So how fast does a scallop grow?

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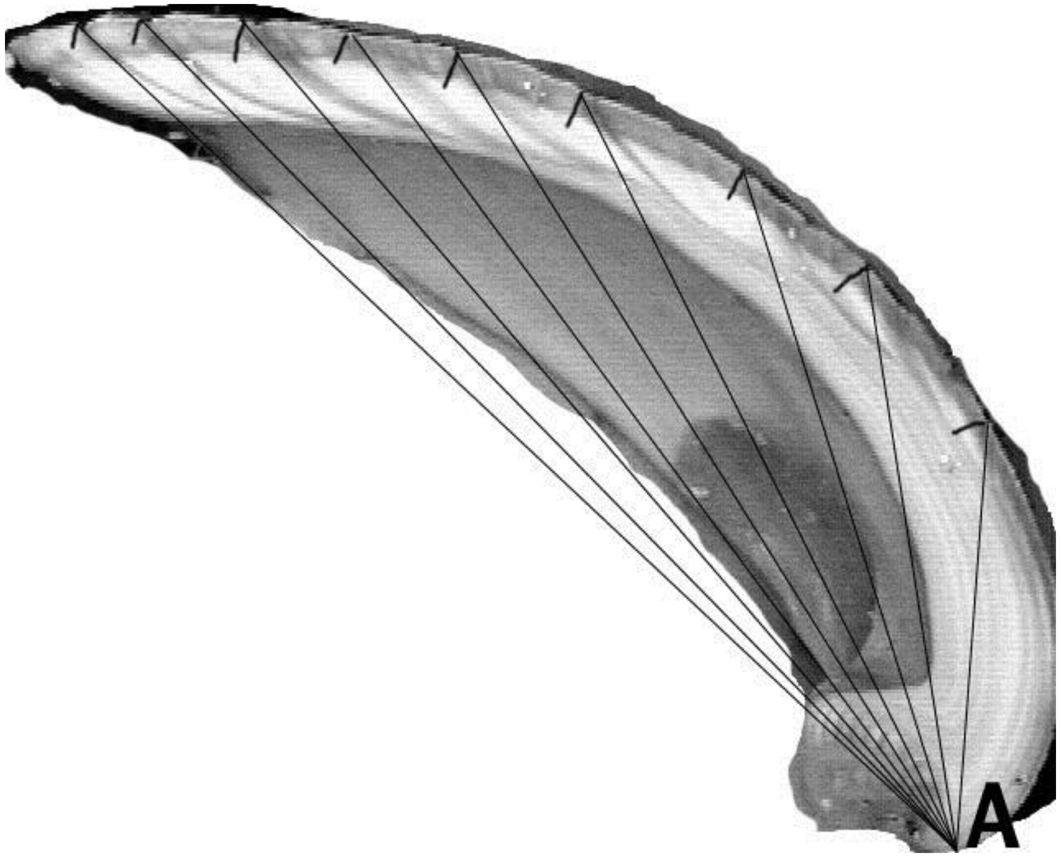
Why the interest in growth rate?

- Fundamental to fishery management
- Does it vary over latitude (southwest to northeast)?
- Does it vary over depth (onshore to offshore)?
- Does it vary over time (~1982-present)?
- Is there any evidence to suggest that any (or all) of these are being driven by environmental change?

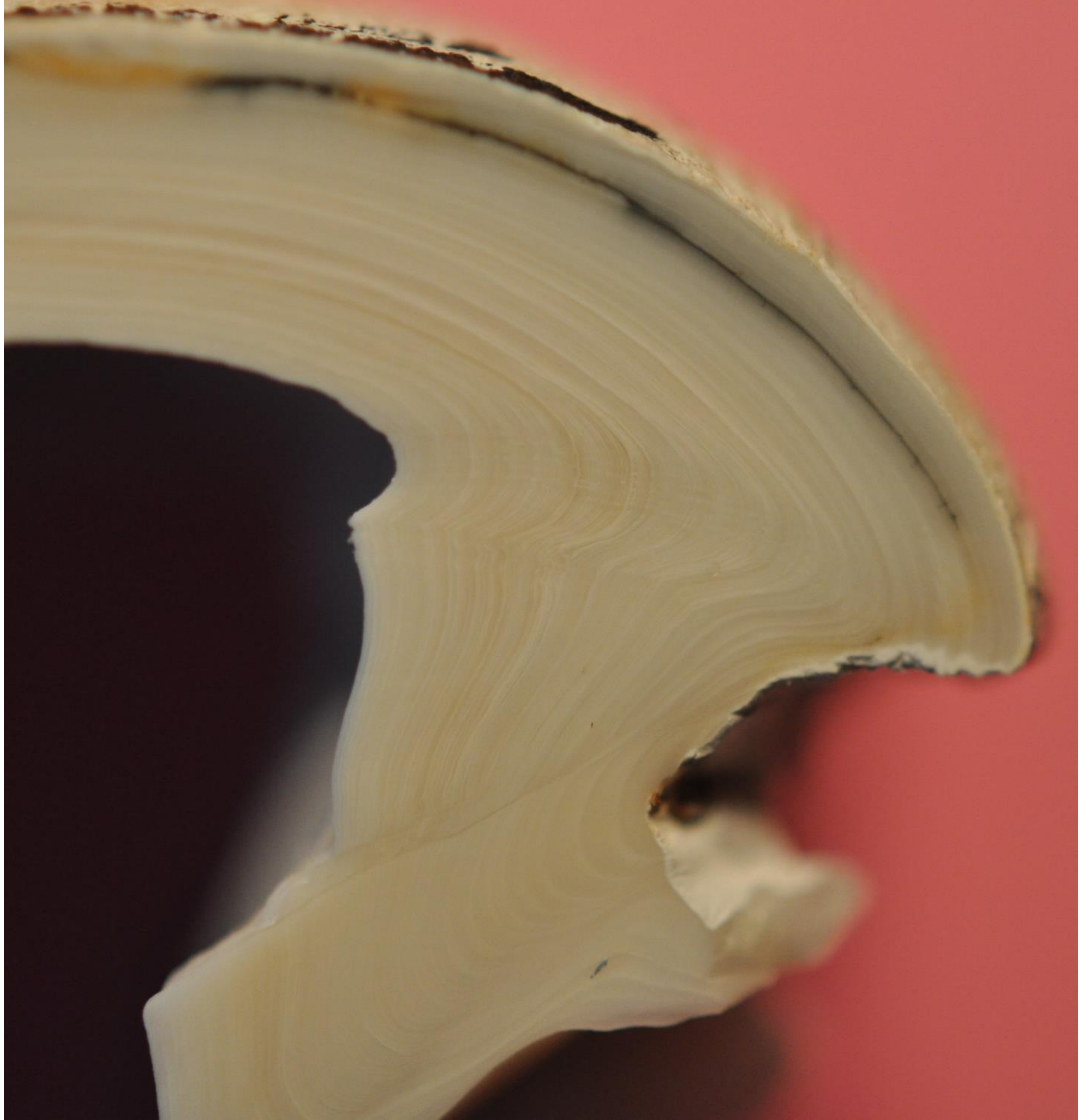
A little background on our lab and how we do things?

- Long standing interest in the growth and physiology of shellfish – in recent years with focus on oyster, hard clams, surf clams and ocean quahogs.
- Bivalves leave records of their growth in their shells. This is typically seen as external signatures and patterns on the shell surface, but those patterns can be eroded…
- So we examine internal growth lines that are preserved over the life time of the individual.

