

Historical perspectives on hatchery and population structure of chum salmon in Prince William Sound, Alaska

C. Habicht, R. Brenner, S. Moffitt, J. Jasper, L. Fox,
S. Rogers, H. Liller, W. Templin



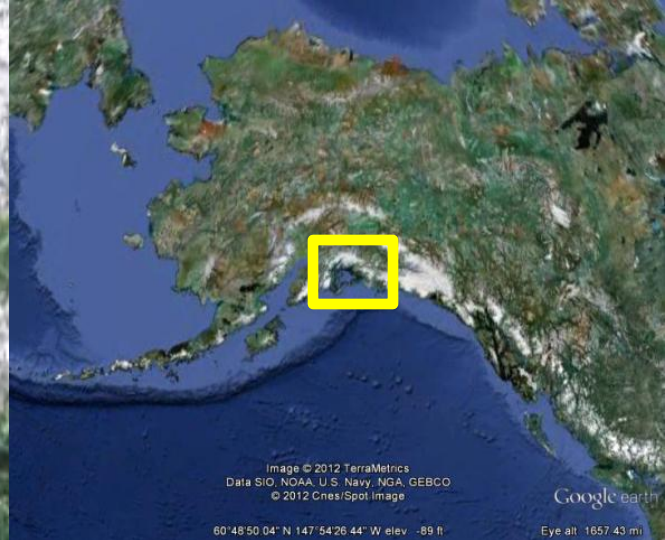


Image © 2012 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image

Google earth

60°48'50.04" N 147°54'26.44" W elev -89 ft

Eye alt 1657.43 mi

Image © 2012 TerraMetrics

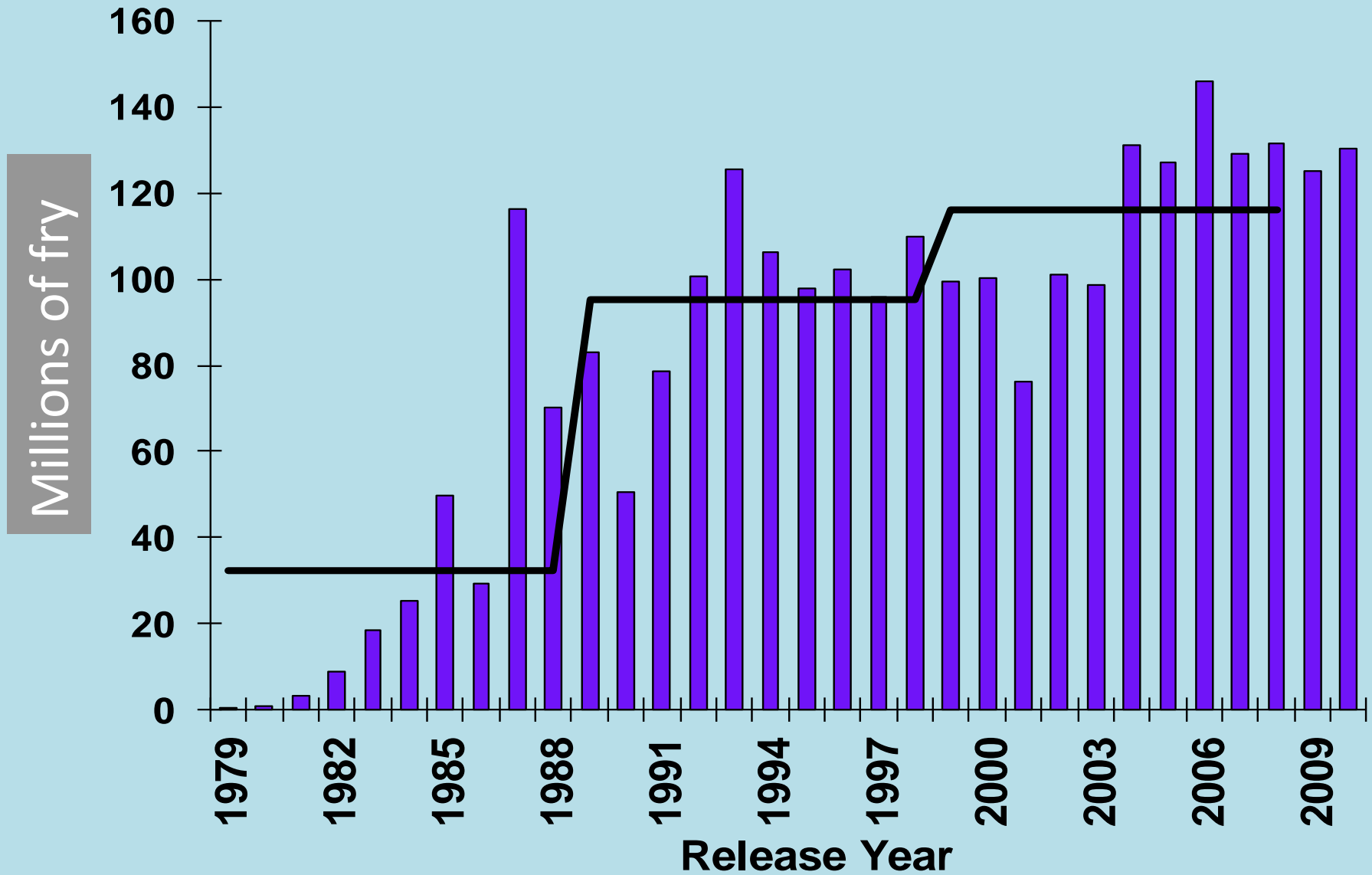
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

60°30'29.89" N 147°05'37.50" W elev -280 ft

Google earth

Eye alt 128.01 mi

PWS hatchery chum salmon fry releases



Concern:

Straying of hatchery-produced fish into wild spawning areas may be eroding adaptive genetic variation

Concern:

Straying of hatchery-produced fish into wild spawning areas may be eroding adaptive genetic variation

Requires two conditions:

- 1) There is adaptive genetic variation among wild streams
- 2) Hatchery fish are genetically contributing to wild populations

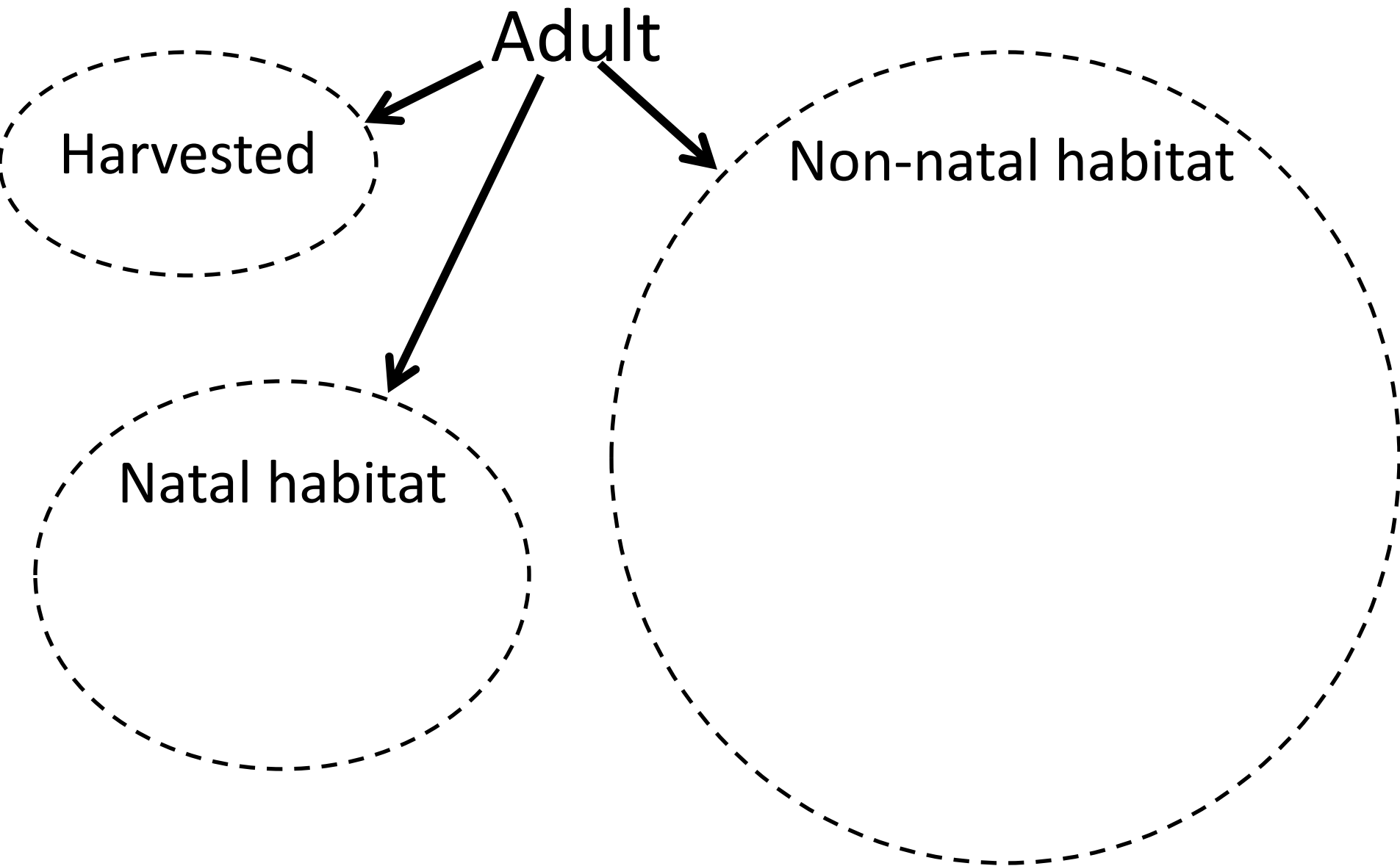
Concern:

Straying of hatchery-produced fish into wild spawning areas may be eroding adaptive genetic variation

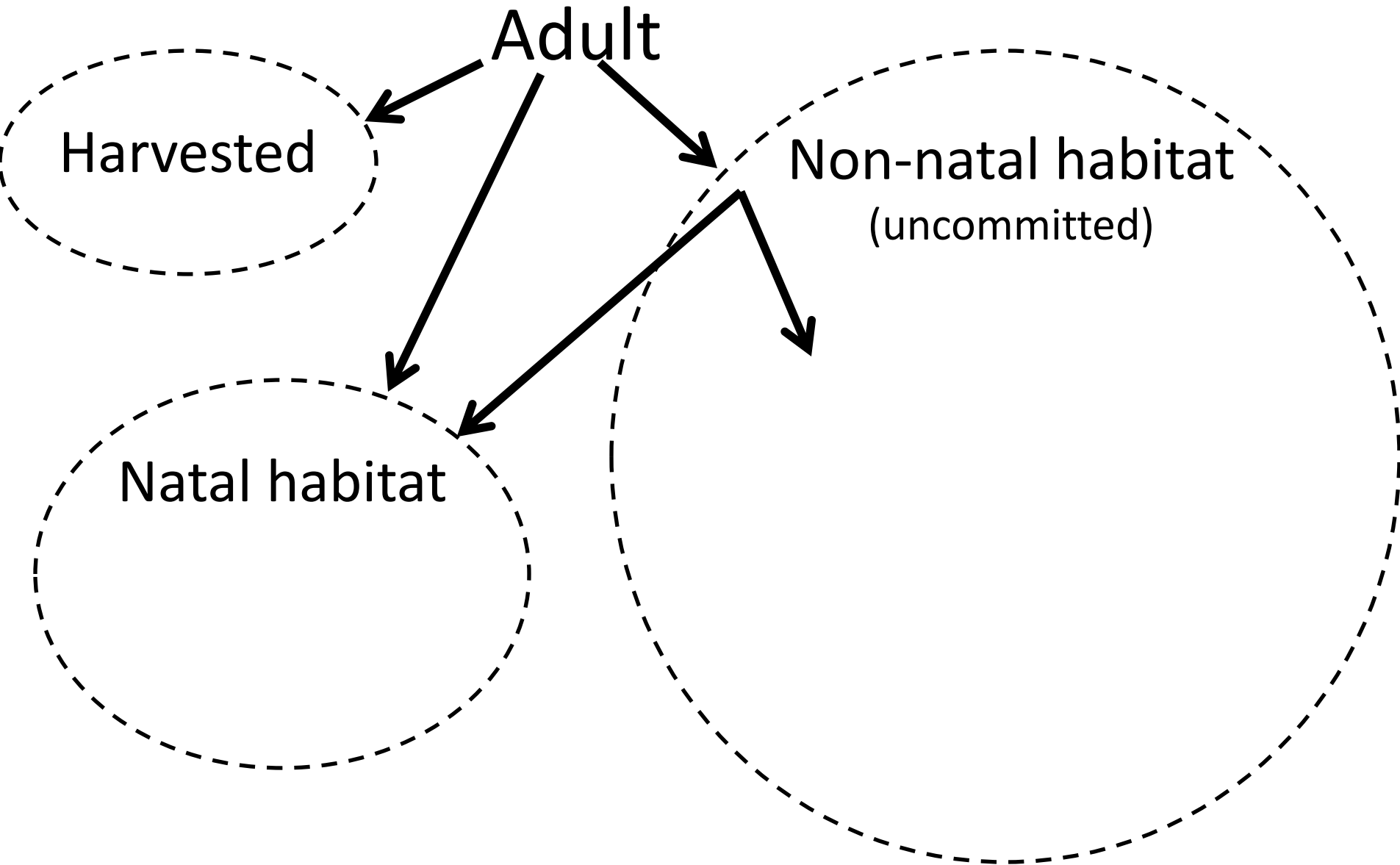
Requires two conditions:

- 1) There is adaptive genetic variation among wild streams
- 2) Hatchery fish are genetically contributing to wild populations

