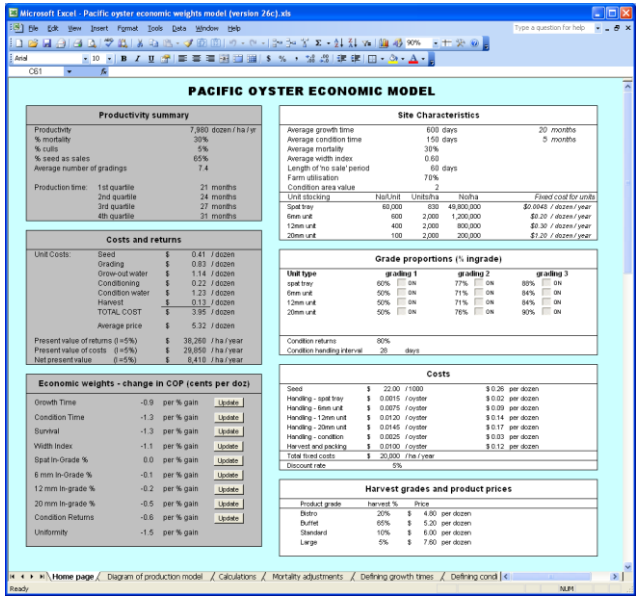
CSIRO

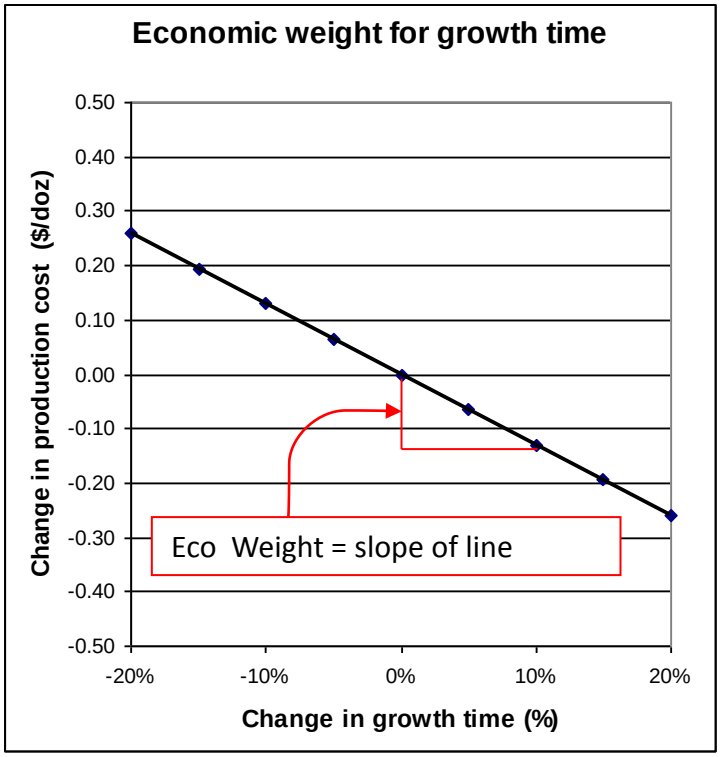
Started: 1997

Funding: Government project →
ASI (breeding company)→
Tax on seed goes to ASI

Traits: Economic weights
Survival – S. Australia
OsHV-1 resistance

Economic model





Shell growth time
Meat growth time
Shell shape
Survival
Uniformity

Graphics credit: Peter Kube

ASI, CSIRO partnership

ASI Thoroughbred Oysters

Started: 1997

Funding: Government project →