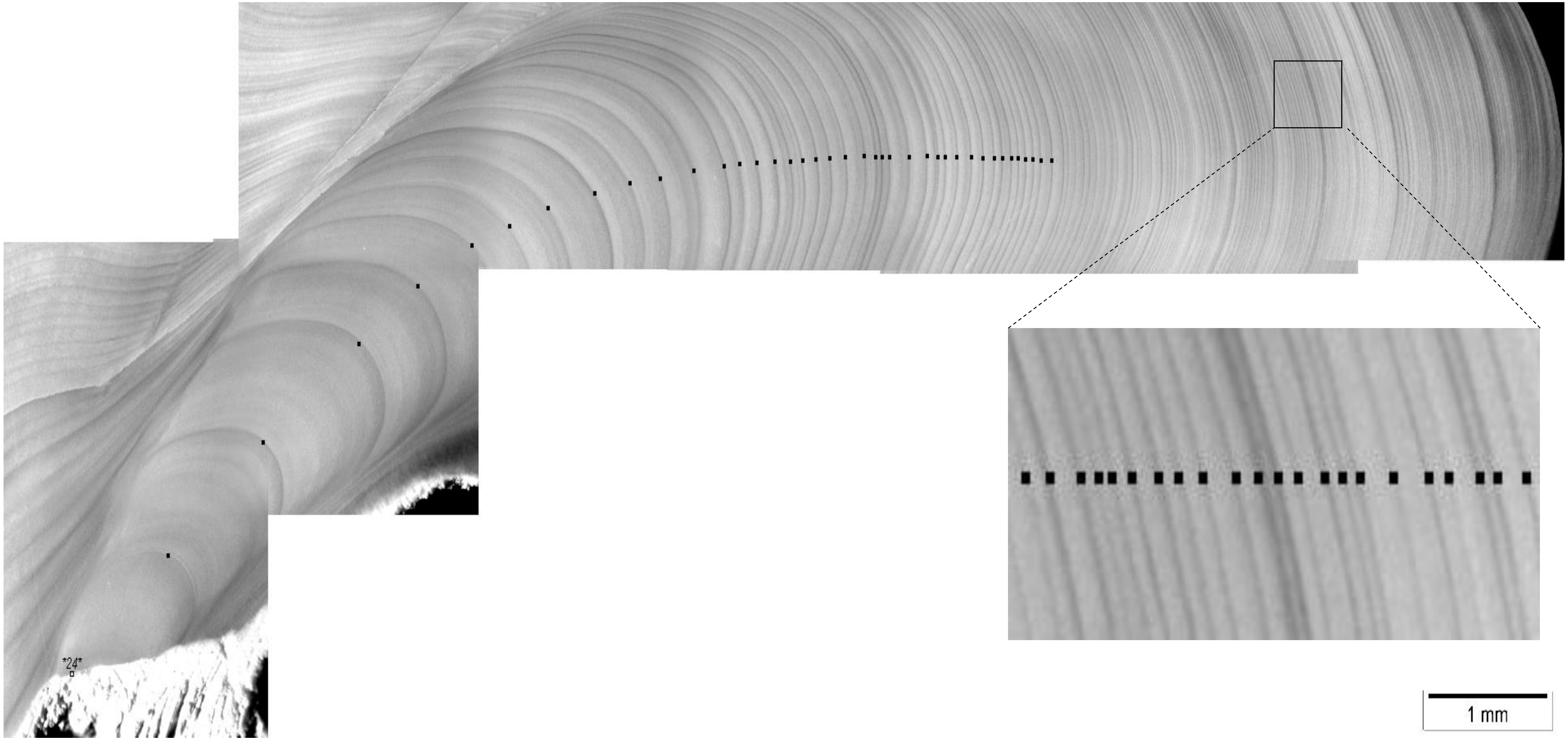


Constructing a growth curve for the hard clam *Mercenaria mercenaria*

We can discriminate and count very large numbers of growth signatures – this is from an ocean quahog

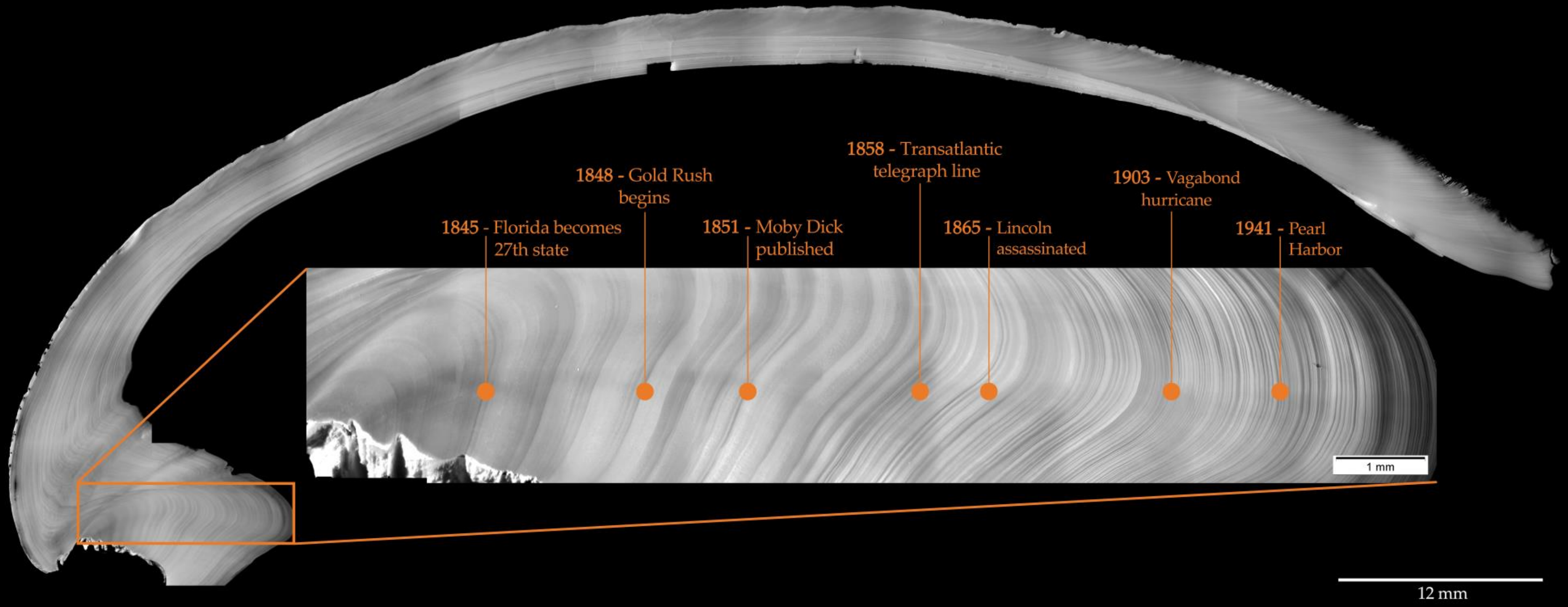


An example of a polished cross-section through the hinge plate of an ocean quahog. The early-in-life annual growth lines are annotated (black dots) with markers using the ObjectJ plugin for the software ImageJ.



The Ocean Quahog

Arctica islandica



Methods

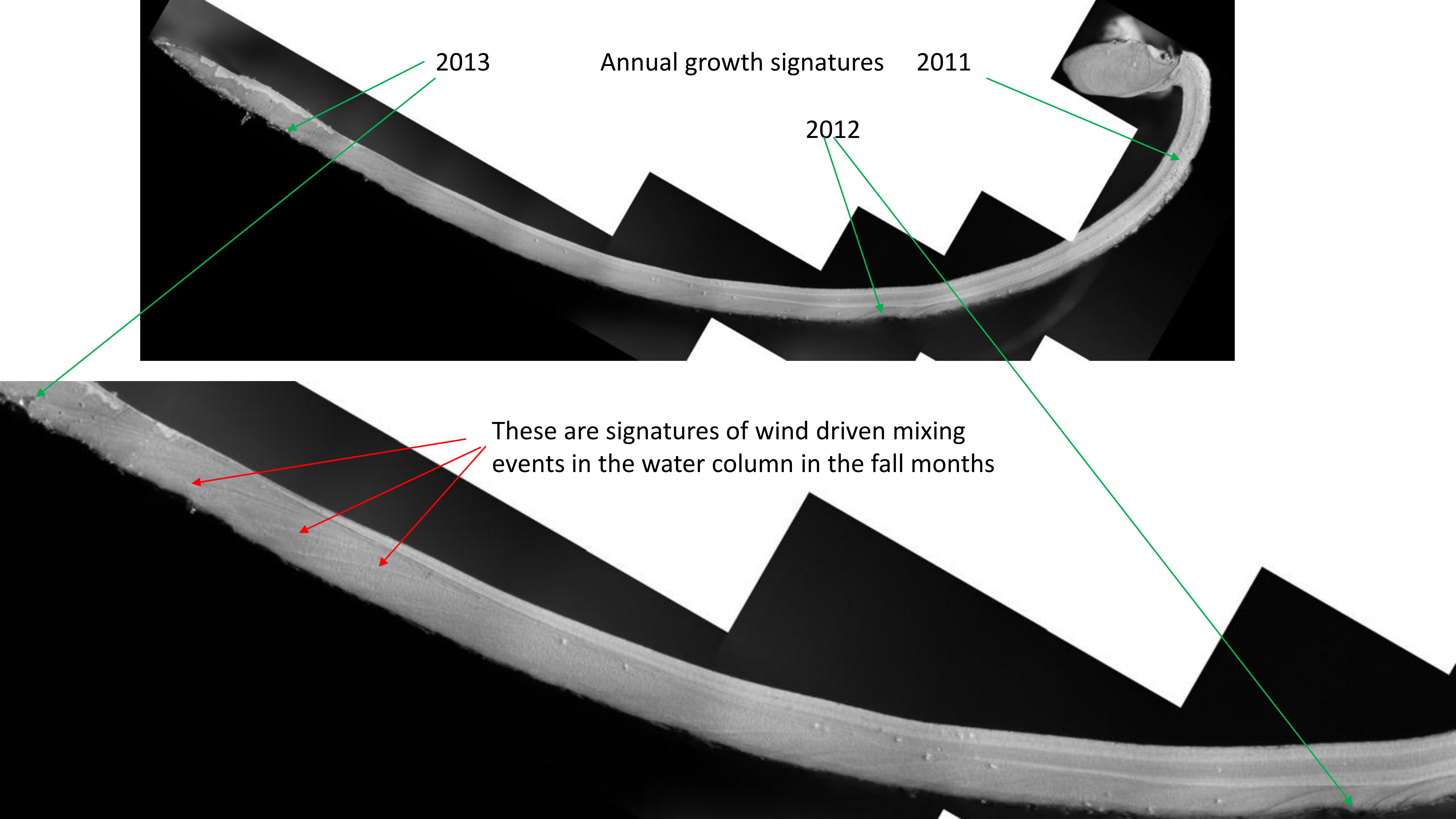
Ocean quahogs were collected off the coast of New Jersey from aboard the F/V *Jersey Girl*. Large, intact clams were selected for age analysis. Clams were measured, cut along the maximum height dimension using a tile saw, polished using diamond suspension solution, and photographed under reflected light using a dissecting microscope camera. Age was determined using ImageJ on a 5k iMac.