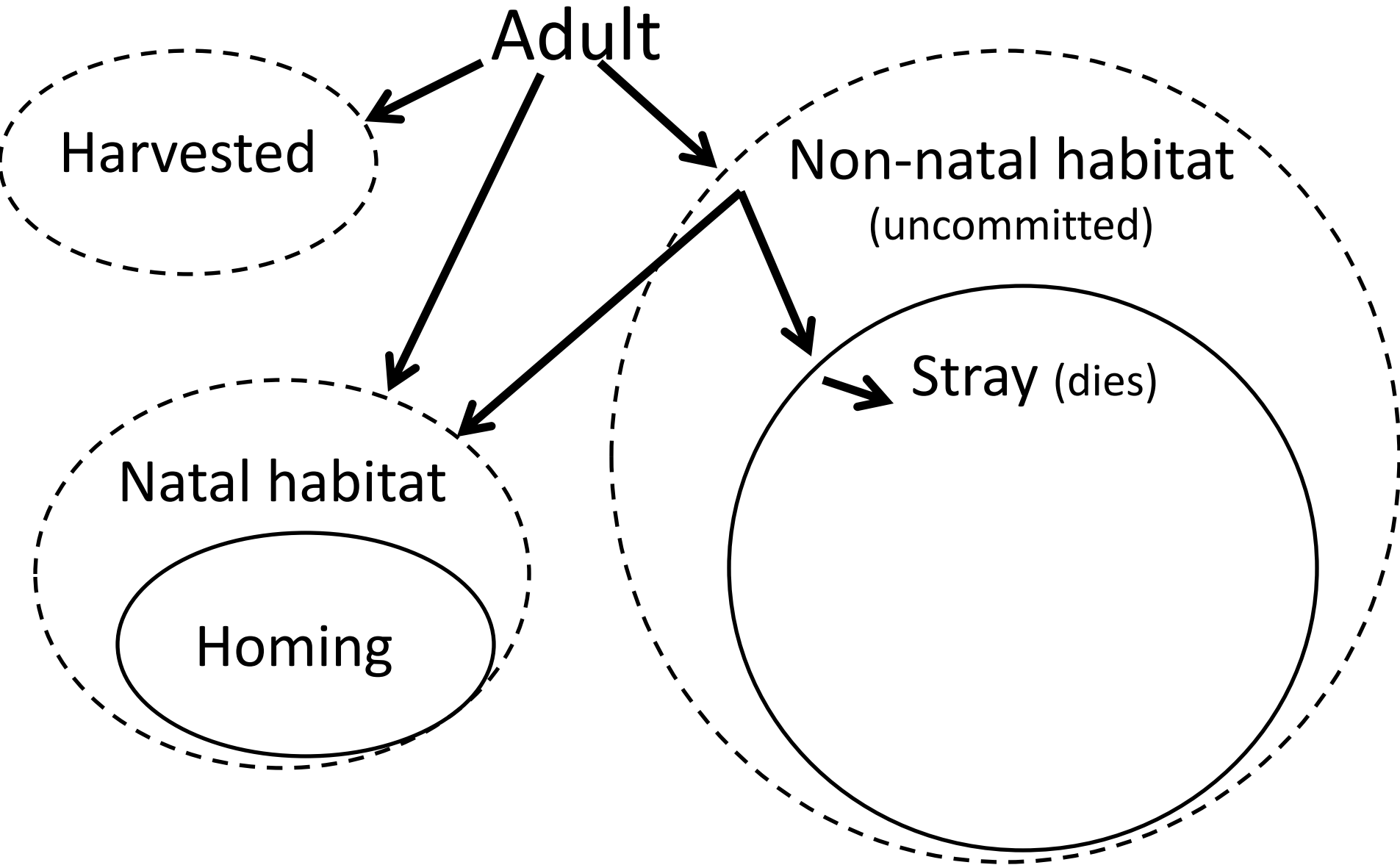
Straying definitions



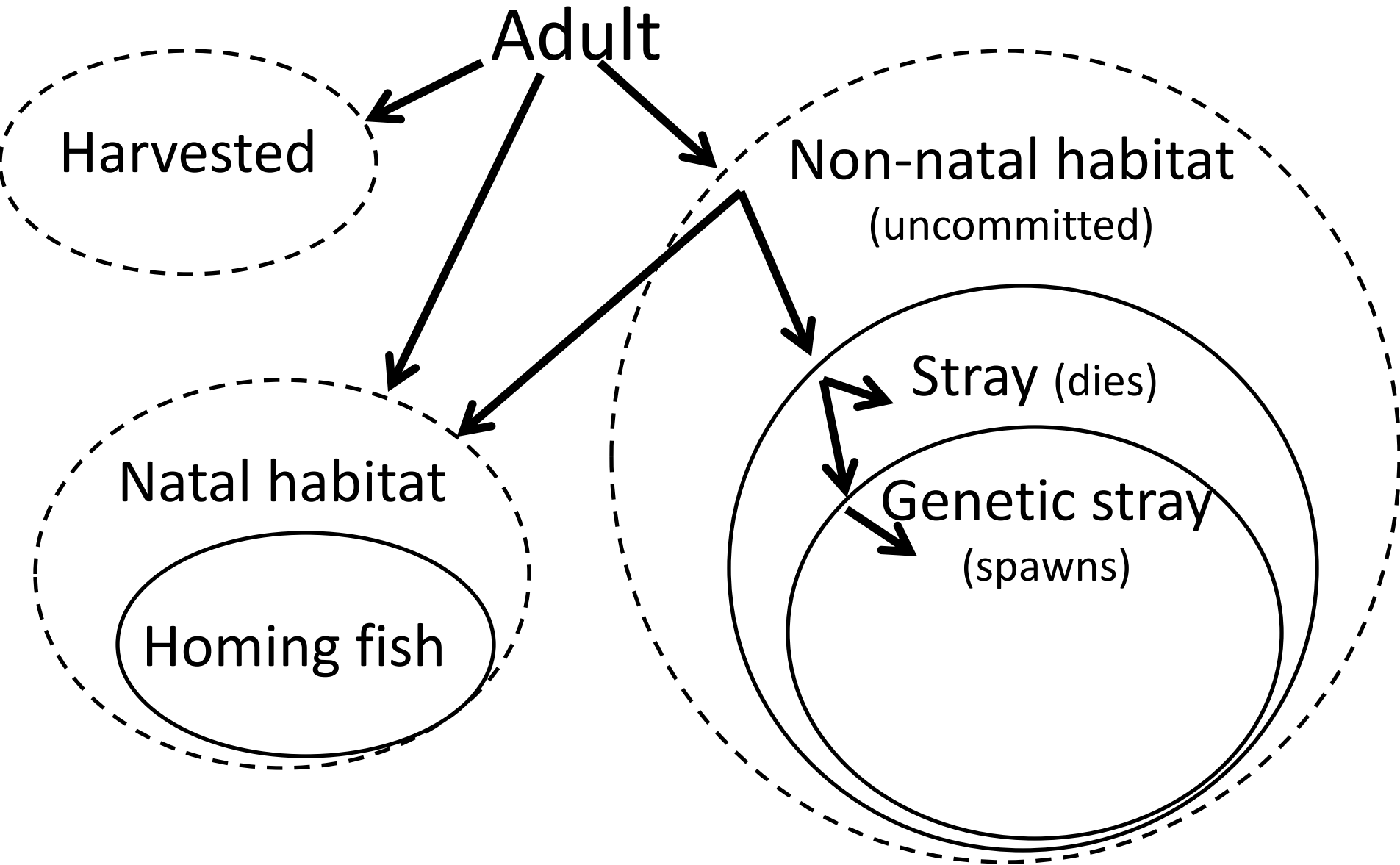
Straying definitions



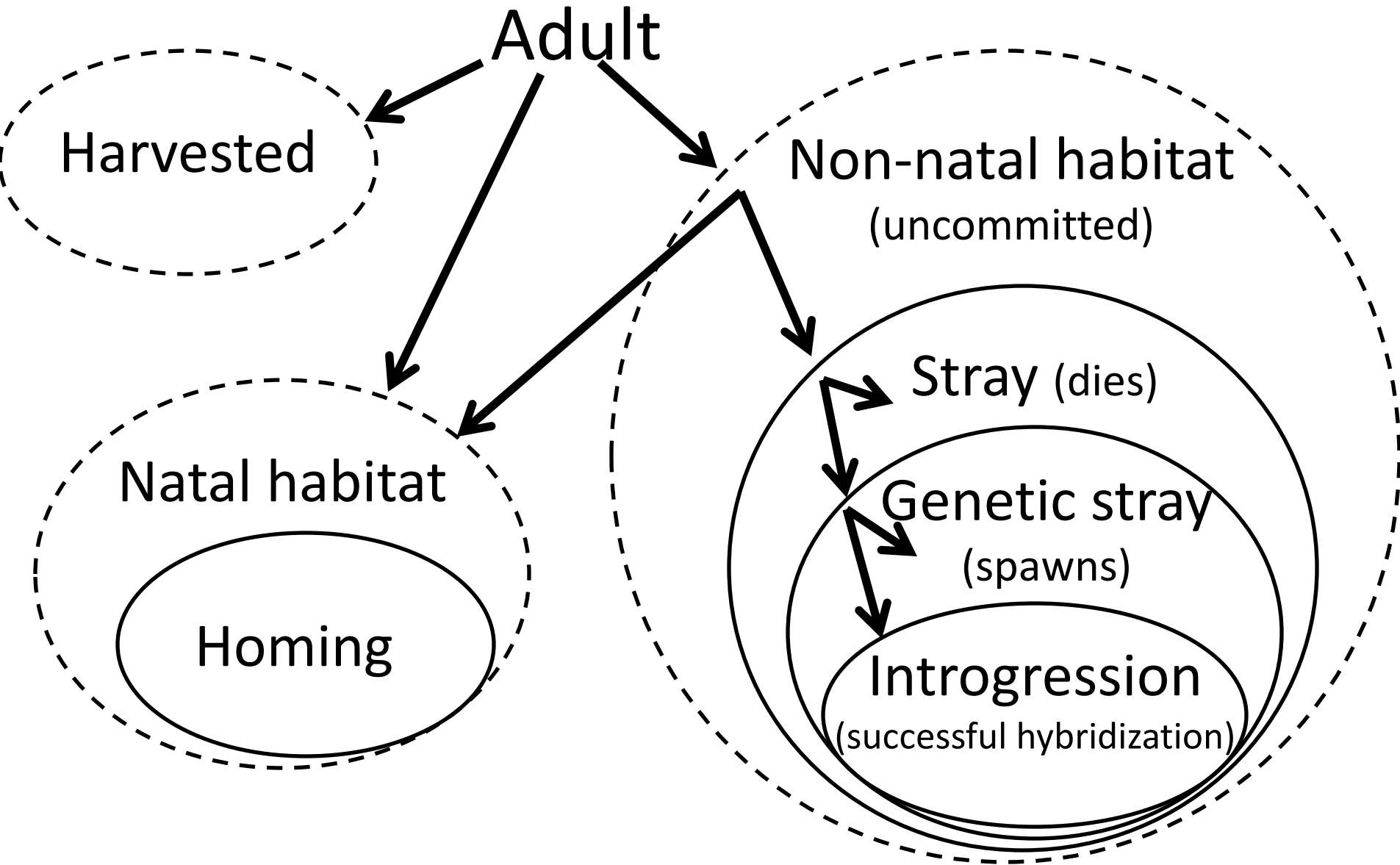
Straying definitions



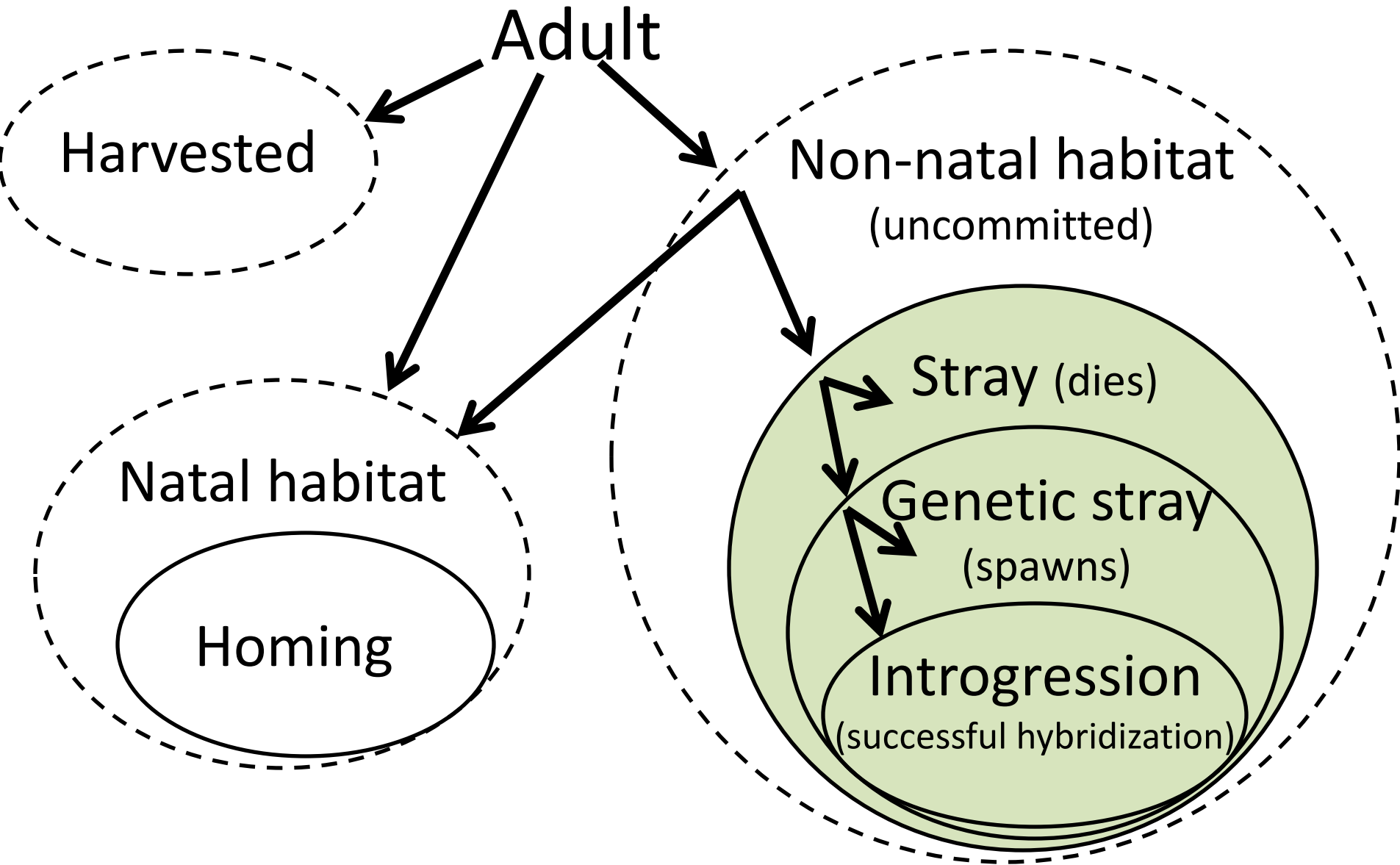
Straying definitions



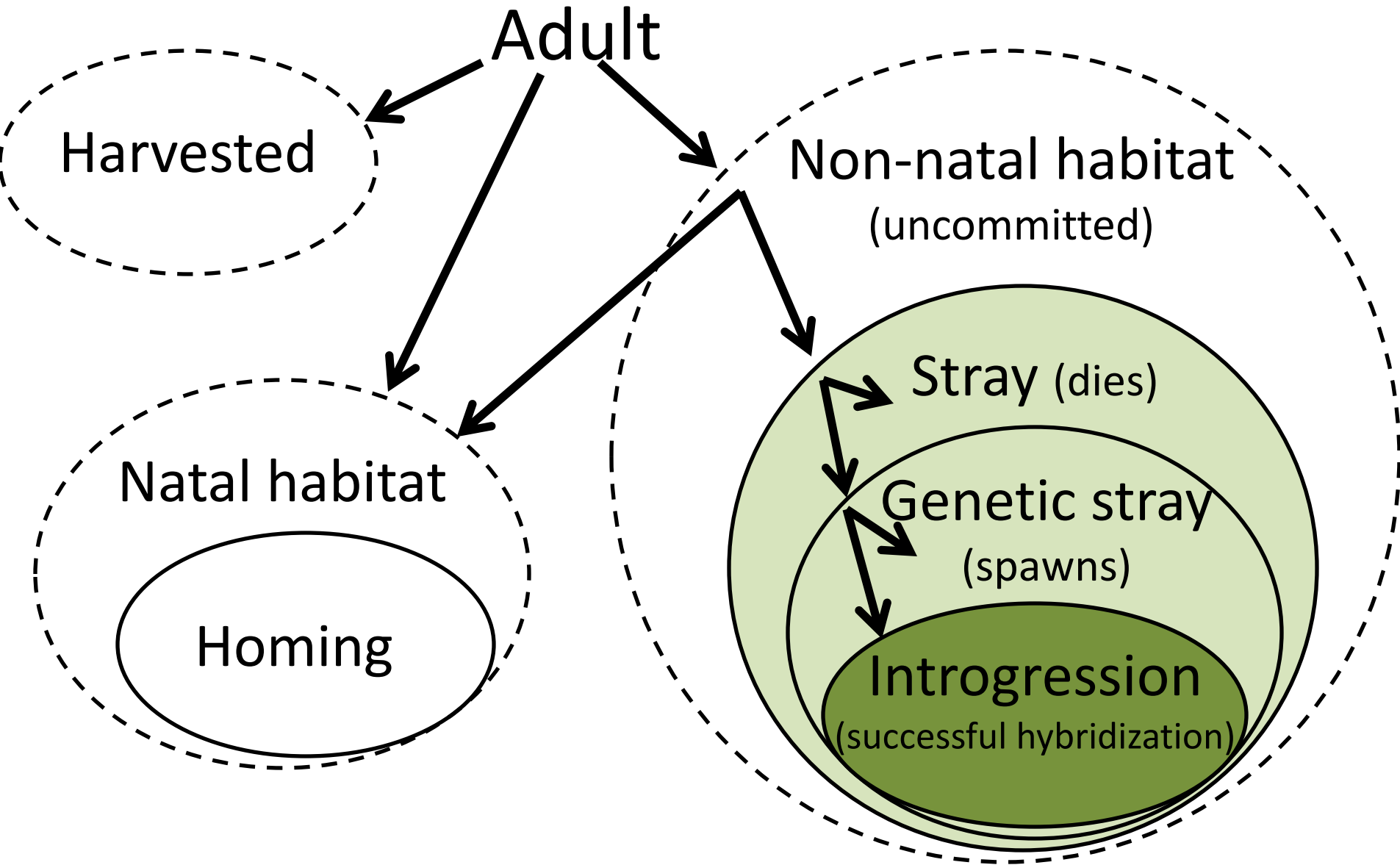
Straying definitions



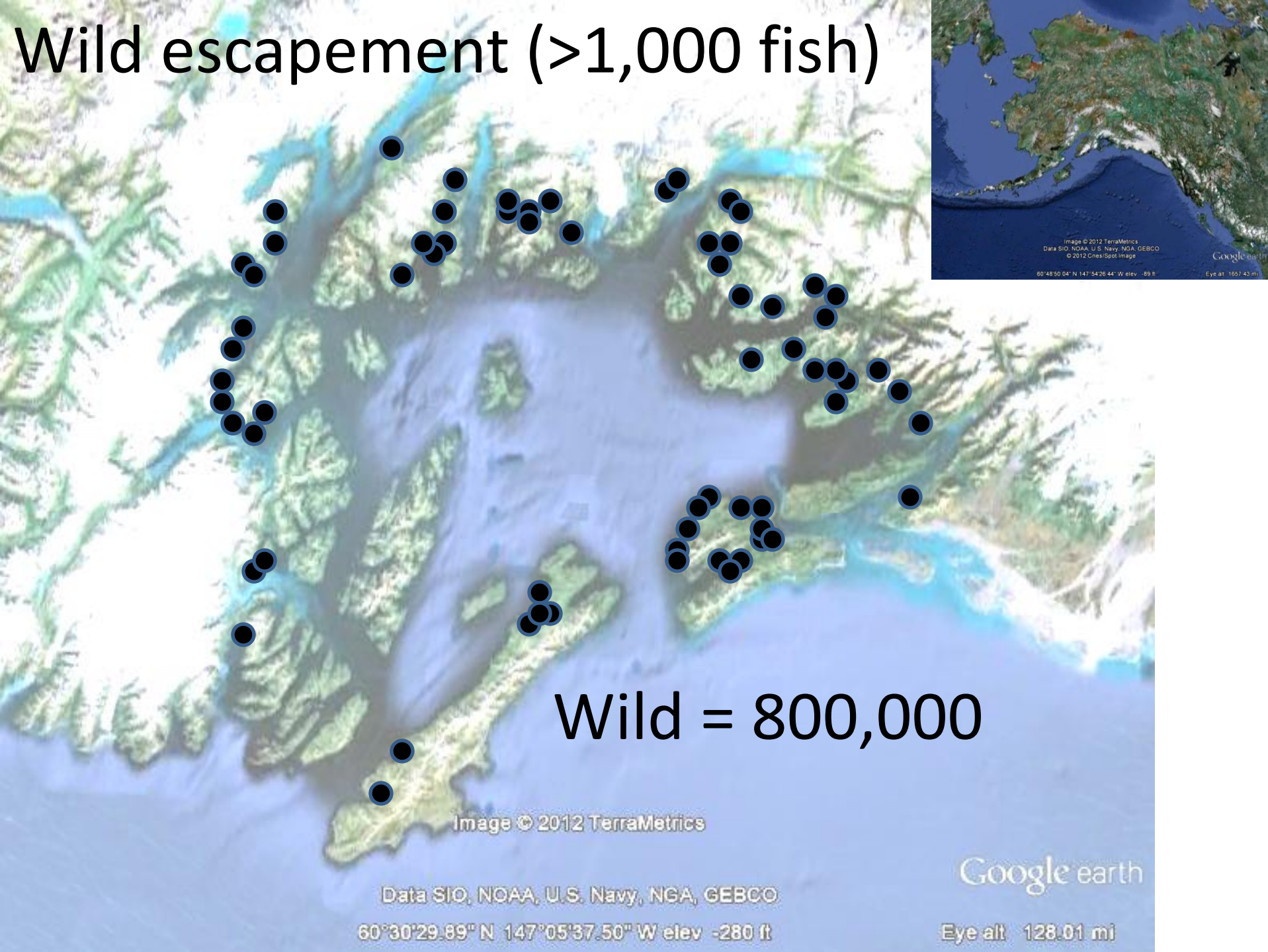
Straying definitions



Straying definitions



Wild escapement (>1,000 fish)



Wild = 800,000

Image © 2012 TerraMetrics

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

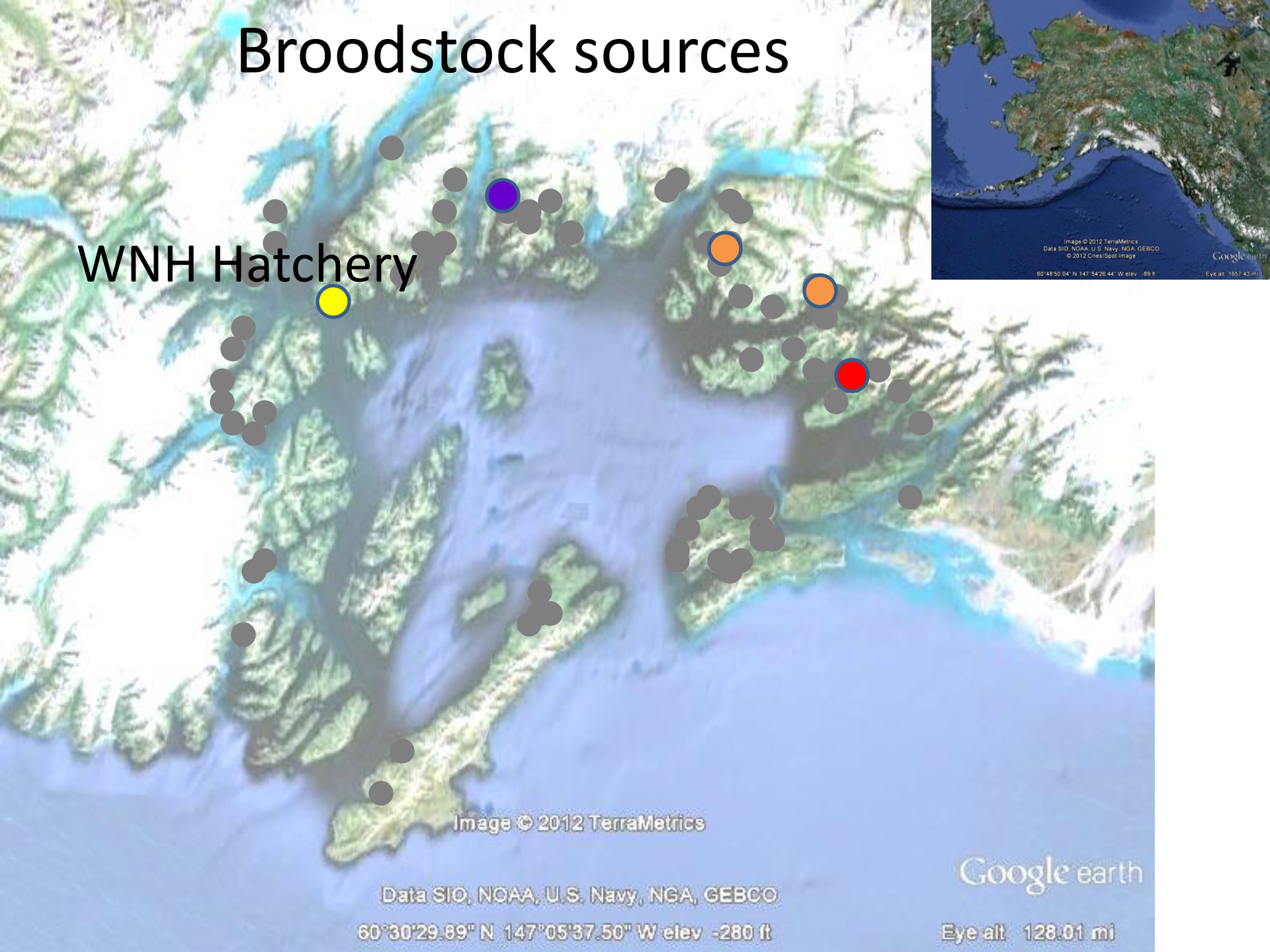
60°30'29.89" N 147°05'37.50" W elev -280 ft

Google earth

Eye alt 128.01 mi

Broodstock sources

WNNH Hatchery

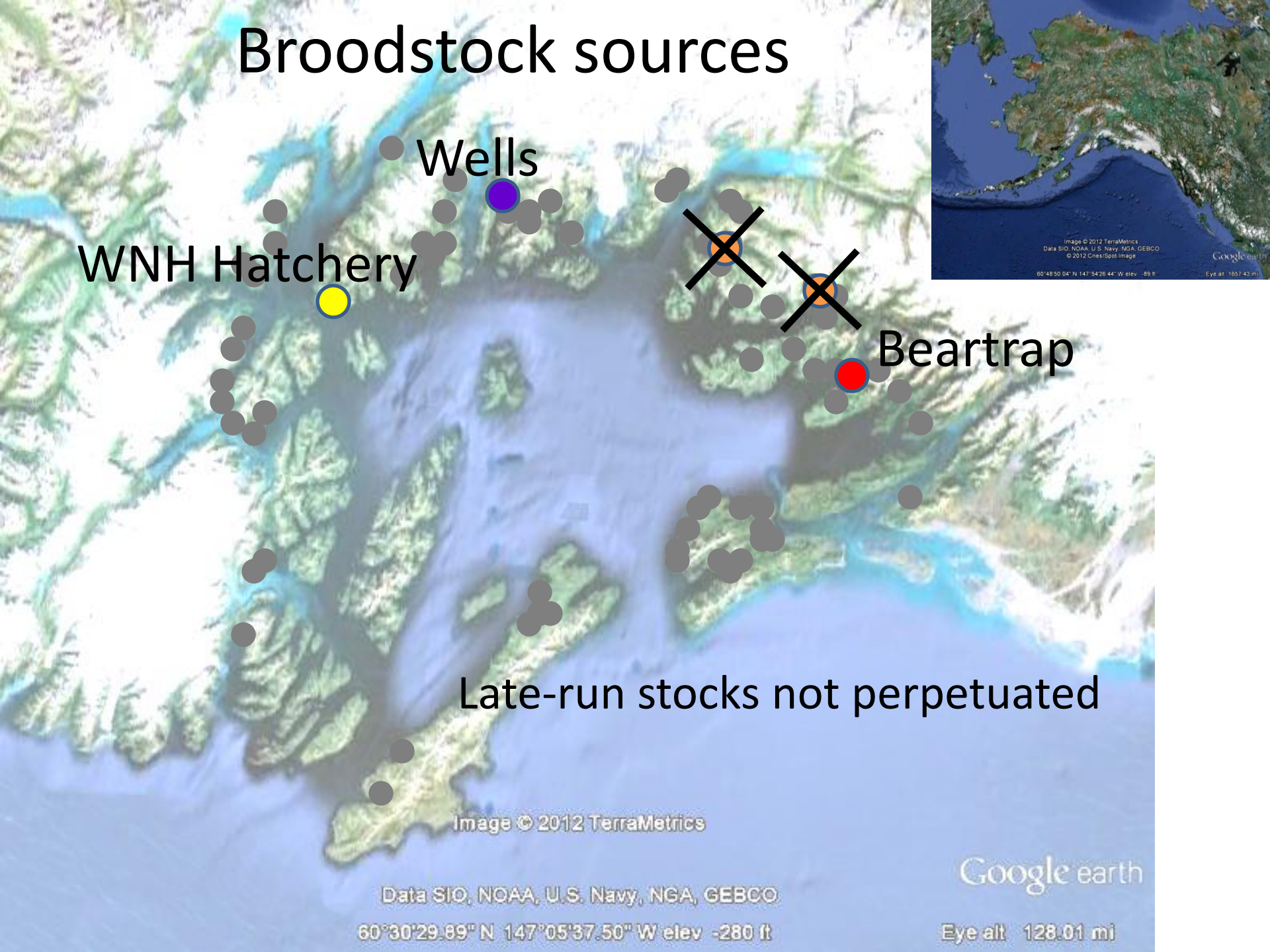


Broodstock sources

Wells

WNH Hatchery

Beartrap



Late-run stocks not perpetuated

Image © 2012 TerraMetrics

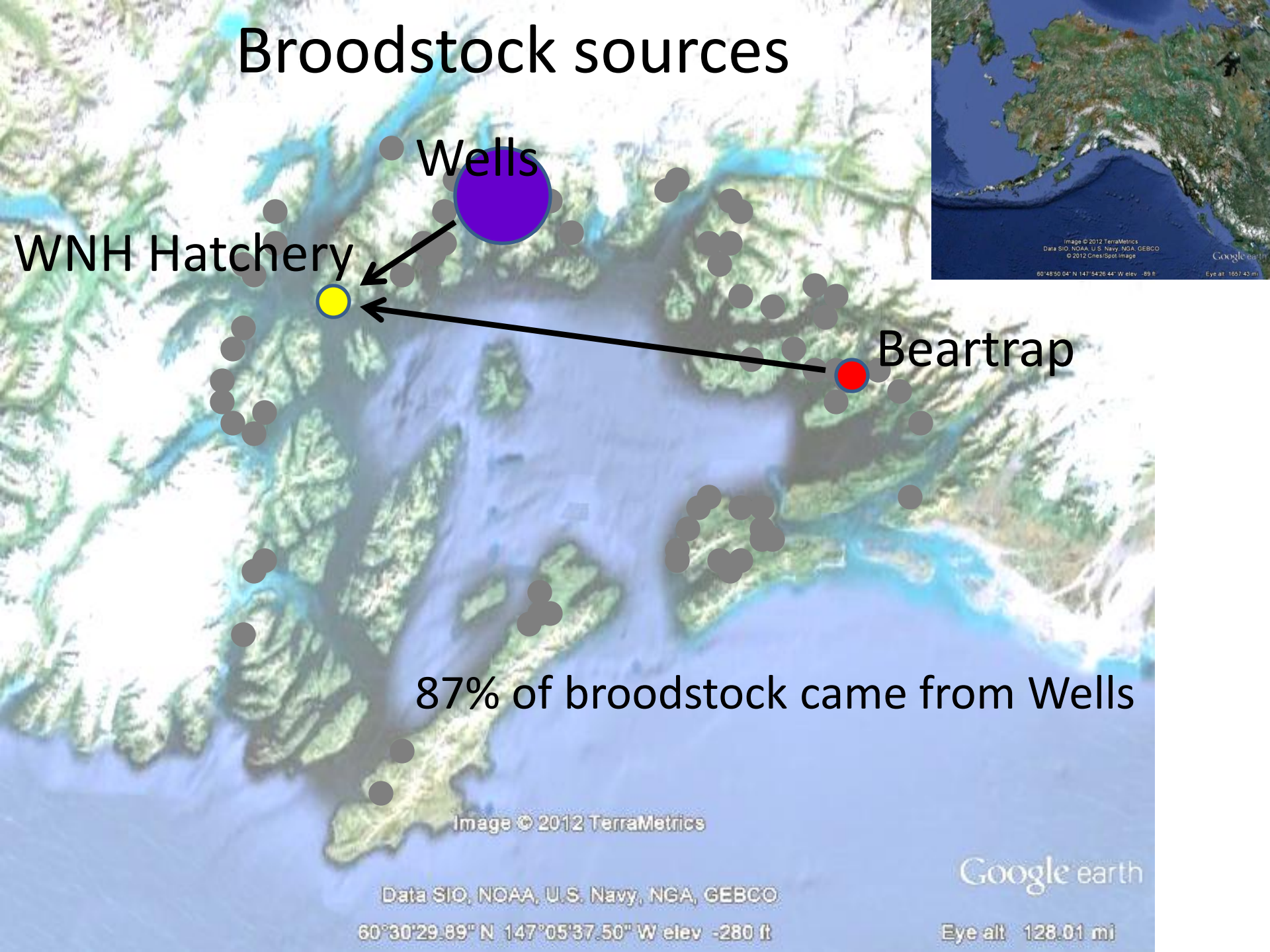
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

