The East of Nantucket Survey

Update

DRAFT-DO NOT DISTRIBUTE

Survey Design – 63 stations

Station grid design:

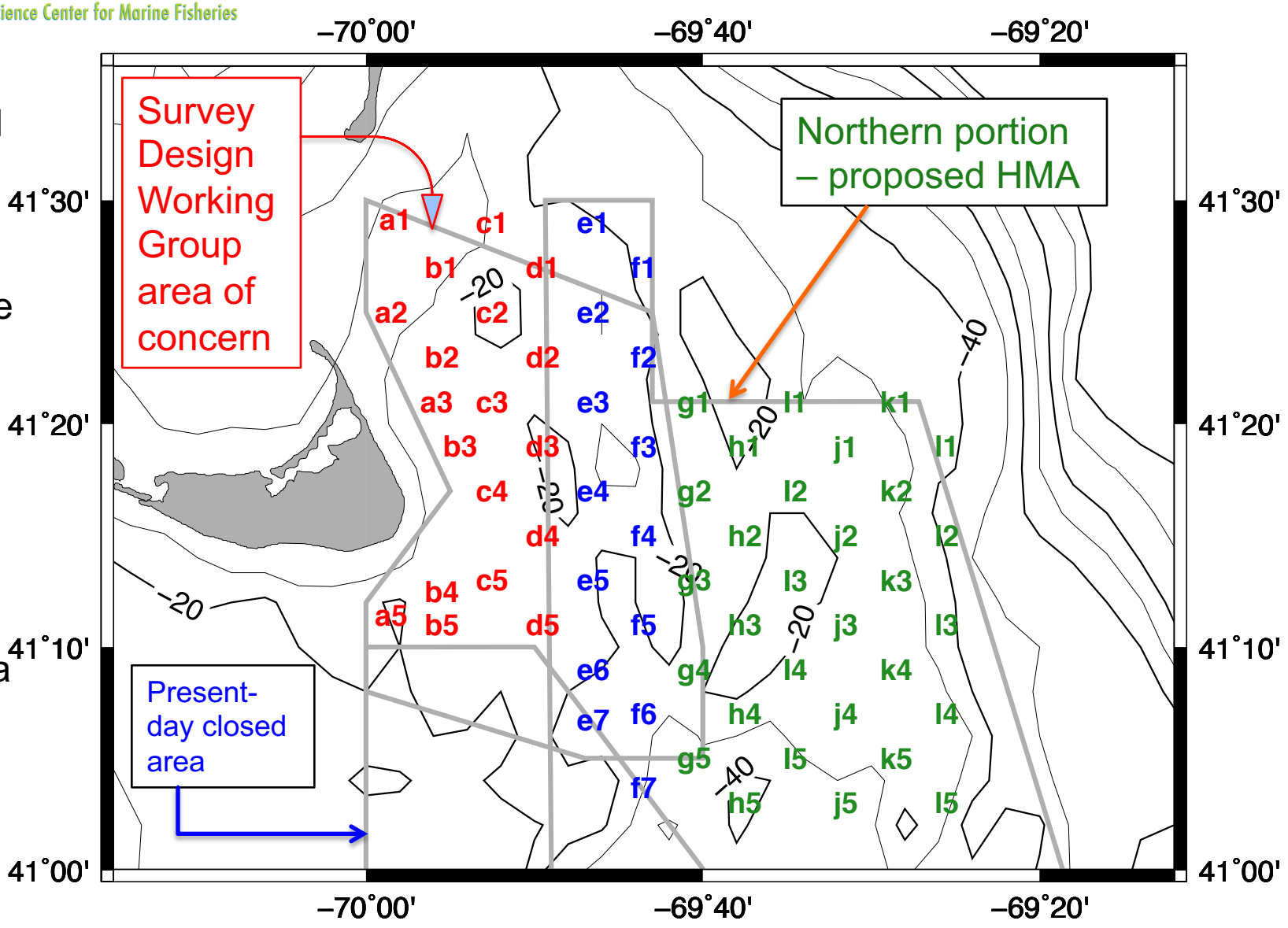
- Hub and spoke
- 3-nm spoke length

Reposition criteria

- depth constraint
- state boundary
- closed area boundary

Reposition distance

- 1-nm search radius



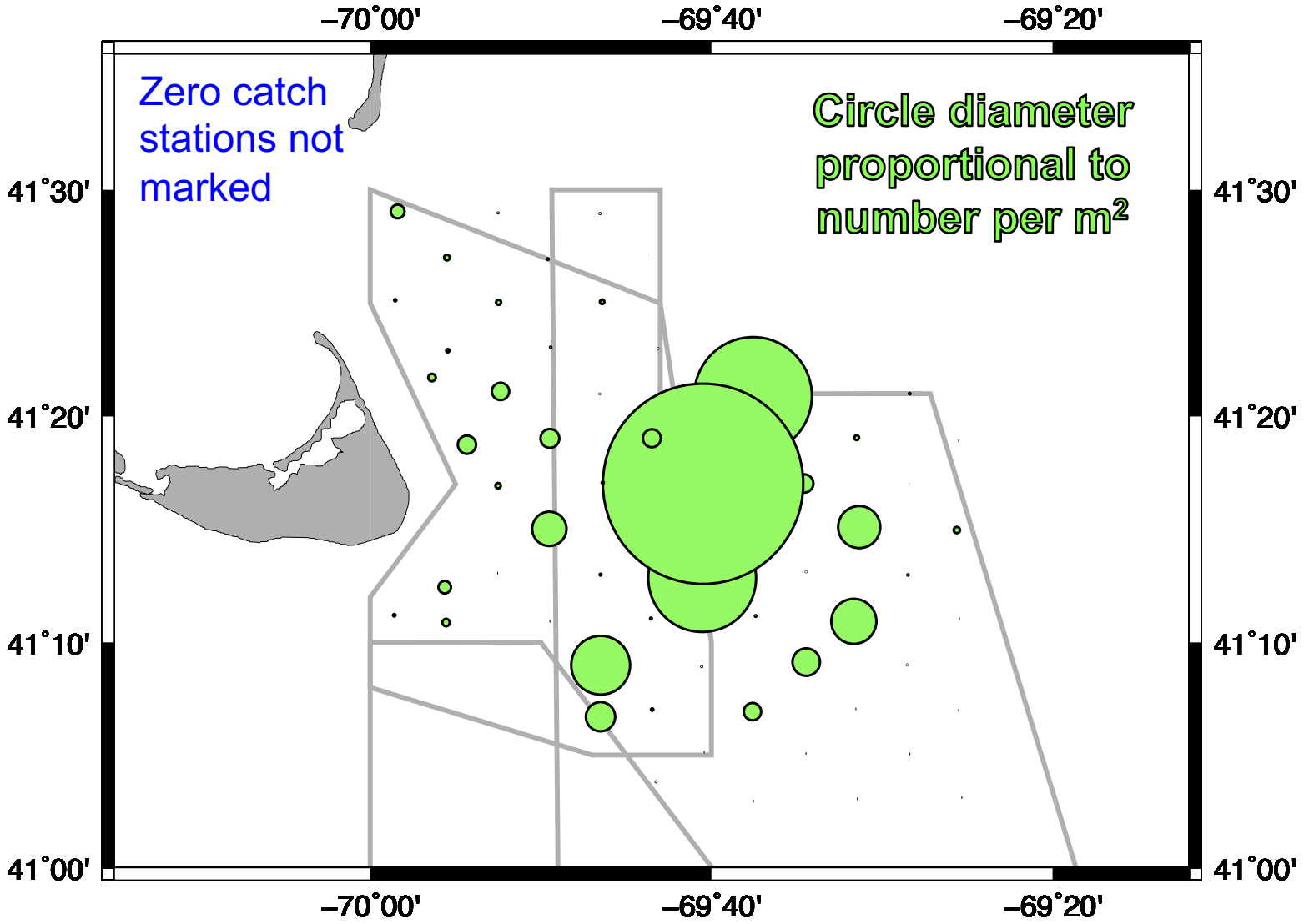
Note: NMFS survey grid 2 nm x 2.5 nm

Survey protocol

- 5-minute tow
- 99 in dredge
- Shaker closed to about 0.75 in
- Tow speed ~3 knots
- Tow coverage: ~1300 m^2 per tow, ~82,000 m^2 total
- All catch sorted
- Delaware II sorting protocol followed as closely as possible
- Deviation: bushel volume measurements used rather than counts for mussels
- Ten haphazardly chosen rocks, cobbles, boulders, shells photographed. Photos biased towards particle side with bionts, if present

Distribution of surfclams

Note:
- Surfclams found throughout the region except the offshore and southern portions of the HMA
- Largest numbers found in the north central portion of the HMA

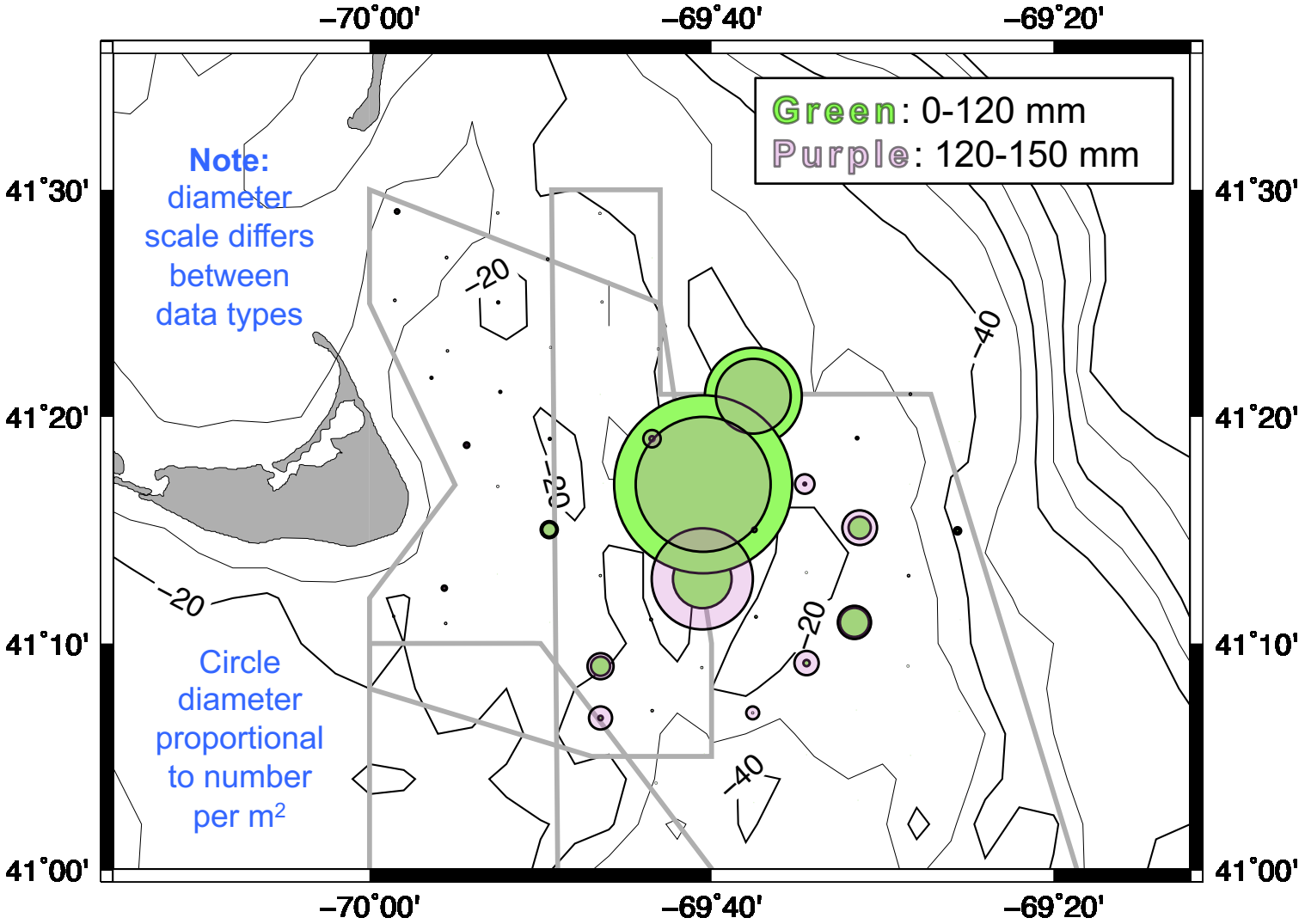


Nantucket Survey: surfclams surfclams–all

Differential distribution: submarket (0-120 mm) versus small market (120-150 mm) surfclams