Authors

Sara M. Pace, M. Chase Long, Roger Mann, Eric N. Powell

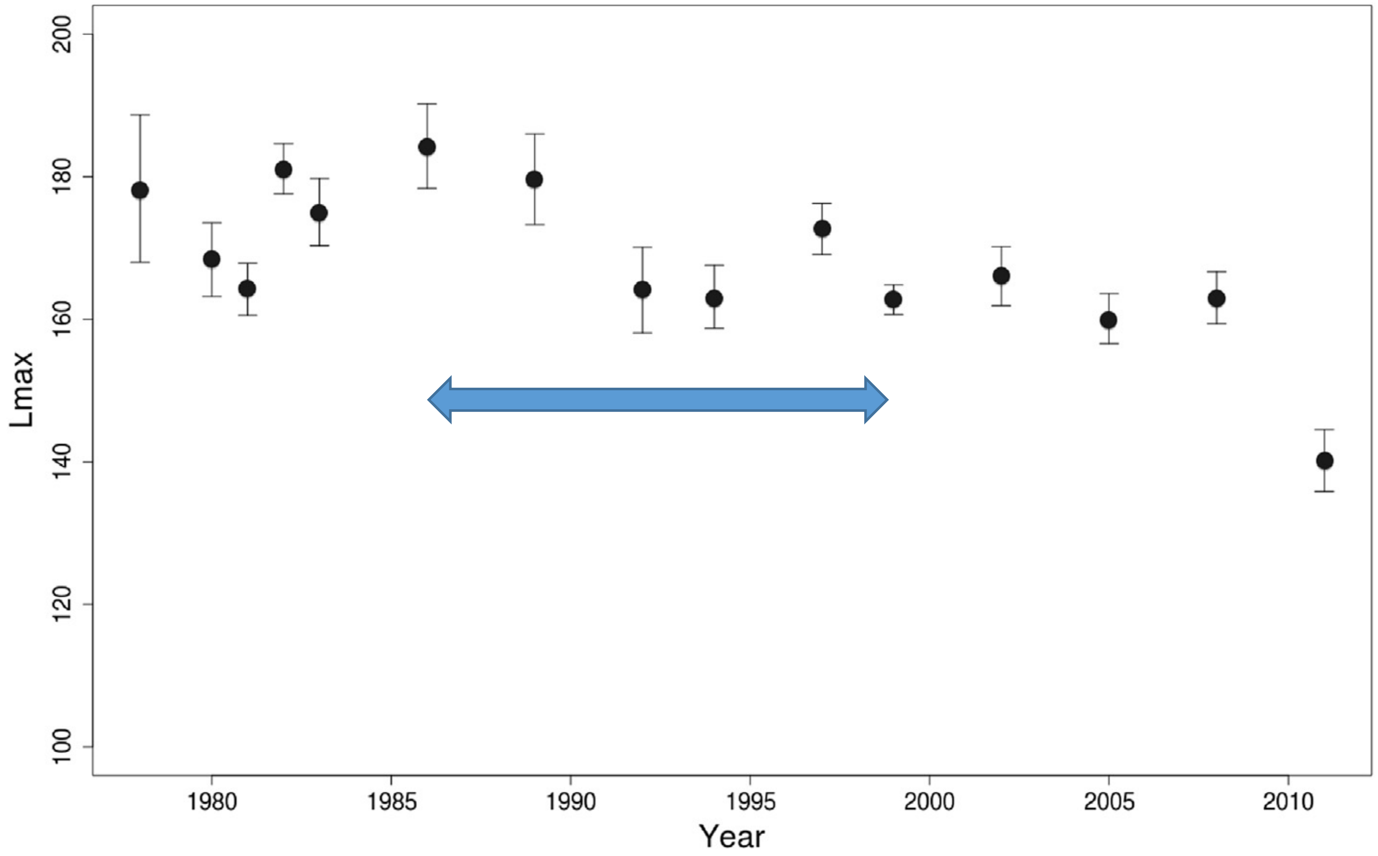
Acknowledgments

Funding provided by NSF and SCeMFiS. Image credit: Sara Pace.



2013
Annual growth signatures
2011
2012
These are signatures of wind driven mixing events in the water column in the fall months

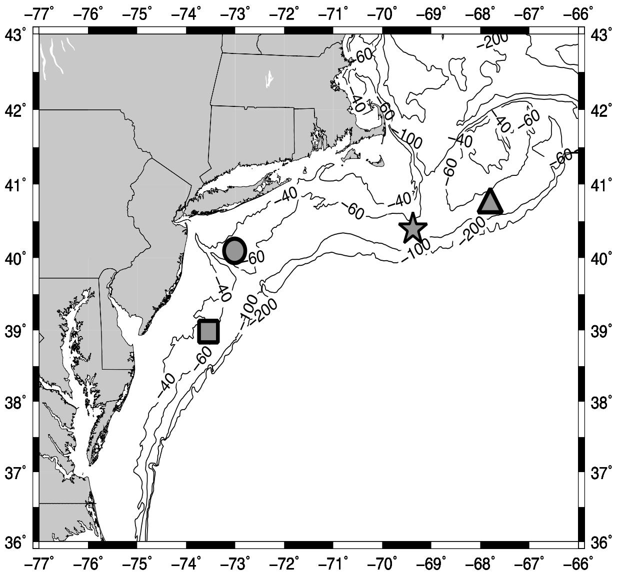
So we can measure growth increments and rate in clams – is there evidence of changing rates or size over time and space in other species that share the MAB and Georges Bank with scallops? Yes, there is – **the maximum size (L_{max}) of surf clams is getting smaller.**



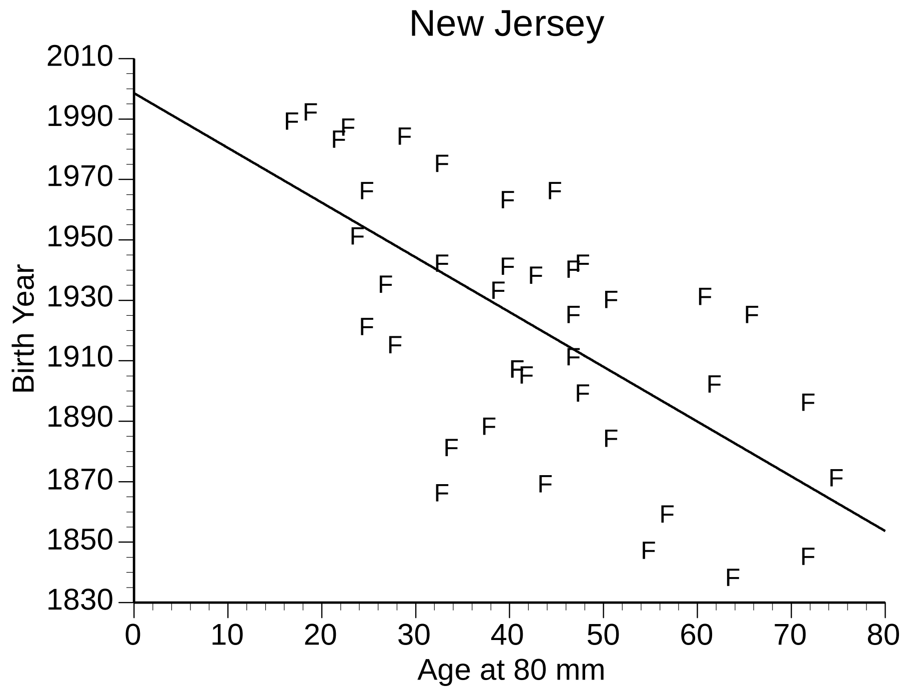
Source - Munroe et al 2016. ECCS. Fig. 2. Surfclam asymptotic length (L^{max}) over time derived from growth curves fit to fishery survey observations made within stratum 21 using a von Bertalanffy growth relationship.

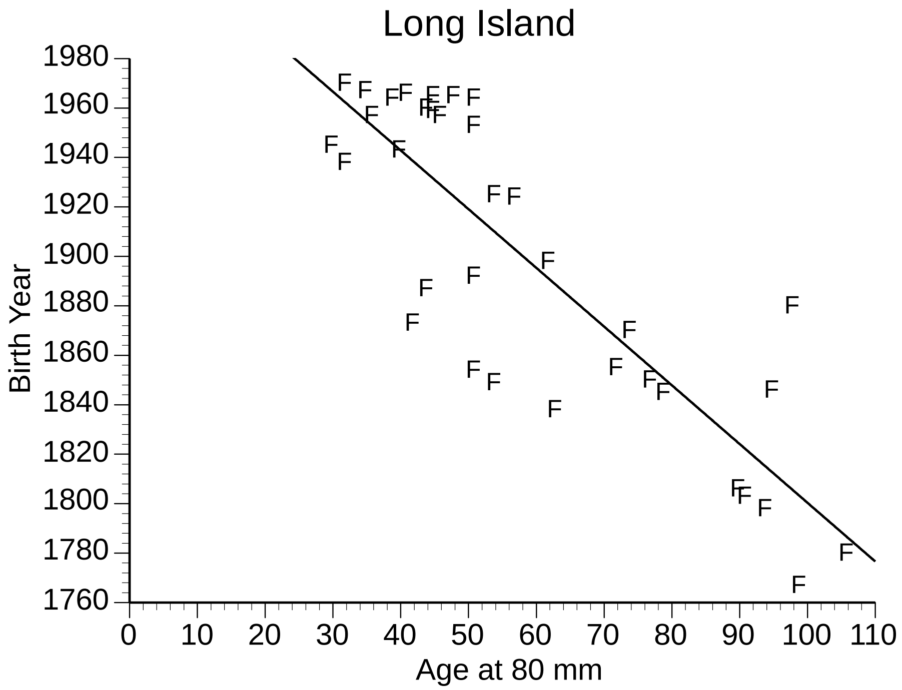
Effects of increasing bottom water temperature on growth rates of ocean quahogs throughout the Mid-Atlantic

Pace, S. M.; Powell, E. N.; Mann, R.; Klinck, J.