60°30'29.89" N 147°05'37.50" W elev -280 ft

Google earth

Eye alt 128.01 mi

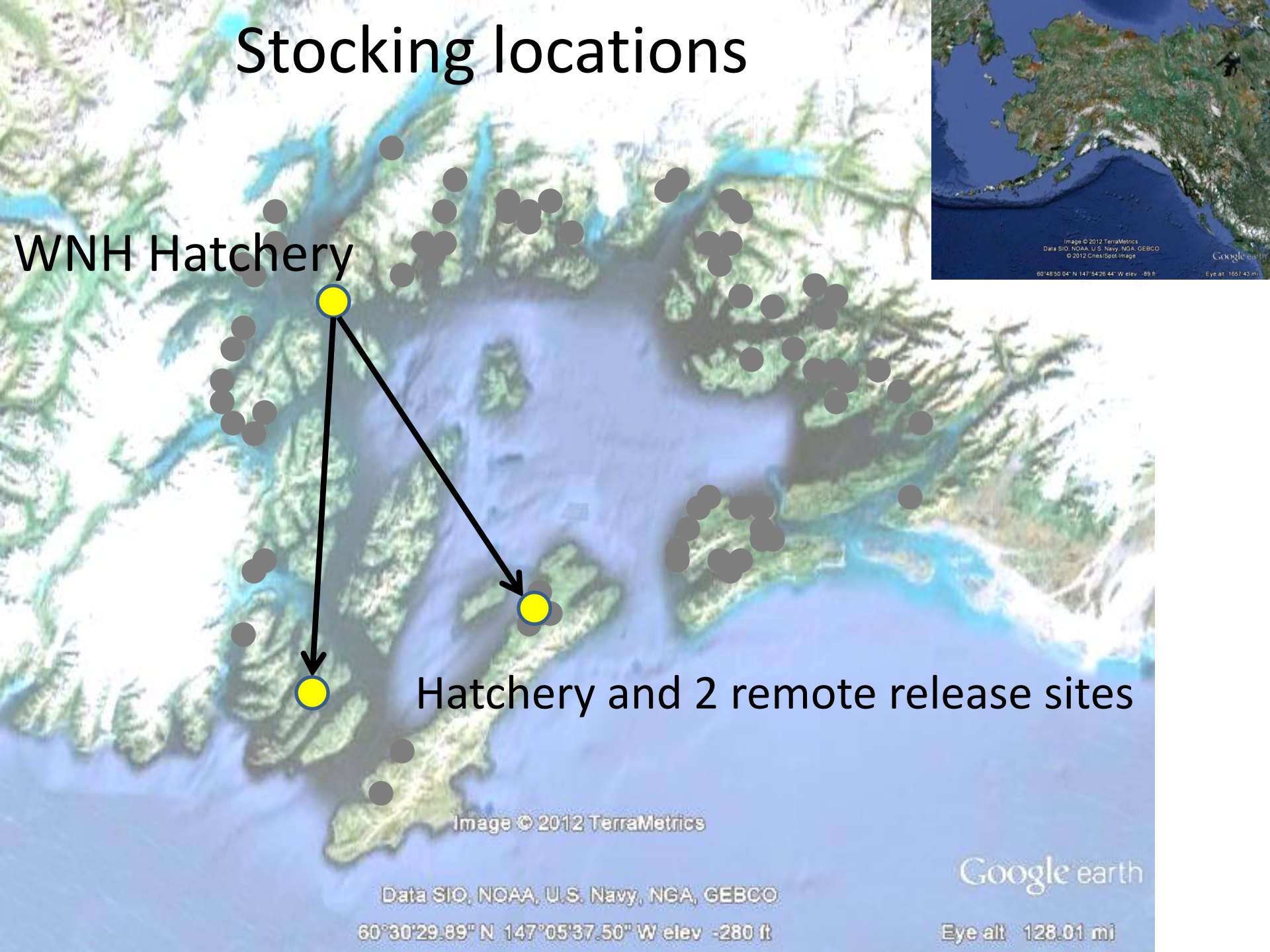
Broodstock sources



Stocking locations

WNH Hatchery

Hatchery and 2 remote release sites



Stocking locations

WNH Hatchery

60%

30%

10%

Hatchery and 2 remote release sites

Image © 2012 TerraMetrics

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

60°30'29.89" N 147°05'37.50" W elev -280 ft

Google earth

Eye alt 128.01 mi



Wild and hatchery returns

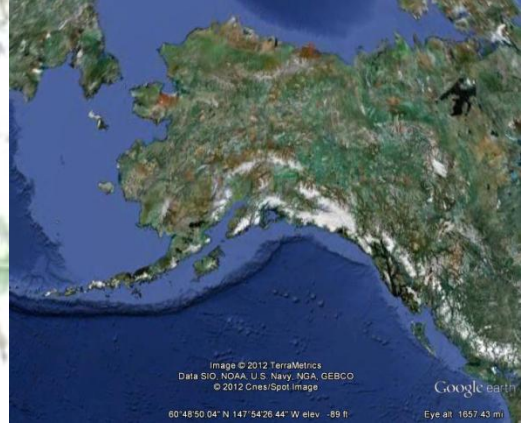
WNH Hatchery

10-year average:
Wild = 800,000
Hatchery = 3,200,000

Image © 2012 TerraMetrics

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

60°30'29.89" N 147°05'37.50" W elev -280 ft



Google earth

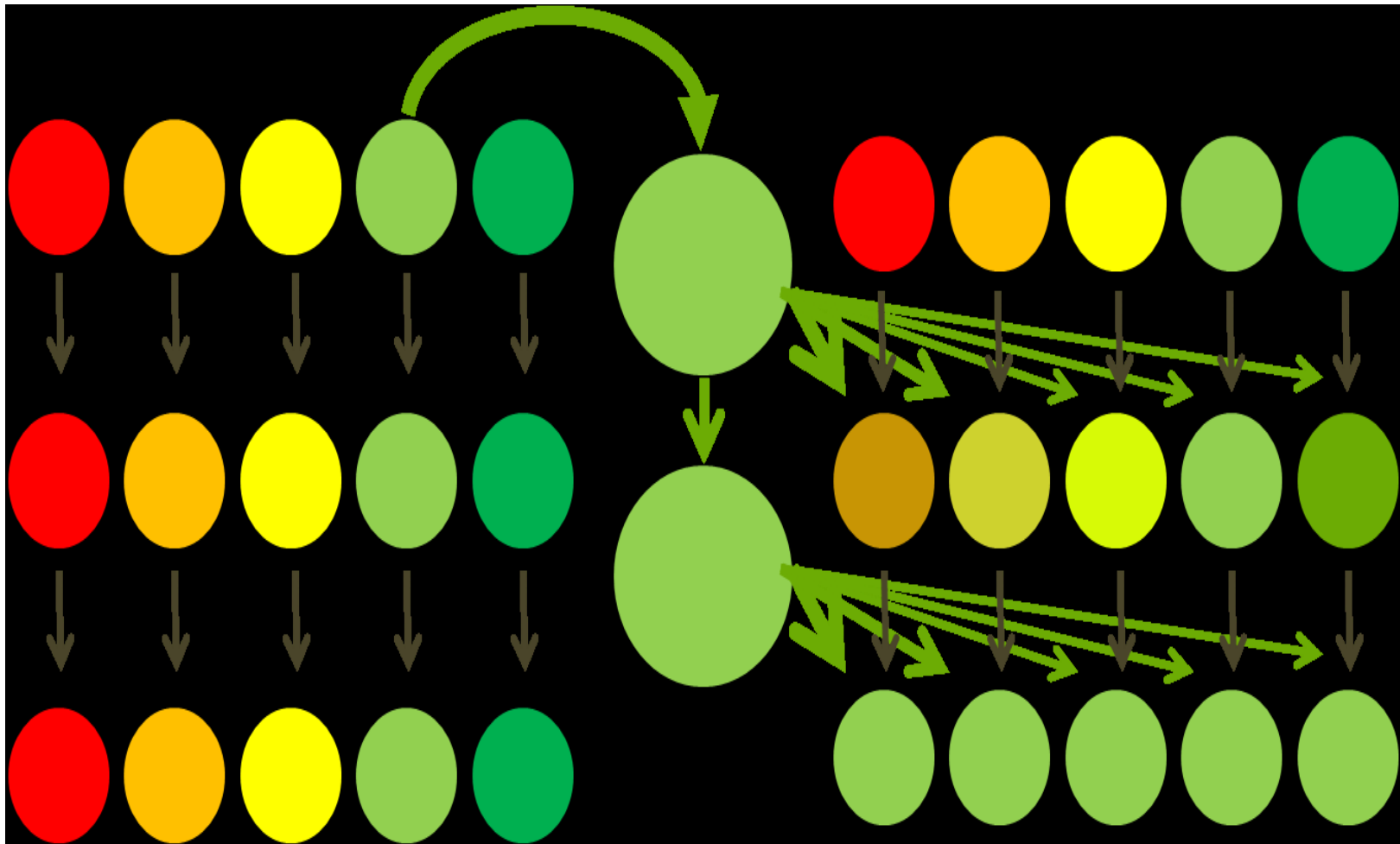
Eye alt 128.01 mi

Effects of straying on homogenization of populations

No introgression

Introgression

Time

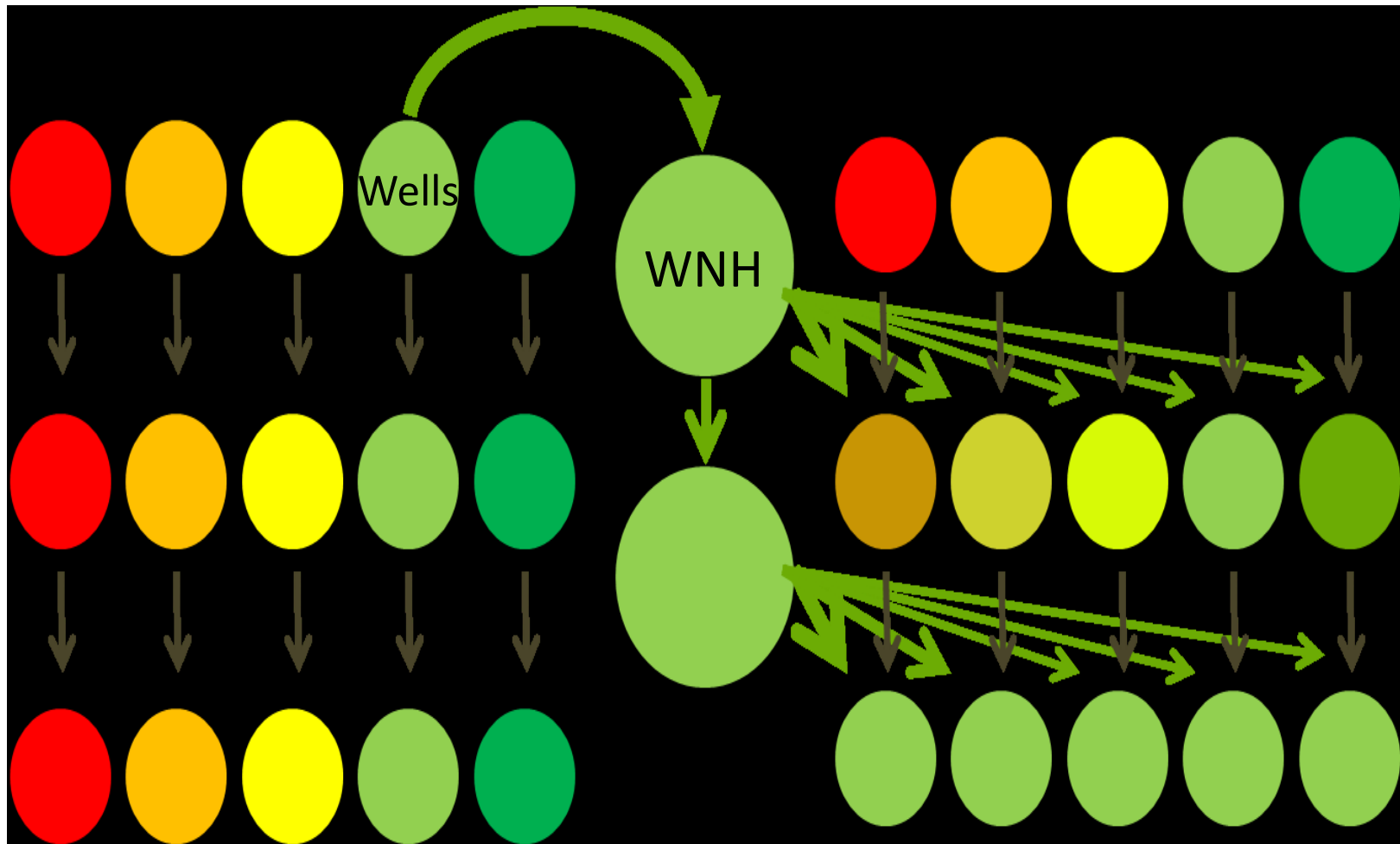


Effects of straying on homogenization of populations

No introgression

Introgression

Time

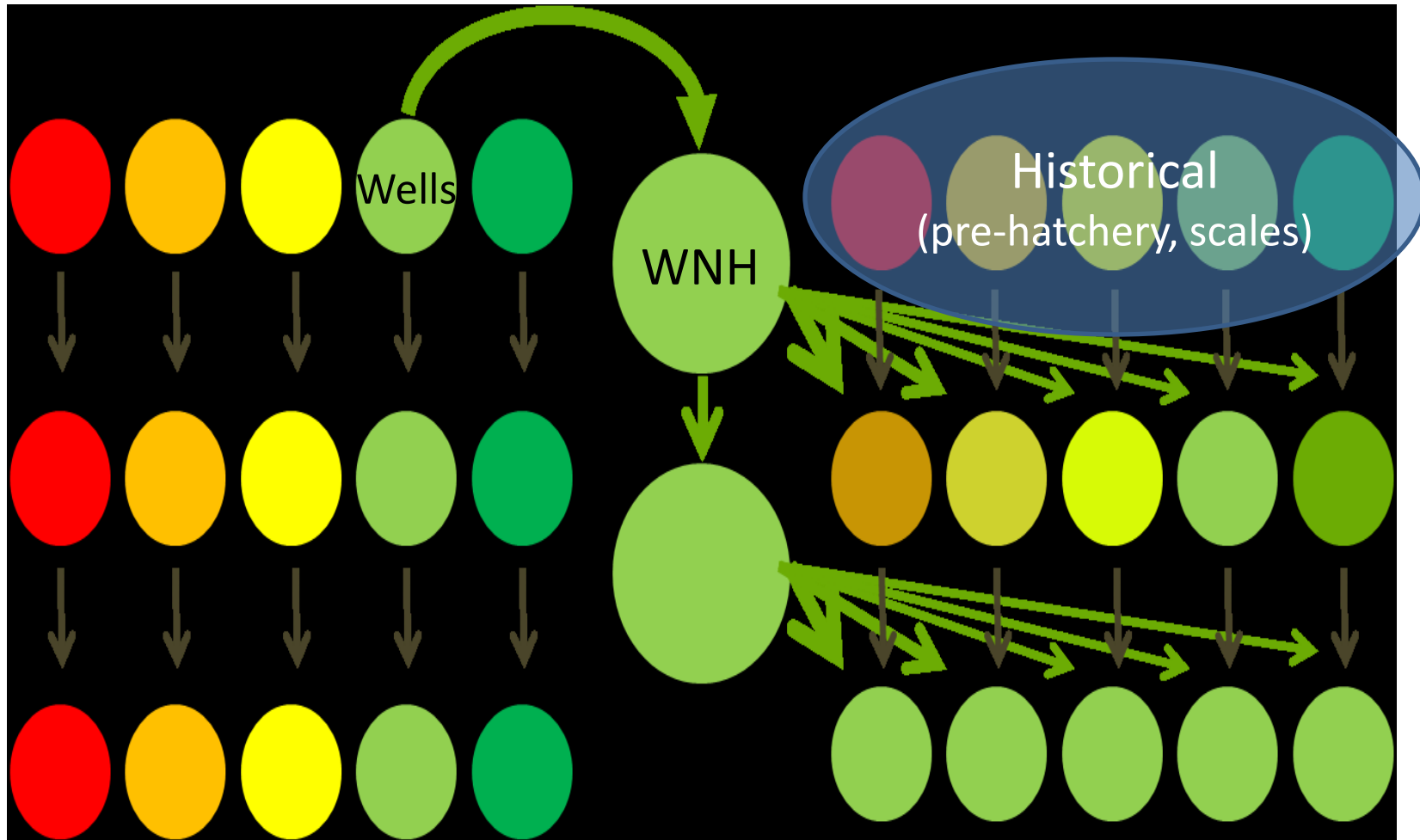


Experimental design

No introgression

Introgression

Time

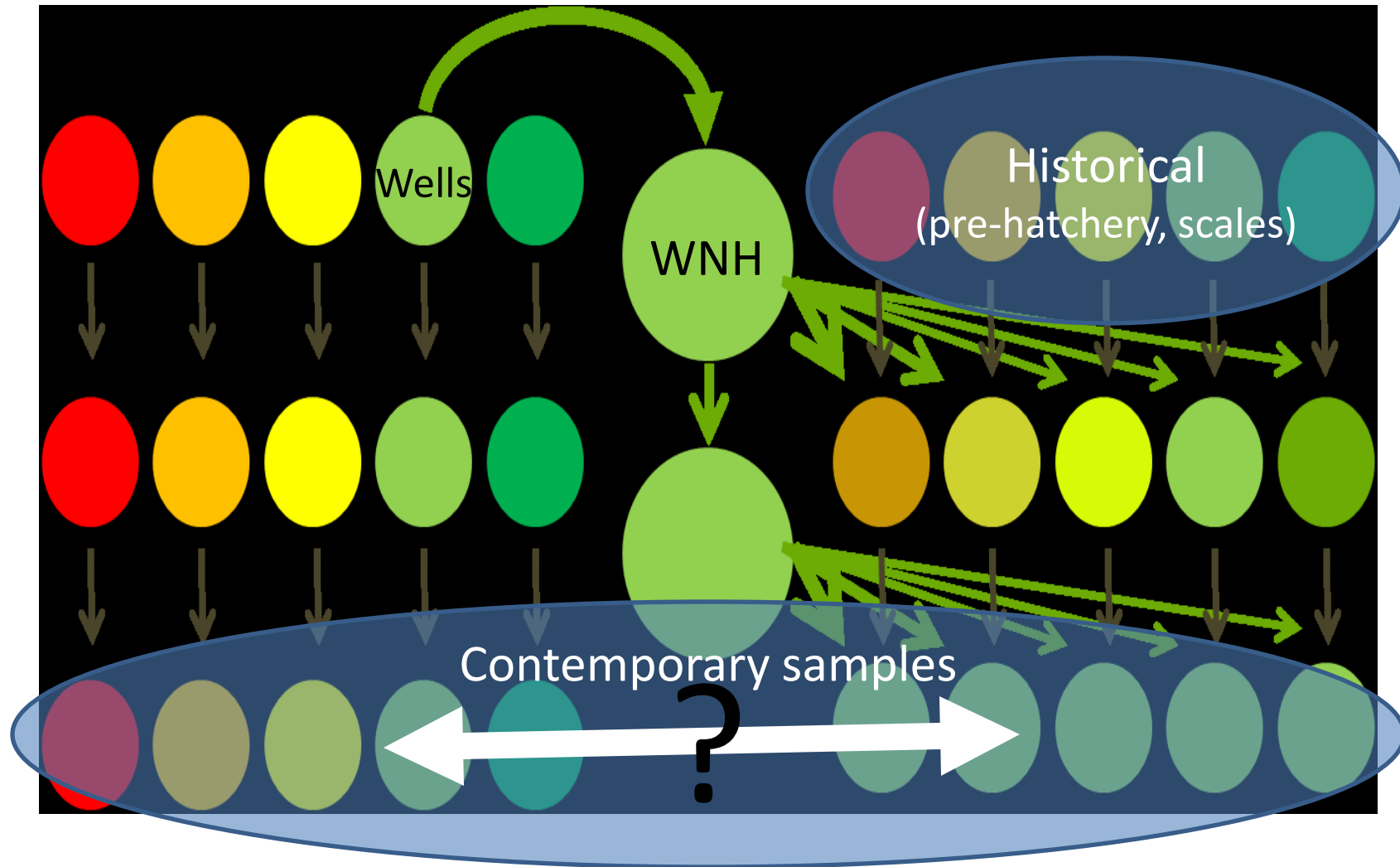


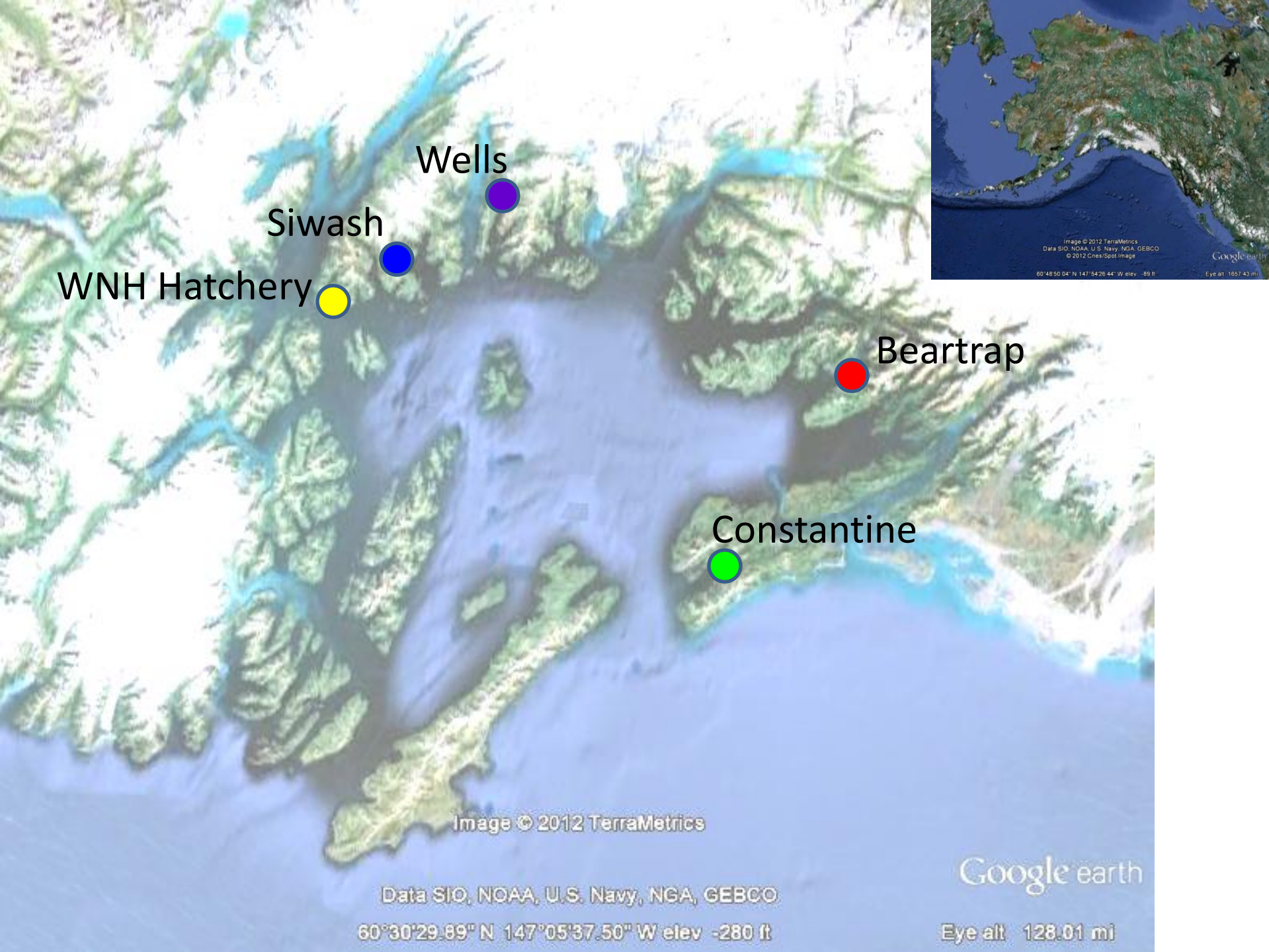
Experimental design

No introgression

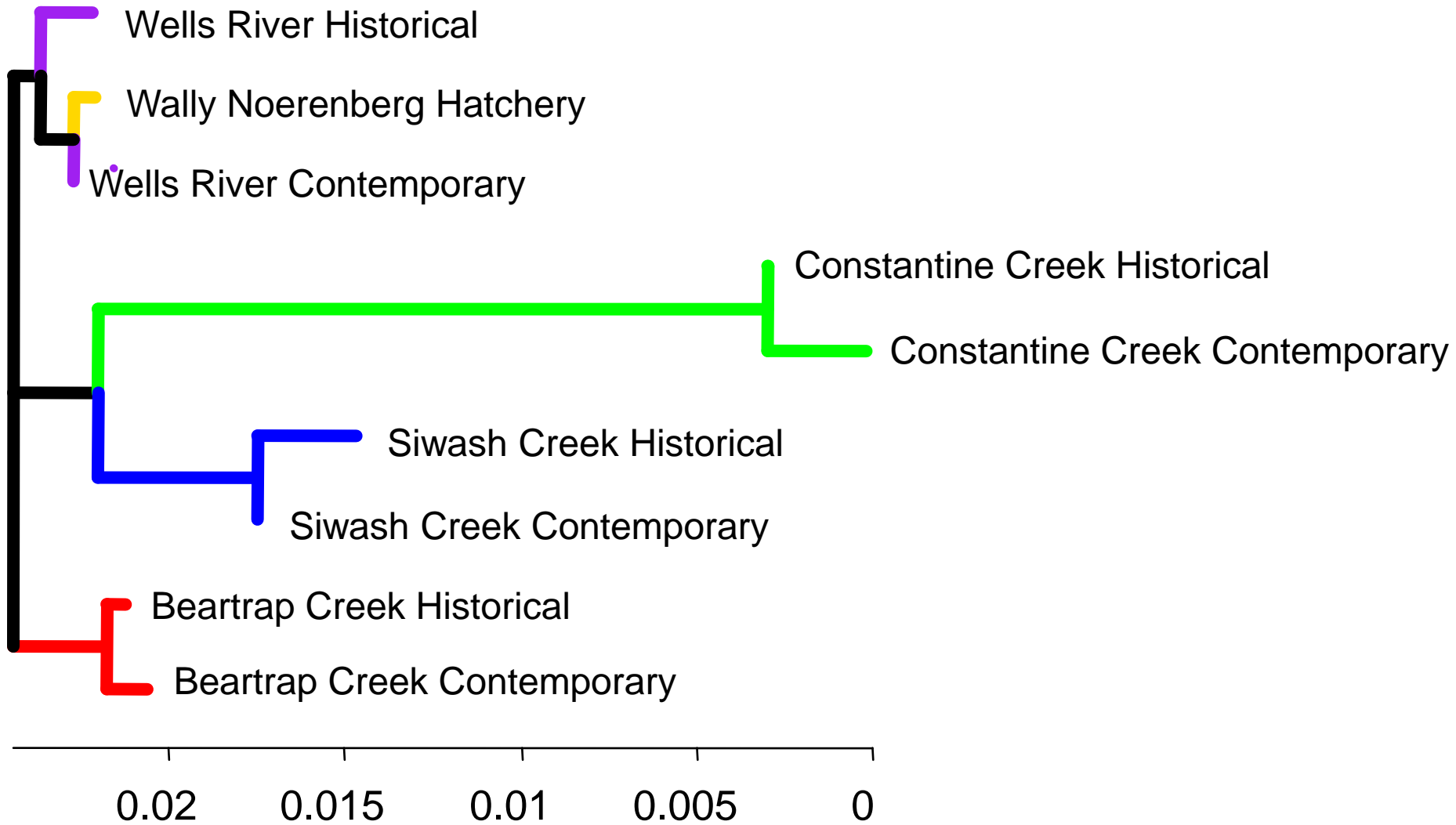
Introgression

Time



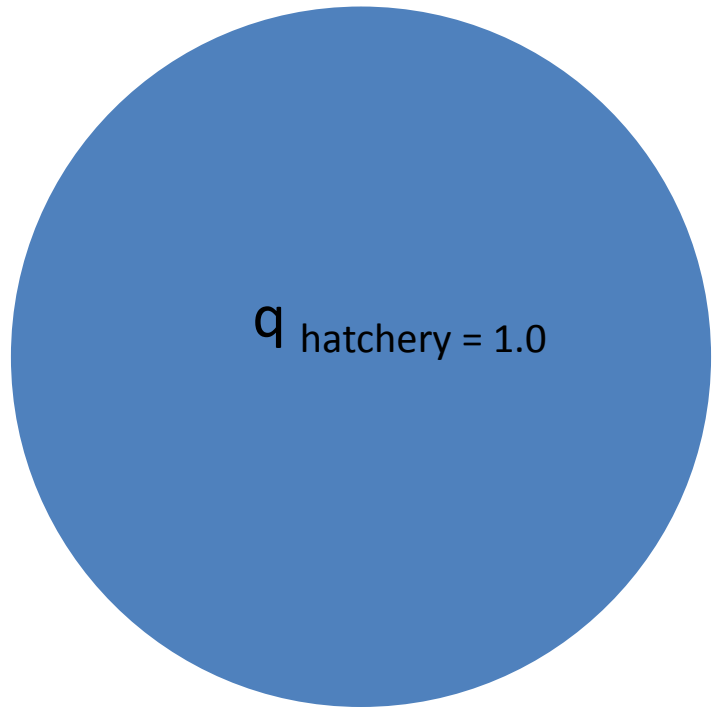


Pair wise Fst

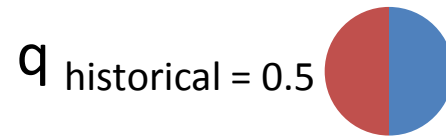


One-way migration (introgression) model one locus...

Source (Hatchery) Population

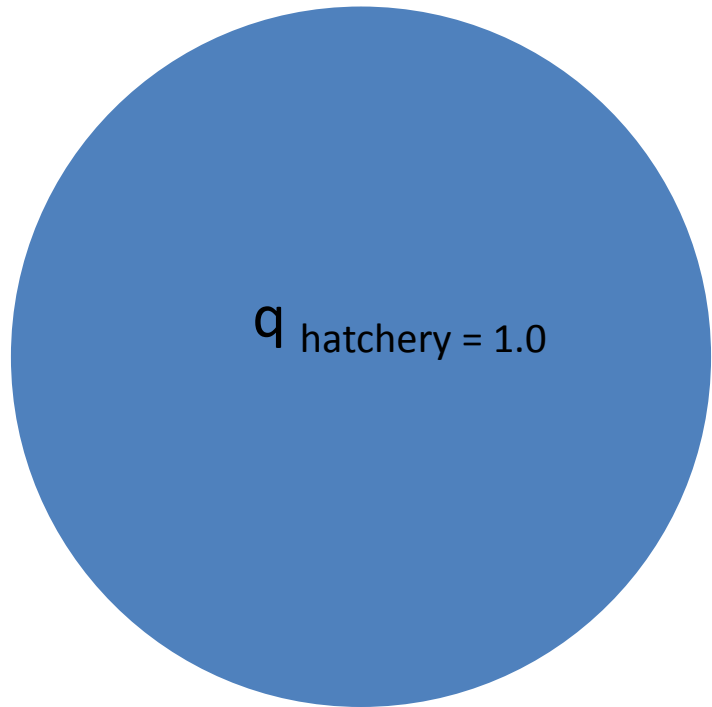


**Island (Wild)
Population**



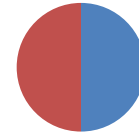
One-way migration model one locus...

Source (Hatchery) Population



**Island (Wild)
Population**

$q_{\text{historical}} = 0.5$

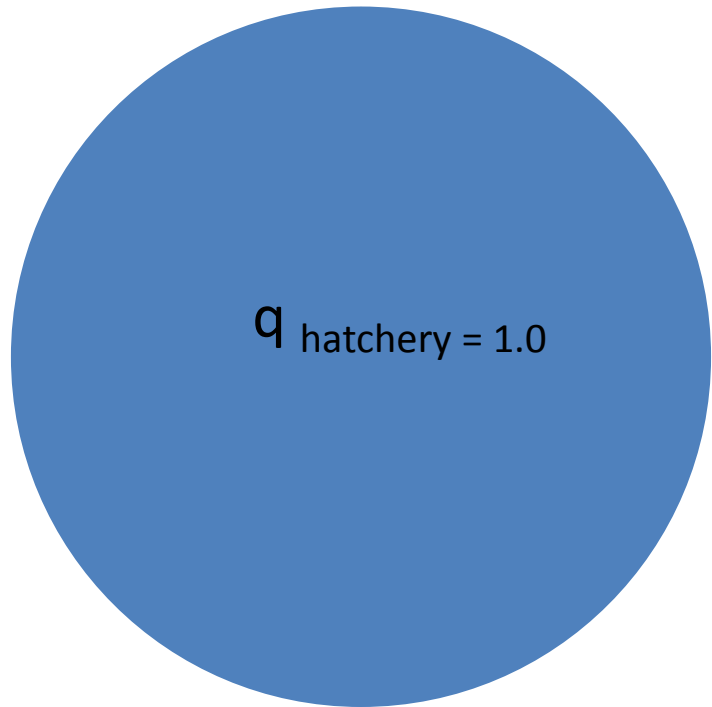


Gene flow



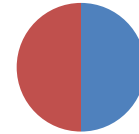