ASI (breeding company)→
Tax on seed goes to ASI

Traits: Economic weights
Survival – S. Australia
OsHV-1 resistance

Type of industry supported: Half shell

Photos: Peter Kube

ASI, CSIRO partnership

ASI Thoroughbred Oysters

Started: 1997

Funding: Government project →
ASI (breeding company)→
Tax on seed goes to ASI

Traits: Economic weights
Survival – S. Australia
OsHV-1 resistance

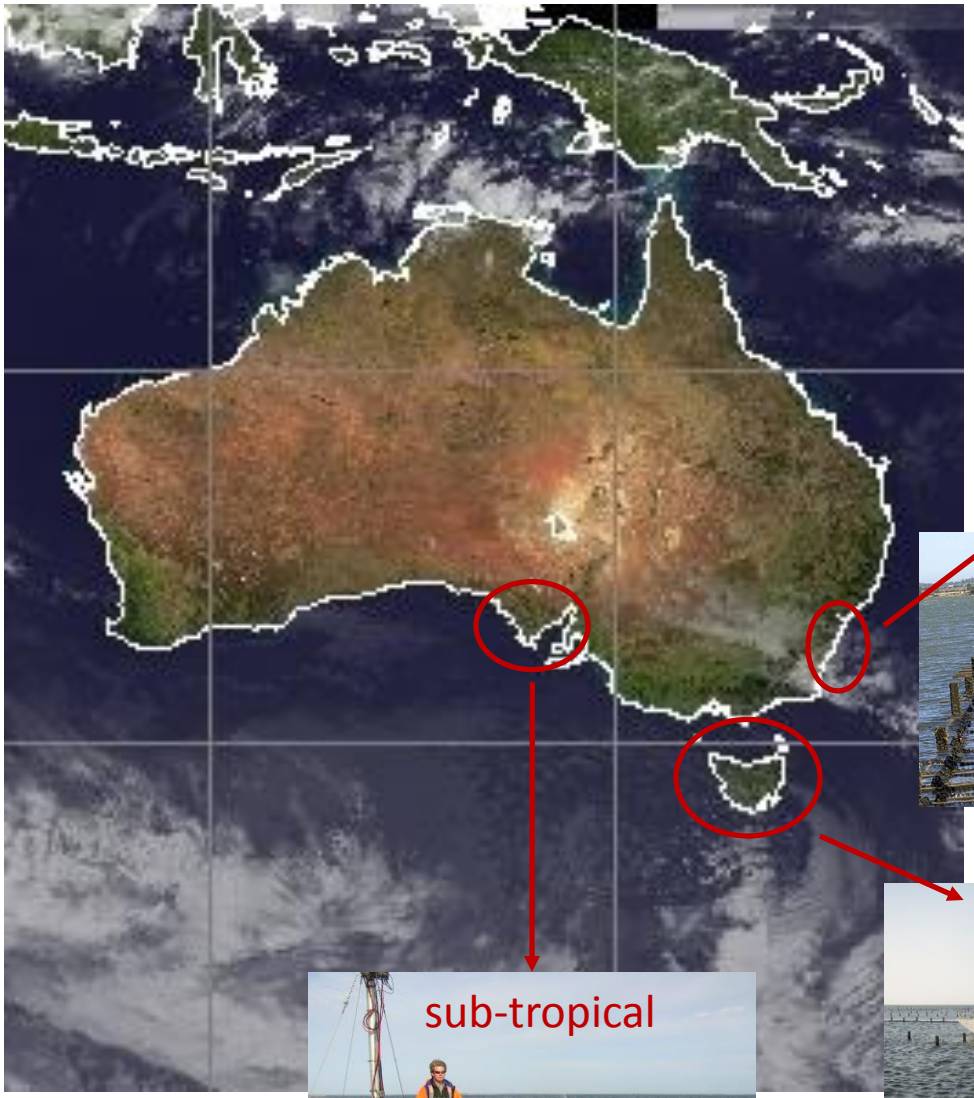
Type of industry supported: Half shell