Ocean quahogs (*Arctica islandica*) are the longest-lived, non-colonial animal known today, with maximum life span estimates exceeding 500 years. …..**That is, ALOG growth curve parameter values vary with birth date at the southern sites, with younger animals growing at a much faster rate than those born many decades ago, while at the northern sites, changes in growth rates through time are limited or not present.**





So back to scallops and this project…There is an archive of scallop shells dating back to the early 1977 in the NEFSC warehouse at Pocasset…..

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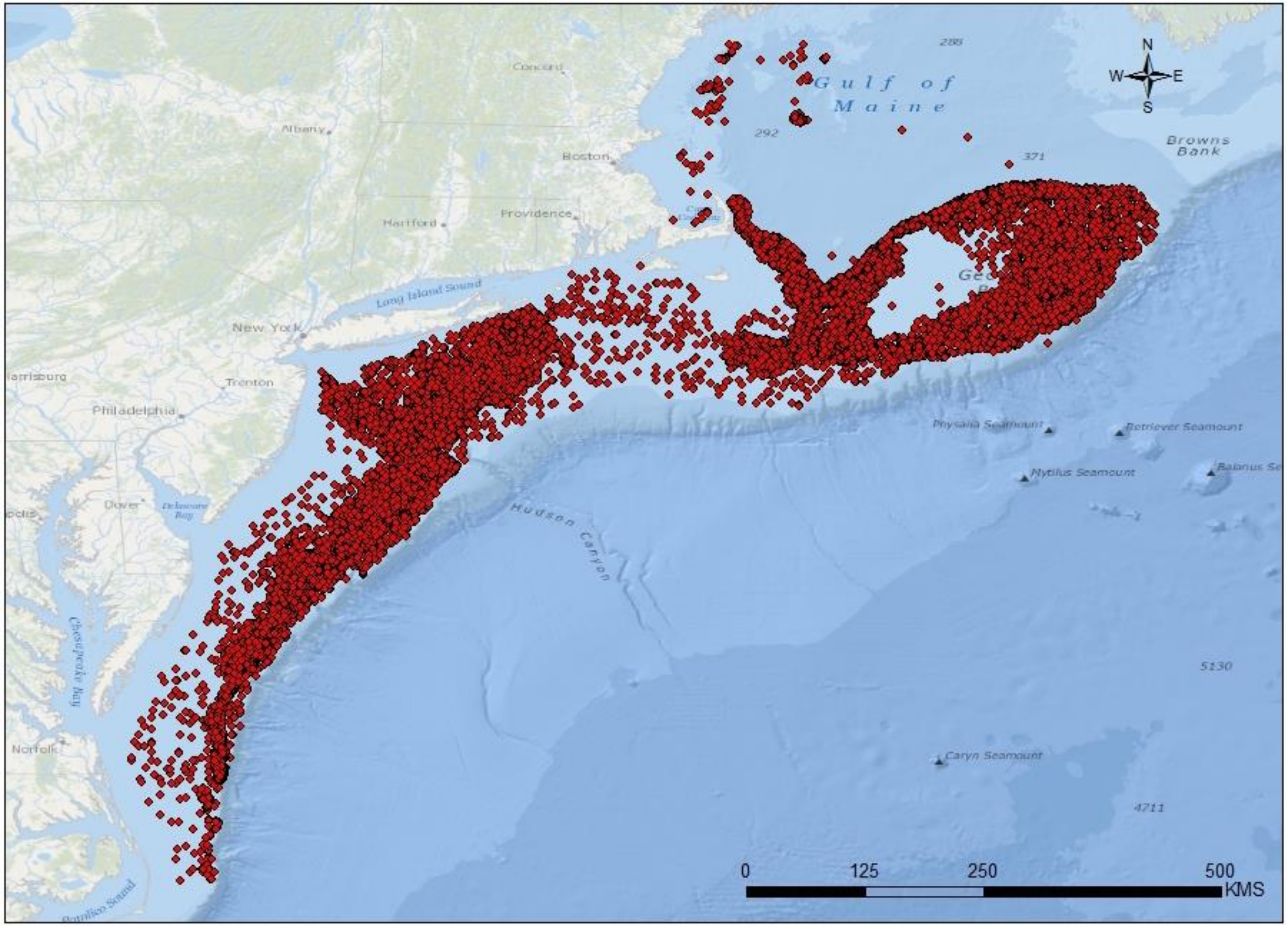
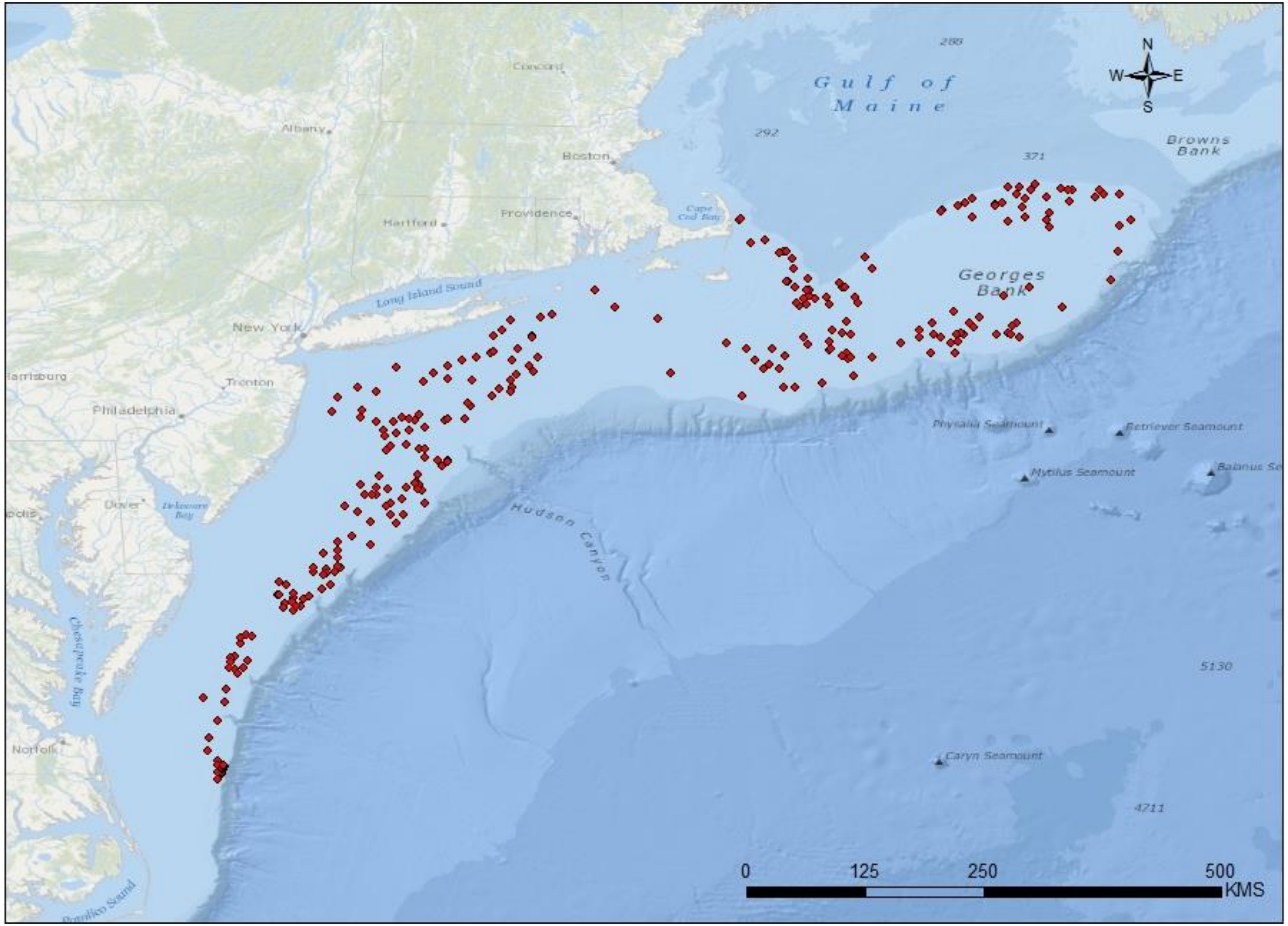
About these scallop shells

- These were collected mostly on annual surveys (Albatross) but also include some industry vessels
- There is very limited age and growth data on these samples before late 1990’s (some collections have never been touched since they were collected - they are dusty and very moldy, but all the labels are intact)
- They span an era from intense fishing through managed fishing
- They correspond to the period of decreased max size in surf clams and the increasing growth rate with increasing temperature in ocean quahogs
- They cover both the latitudinal and bathymetric ranges
- So we can address questions of growth rate and its possible changes (even continuing change) over time and space.
- Recall that the data from clams suggests this is a period of environmental change…..