One-way migration model one locus...

Source (Hatchery) Population



Island (Wild)
Population

$q_{\text{historical}} = 0.5$



Gene flow



High (50%)

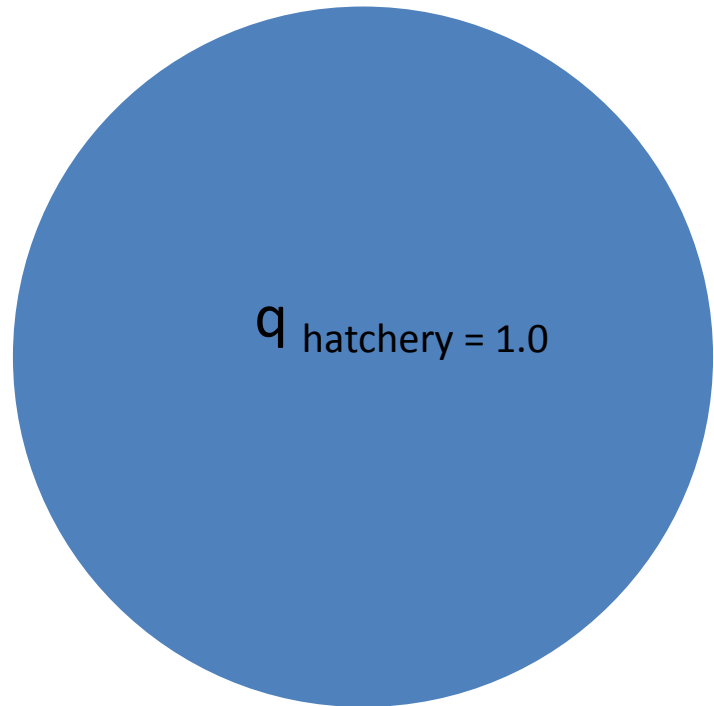
Low (2%)

Time



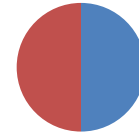
One-way migration model one locus...

Source (Hatchery) Population



Island (Wild)
Population

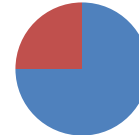
$q_{\text{historical}} = 0.5$



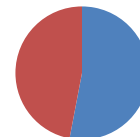
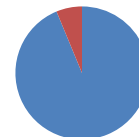
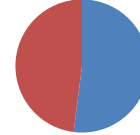
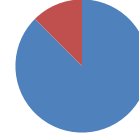
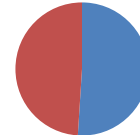
Gene flow



High (50%)



Low (2%)

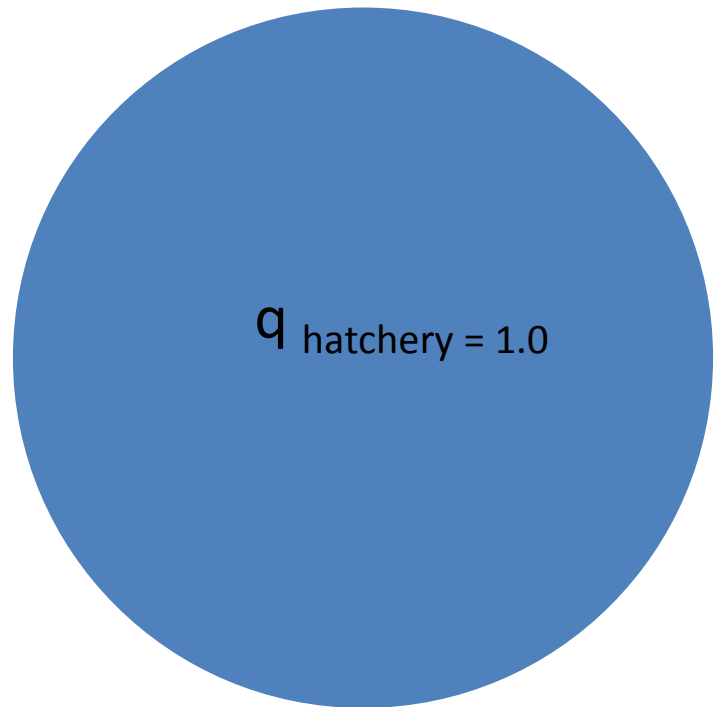


Time



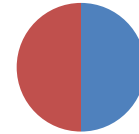
One-way migration model one locus...

Source (Hatchery) Population



Island (Wild)
Population

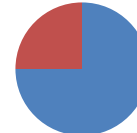
$q_{\text{historical}} = 0.5$



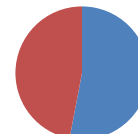
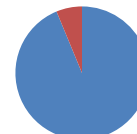
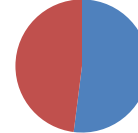
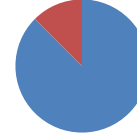
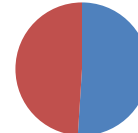
Gene flow



High (50%)



Low (2%)



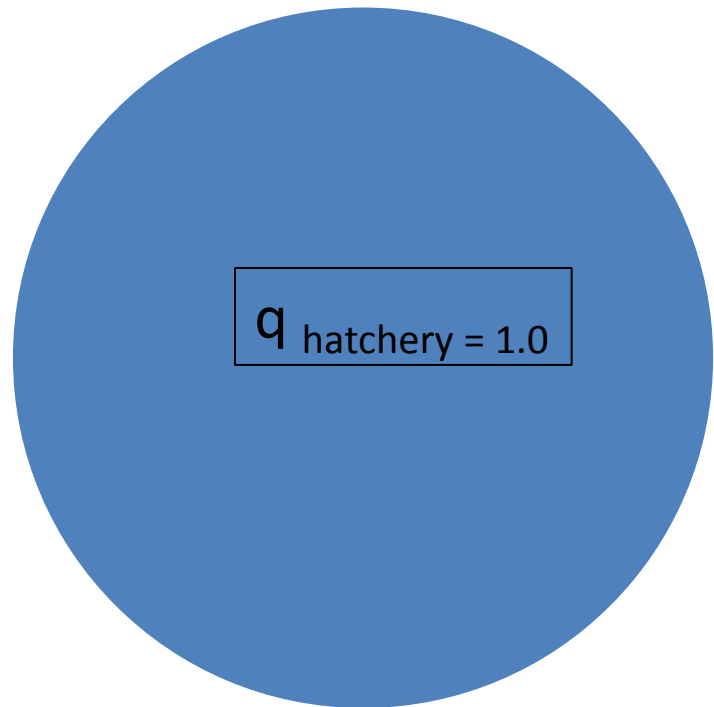
$q_{\text{contemporary}} = 0.06 \text{ or } 0.47?$

Time

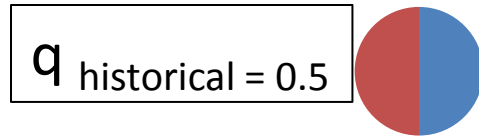


One-way migration model one locus...

Source (Hatchery) Population

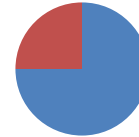


Island (Wild)
Population

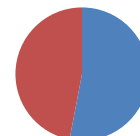
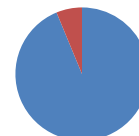
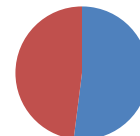
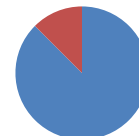
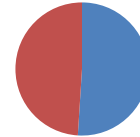


Gene flow
→

High (50%)



Low (2%)



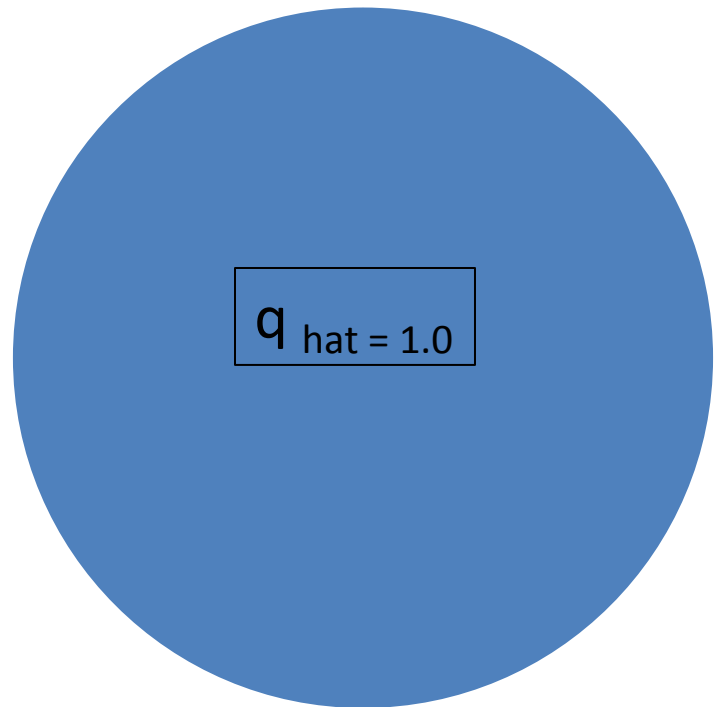
$q_{\text{contemporary}} = 0.06 \text{ or } 0.47?$

Time



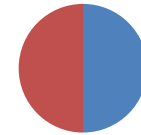
One-way migration model one locus...