Testing system: Commercial sites tended by industry

~ 50-60 families/ year

Production traits
- 4-6 test sites
- commercial farms

OsHV-1
- NSW only
- challenge experiments



Photos: Peter Kube

ASI, CSIRO partnership

ASI Thoroughbred Oysters

Started: 1997

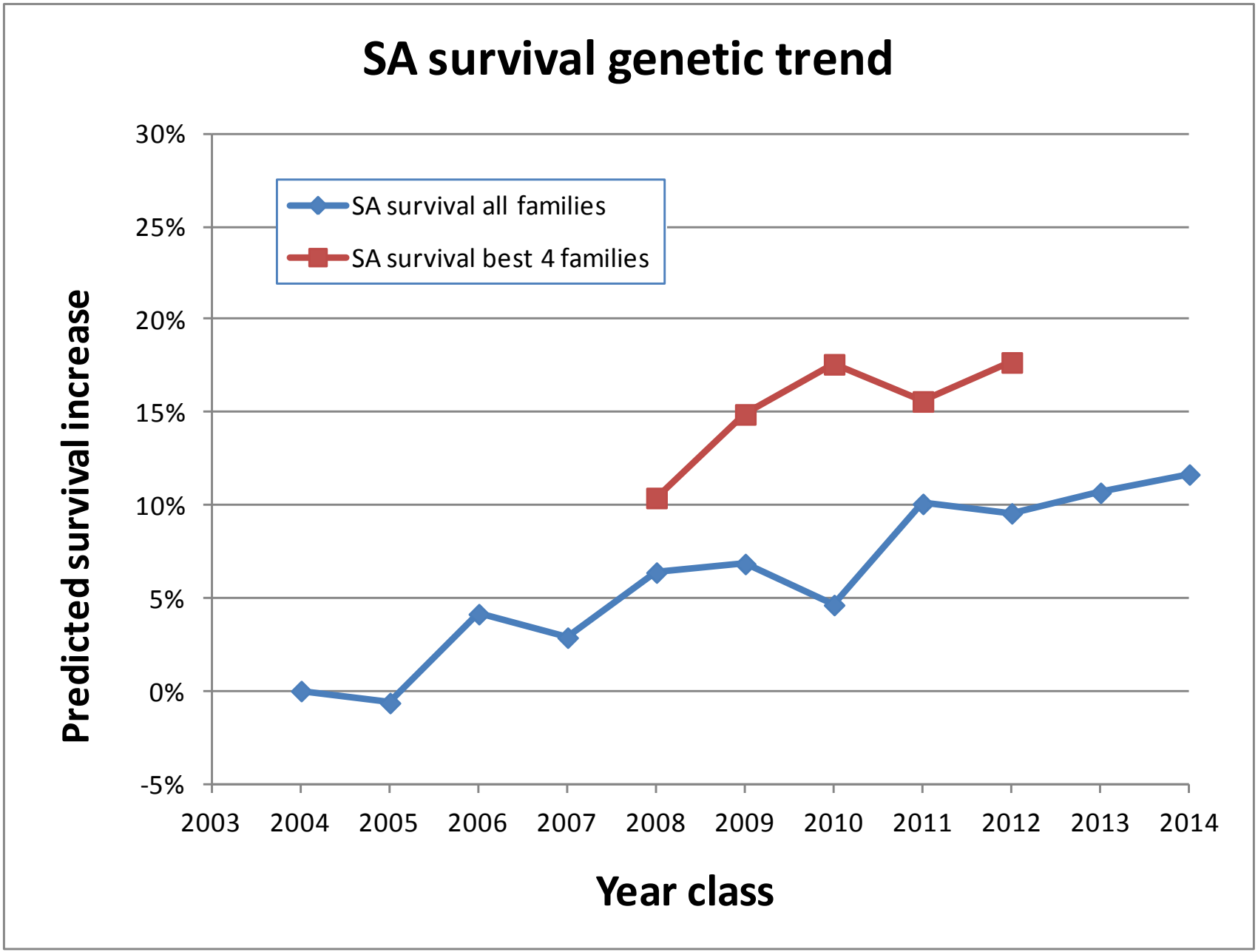
Funding: Government project →
ASI (breeding company)→
Tax on seed goes to ASI

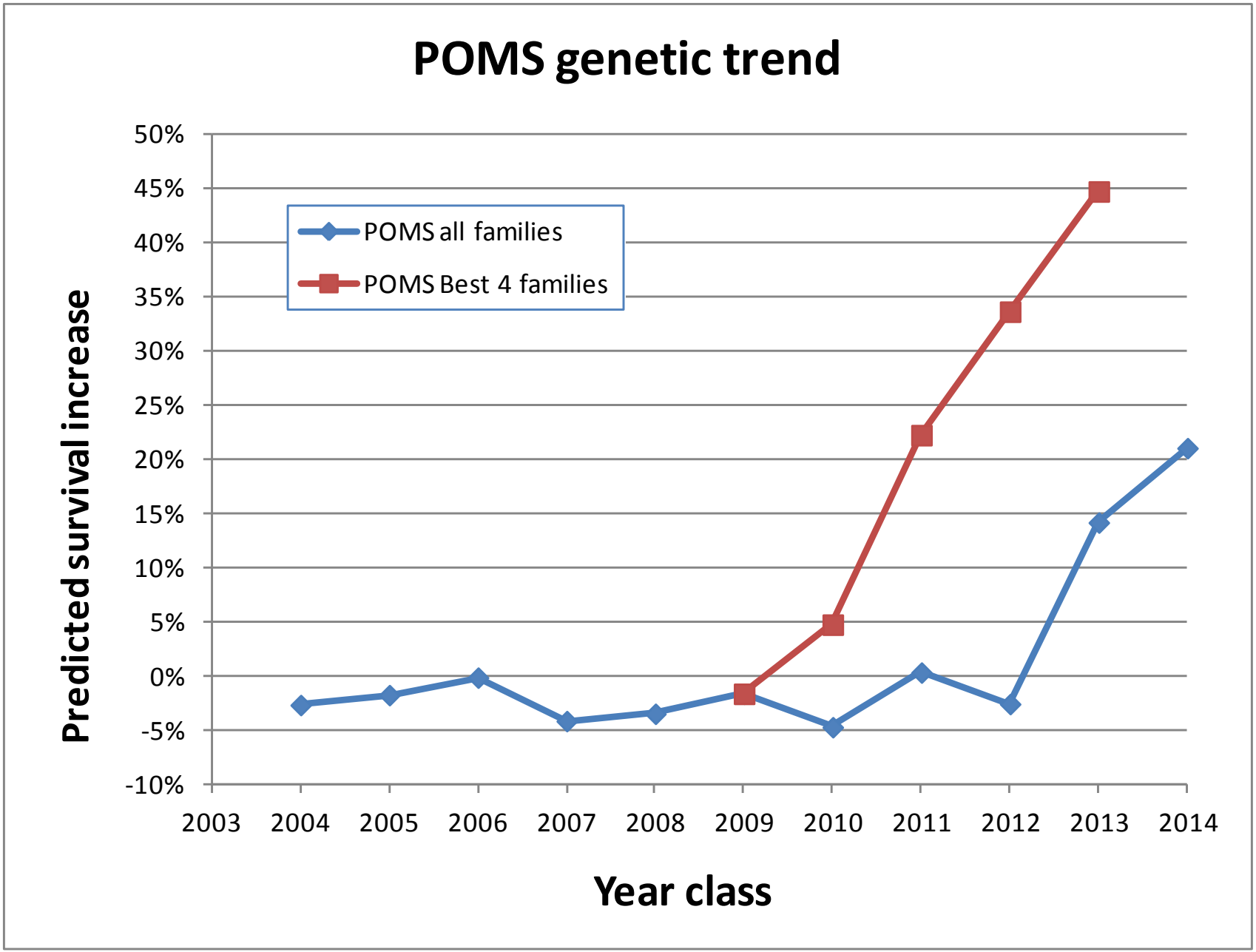
Traits: Economic weights
Survival – S. Australia
OsHV-1 resistance