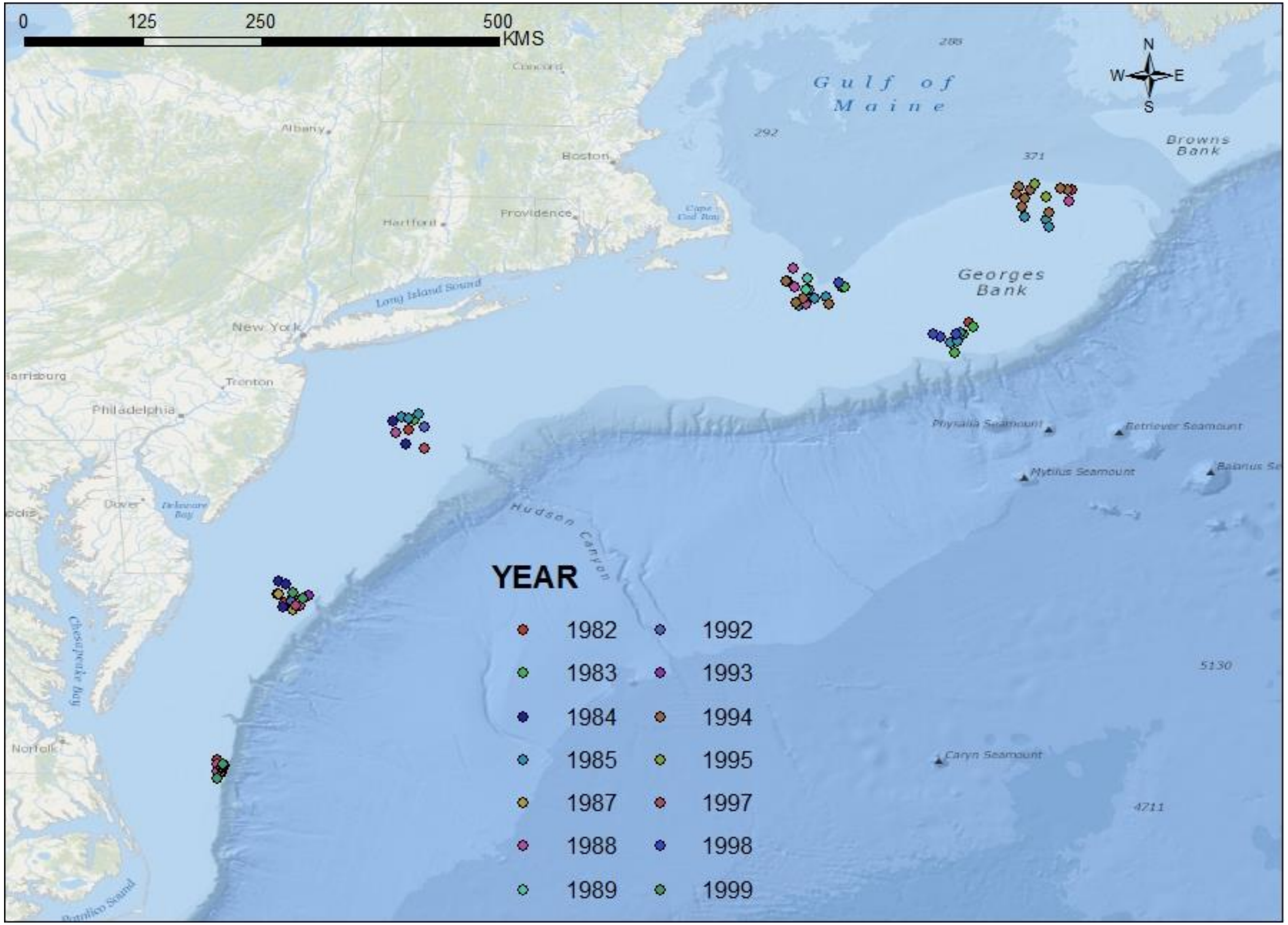
Distribution of stations sampled by NEFSC (1982-1998) but not all have shells in the collection



Distribution of stations represented in the 1977-1998 archive materials currently at VIMS



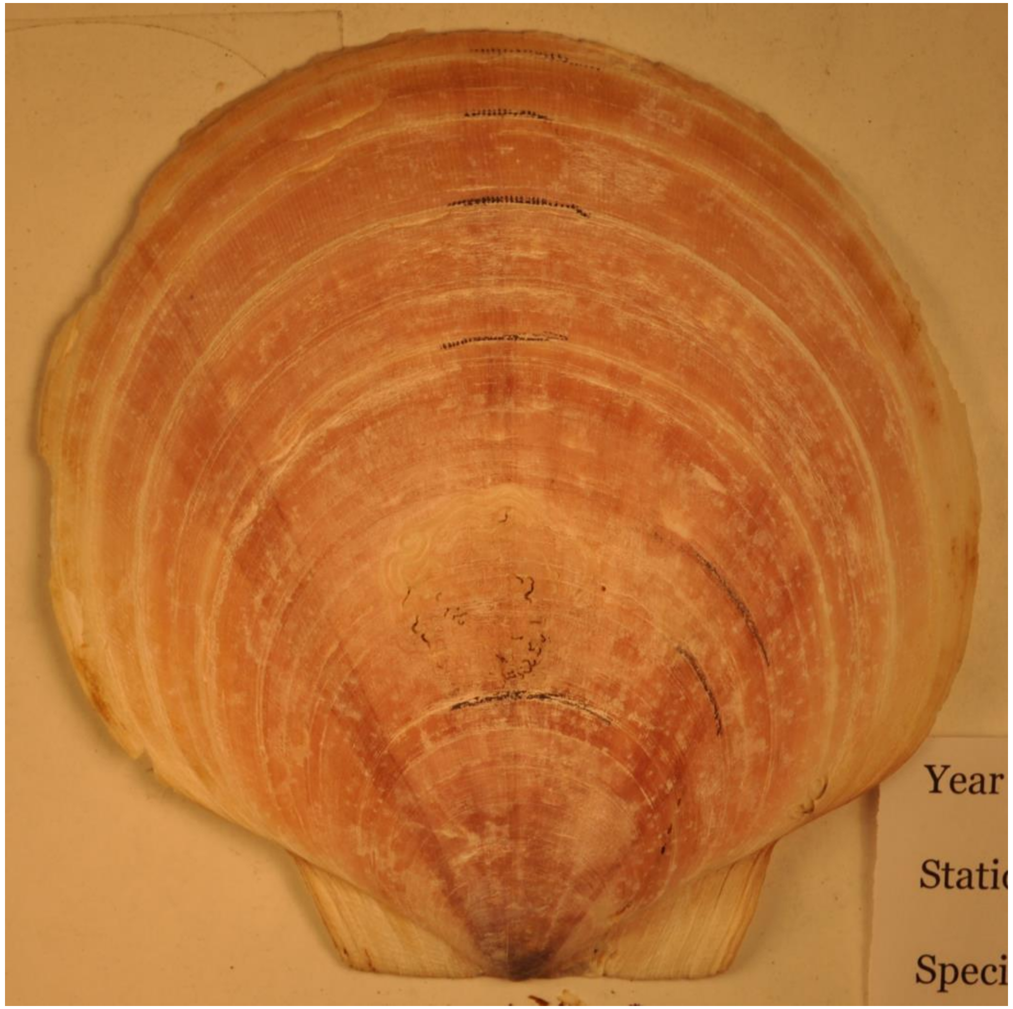
Targeted stations for examination by year, location and depth