Note:

- Surfclams <120 mm and surfclams 120-150 mm are distributed almost identically
- Few small surfclams are found inshore
- Nearly all submarket and small market size clams are in the north-central portion of the proposed HMA

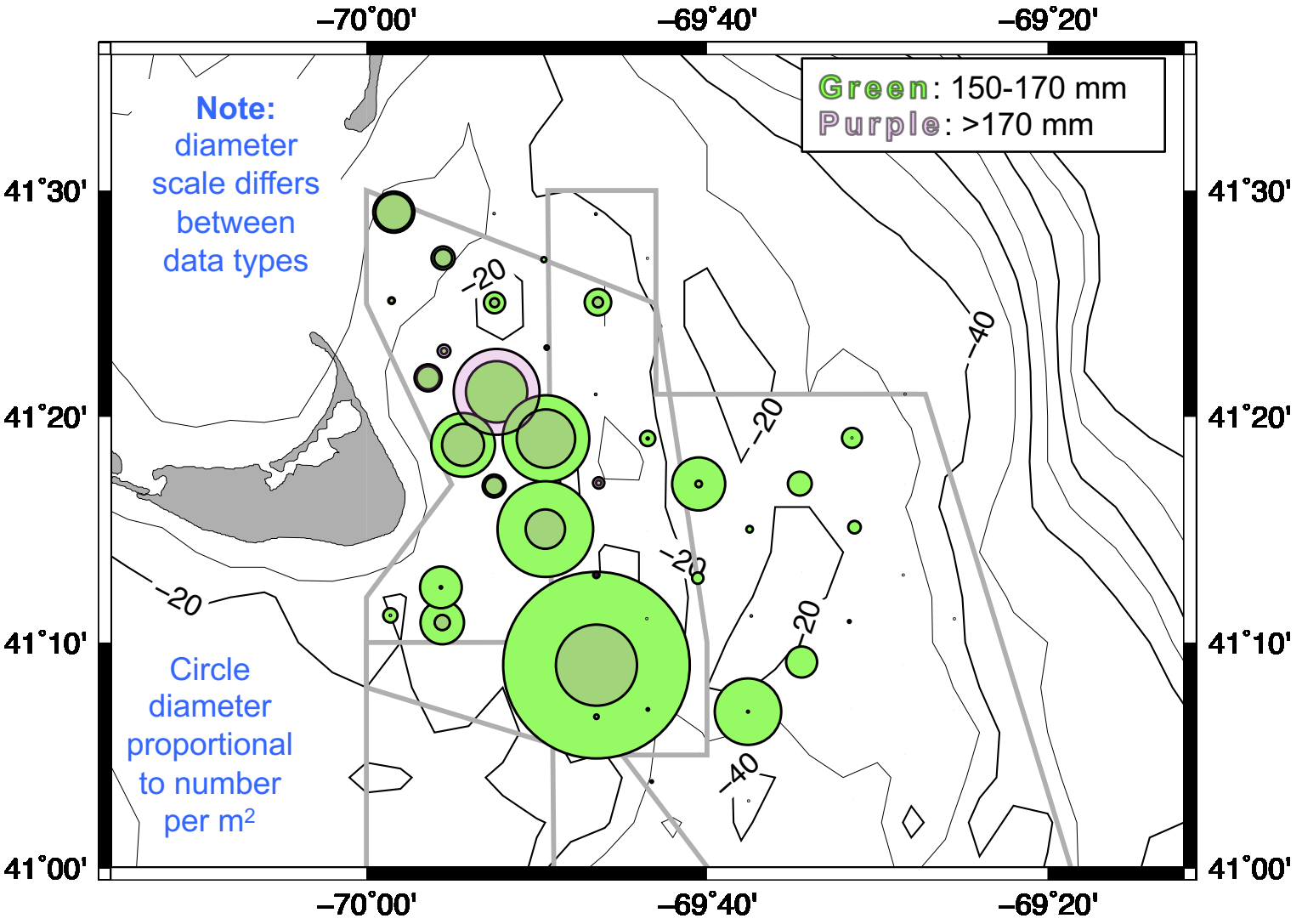


Nantucket Survey: surfclams 120–150 mm over 0–120 mm

Differential distribution: large surfclams

Note:

- Surfclams >170 mm and surfclams 150-170 mm are distributed almost identically
- Few large surfclams are found offshore
- Nearly all market size surfclams are east of or in the eastern portion of the proposed HMA
- Clams 150-170 mm are biased south of the largest clams
- This is the largest concentration of very large (>170 mm) clams in the federal stock!



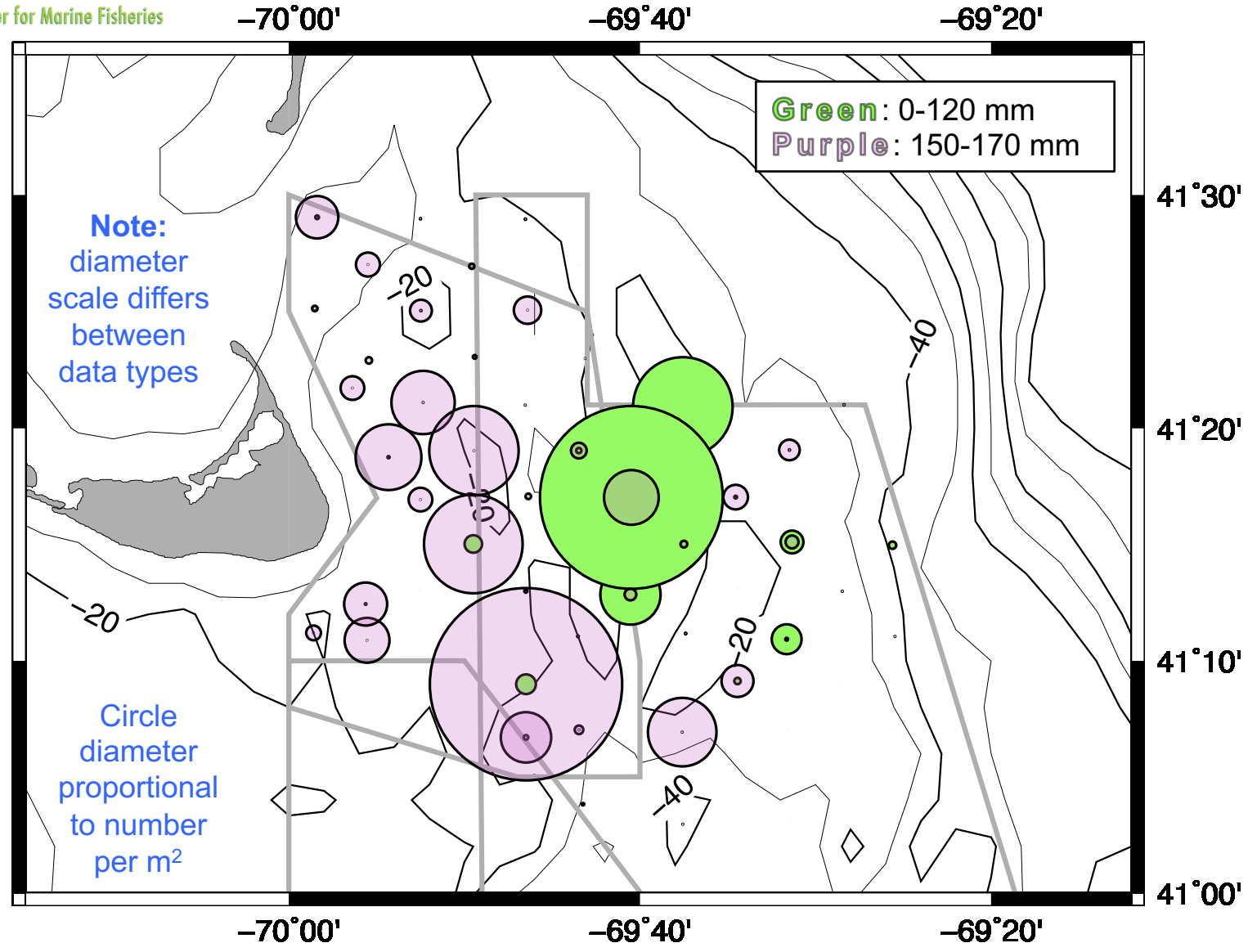
Nantucket survey: surfclams >170 mm over 150-170 mm

Differential distribution: small versus large surfclams

Science Center for Marine Fisheries

Note:

- Large surfclams are distributed inshore of small surfclams with very limited overlap
- Recent recruitment is offshore
- Surfclams are moving into deeper water as observed throughout the range
- Suggested time frame for deep-water colonization: 10-15 years