Type of industry supported: Half shell

Testing system: Commercial sites tended by industry

Example results: Survival


SA survival genetic trend
SA survival all families
SA survival best 4 families
Predicted survival increase
30%
25%
20%
15%
10%
5%
0%
-5%
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year class


POMS genetic trend
Predicted survival increase
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
-5%
-10%
POMS all families
POMS Best 4 families
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year class

ASI, CSIRO partnership

ASI Thoroughbred Oysters

Started: 1997

Funding: Government project →
ASI (breeding company)→
Tax on seed goes to ASI

Traits: Economic weights
Survival – S. Australia
OsHV-1 resistance

Type of industry supported: Half shell

Testing system: Commercial sites tended by industry

Example results: Survival

Distribution: EBVs released to industry; hatcheries decide what families to use based on customer base

ASI, CSIRO partnership

ASI Thoroughbred Oysters

Started: 1997

Funding: Government project →
ASI (breeding company)→
Tax on seed goes to ASI

Traits: Economic weights
Survival – S. Australia
OsHV-1 resistance

Type of industry supported: Half shell

Testing system: Commercial sites tended by industry

Example results: Survival

Distribution: EBVs released to industry; hatcheries decide what families to use based on customer base

IP diploids / tetraploids: owned by ASI but not exploited (industry tax) / no

IFREMER R&D

Started: 1990s *Bonamia* resist.
2001 MOREST
2009 OsHV-1

Funding: Government project

Traits: Summer mortality
OsHV-1 resistance
Vibrio aestuarianus resistance

Type of industry supported: Half shell

Seed production

- 3 billion hatchery
- ~7-25 billion wild caught

130,000 mt product

IFREMER R&D

Started: 1990s *Bonamia* resist.
2001 MOREST
2009 OsHV-1

Funding: Government project

Traits: Summer mortality
OsHV-1 resistance
Vibrio aestuarianus resistance

Type of industry supported: Half shell

Testing system: IFREMER controlled sites according to project

IFREMER R&D

Started: 1990s *Bonamia* resist.
2001 MOREST
2009 OsHV-1

Funding: Government project

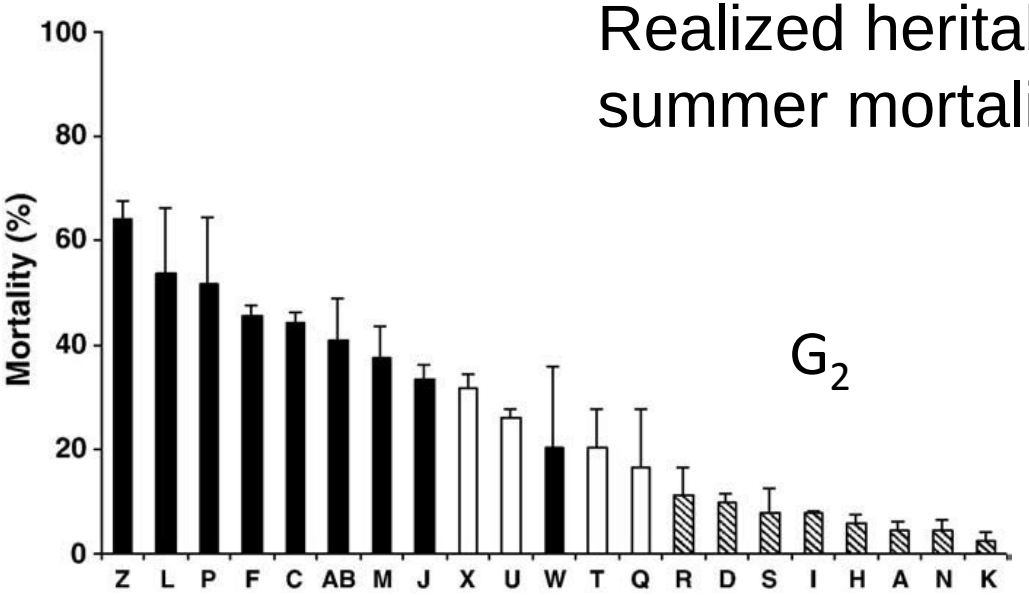
Traits: Summer mortality
OsHV-1 resistance
Vibrio aestuarianus resistance