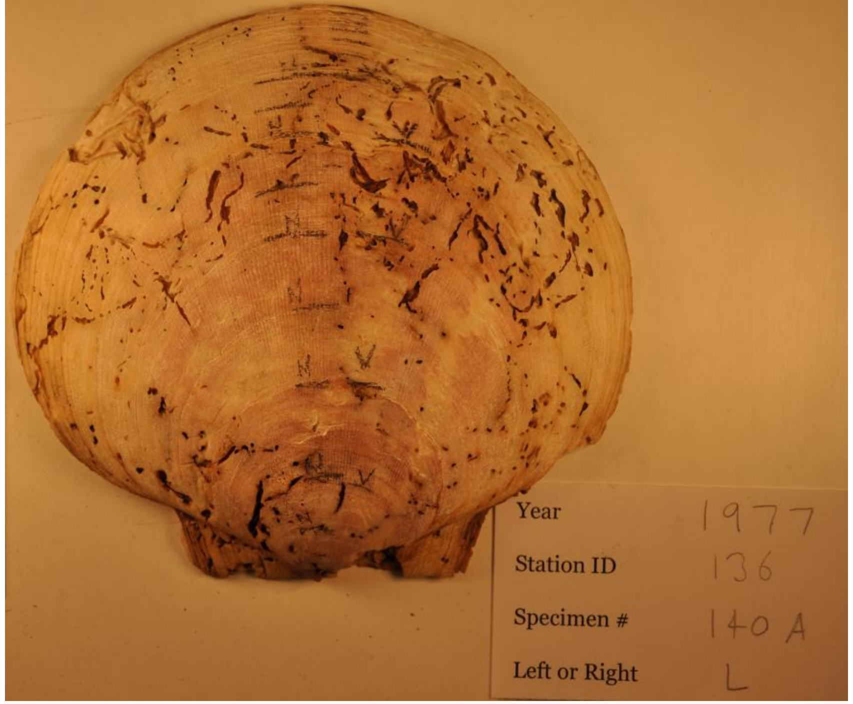


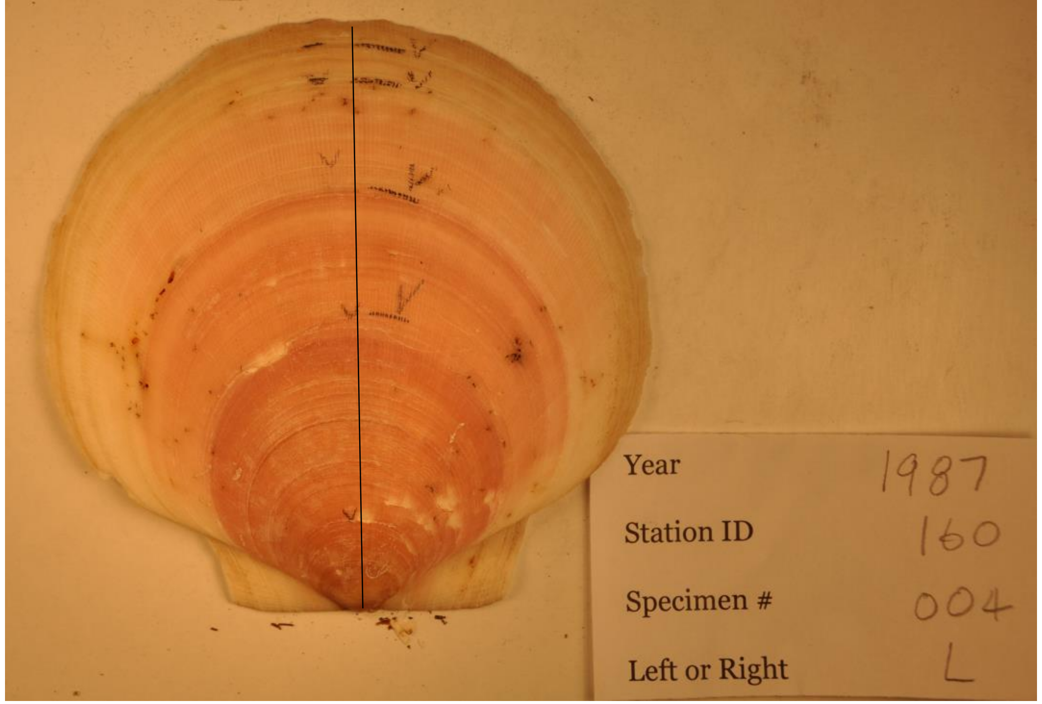
Original methods plan (and what really works)

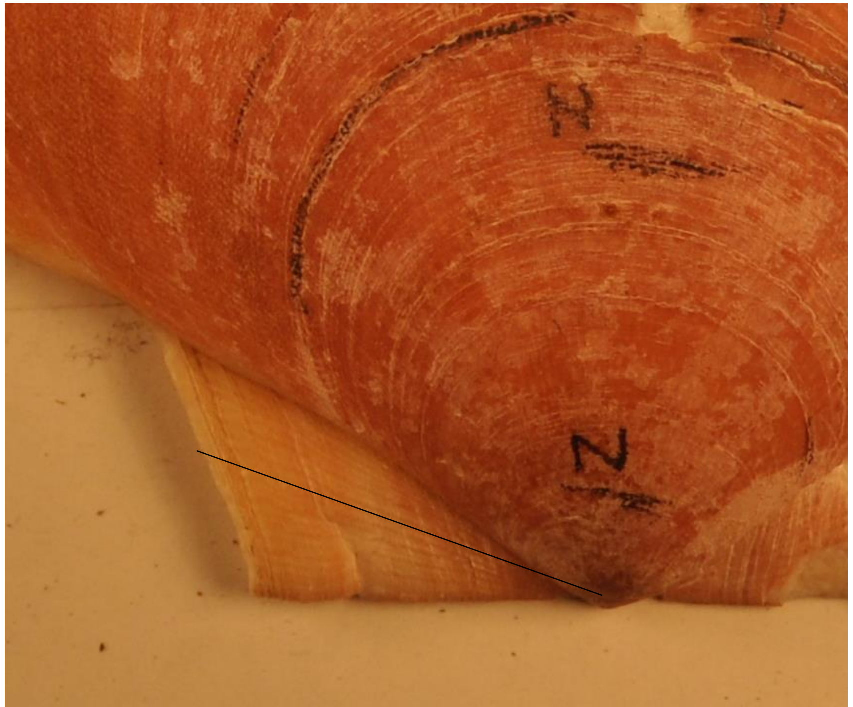
- Measurement of external growth lines, use the increments to generate age v length curves.
- Section the valves or the hinge regions and count the internal lines
- Blind check with isotopes of oxygen in the carbonate of the shell (Chute et al 2012).
- So how well are we doing?

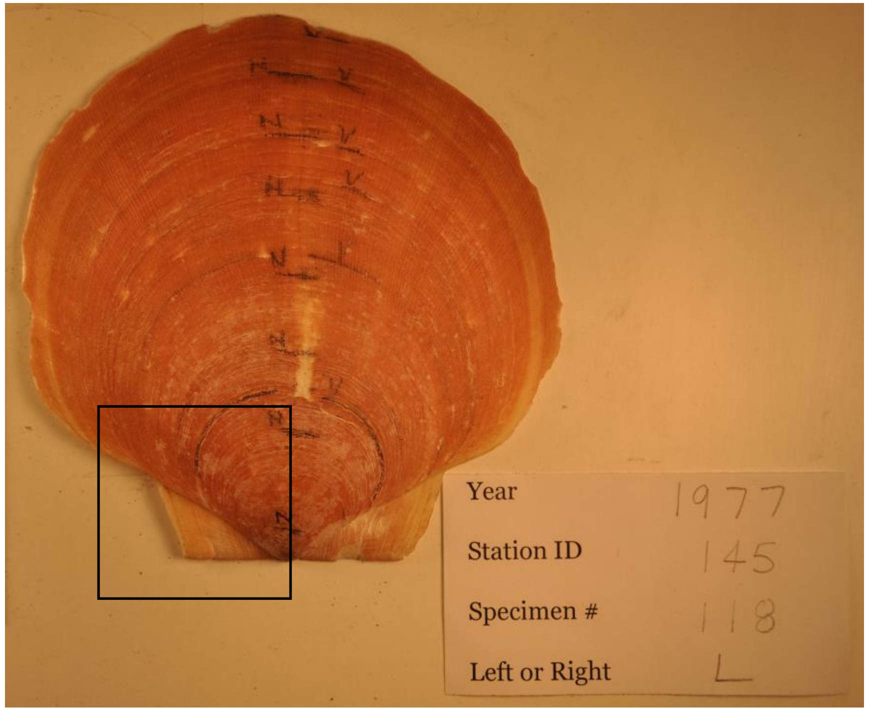
Variability in quality complicates identification