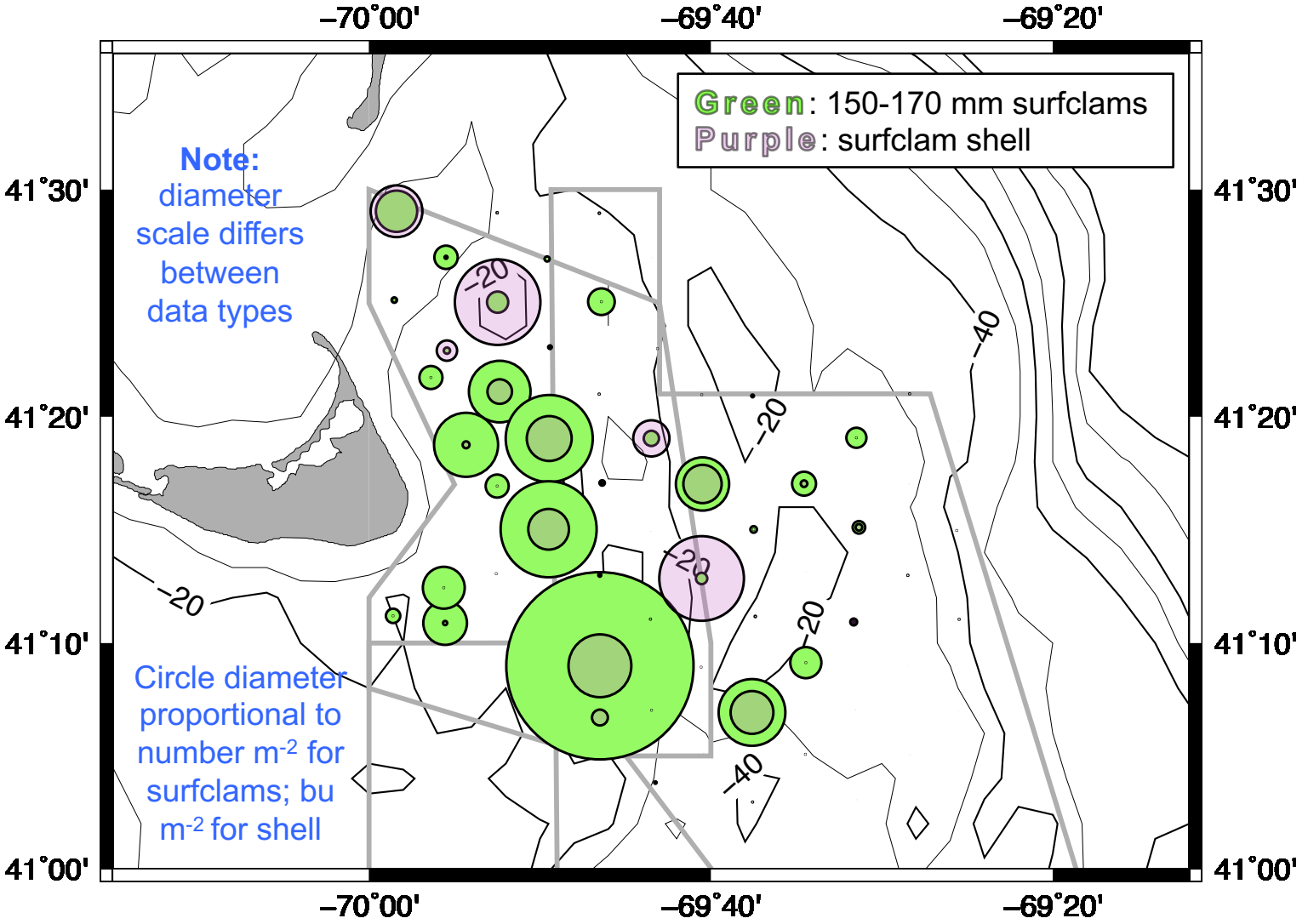


Nantucket Survey: surfclams 150–170 mm over 0–120 mm

Differential distribution: surfclam shell versus large surfclams

Note:

- Large surfclams and shell overlap relatively consistently
- Surfclam shell is taphonom-ically robust – thus, presence of shell is indicative of long-term habitation

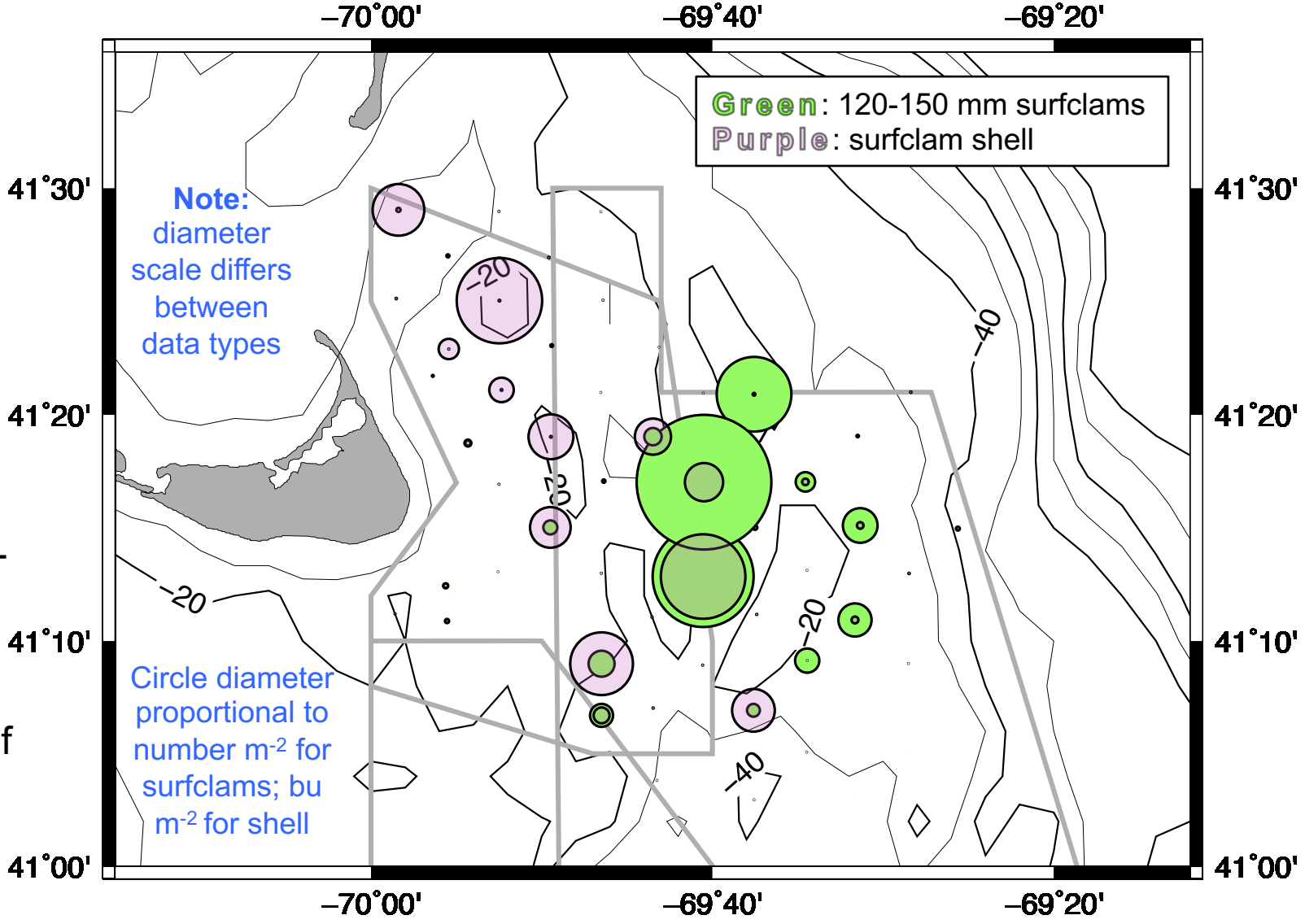


Nantucket Survey: surfclam shell over 150–170 mm surfclams

Differential distribution: surfclam shell versus small surfclams

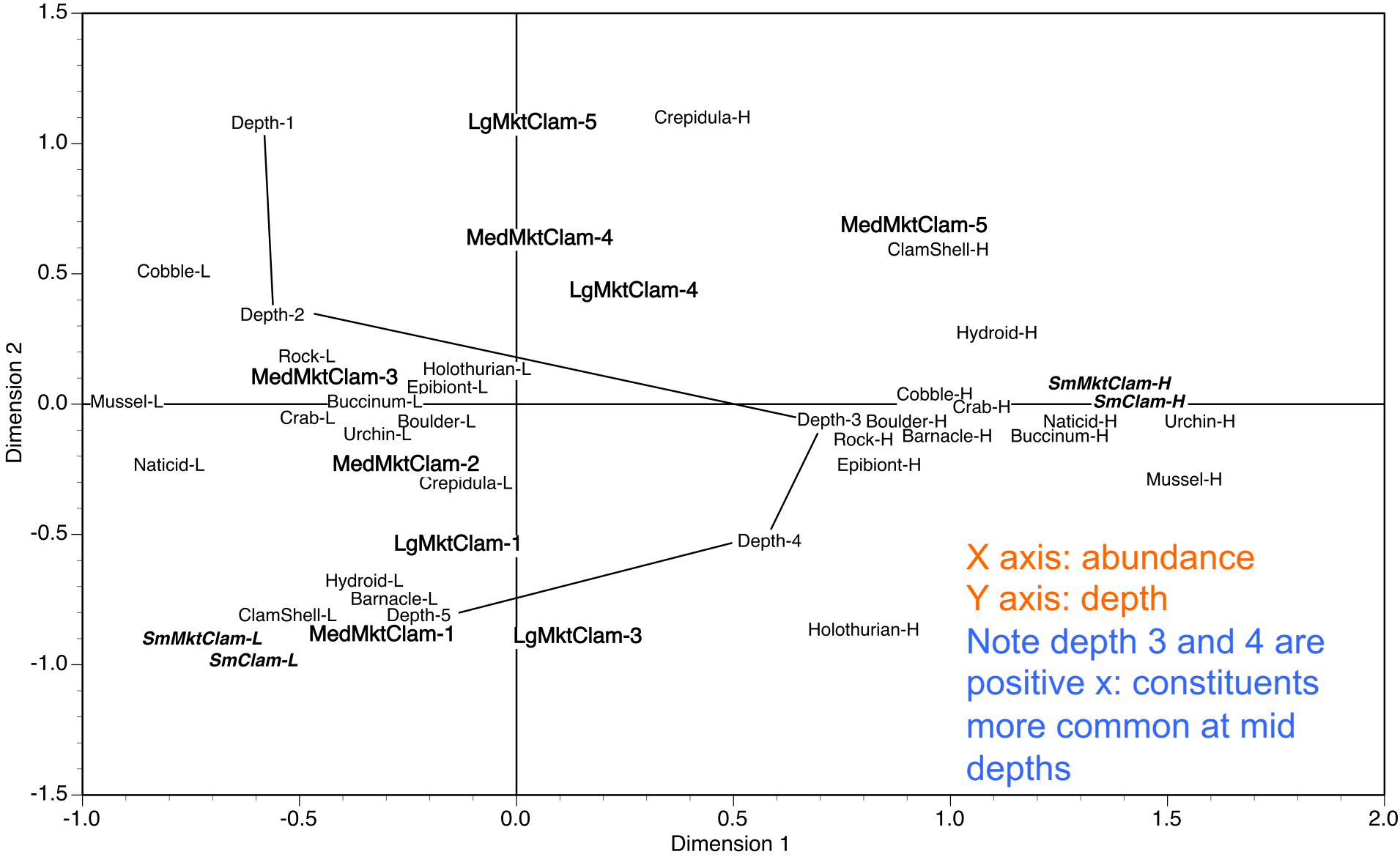
Note:

- Small surfclams and shell overlap relatively poorly
- Surfclam shell is taphonom-ically robust – thus, absence of shell is indicative of recent habitation