Source (Hatchery) Population



Island (Wild)
Population

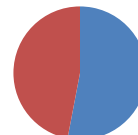
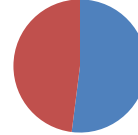
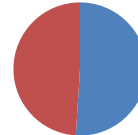
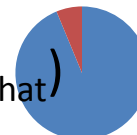
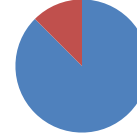
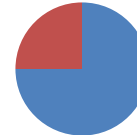
$q_{\text{hist}} = 0.5$



Gene flow

High (50%)

Low (2%)



Time

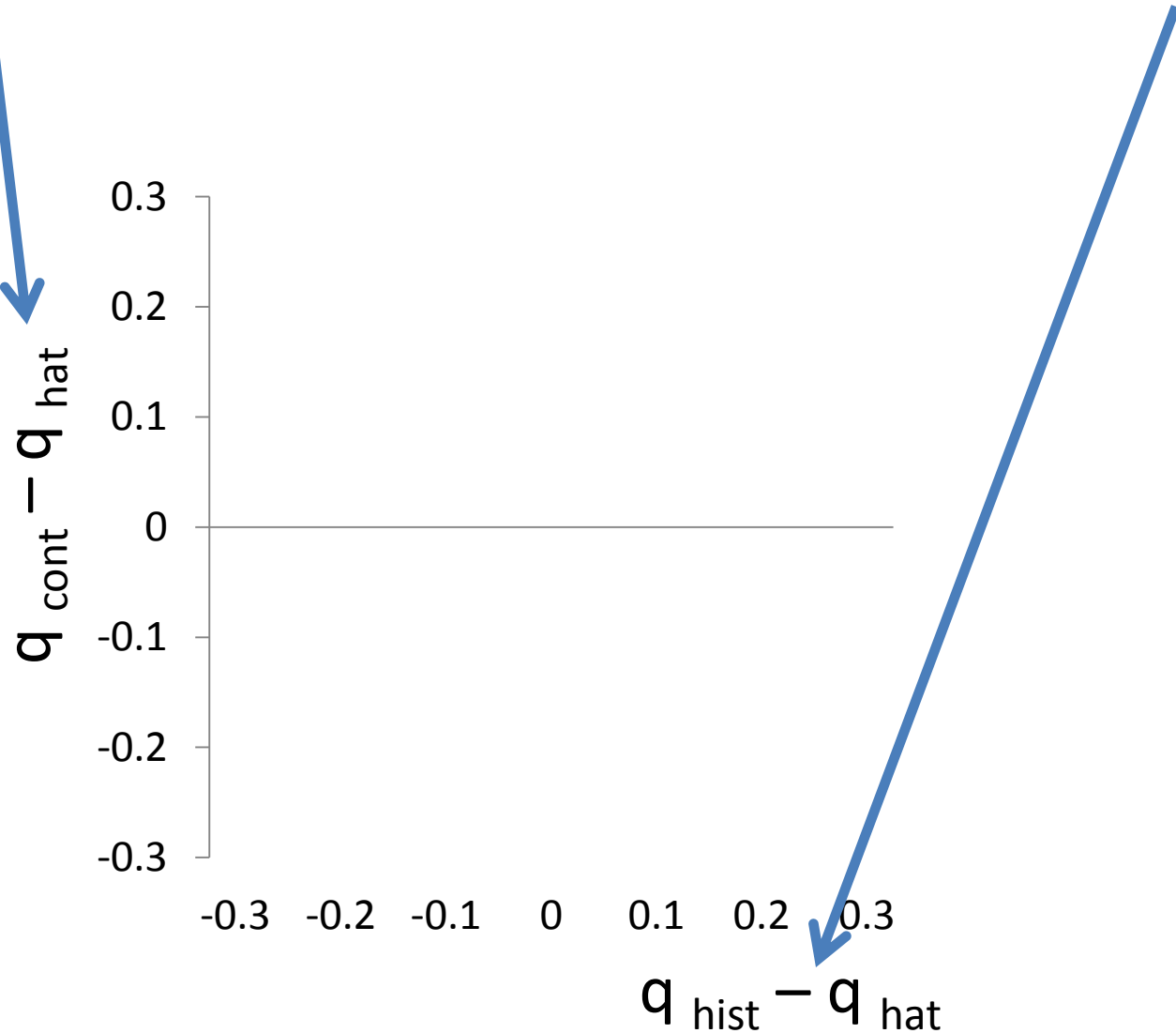


$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

$q_{\text{cont}} = 0.06 \text{ or } 0.47?$

One-way migration model

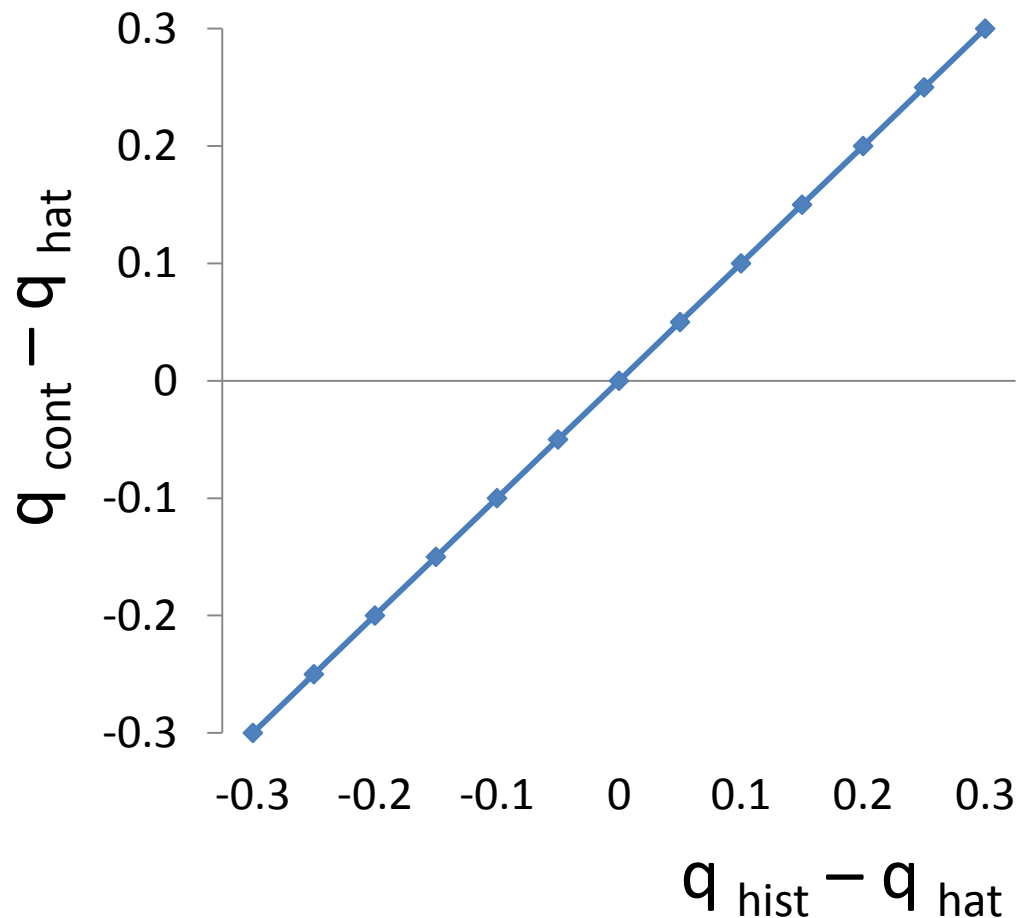
$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$



One-way migration model

$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

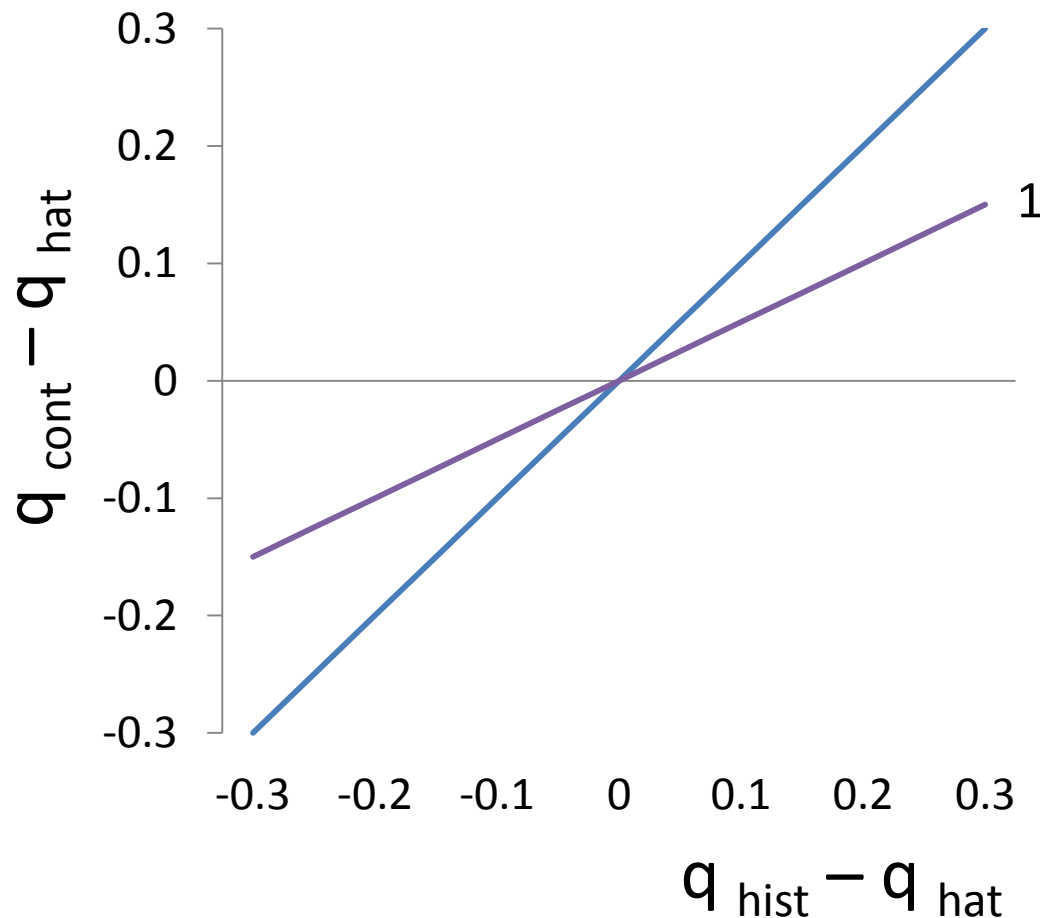
No introgression: Original frequencies are the same as current frequencies



One-way migration model

$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

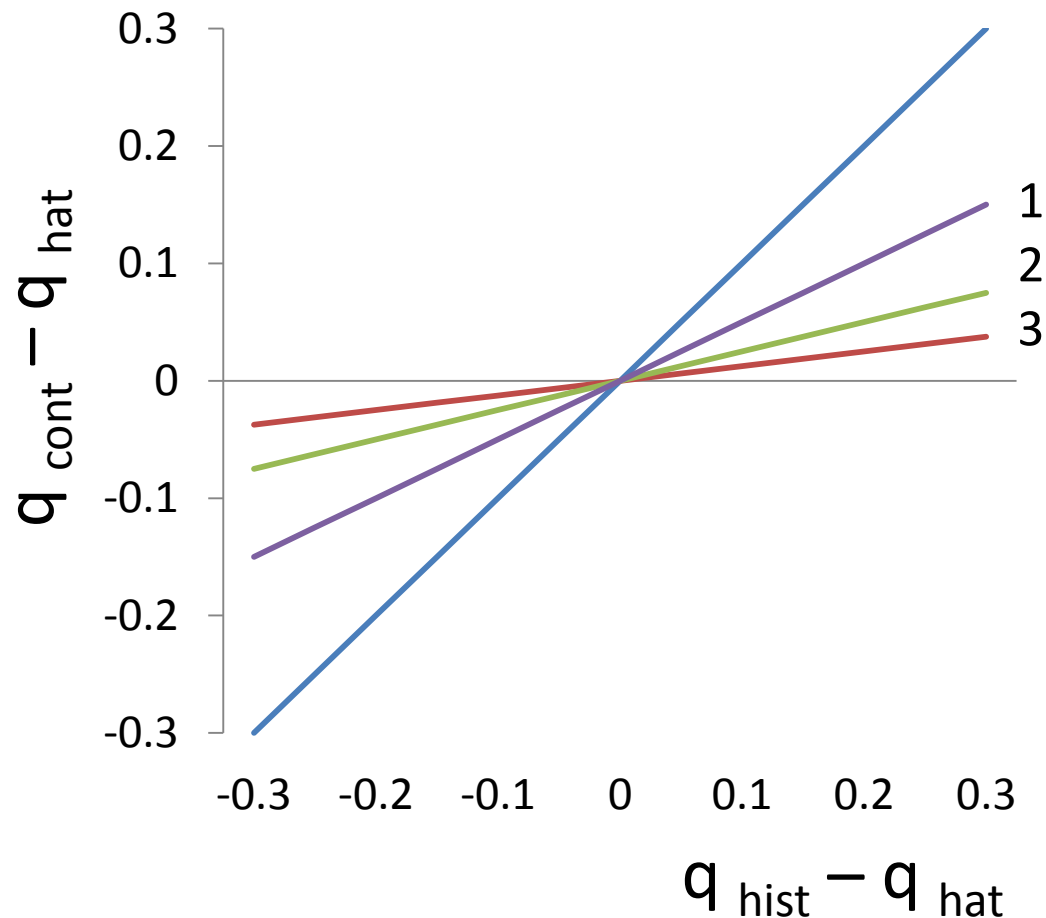
Introgression = 50% after 1 generation...



One-way migration model

$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

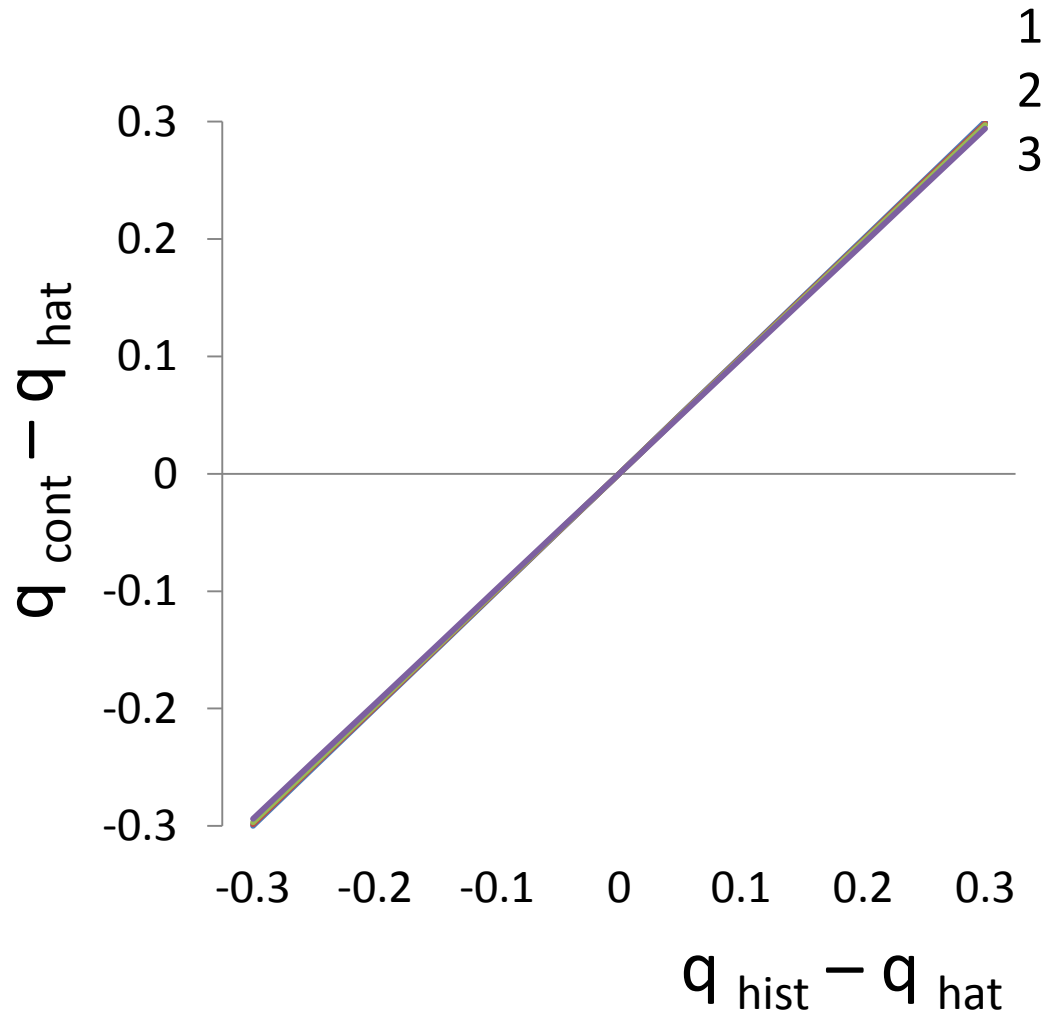
Migration = 50% after 1, 2 and 3 generations



One-way migration model

$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

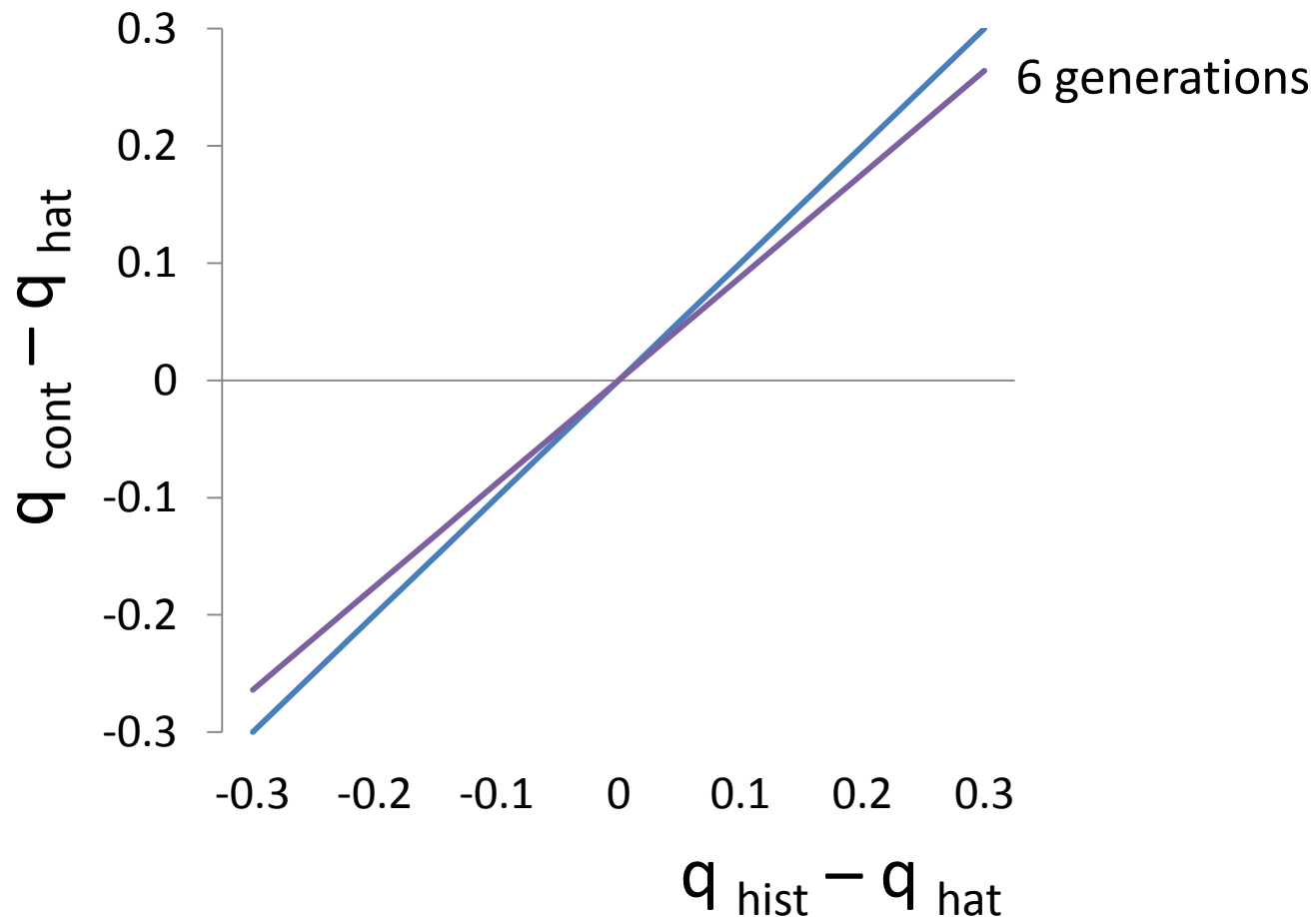
Introgression = 2% at 1, 2 and 3 generations



One-way migration model

$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

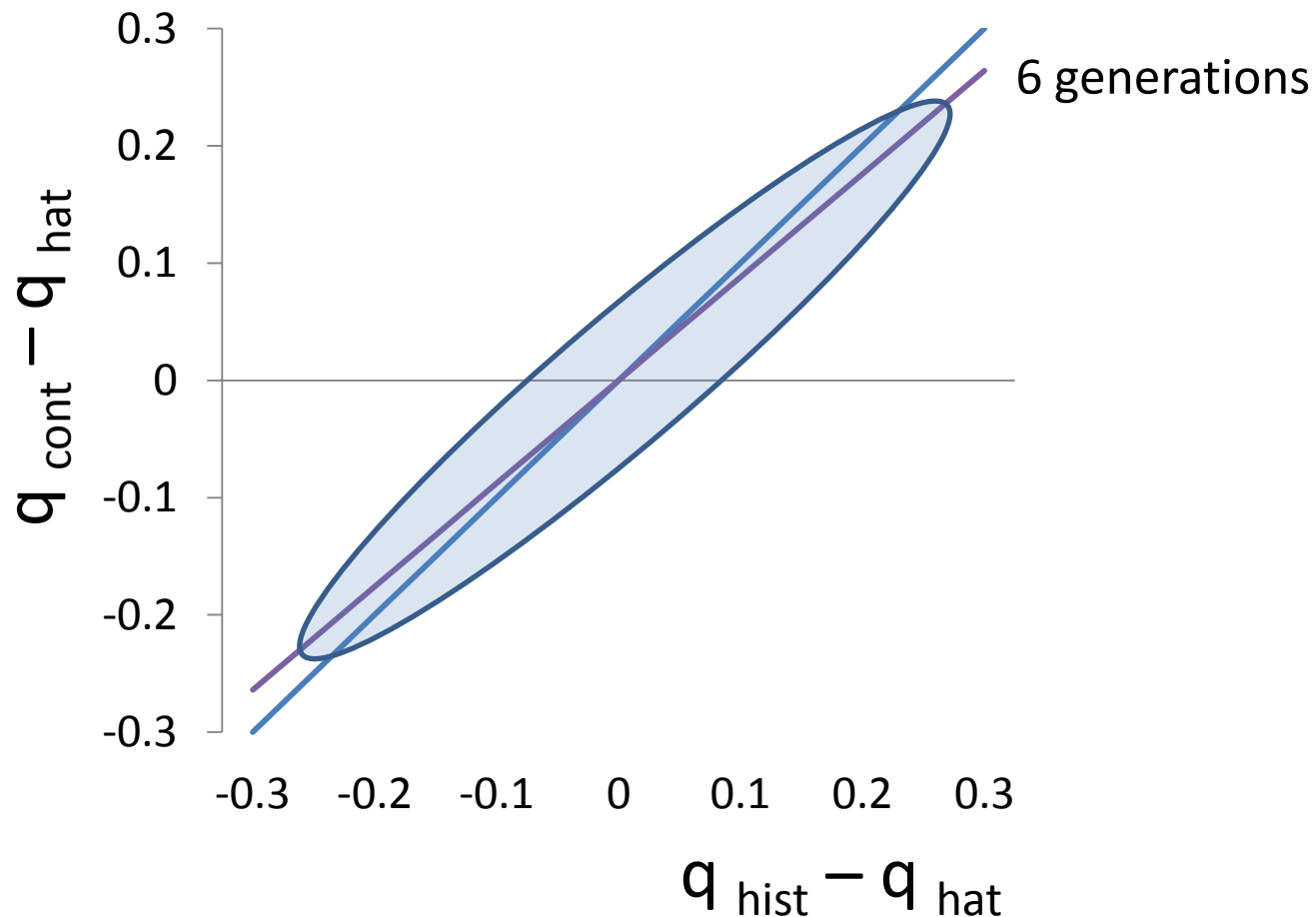
Introgression = 2% at 6 generations

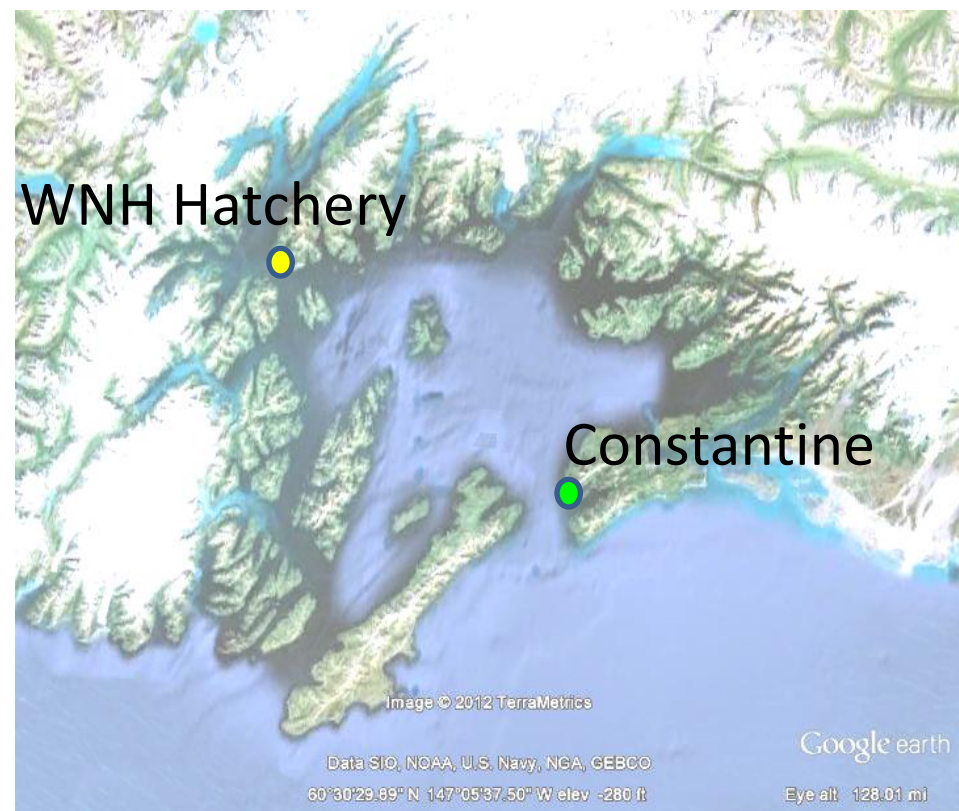
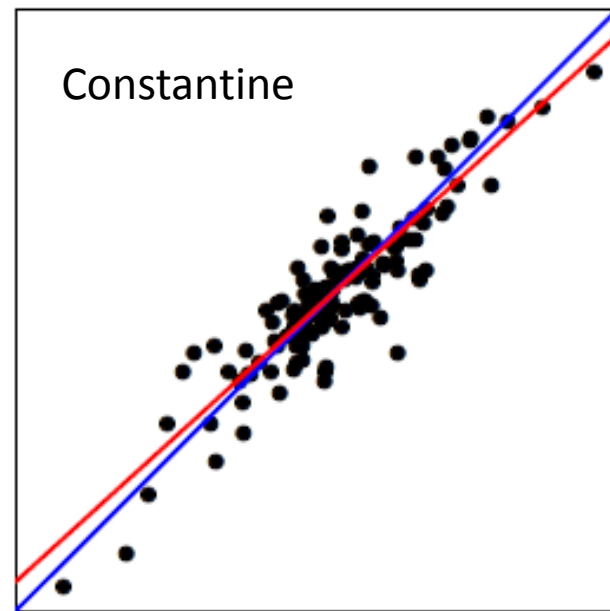