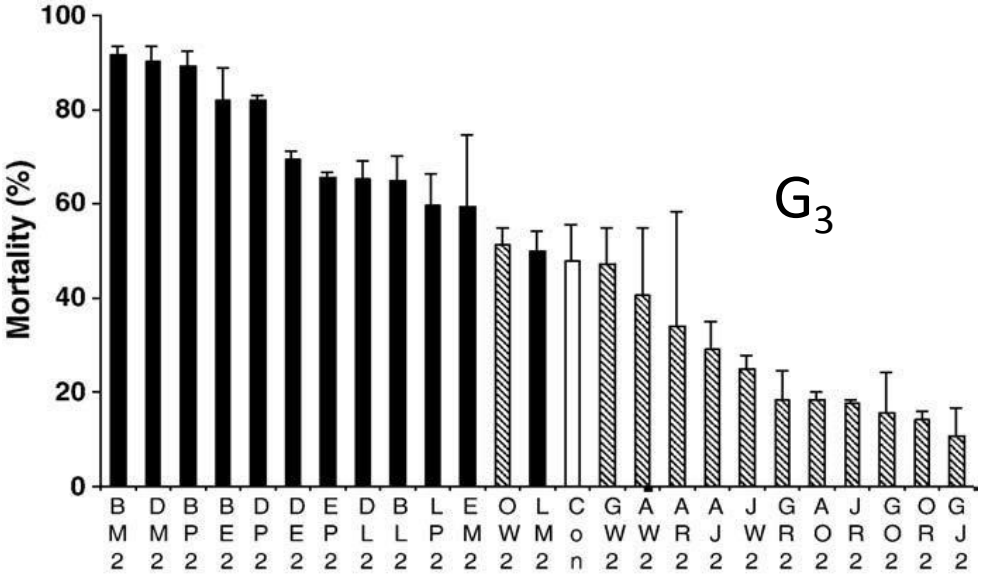
Type of industry supported: Half shell

Testing system: IFREMER controlled sites according to project

Example results: “R” lines and resistant strains

Realized heritability for resistance to summer mortality: 0.64 – 0.95, by site





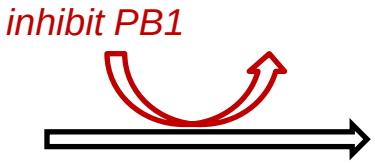
Degremont, Bedier, Boudry, 2010

2008 – emergence of OsHV-1µvar

"R" line revived

Tetraploid "R" lines developed

RR
x
RR

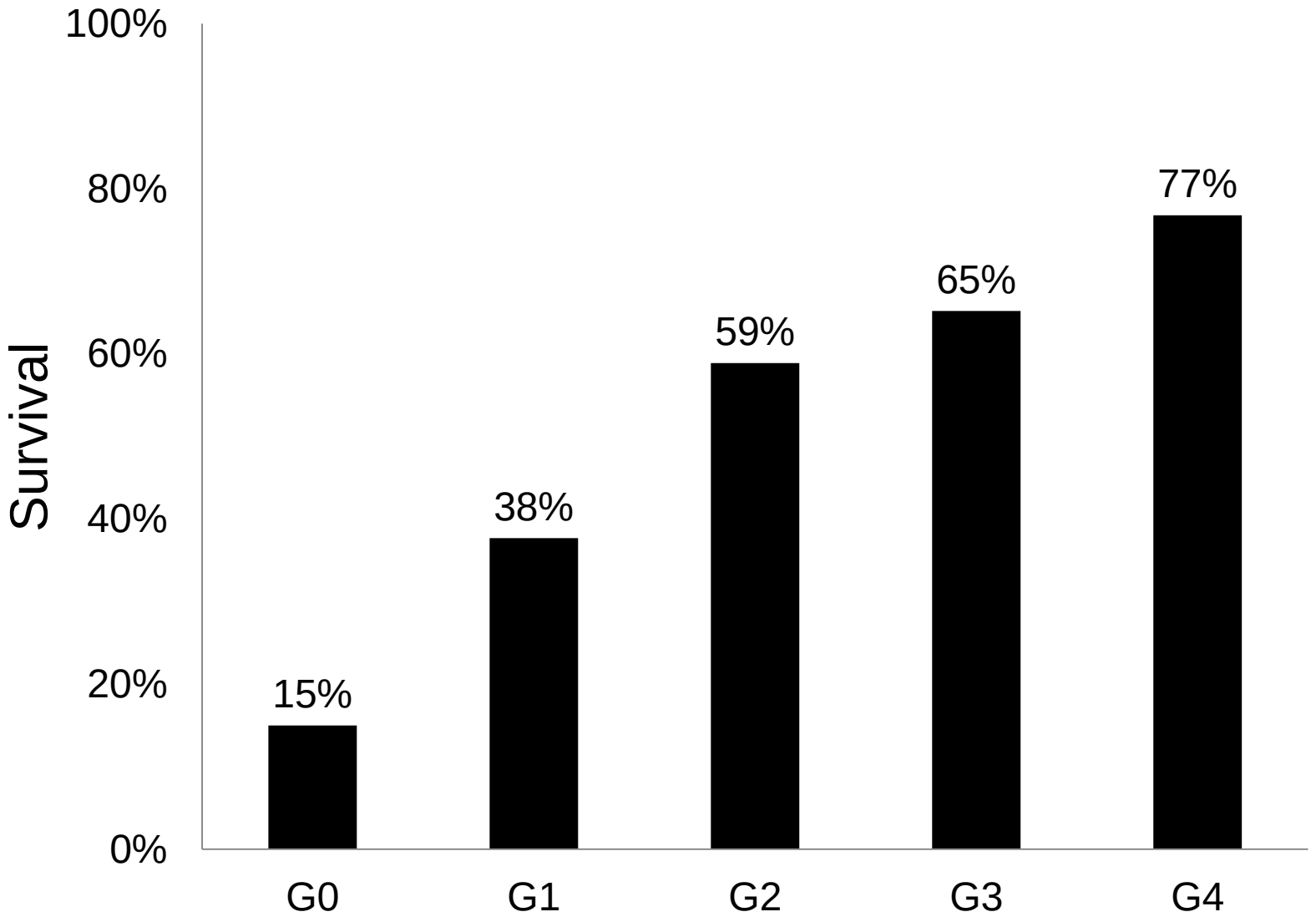


RRRR

RR
x
RRRR

RRR possible commercially

Survival of successive generations of *C. gigas* when exposed to OsHV-1 under field conditions



L. Degremont et al., 2015

IFREMER R&D

Started: 1990s *Bonamia* resist.
2001 MOREST
2009 OsHV-1

Funding: Government project

Traits: Summer mortality
OsHV-1 resistance
Vibrio aestuarianus resistance

Type of industry supported: Half shell

Testing system: IFREMER controlled sites according to project

Example results: “R” lines and resistant strains

Distribution: No distribution except for “R” lines

Ifremer

research

INRA
SCIENCE & IMPACT

SYSAAF

Syndicat des Sélectionneurs
Avicoles et Aquacoles Français

advisory and breeding services,
breeding research

FRANCE TURBOT

SODABO
AQUACULTURE

SATMAR

Vendée Naissain

Novostrea
Bretagne

IFREMER R&D

Started: 1990s *Bonamia* resist.
2001 MOREST
2009 OsHV-1

Funding: Government project

Traits: Summer mortality
OsHV-1 resistance
Vibrio aestuarianus resistance

Type of industry supported: Half shell

Testing system: IFREMER controlled sites according to project

Example results: “R” lines and resistant strains

Distribution: No distribution except for “R” lines

IP diploids / tetraploids: “R” lines, diploid and tetraploid are released by IFREMER; tetraploids sold to hatchery

Haskin Shellfish Research Lab

RUTGERS

Started: ca 1960

Funding: State “hard” money
IP revenues / seed sales

Traits: Disease resistance, growth – mass
Development of tetraploid lines – domestication