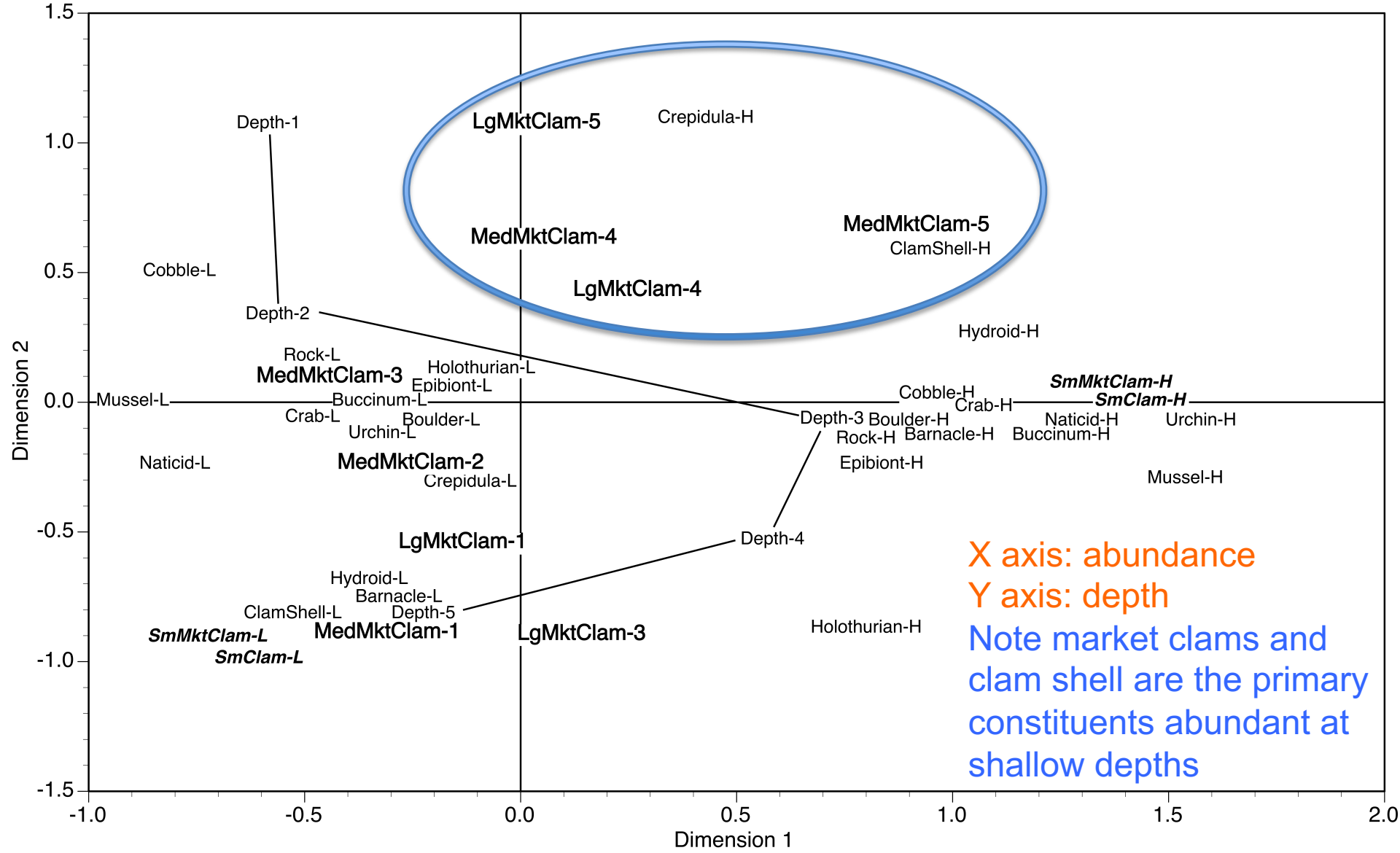
Nantucket Survey: surfclam shell over 120–150 mm surfclams

Correspondence Analysis



Correspondence Analysis

Where are the market clams?



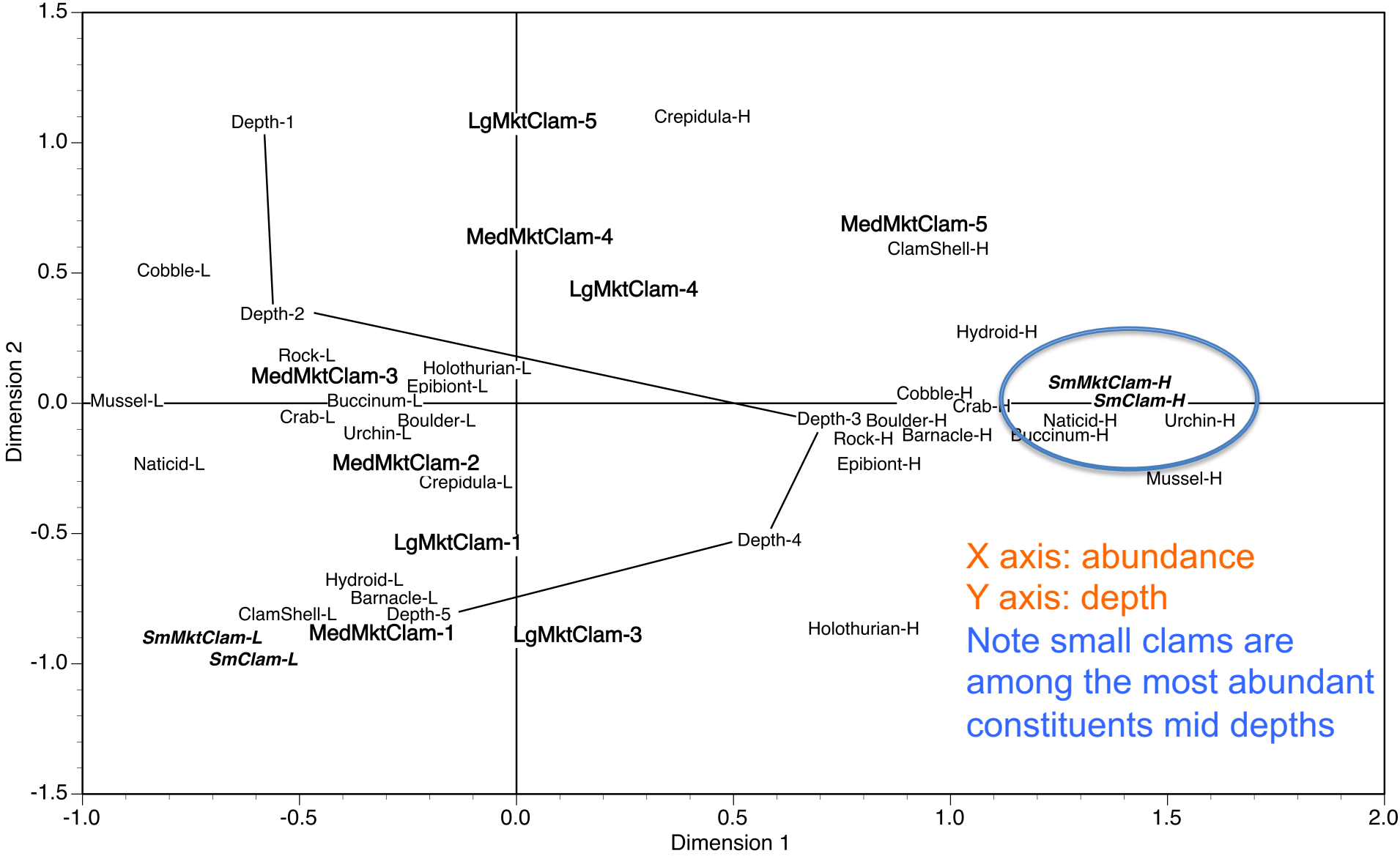
X axis: abundance

Y axis: depth

Note market clams and clam shell are the primary constituents abundant at shallow depths

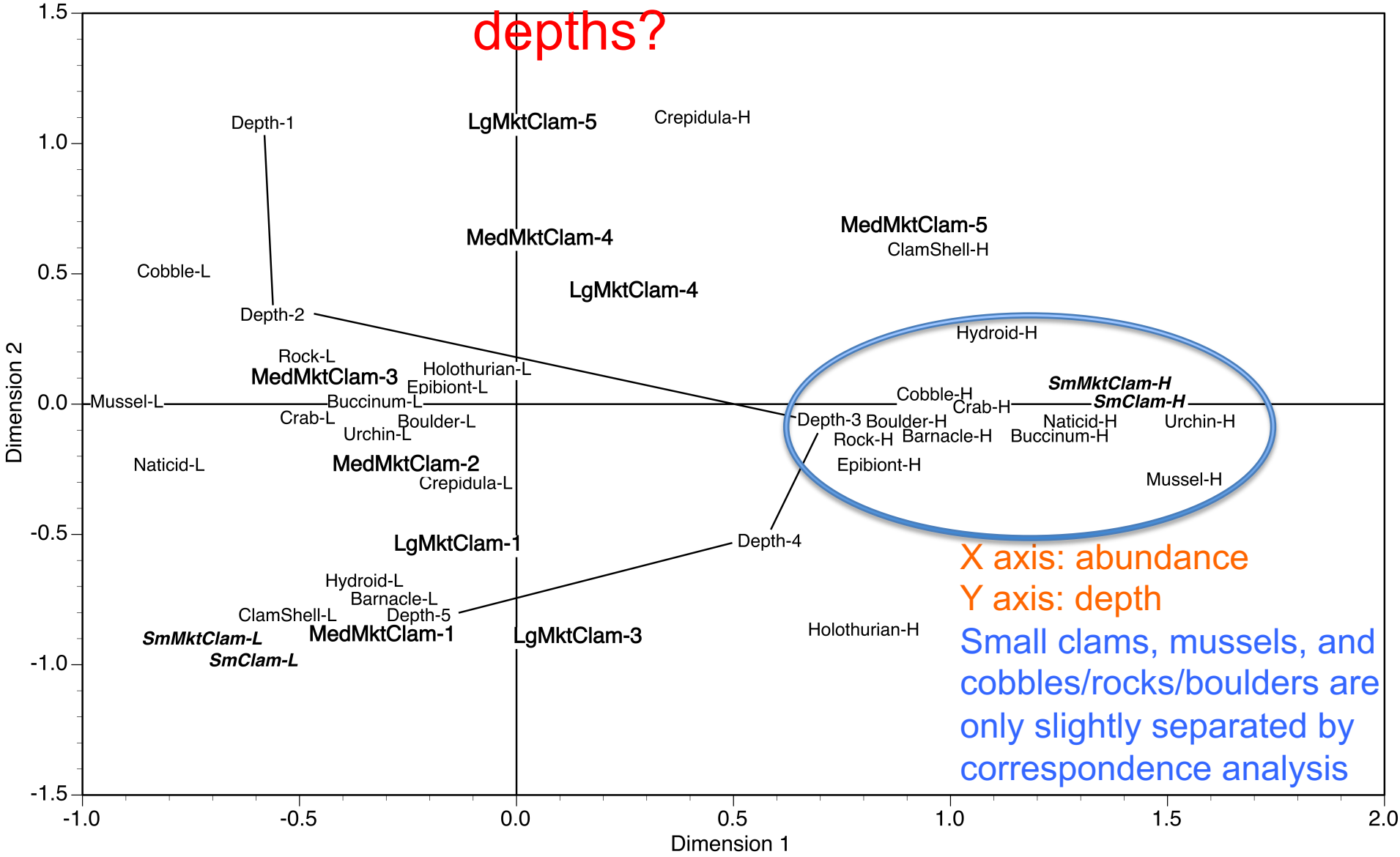
Correspondence Analysis

Where are the small clams?