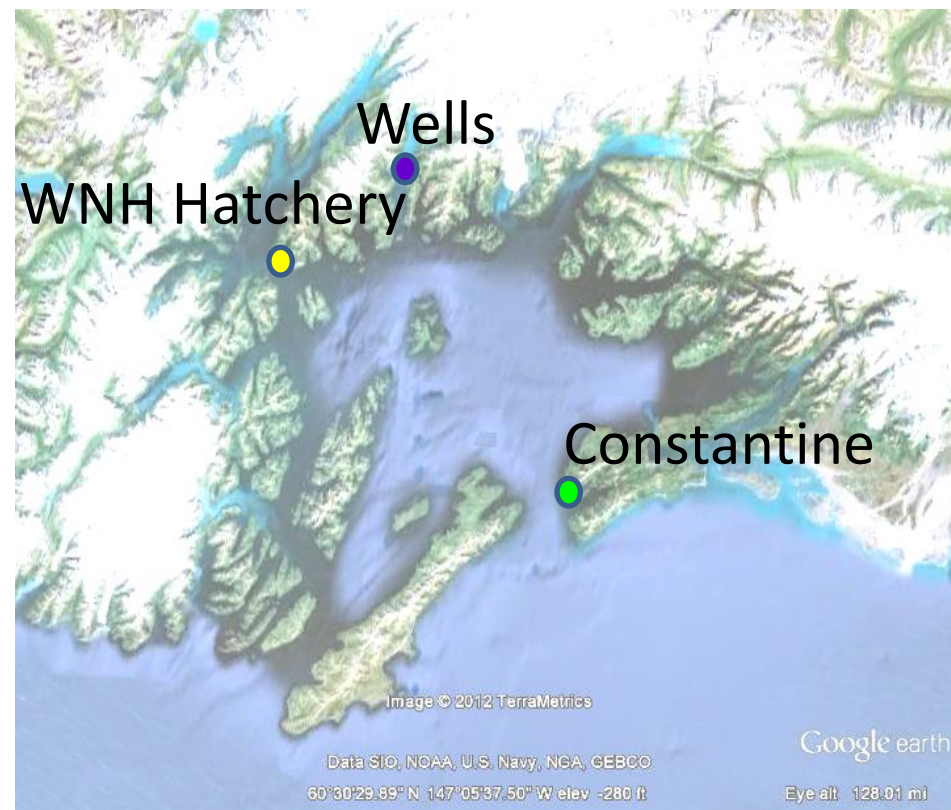
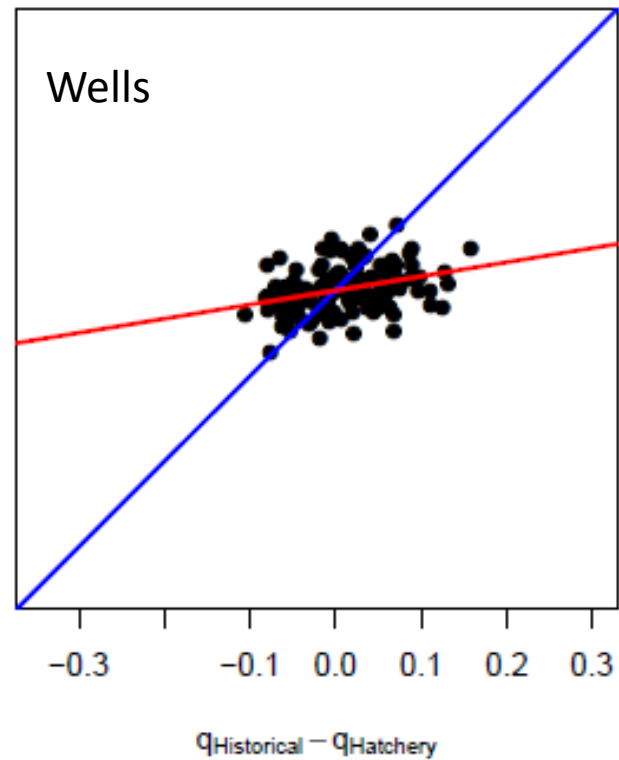
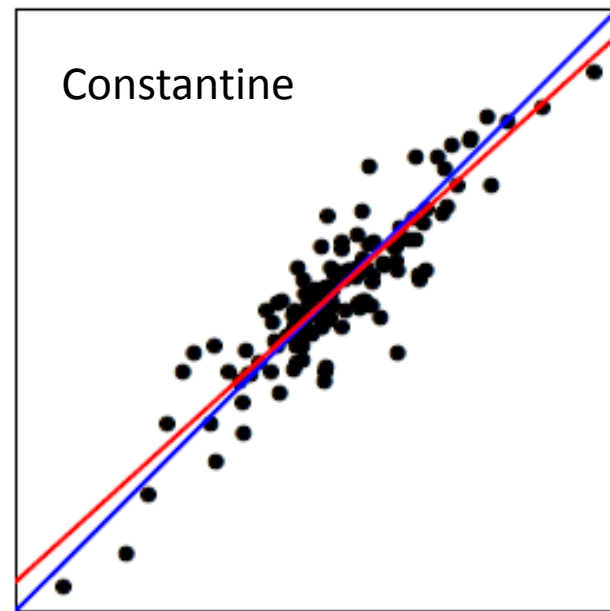
One-way migration model

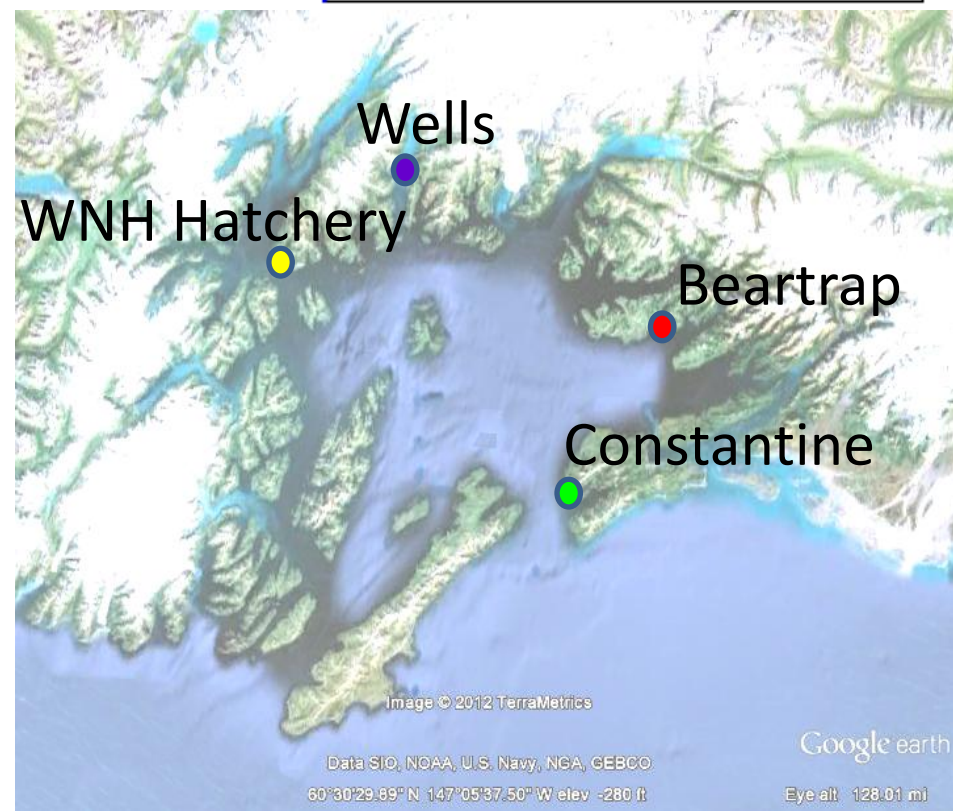
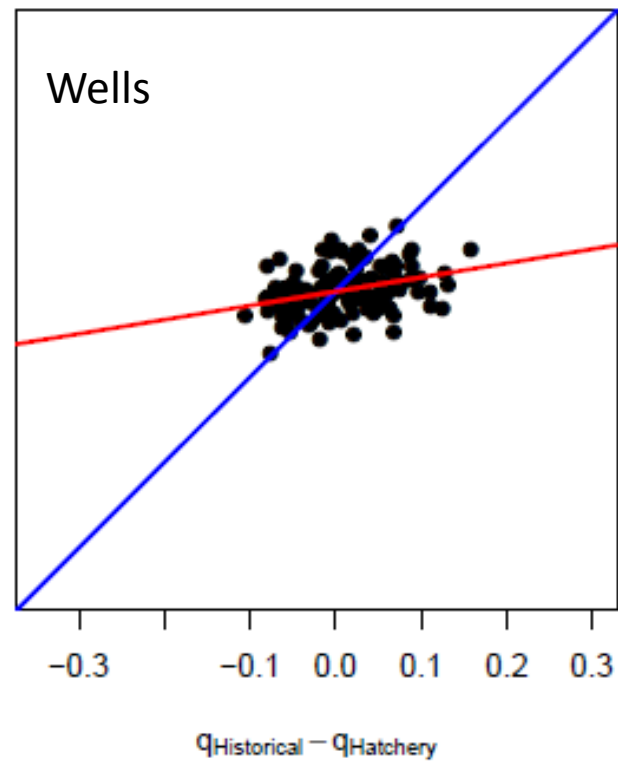
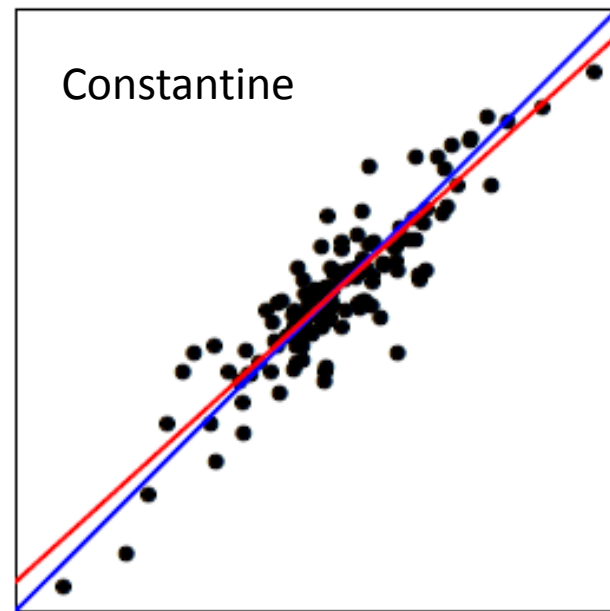
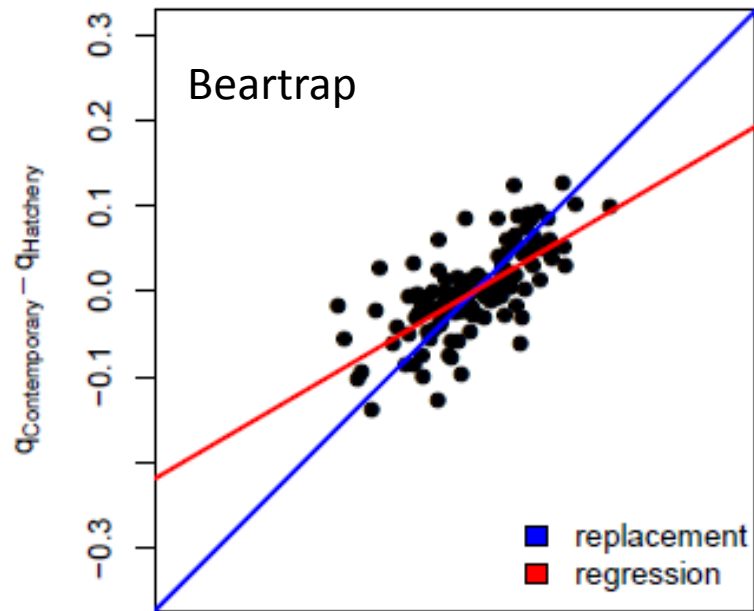
$$q_{\text{cont}} - q_{\text{hat}} = (1 - \text{introgression rate})^{\# \text{ generations}} (q_{\text{hist}} - q_{\text{hat}})$$

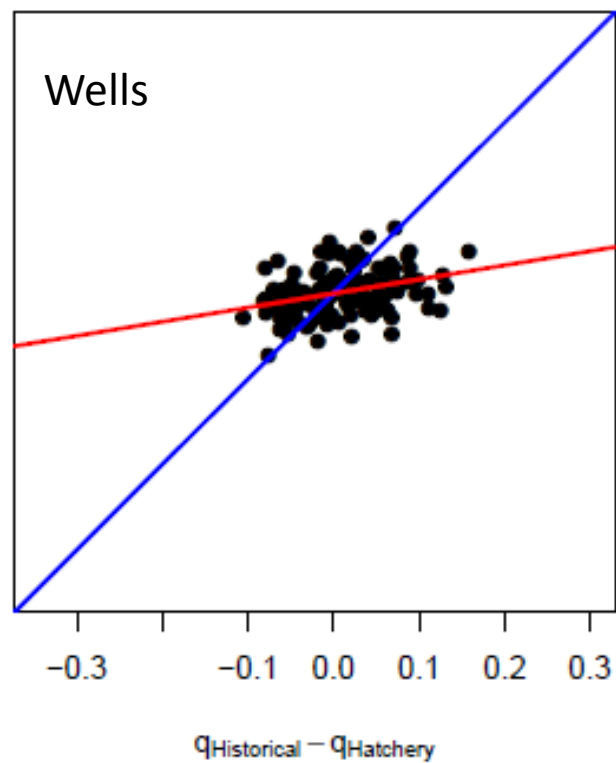
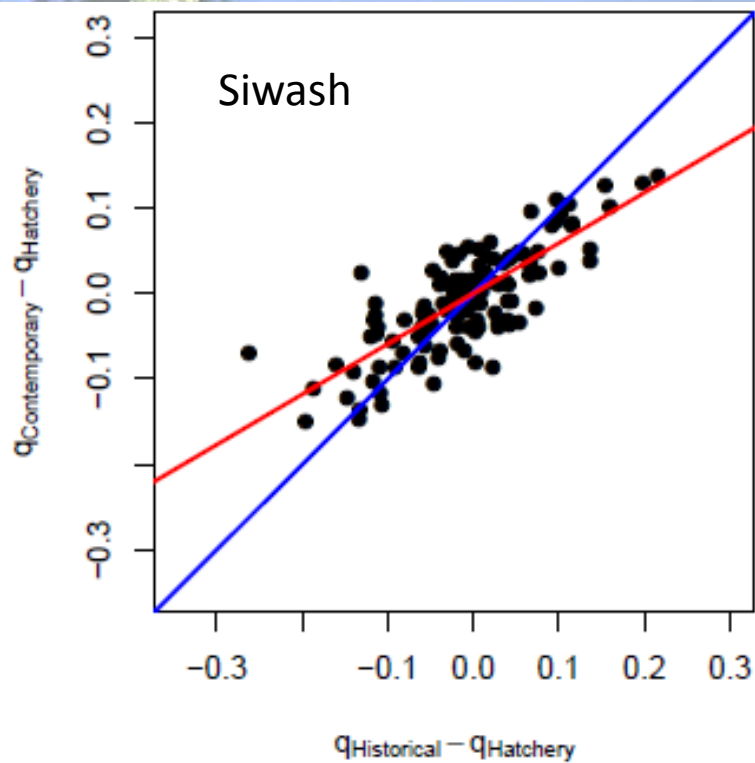
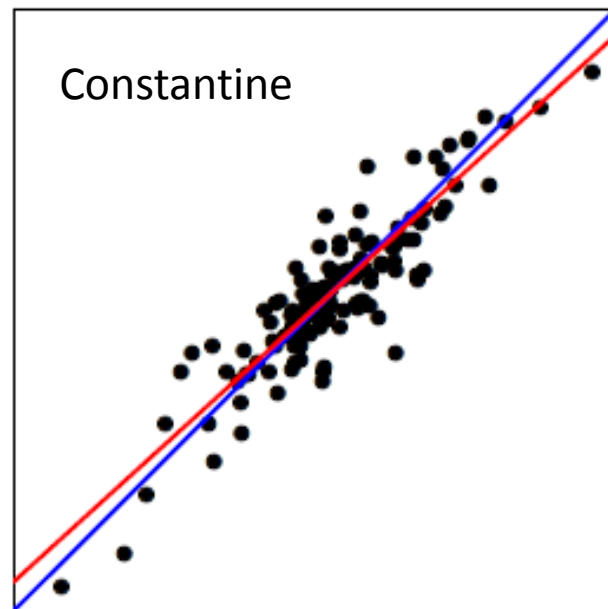
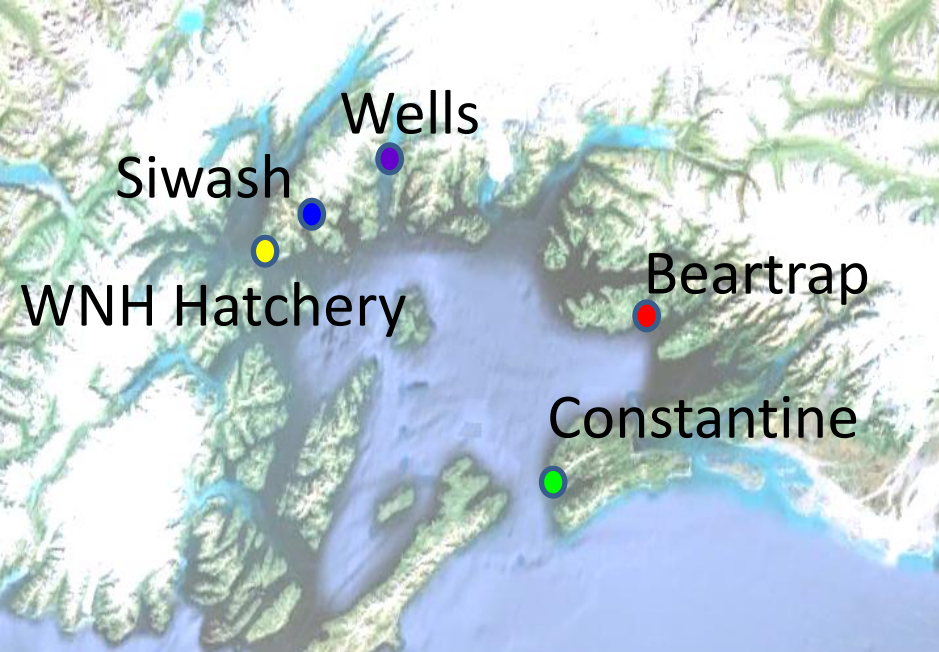
Introgression = 2% at 6 generations

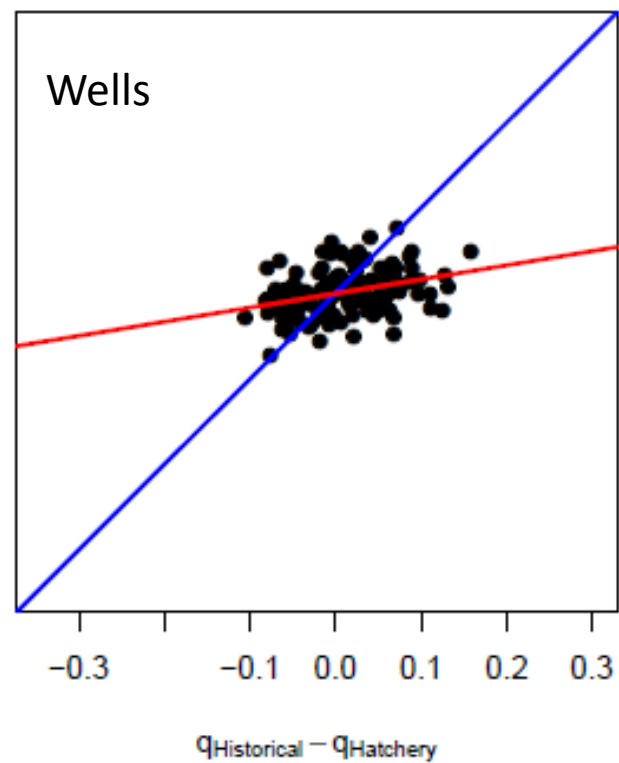
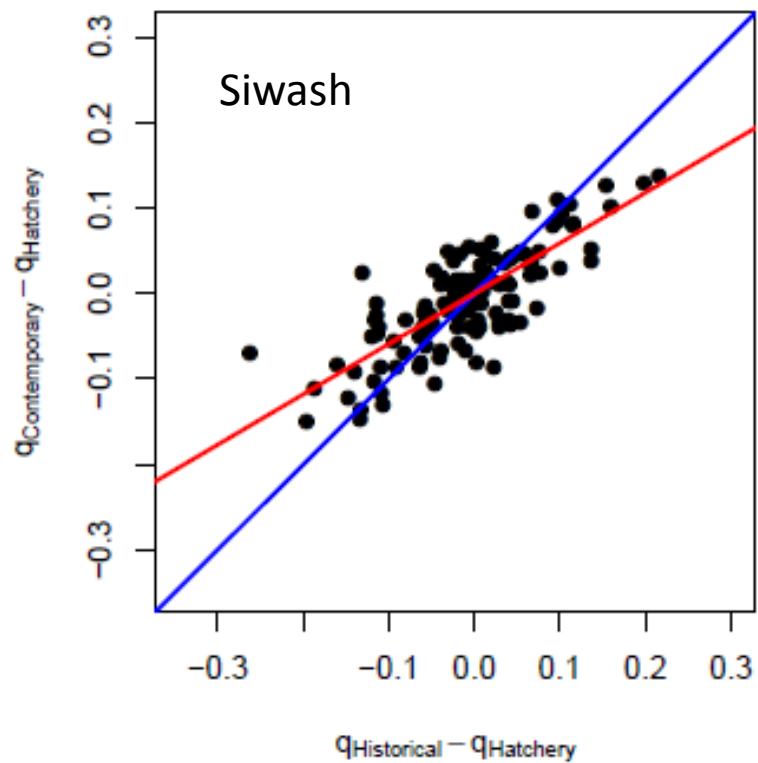
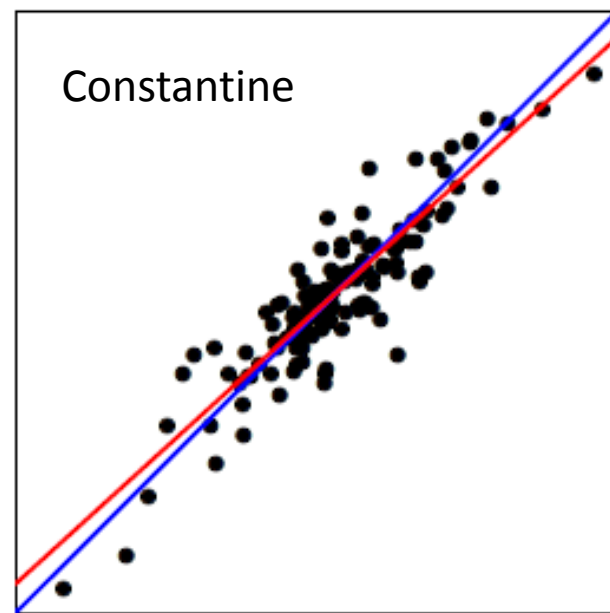
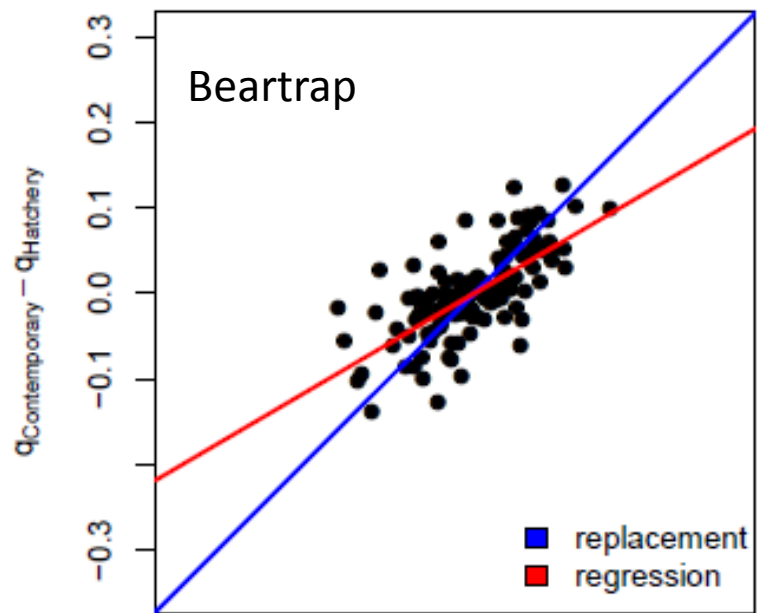