Type of industry supported: Half shell – Northeast US

Haskin Shellfish Research Lab

RUTGERS

Started: ca 1960

Funding: State “hard” money
IP revenues / seed sales

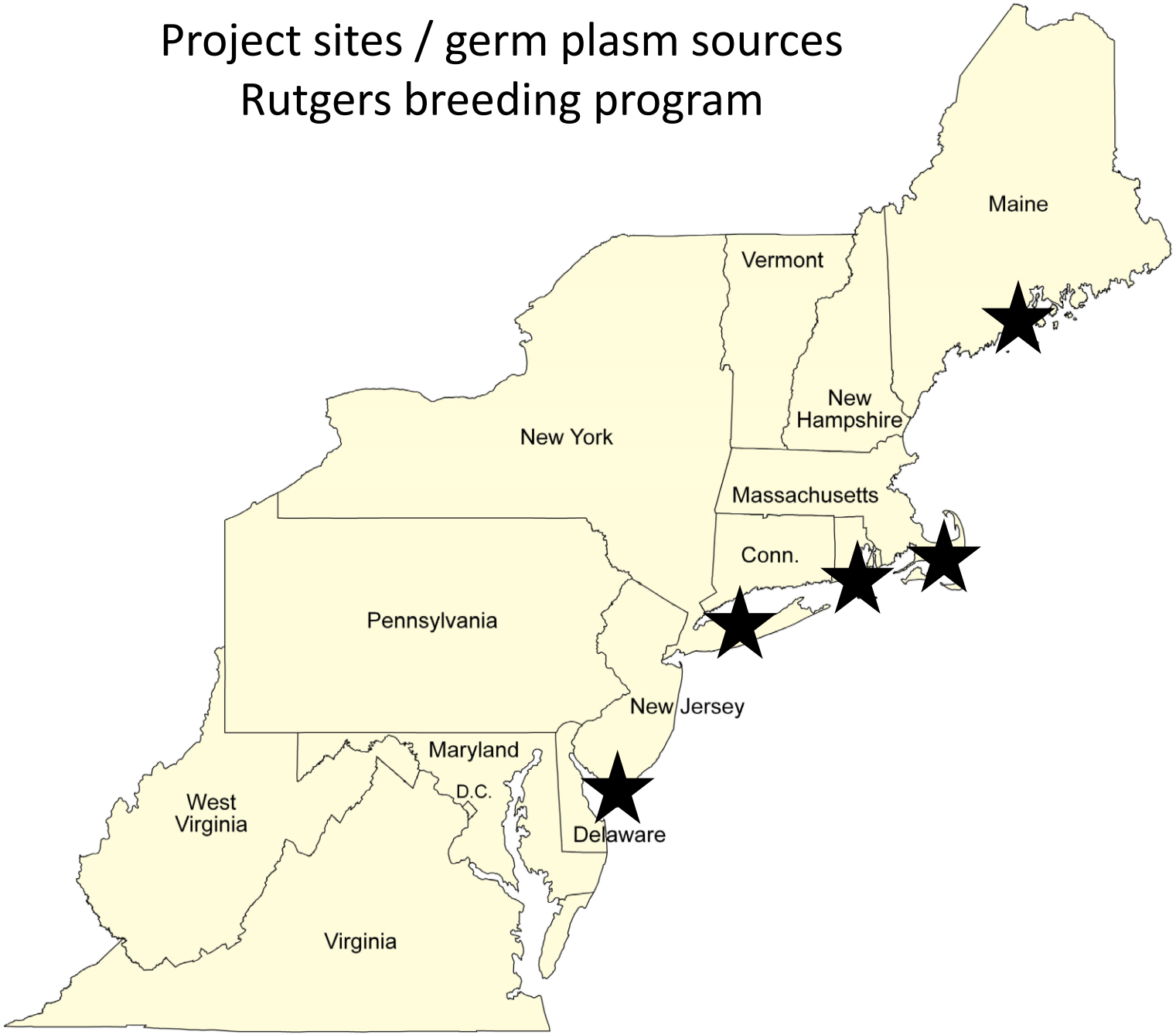
Traits: Disease resistance, growth – mass
Development of tetraploid lines – domestication

Type of industry supported: Half shell – Northeast US

Testing system: Institutional, collaborators for special projects

Waynesboro
Hagerstown
Westminster
Newark
Pike Creek
Glassboro
Williamstown
Bel Air South
Elkton
Bear
Hammonton
Mystic Island
Tuckerton
Reisterstown
Middletown
Vineland
Frederick
Pikesville
Towson
Parkville
Bridgeton
Millville
Ellicott City
Baltimore
Smyrna
Columbia
Elkridge
Woodbine
Gaithersburg
Olney
Glen Burnie
Dover
Delaware Bay
Leesburg
Rockville
Silver Spring
Bowie
Villas
Bethesda
Arnold
Chantilly
Arlington
Annapolis
Milford
North Cape May
Cape May
Denton
Harrington
Centreville
Washington
Manassas
Burke
Alexandria
Easton
Lewes
Federalsburg
Georgetown
Woodbridge
Seaford
Long Neck
Dale City
La Plata
Cambridge
Laurel
Millsboro
Aquia Harbour
Delmar
Selbyville
Ocean Pines
Salisbury
Pittsville
Lusby
Ocean City
Colonial Beach
California
Eden
Fruitland
Berlin
Fredericksburg
Lexington Park
Princess Anne
Snow Hill
Pocomoke City
Crisfield
Chincoteague Island
Tappahannock
Parksley
Ashland
Kilmarnock
Glen Allen
Mechanicsville
Onancock
Richmond
Highland Springs
West Point
Exmore
Gloucester Courthouse
Chesterfield Court House
Bellwood
Hopewell
Williamsburg
Gloucester Point
Cape Charles
Petersburg
Fort Lee
Hampton
Newport News
Norfolk