Correspondence Analysis

Habitat complexity at mid depths?



X axis: abundance

Y axis: depth

Small clams, mussels, and cobbles/rocks/boulders are only slightly separated by correspondence analysis

Some Spearman Correlations

	surf120	surf150	surf170	surf200	mussel
surf150	0.8885 <.0001				
surf170	0.64588 <.0001	0.70878 <.0001			
surf200	.33233 0.0078	.33361 0.0075	0.77439 <.0001		
mussel	0.39842 0.0012	0.42388 0.0005	0.14486 0.2573	-0.05249 0.6829	
cobble	0.34843 0.0051	0.38544 0.0018	0.12712 0.3208	-01813 0.8823	0.64893 <.0001

Some Pearson Correlations

	surf120	surf150	surf170	surf200	mussel
surf150	0.93434 <.0001				
surf170	0.14817 0.2465	0.20538 0.1064			
surf200	-0.00954 0.9408	-0.00950 0.9411	0.80197 <.0001		
mussel	0.03205 0.8031	0.04502 0.7261	0.09322 0.4674	-0.04127 0.7481	
cobble	0.31664 0.0115	0.53001 <.0001	0.13226 0.3014	0.00366 0.9773	0.11769 0.3583

Note: significance with cobbles ceases if zero stations are removed

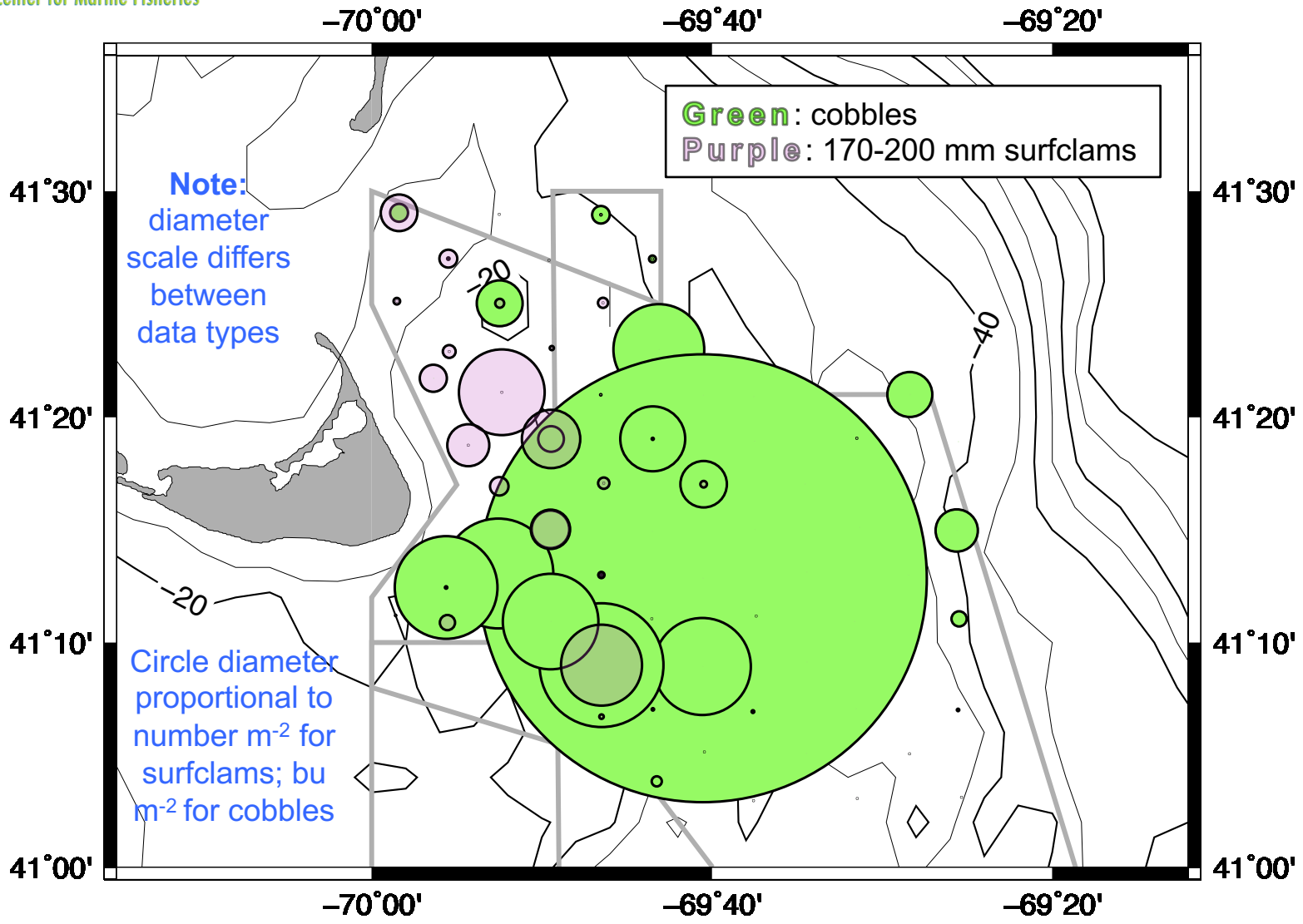
Basic Relationships

- Correspondence analysis and correlation analysis confirm that sites with abundant large surfclams are found in locations where small surfclams are less abundant.
- Mussels, cobbles, and abundant small surfclams are found at similar depths and deeper than sites where large surfclams are abundant.
- The differential between Pearson and Spearman results show the influence of sites with few mussels or surfclams in determining associations within the correspondence analysis.
- The Pearson results confirm the inference from correspondence analysis that mussels and abundant small surfclams have limited overlap spatially.
- The Pearson results confirm the inference from correspondence analysis that mussels and cobbles have limited overlap spatially.

Differential distribution: cobbles versus large surfclams

Note:

- Cobbles are 2-6 inches across
- Cobbles are common in the west central portion of the HMA and southeast of Nantucket
- Large surfclams and cobbles overlap relatively poorly

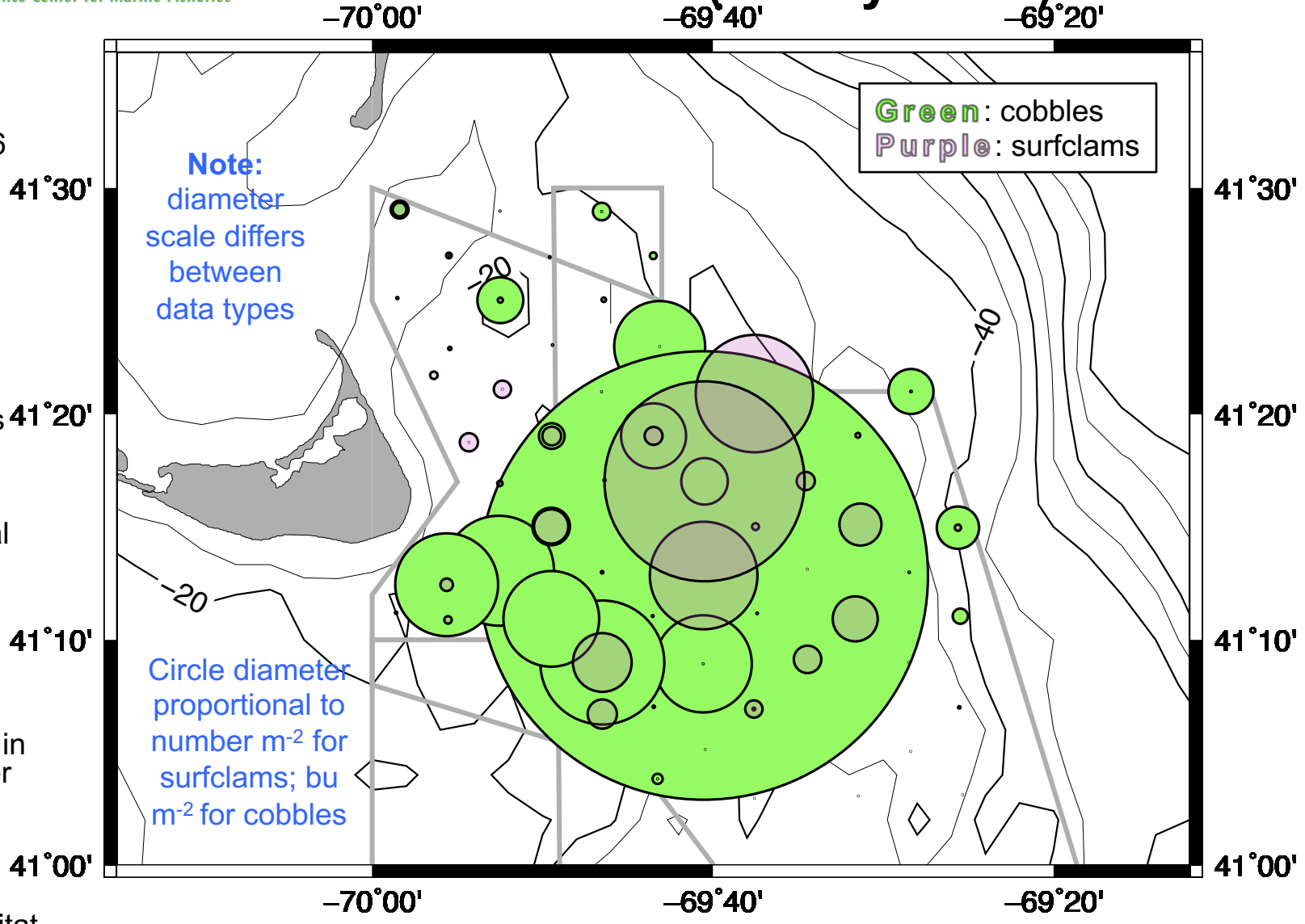


Nantucket Survey: 170–200 mm surfclams over cobbles

Differential distribution: cobbles versus all (mostly small) surfclams

Note:

- Cobbles are 2-6 inches across
- Cobbles are common in the west central portion of the HMA and southeast of Nantucket
- Small surfclams and cobbles overlap considerably in the north central portion of the HMA
- However, at a smaller scale, small surfclams are generally more abundant in areas with fewer cobbles
- Surfclams are moving into increasingly cobble-rich habitat