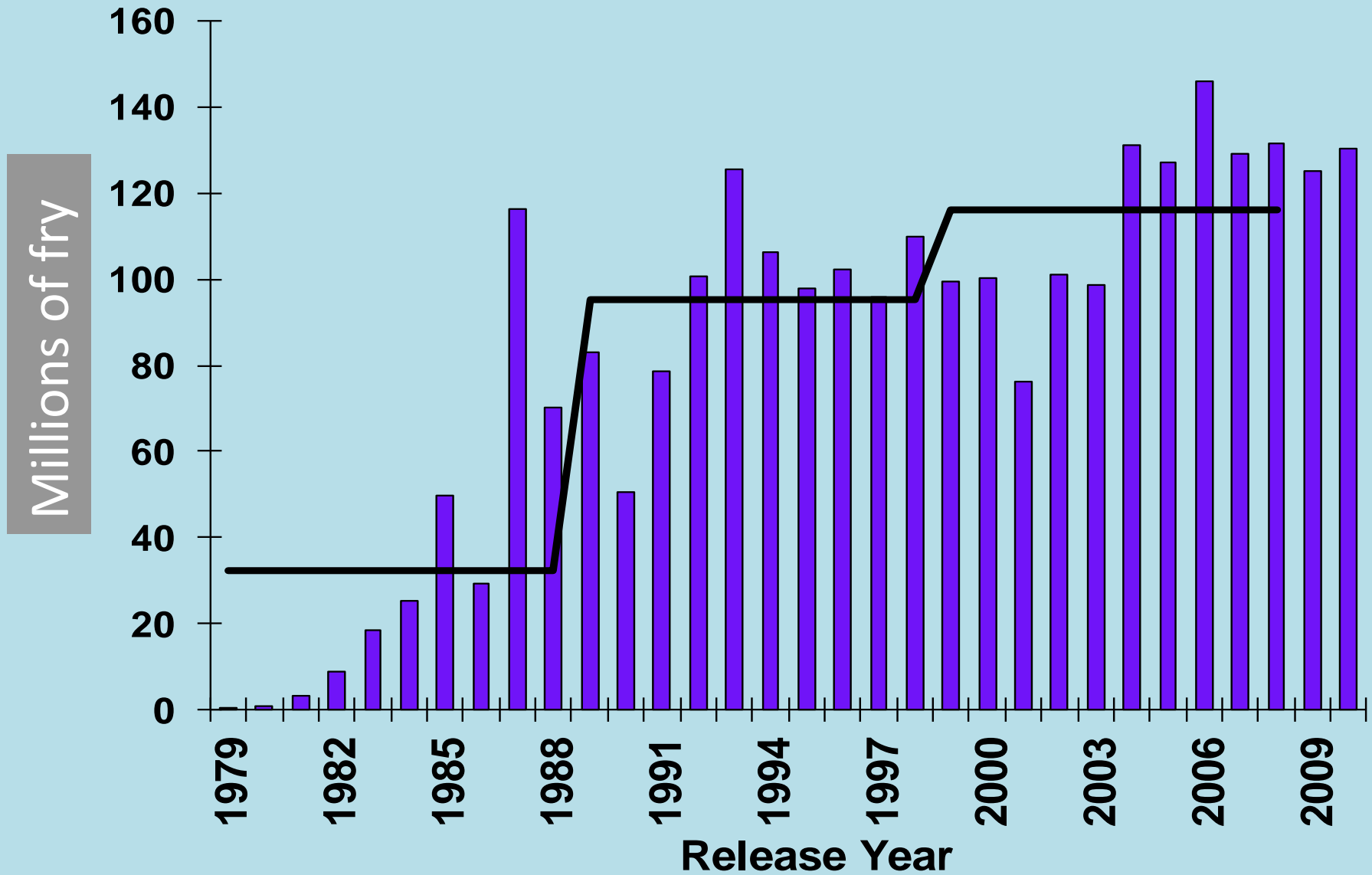




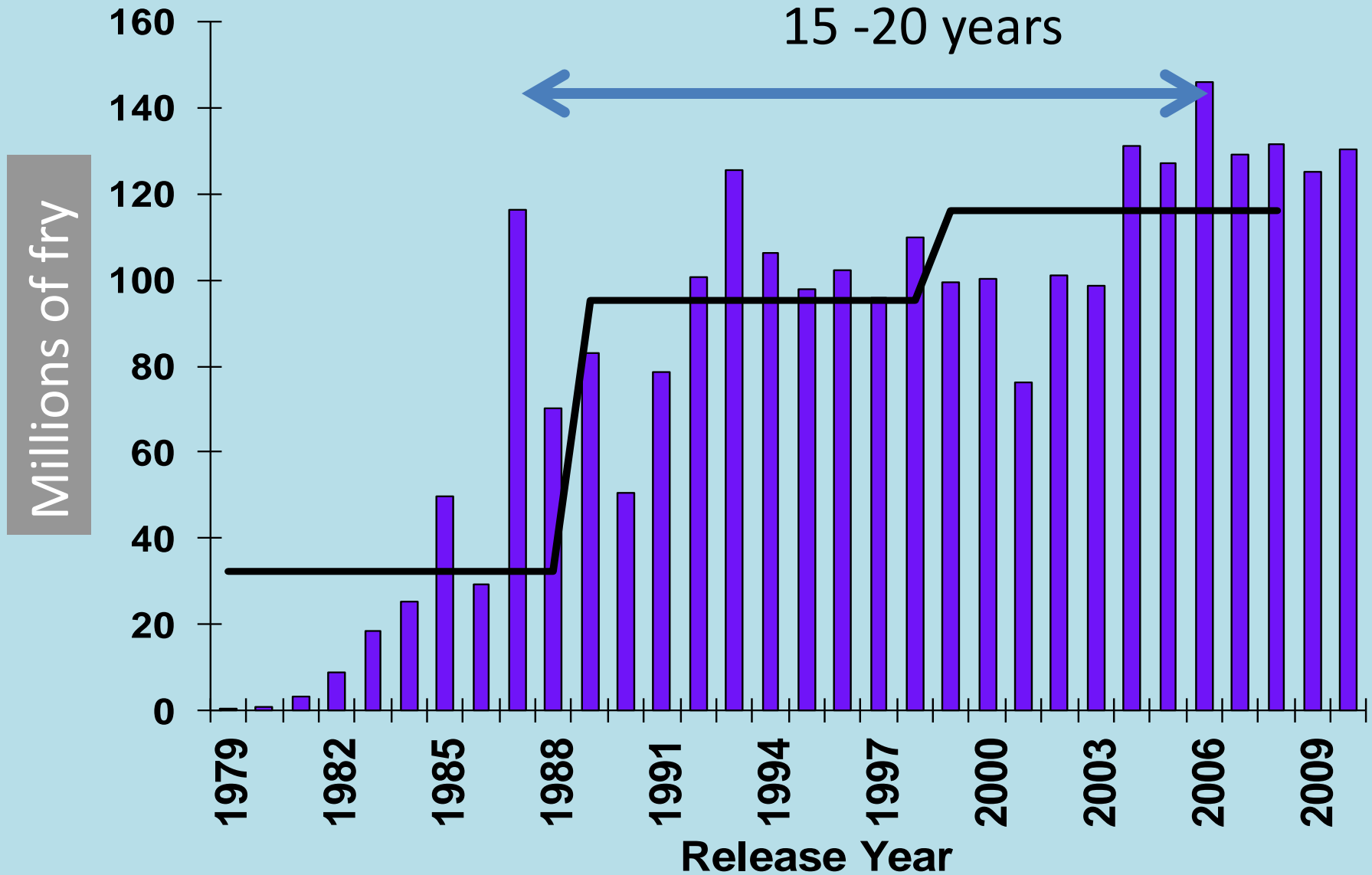




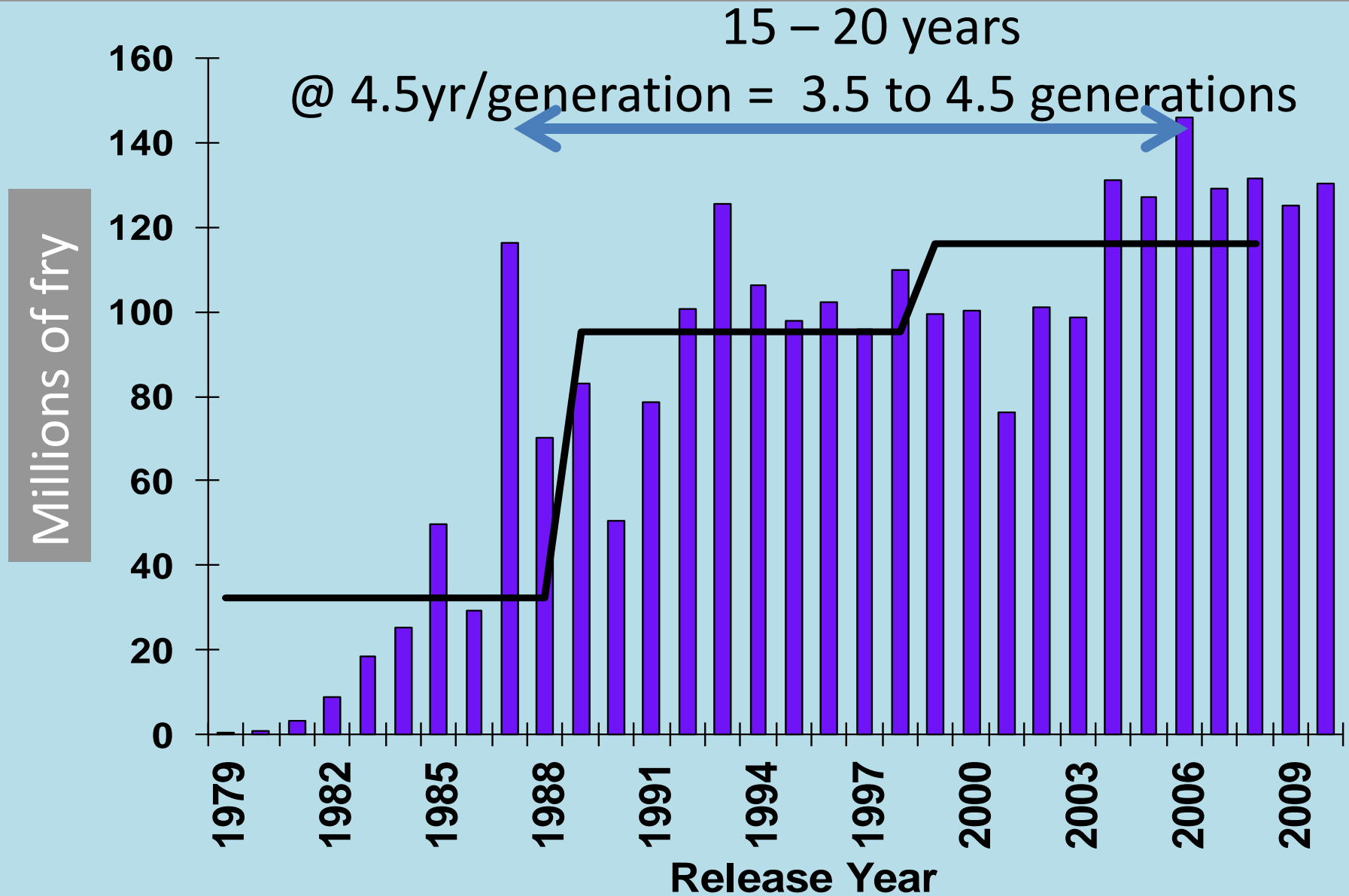
PWS hatchery chum salmon fry releases



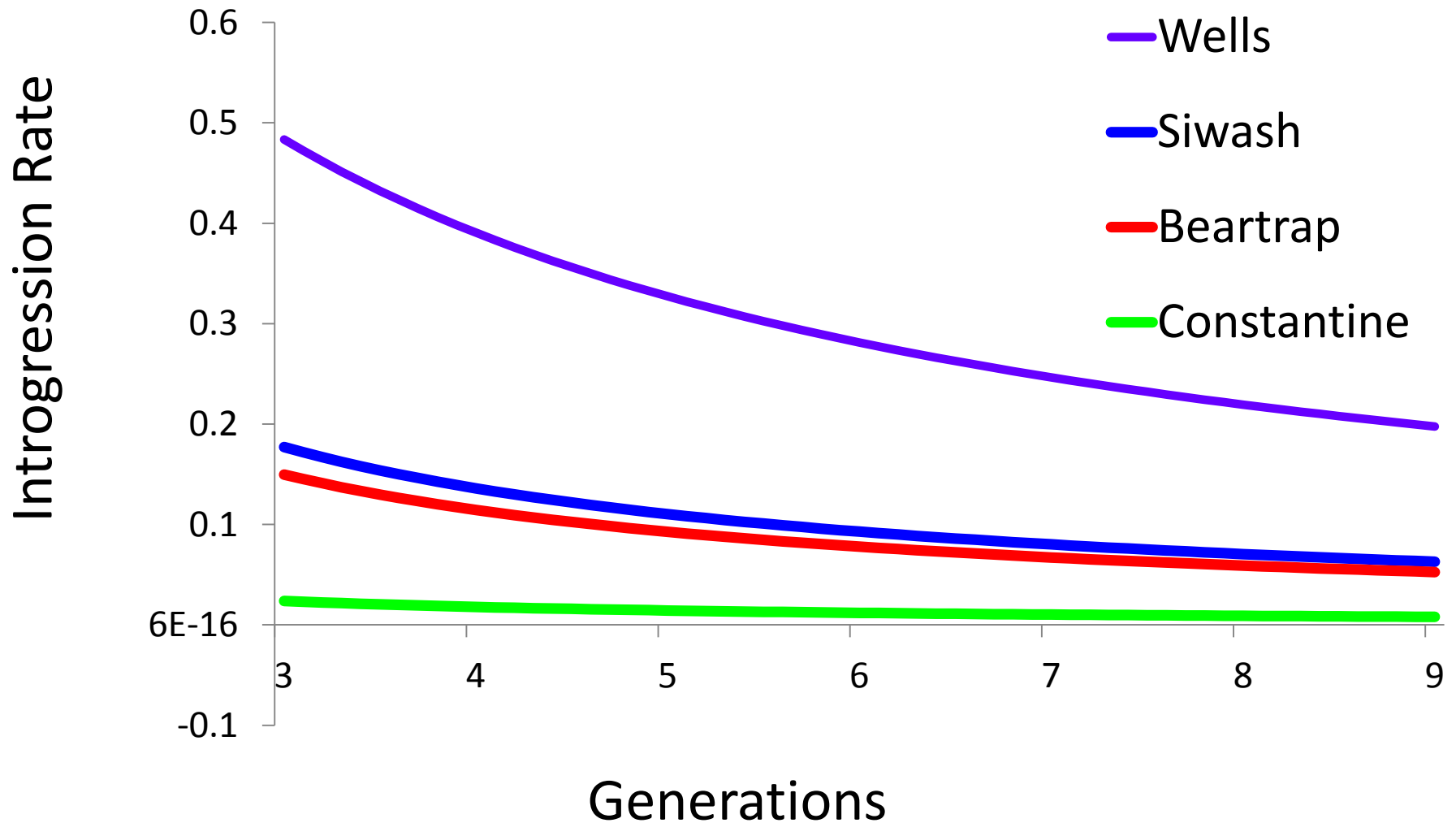
PWS hatchery chum salmon fry releases



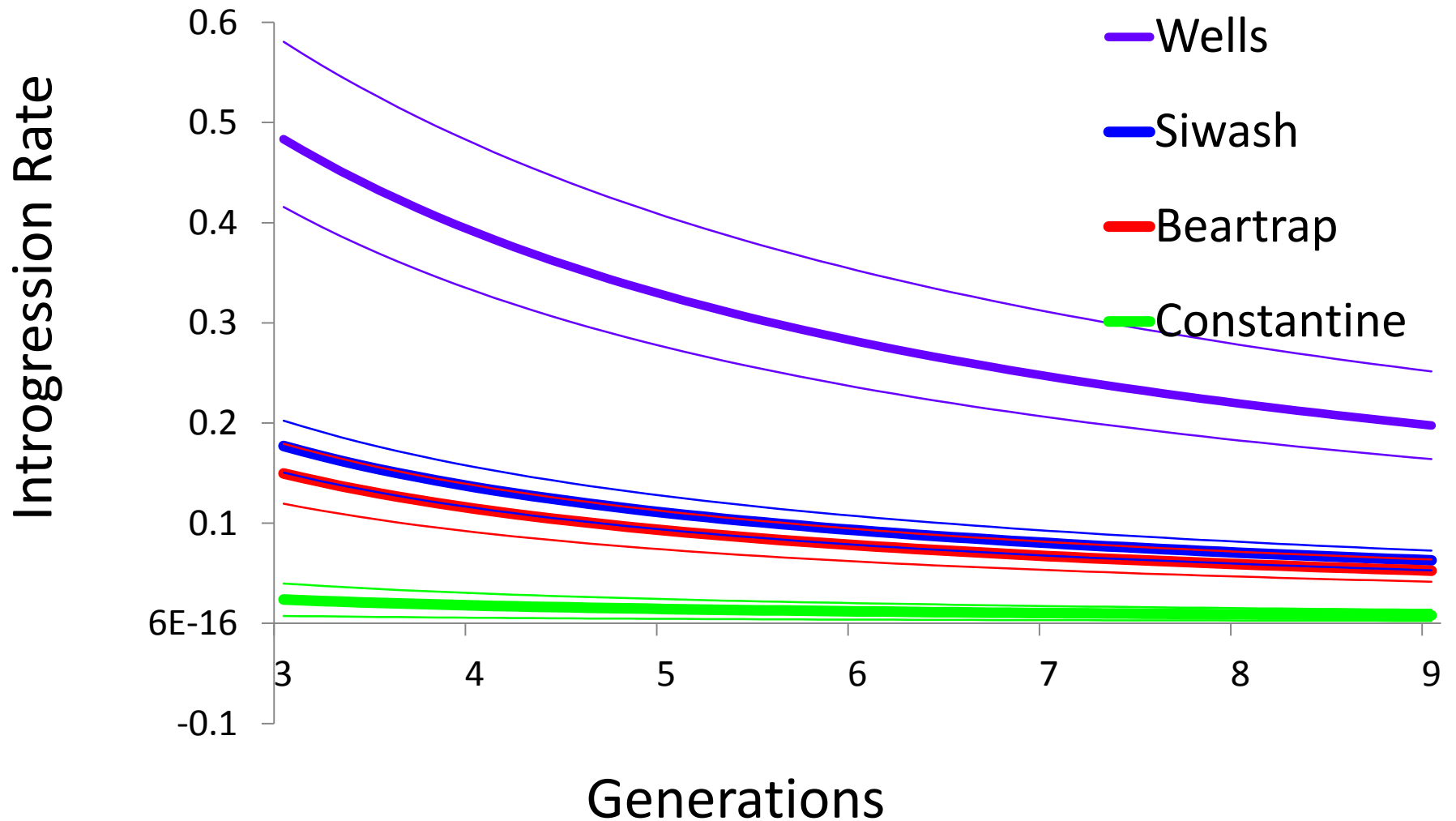
PWS hatchery chum salmon fry releases



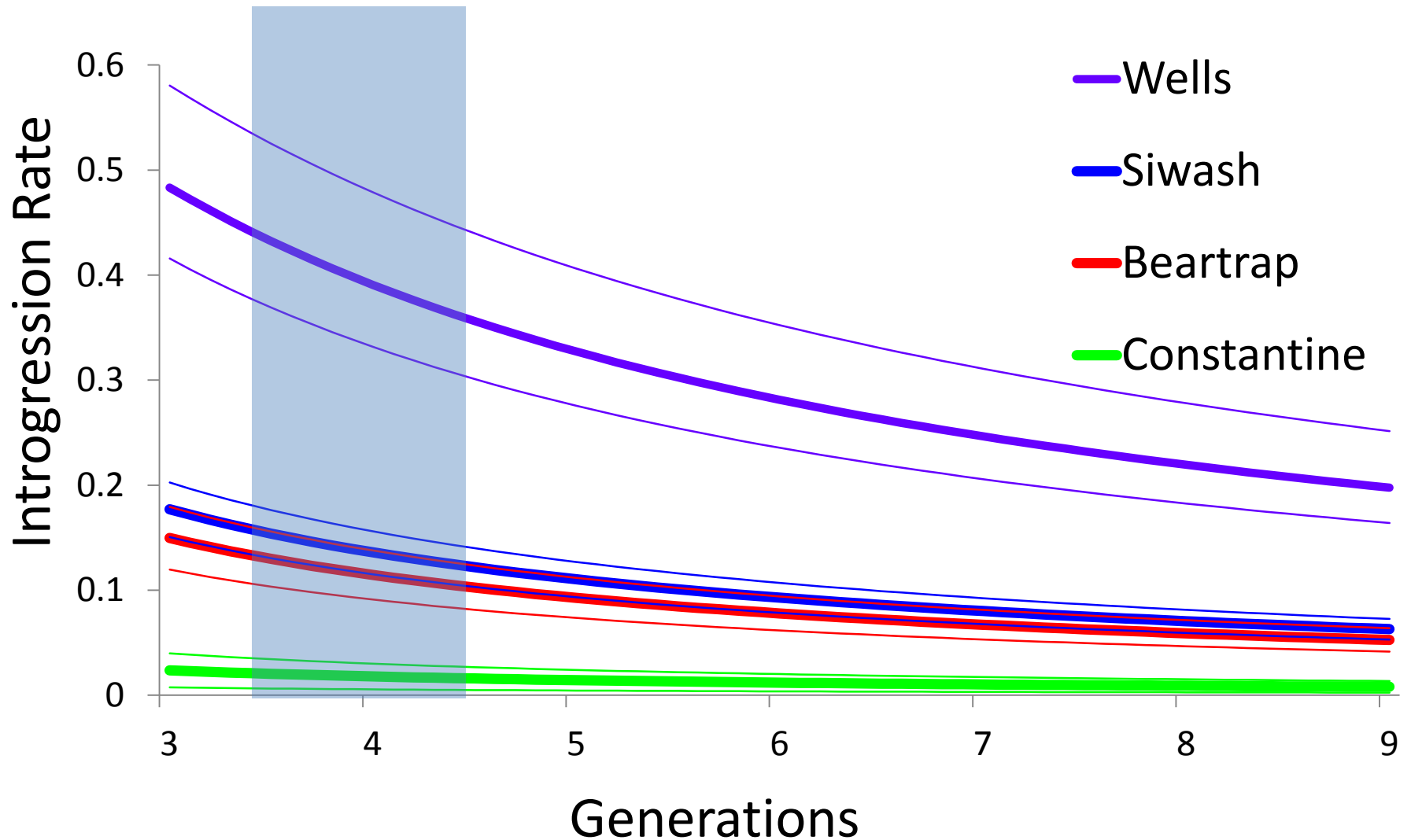
Estimated introgression rates



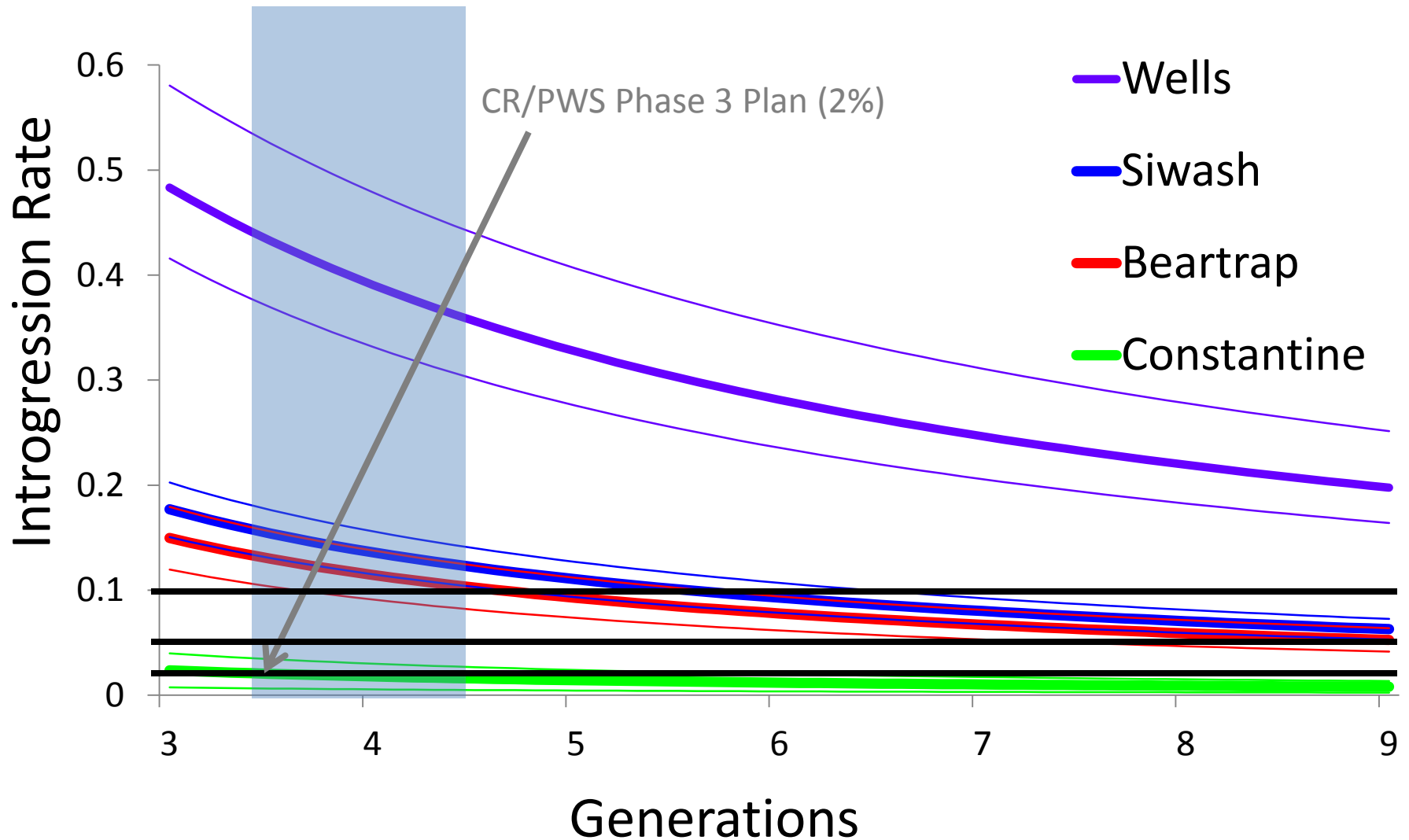
Estimated introgression rates



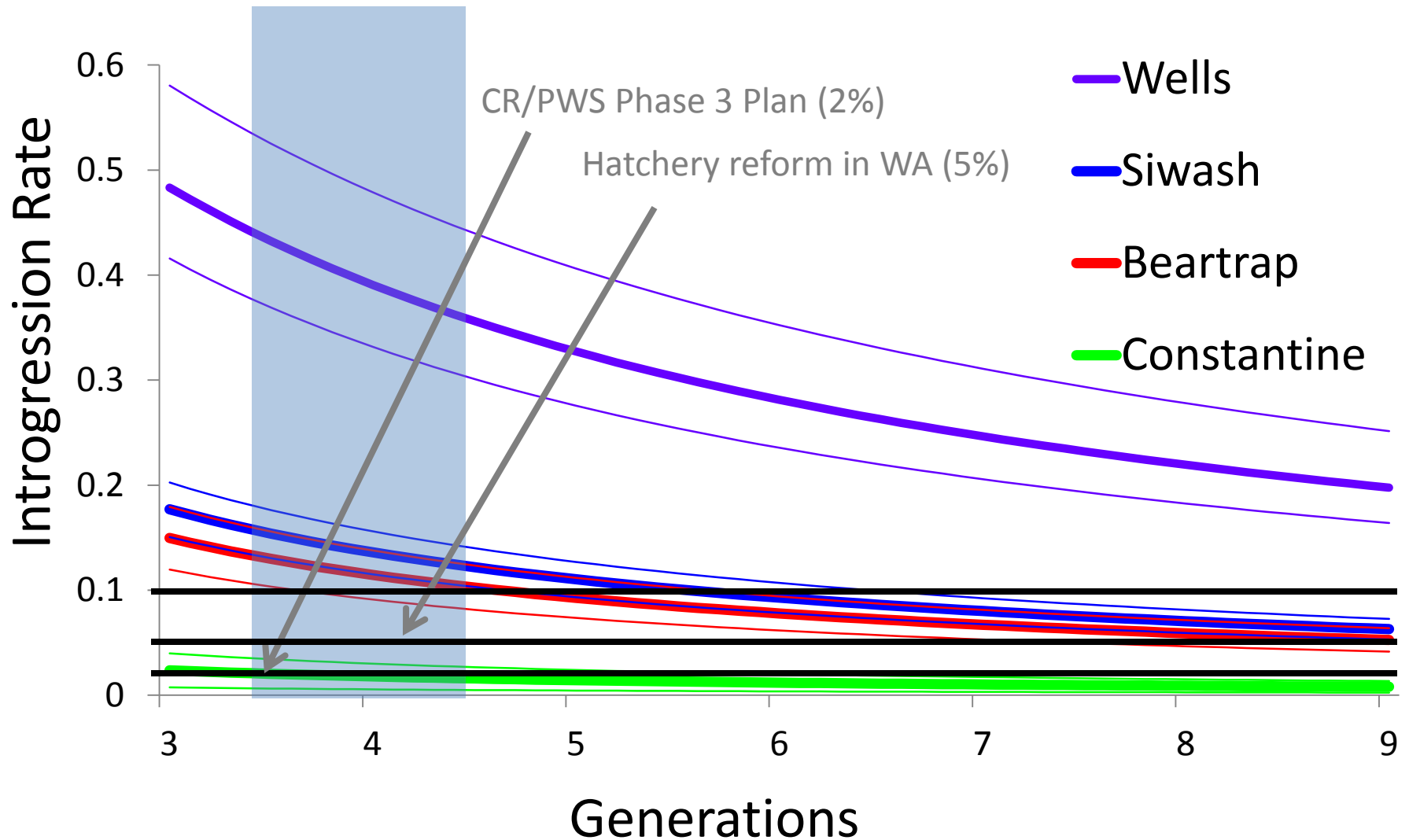
Estimated introgression rates



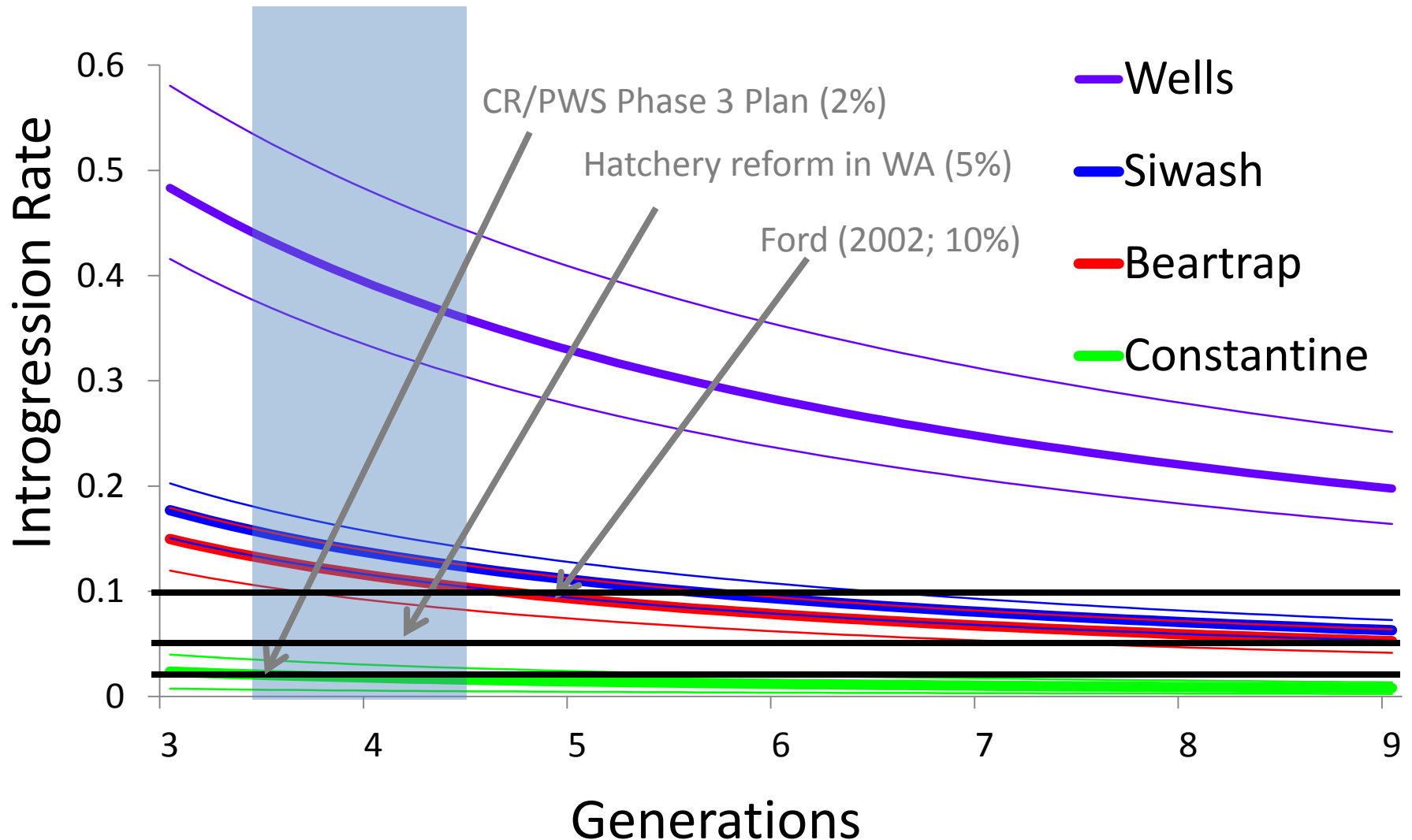
Estimated introgression rates



Estimated introgression rates



Estimated introgression rates



Introgression results

- Take home message:
 - Introgression rates are highly variable among locations
 - Populations closer the hatchery had higher introgression rates
 - Some rates exceed acceptable recommended levels

Assumptions of the one-way migration model

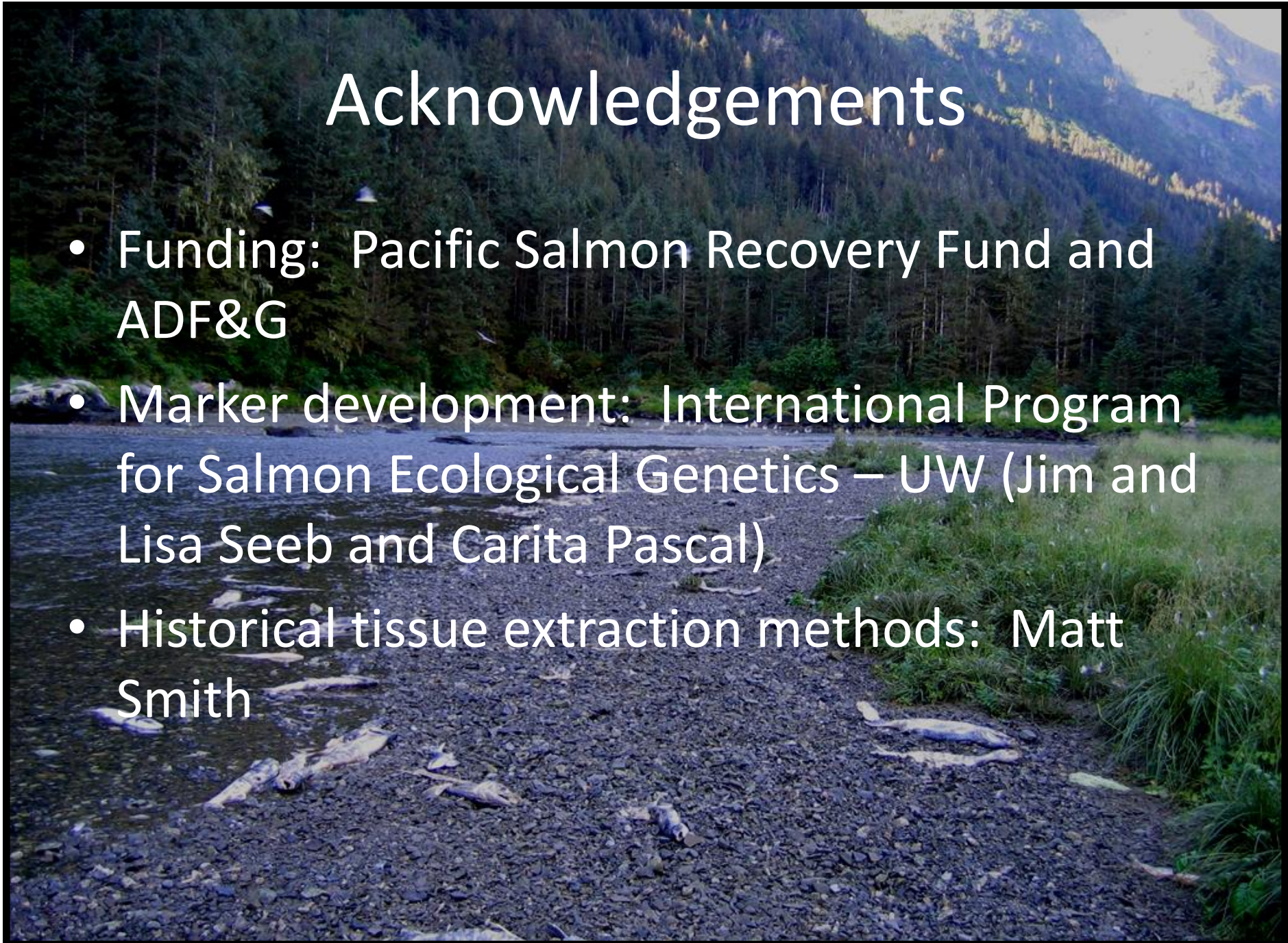
- Neutral loci
 - Loci under selection may be resisting adaptive changes within populations
- Constant annual introgression rate
 - Unlikely. Harmonic mean means?
- Migration only from mainland to island
 - Hatchery out-produces wild by 4:1
 - Deep historical population structure suggest little wild to wild straying in historical samples
 - May be a stepping-stone model

Where do we go from here?

- Look at other streams to define patterns of introgression
- Test for fitness of wild and hatchery spwaners
- Find ways to decrease straying:
 - Culture practices
 - Numbers released

Acknowledgements

- Funding: Pacific Salmon Recovery Fund and ADF&G
- Marker development: International Program for Salmon Ecological Genetics – UW (Jim and Lisa Seeb and Carita Pascal)
- Historical tissue extraction methods: Matt Smith