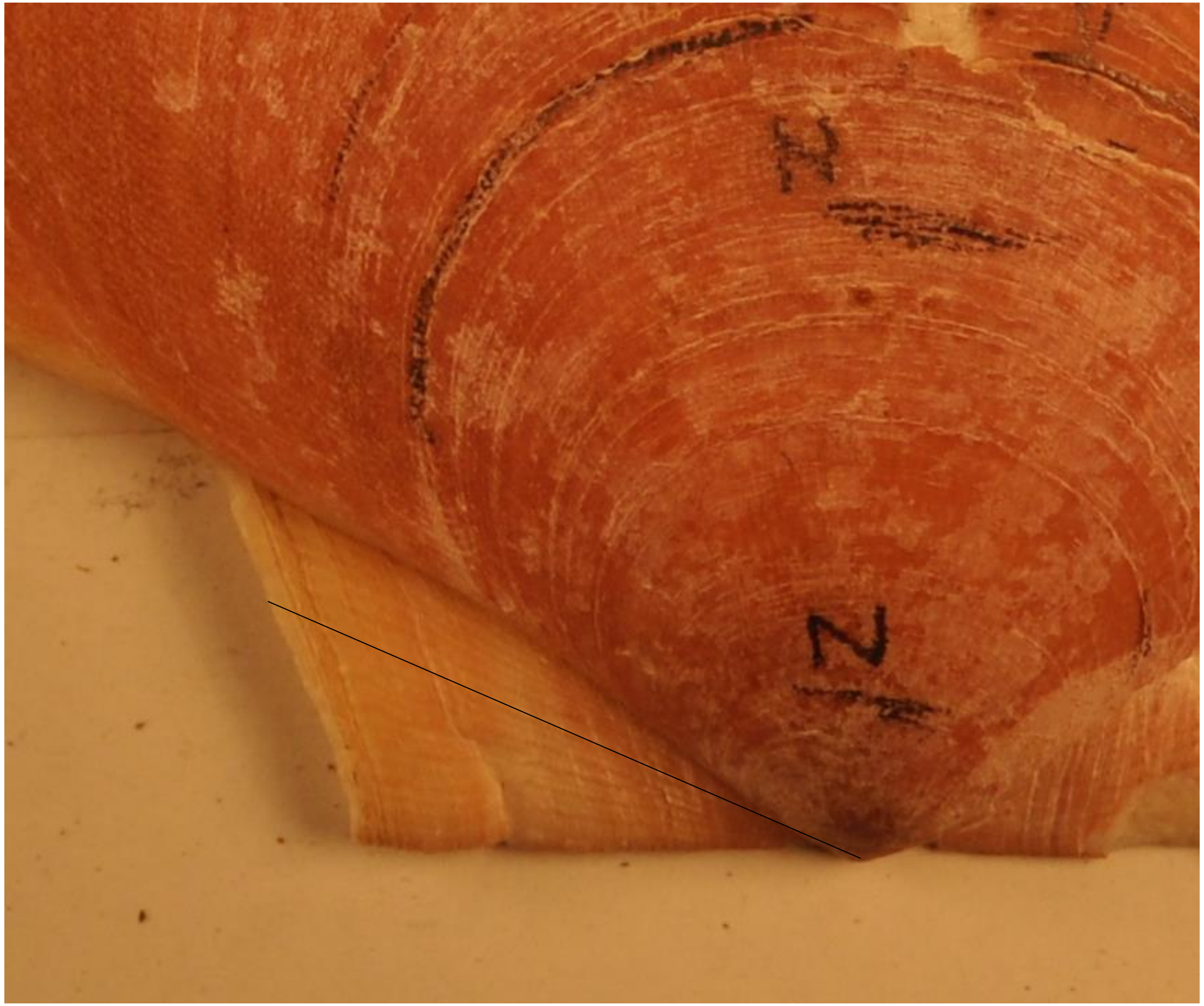



Year 1977
Station ID 136
Specimen # 140 A
Left or Right L


Year 1987
Station ID 160
Specimen # 004
Left or Right L

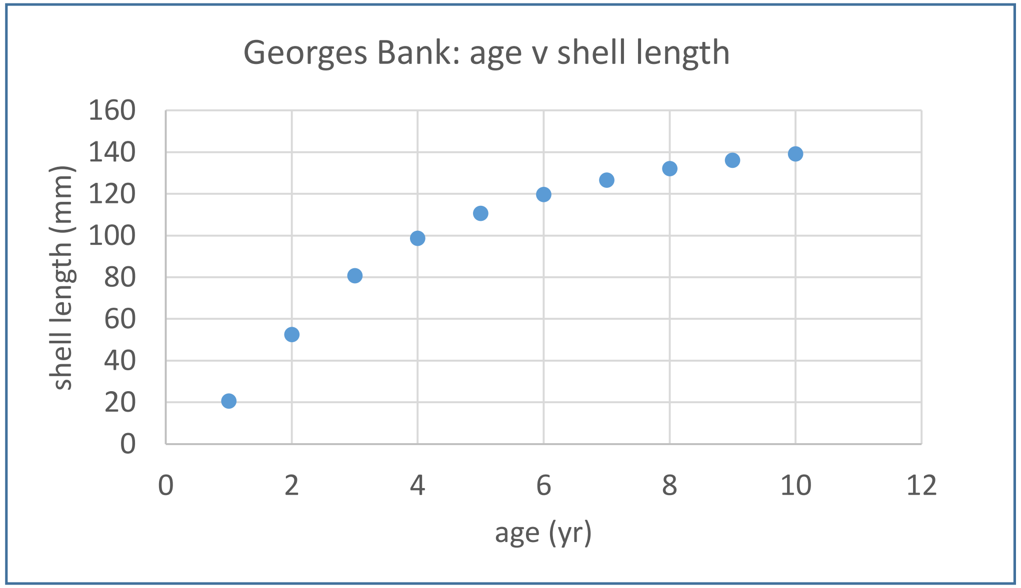



Year 1977
Station ID 145
Specimen # 118
Left or Right L

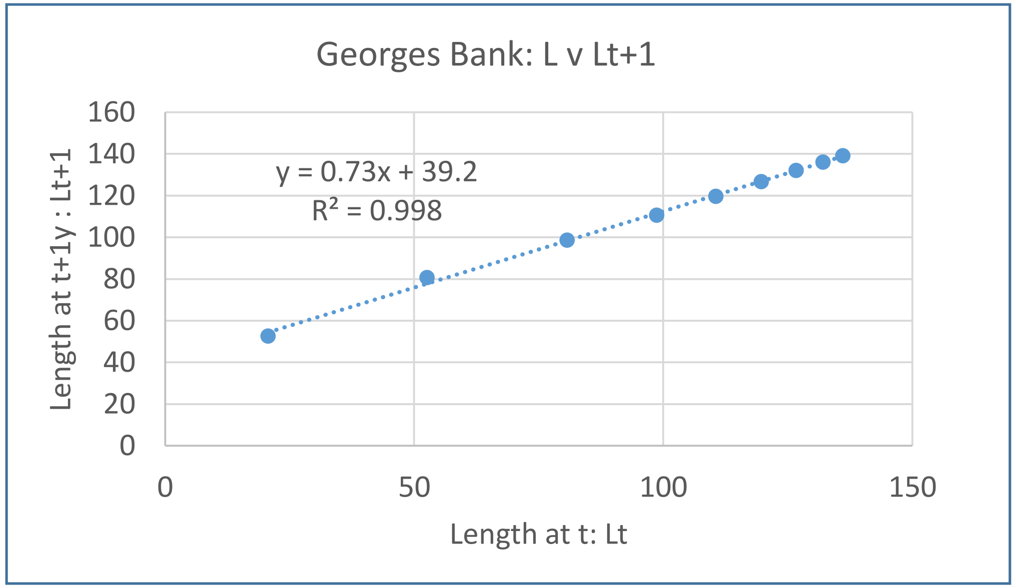


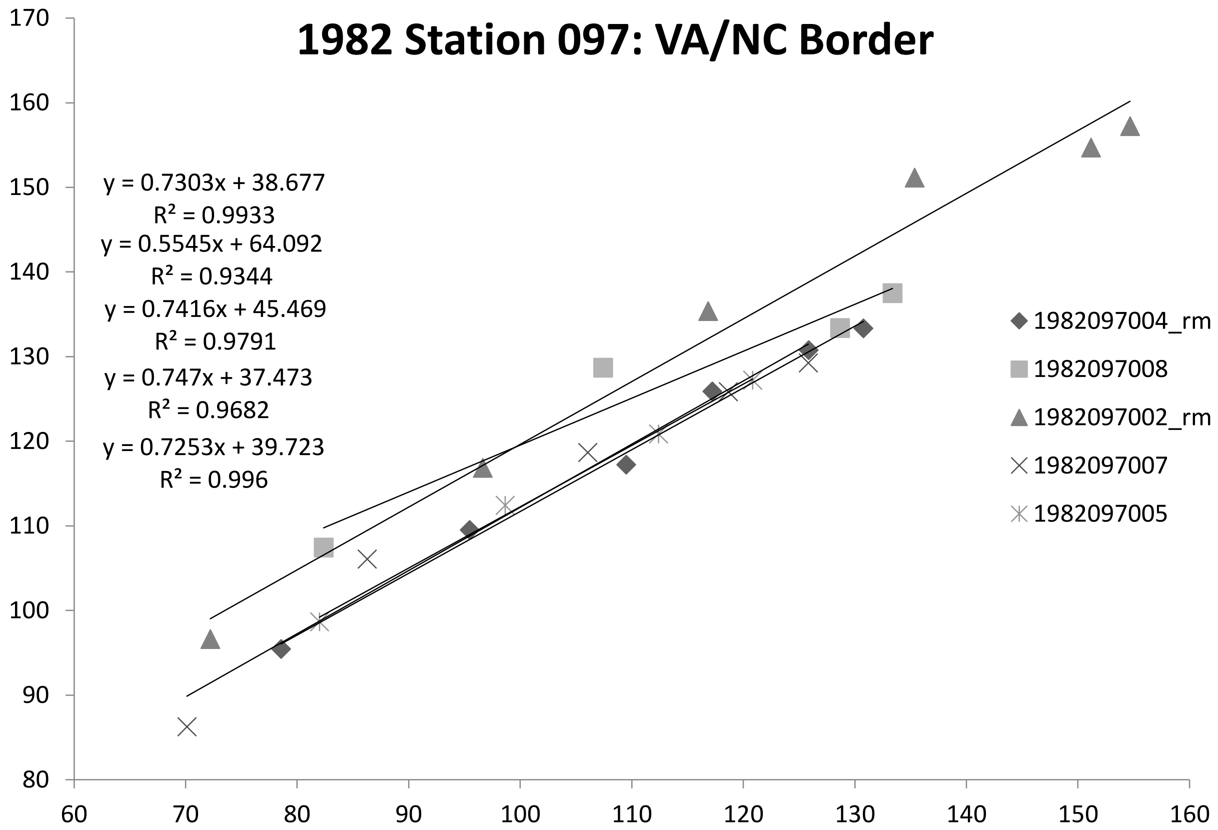
What is quite remarkable about sectioning both the entire shell and across the “ear” is that that there are abundant external growth signatures but very little corresponding internal signatures. But all is not lost….(I will give you the additional methods a bit later, back to the growth rings……)