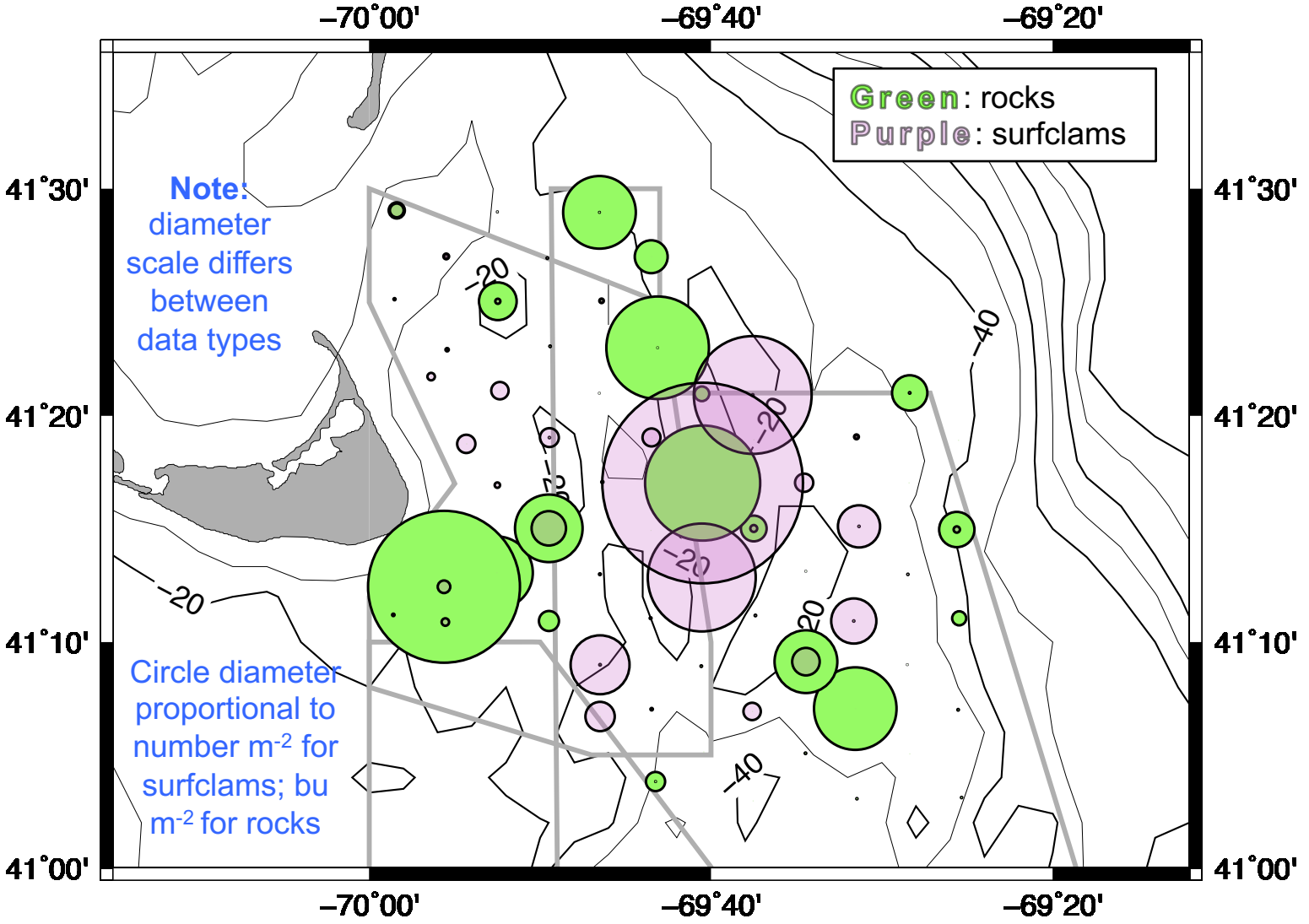


Nantucket Survey: all surfclams over cobbles

Differential distribution: rocks versus all (mostly small) surfclams

Note:

- Rocks are 6-12 inches across
- Rocks are frequently encountered in the north and central portion of the HMA and southeast of Nantucket
- Surfclams and rocks do not overlap consistently
- However, rocks do not limit surfclam colonization potential

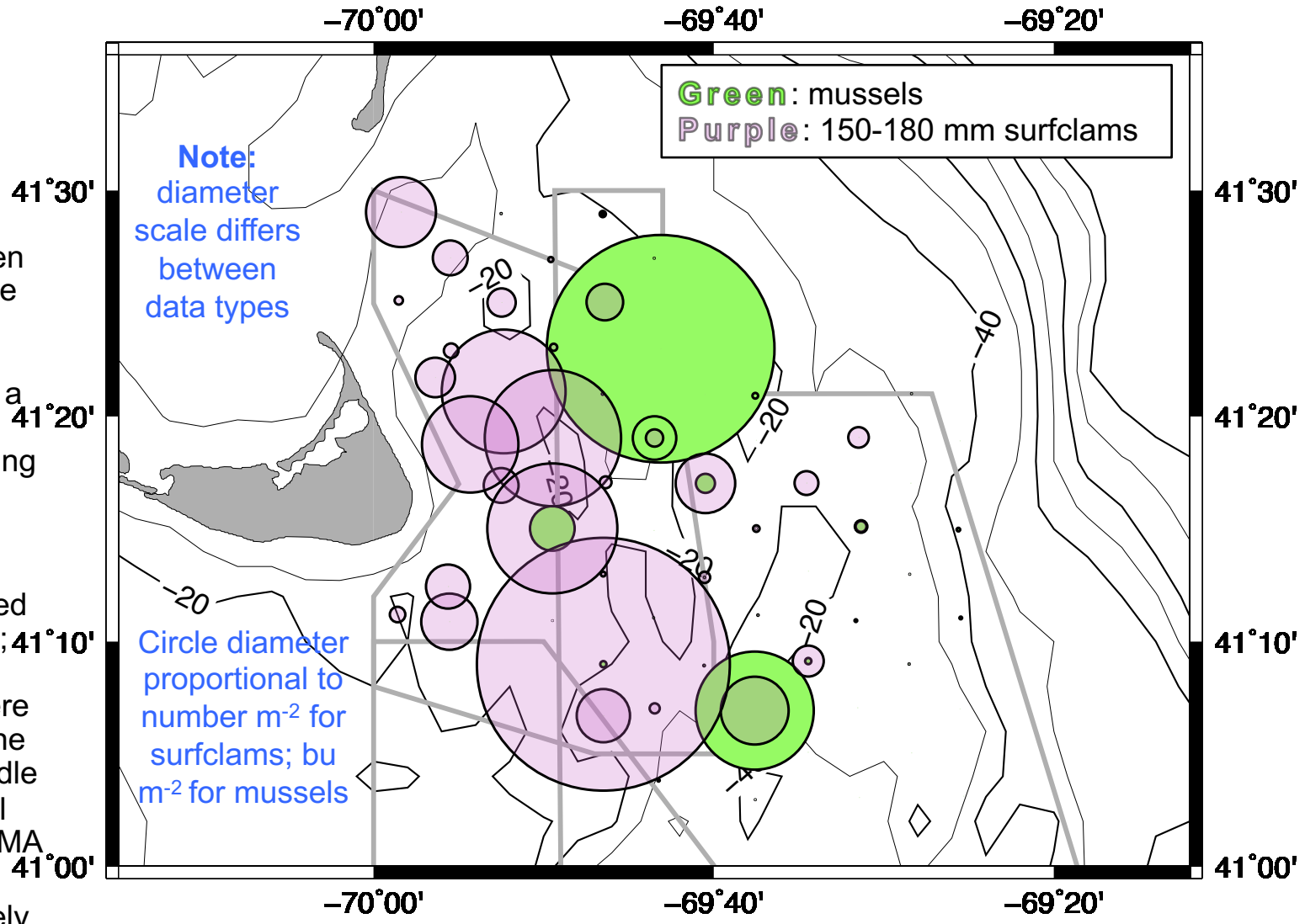


Nantucket Survey: all surfclams over rocks

Differential distribution: large surfclams versus mussels

Note:

- Mussels were *Mytilus* cf. *edulis* and *Modiolus modiolus*
- Both species often co-occurred in the same bed; both species were characterized by a dispersed size-frequency including new recruits and adults
- Mussels were rarely encountered in large numbers; stations yielding large catches were encountered in the northern panhandle and south central portions of the HMA
- Large surfclams and mussels rarely occurred commonly at the same station

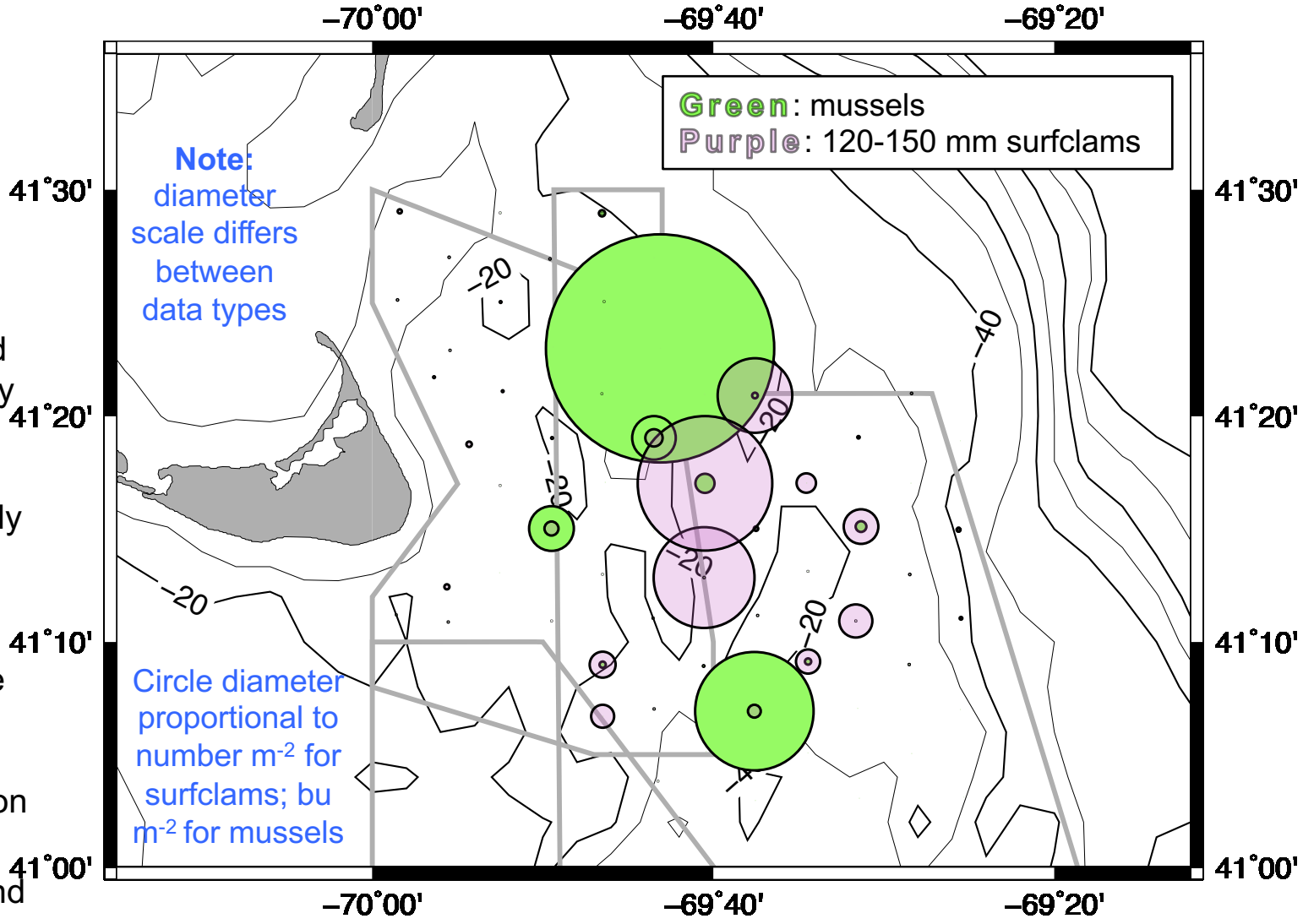


Nantucket Survey: surfclams 150–180 mm over mussels

Differential distribution: small surfclams versus mussels

Note:

- Mussels were *Mytilus* cf. *edulis* and *Modiolus modiolus*
- Both species often co-occurred; both were characterized by a size-frequency including new recruits and adults
- Mussels were rarely encountered in large numbers; stations yielding large catches were in the northern panhandle and south central portion of the HMA
- Small surfclams and mussels rarely occurred commonly at the same station

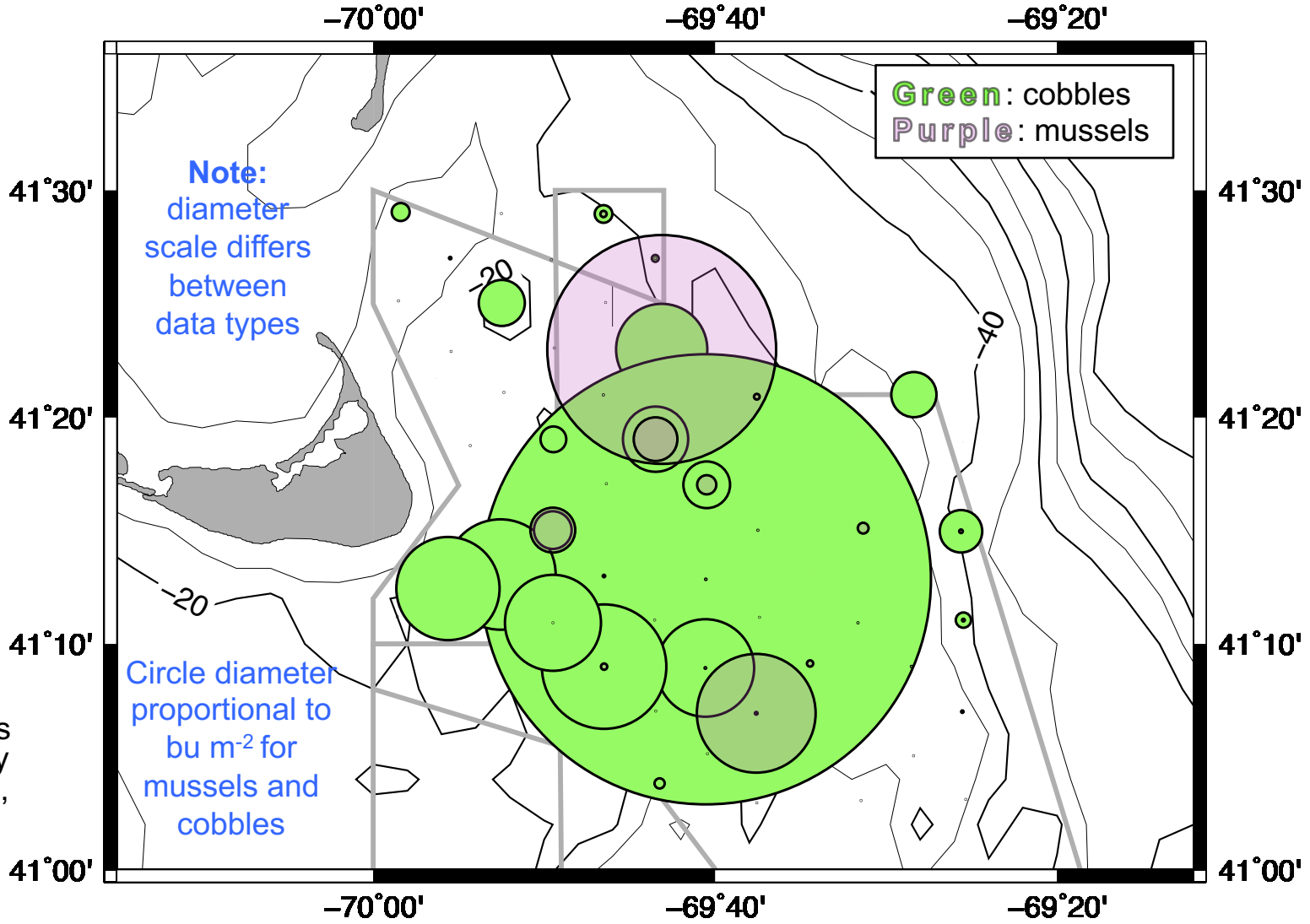


Nantucket Survey: surfclams 120–150 mm over mussels

Differential distribution: cobbles versus mussels

Note:

- Mussels were *Mytilus* cf. *edulis* and *Modiolus modiolus*
- Both species often co-occurred in the same bed
- Cobbles were 2-6 inches
- Mussels were rarely encountered in large numbers; stations yielding large catches were in the northern panhandle and south central portion of the HMA
- Cobbles and mussels sometimes occurred commonly at the same station, but cobbles were not required to support mussel habitation



Nantucket Survey: mussels over cobbles

Why are mid-depth surfclams small?

Possibilities

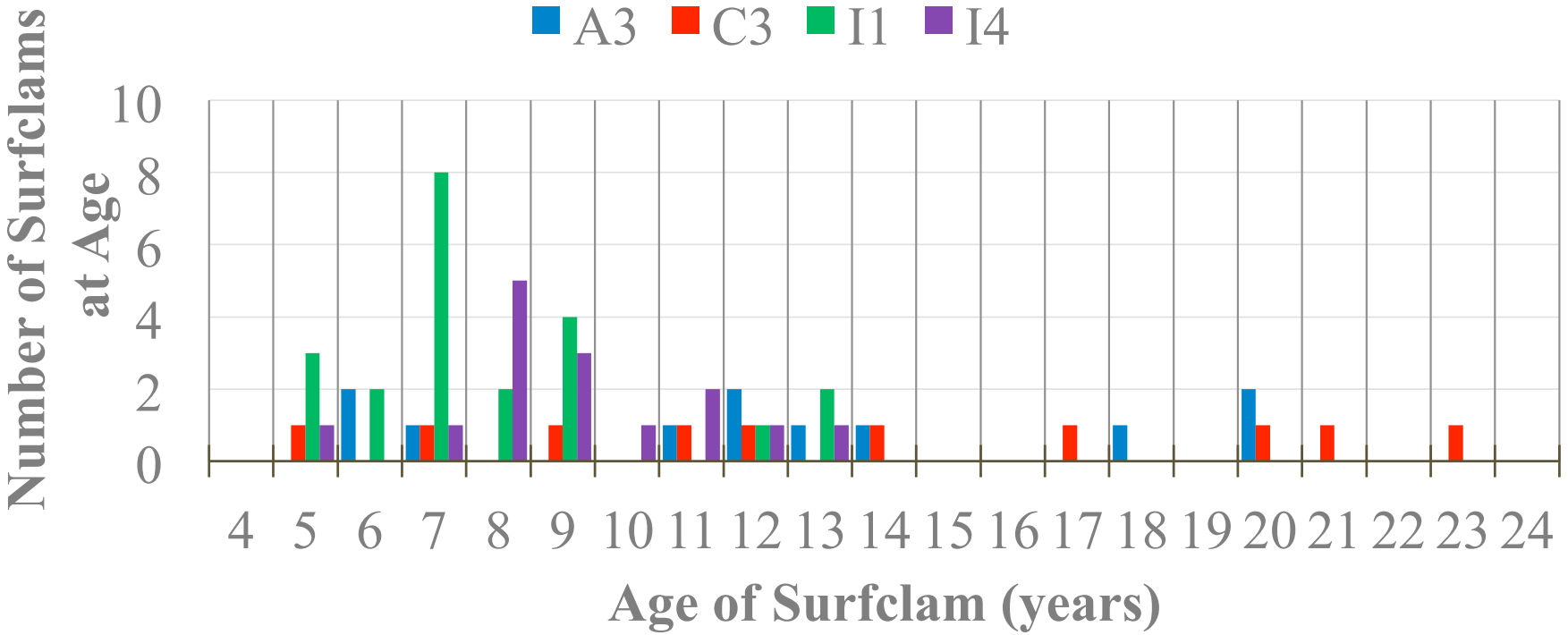
- Growth rates may be lower in deeper water
- The surfclams may be younger

Evidence for Differential Growth Rates and Age Distributions

Methods:

- Four sites were sampled and selected individuals across the size spectrum aged
- Two sites were shallow and characterized by large surfclams
- Two sites were deeper and characterized by smaller surfclams
- Ages were intercalibrated between USM, VIMS, and NEFSC
- Growth increments were compared between ages 1 and 2, 3 and 4, and 7 and 8.
- Based on previous statistical analyses and correspondence analysis, a nested ANOVA was run with location nested within group (group = shallow or deep)
- Based on Pace et al. (2017) evidence from ocean quahogs and Munroe et al. (2016) evidence for surfclams, birth date was included as a covariate.
- All data met assumptions of normality and heteroscedasticity.

Surfclam age distributions



- Clams exceeding 13 yr of age were found only at the shallow water sites.
- Populations with clams 20+ yr of age are characteristic of mature populations with a long history of recruitment; indeed these populations also had high quantities of surfclam shell.

Why are mid-depth surfclams small?

Possibilities

- The surfclams may be younger

➢ No old surfclams were collected at mid-depth sites.

➢ This is consistent with the limited amount of surfclam shell also collected at these sites

➢ Analysis of clam ages suggests a relatively recent colonization event (post-2000: the oldest animal aged recruited in 2004)

Growth Rate Statistics

Results: Growth increment 1 to 2 years

Group: $P > 0.05$

Locale(group): $P > 0.05$

Birth date: $P > 0.05$

Birth date-group interaction: $P > 0.05$

Lease squares means test on Locale: no significant differences

Conclusion: Early growth rates do not vary between locales or over depths

Growth Rate Statistics

Results: Growth increment 3 to 4 years

Group: P = 0.03

Locale(group): P > 0.05

Birth date: P = 0.0026

Birth date-group interaction: P = 0.03

Lease squares means test on Locale: Shallow sites routinely had significantly higher growth rates.