Project sites / germ plasm sources
Rutgers breeding program



Haskin Shellfish Research Lab

RUTGERS

Started: ca 1960

Funding: State “hard” money
IP revenues / seed sales

Traits: Disease resistance, growth – mass
Development of tetraploid lines – domestication

Type of industry supported: Half shell – Northeast US

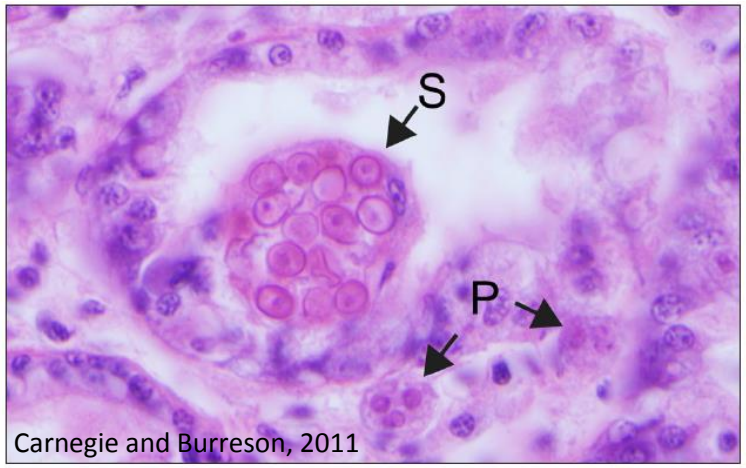
Testing system: Institutional, collaborators for special projects

Example results: MSX resistance
JOD resistance
Mechanism of Dermo resistance

Diseases

MSX

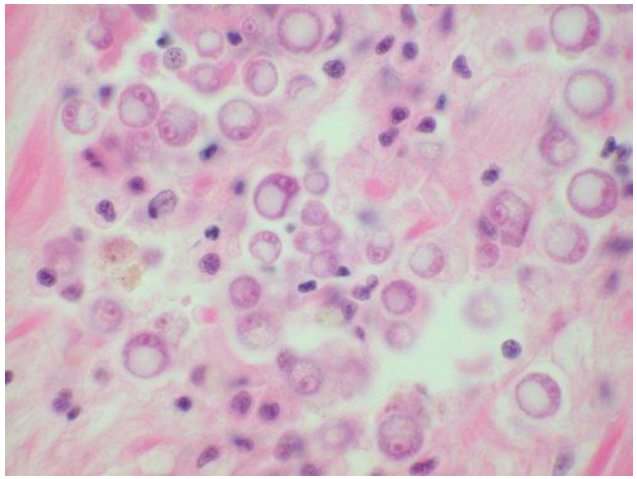
Haplosporidium nelsoni



- Introduced to East coast
- Highly heritable – few genes

Dermo

Perkinsus marinus



- Endemic to East coast
- Polygenic, low h^2 ?

Haskin Shellfish Research Lab

RUTGERS

Started: ca 1960

Funding: State “hard” money
IP revenues / seed sales

Traits: Disease resistance, growth – mass
Development of tetraploid lines – domestication

Type of industry supported: half shell – Northeast US

Testing system: Institutional, collaborators for special projects

Example results: MSX resistance
JOD resistance
Mechanism of Dermo resistance

Distribution: NEH, NEH hybrids (for JOD) / tetraploid NEH

Haskin Shellfish Research Lab

RUTGERS

Started: ca 1960

Funding: State “hard” money
IP revenues / seed sales

Traits: Disease resistance, growth – mass
Development of tetraploid lines – domestication

Type of industry supported: half shell – Northeast US

Testing system: Institutional, collaborators for special projects

Example results: MSX resistance
JOD resistance
Mechanism of Dermo resistance

Distribution: NEH, NEH hybrids (for JOD) / tetraploid NEH

IP diploids / tetraploids: Both diploids and tetraploids licensed to hatcheries

General summary of oyster breeding

- Comparatively, oysters originating from hatcheries is a small percentage of world production
- Australia, Pacific NW, East coast US, and France are principal locations for hatchery production
- Sustained funding for oyster breeding is rare, often dependent on individual effort
- Disease resistance is a prime motivator for entering a breeding program
- Without a disease, it is hard to convince growers of the long term value of breeding
- Triploidy is major contributor to genetic improvement, impelling tetraploid production

Example oyster breeding programs