Chum salmon mean of $> 1,000$ in esc.

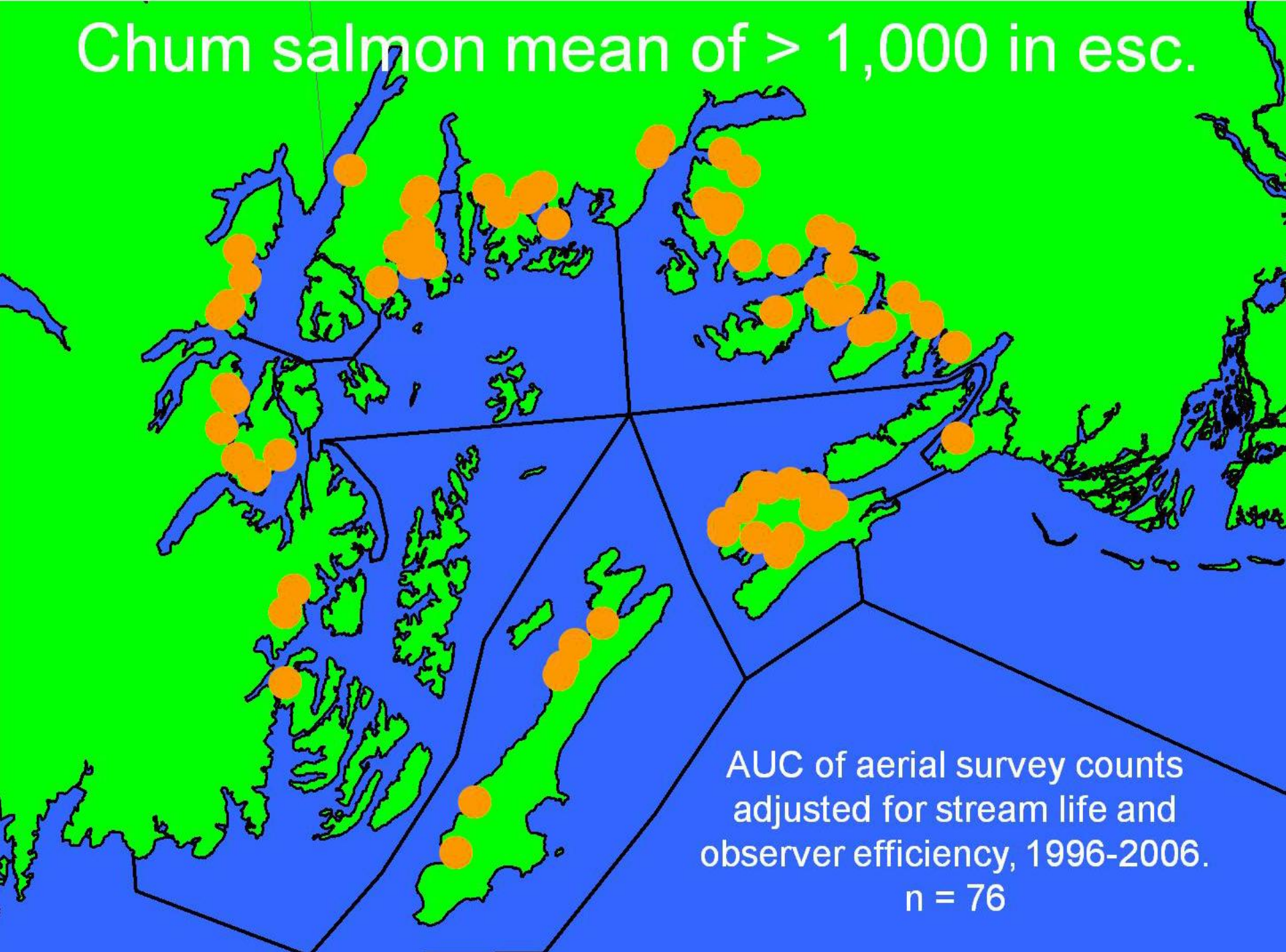




Image © 2012 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image

60°48'50.04" N 147°54'26.44" W elev. -89 ft

Google earth
Eye at 1057.43 mi

Image © 2012 TerraMetrics

Data SIO, NOAA, U.S. Navy, NGA, GEBCO

60°30'29.89" N 147°05'37.50" W elev. -280 ft

Google earth

Eye alt 128.01 mi

Hatchery originator stocks

Brood Year	Green eggs	Location	Egg take type	Original stock	Run timing	Transfer history
1983	21,560,438	Wells River	Remote	Wells River	Early	Eggs incubated at Main Bay Hatchery; unfed fry transferred to WNH for release.
1984	33,600,000	Wells River	Remote	Wells River	Early	Eggs incubated at Main Bay Hatchery; unfed fry transferred to WNH for release.
1985	10,653,600	Wells River	Remote	Wells River	Early	Eggs incubated at Main Bay Hatchery; unfed fry transferred to WNH for release.
1985	9,746,879	Port Fidalgo	Remote	Port Fidalgo	Late	Eggs to eyed stage at AFK and then transferred to WNH for rearing and release.
1986	5,680,000	Wells River	Remote	Wells River	Early	Eggs flown to WNH for rearing and release
1986	20,430,000	Beartrap Creek	Remote	Beartrap Creek	Early	Eggs flown to WNH for rearing and release
1986	14,070,000	AFK	Onsite	Sunny River/Galena Bay	Late	Eggs to eyed stage at AFK and then transferred to WNH for rearing and release.
1987	13,695,531	WNH	Onsite	Wells River/Beartrap	Early	First WNH onsite egg take.
1987	67,000,000	Main Bay Hatchery	Onsite	??	Early	Green eggs and milt transferred to WNH for spawning, rearing, and release.
1987	2,000,000	AFK	Onsite	Sunny River/Galena Bay	Late	Eggs to eyed stage at AFK and then transferred to WNH for rearing and release.
1988	101,500,873	WNH	Onsite	Wells River/Beartrap	Early	All onsite with no transfers

Estimated introgression rates