Conclusion: Birth date has a strong influence on growth rate. Clams at shallow sites grew faster in the first years after colonization in deeper water (note that these clams reached 3 years of age many years later in many cases)

Growth Rate Statistics

Results: Growth increment 7 to 8 years

Group: $P > 0.05$

Locale(group): $P > 0.05$

Birth date: $P > 0.05$

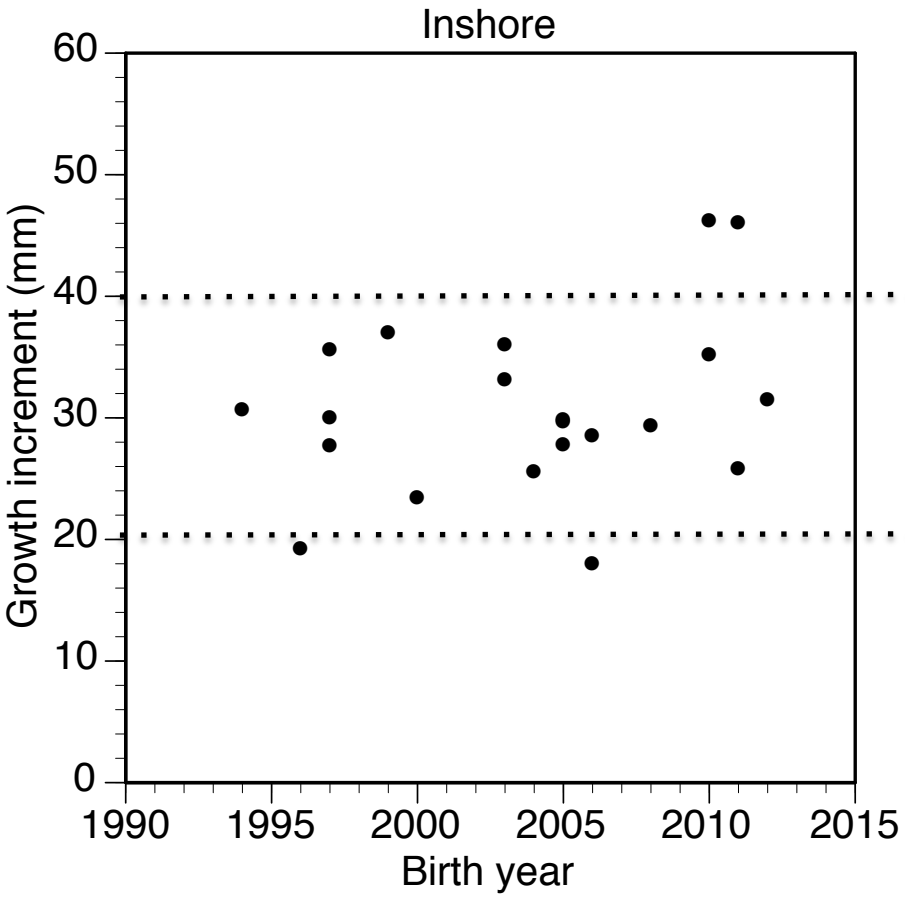
Birth date-group interaction: $P > 0.05$

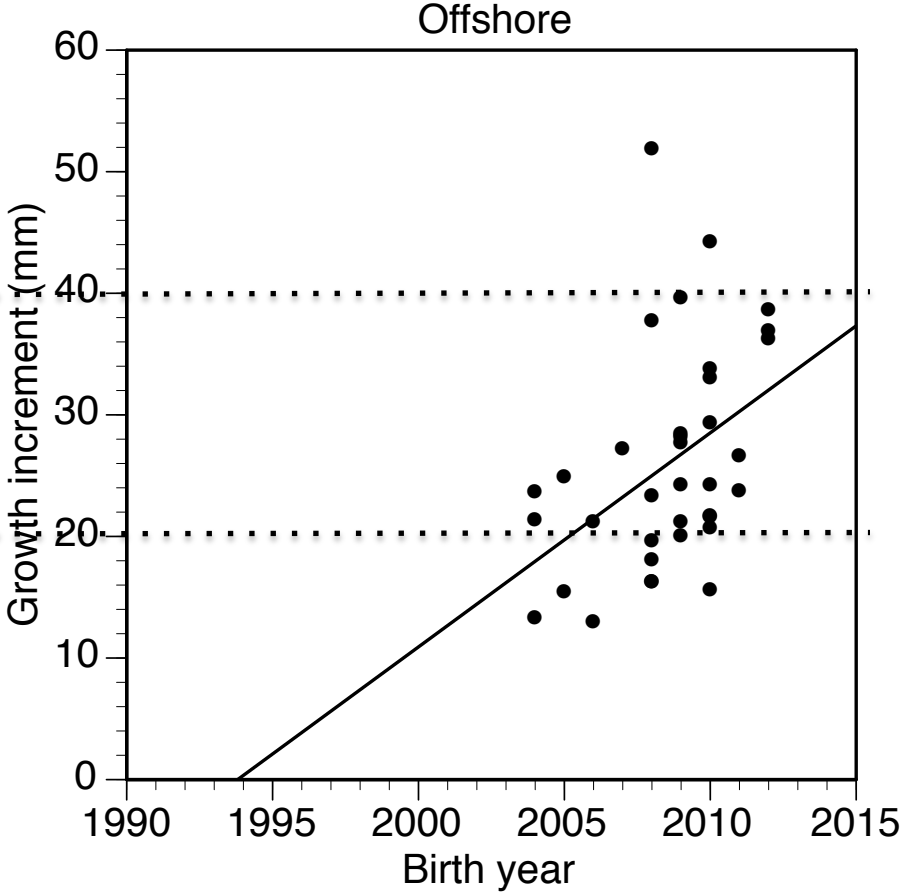
Lease squares means test on Locale: Growth rates were highly significantly faster at one deep site in comparison to either shallow site ($P < 0.007$)

Conclusion: Adult growth rates do not vary uniformally between locales or over depths, but clams at one deeper site grew faster (note that these clams reached 7 years of age many years later)

But: very few deeper water clams were this old, so conclusions are based on a small sample size

Growth rates between age 3 and 4 by birth year





- Note that offshore growth rates were low for the early colonizers; recent colonizers are growing at about the same rate as inshore clams have grown over the last 2 decades.
- Note that the birth year effect only offshore explains the significant interaction term in ANOVA and also the lower growth early also explains the significant locale main effect.

Why are mid-depth surfclams small?

Possibilities

- Growth rates may be lower in deeper water

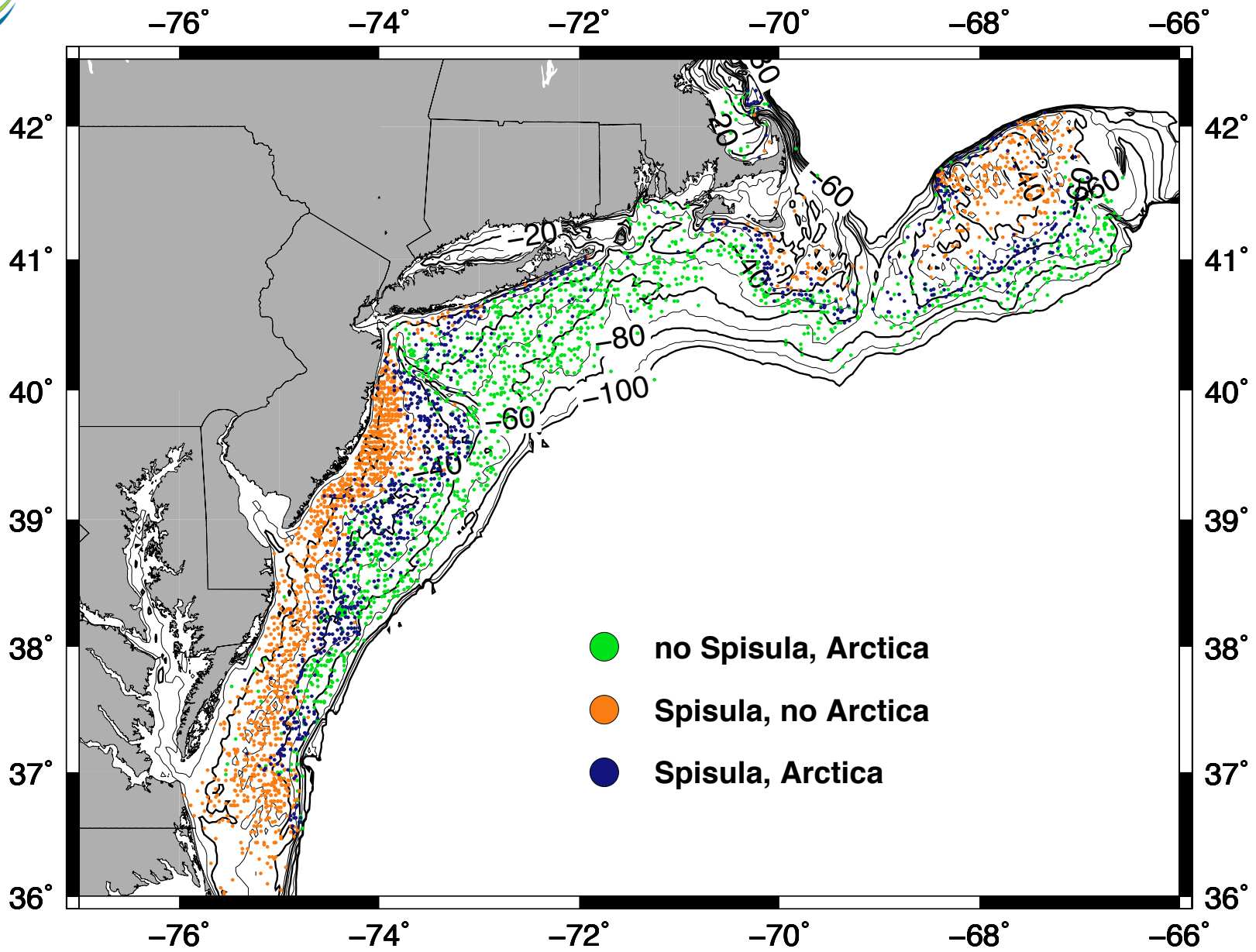
- No evidence is present that slower growth explains the size disparity
- Birth date is the primary variable influencing growth rate and is only important for deeper water clams
- Shallow water clams have been growing at about the same rate since the mid-1990s
- Deeper water clams initially grew slower, but have caught up and now have growth rates similar to shallow water clams.
- Growth rates of early colonizers are responsible for main effect (locale) differences in the ANOVA

The Circa-2000 Regime Shift (Atlantic Multidecadal Oscillation)

What did warmer temperatures do?

1. Growth dynamics in Delaware Bay oysters profoundly changed (Powell et al. 2009)
2. Population dynamics in Gulf of Mexico oysters profoundly changed: influence of ENSO ceased (Powell, 2016)
3. EEZ surfclams died off Delmarva (Kim and Powell, 2004 and others)
4. New Jersey state water fishery collapsed
5. Surfclams moved offshore significantly (Timbs et al., submitted)
6. Surfclams colonized deeper depths east of Nantucket

The surfclam invasion front



Expectations

- Surfclams will expand in deeper water east of Nantucket; fishable stocks should be present if not now then within 5 years.
- Where will the mussels go? *Mytilus* northward movement is well documented. Region is likely already too warm for *Modiolus* (we did not catch one large *Modiolus*)
- Coincident occupation of surfclams and mussels at mid-depth is likely transient; are these transient multiple stable points?