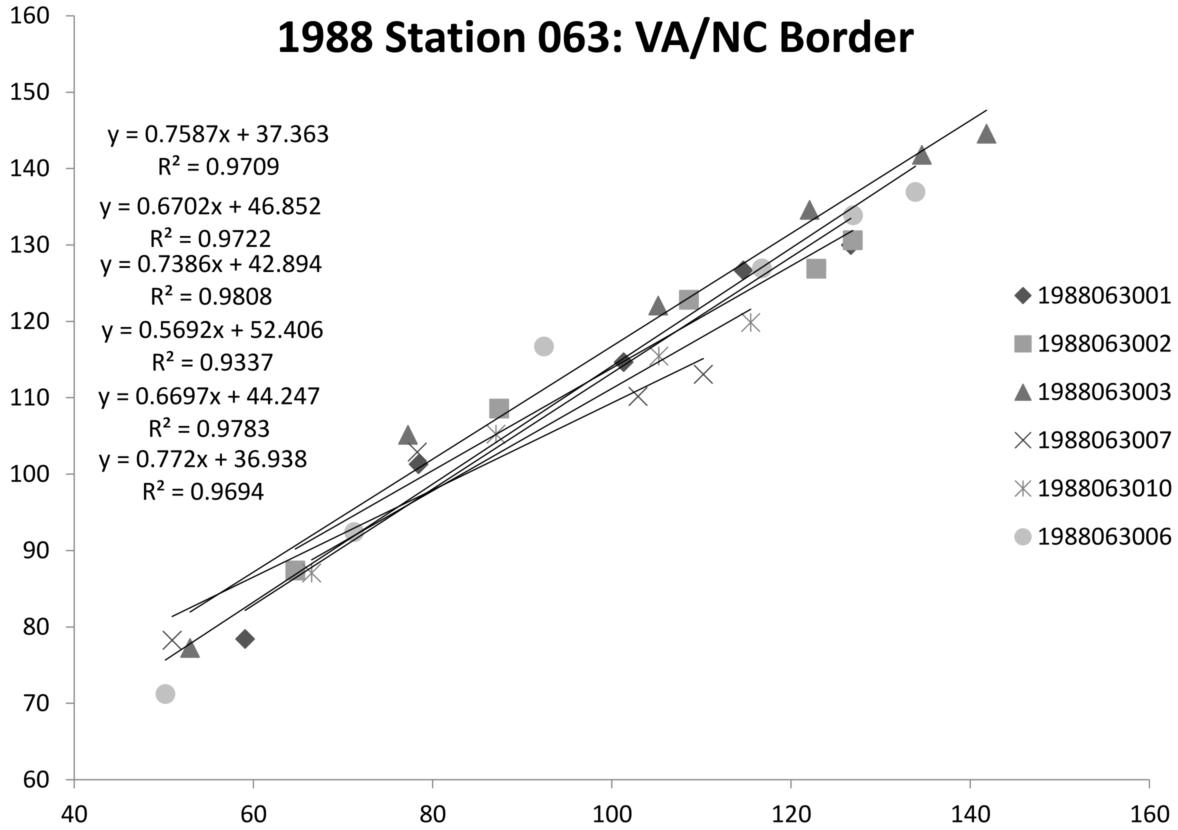
Using external growth increments we can generate growth curves by sequential measures of growth signatures at increasing distance from the hinge and fit a von Bertalanffy curve, or measure growth increments alone (which can be accomplished even if you cannot distinguish the early growth signatures) and use a Ford-Walford plot of Lt v Lt+1. The latter can be improved using the linear mixed effects model described by Hart and Chute (2009, ICES 66: 2165-2175). We have not yet completed all measurements and run the mixed effects model, so the data I am showing today are simply the Lt v Lt+1 plots (after double blind reading).



Lt+1 = a bLt
Linf = a/1-b
K= -log b
Linf= 146.8mm
K= 0.31

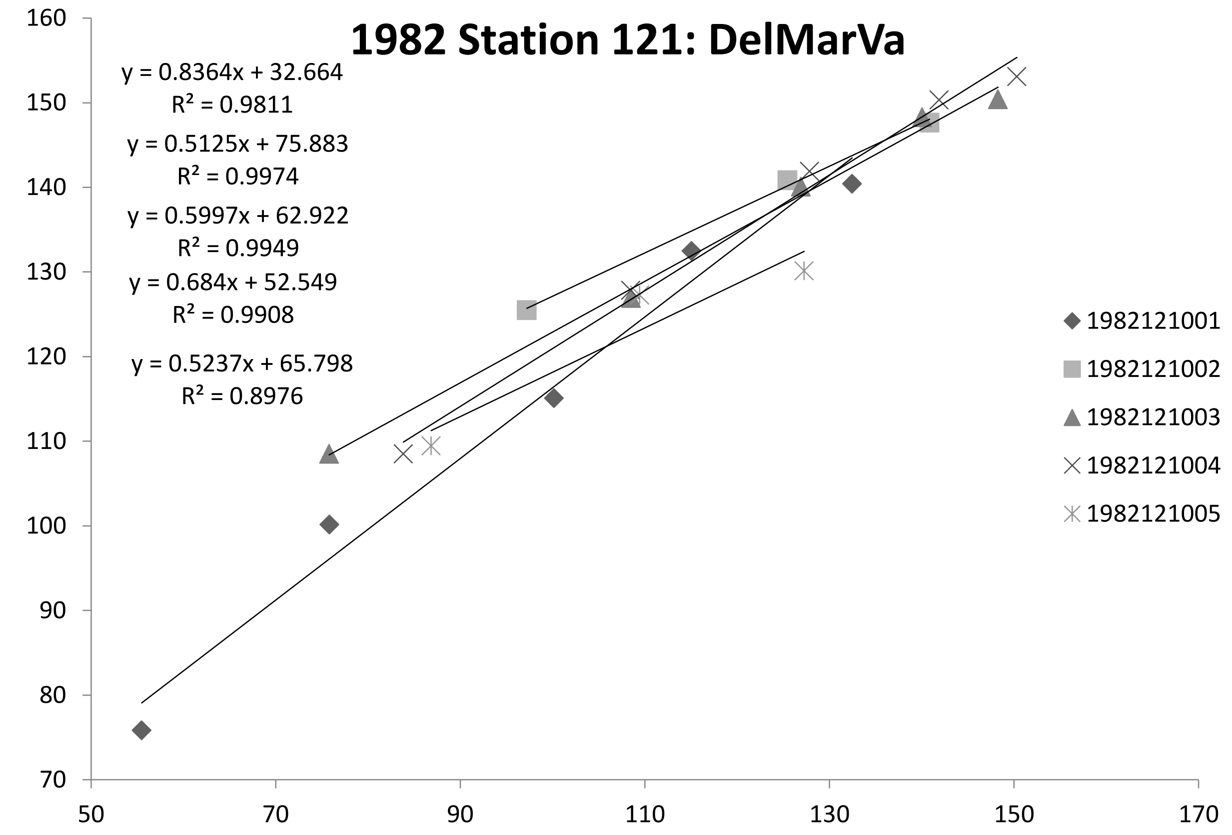


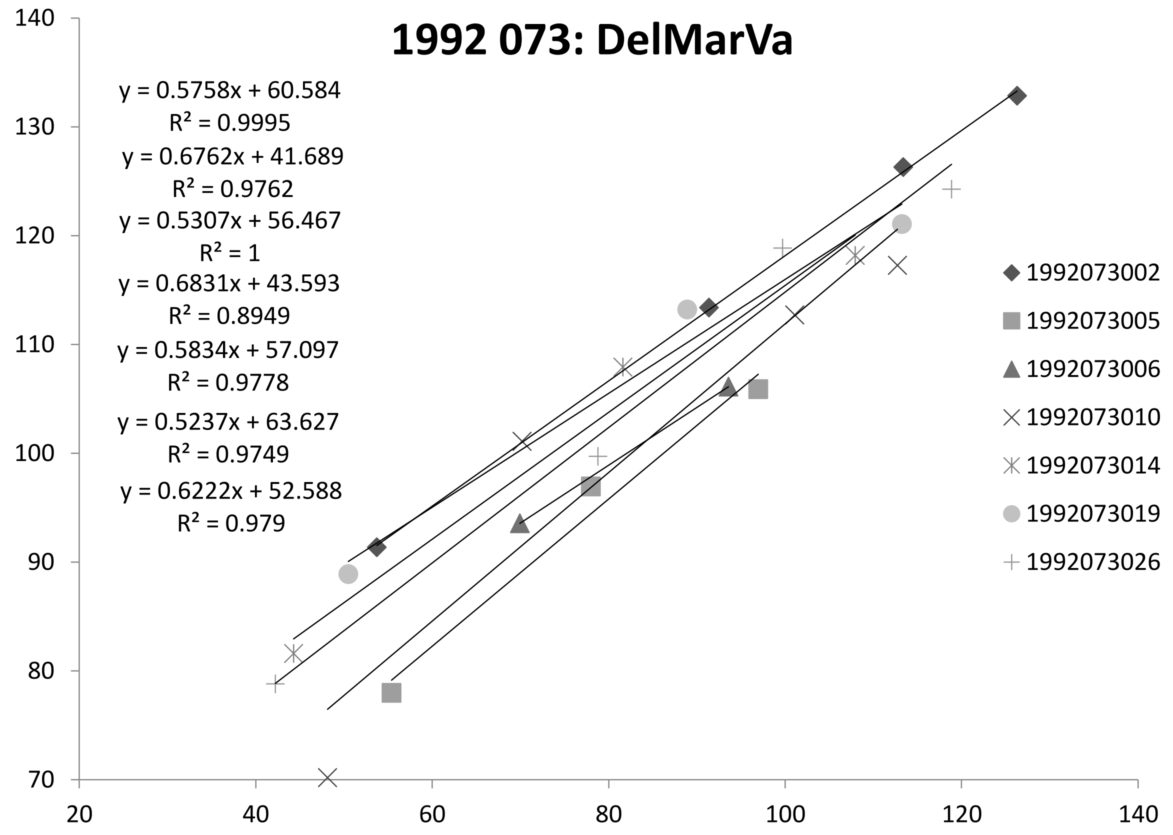




VA/NC Border

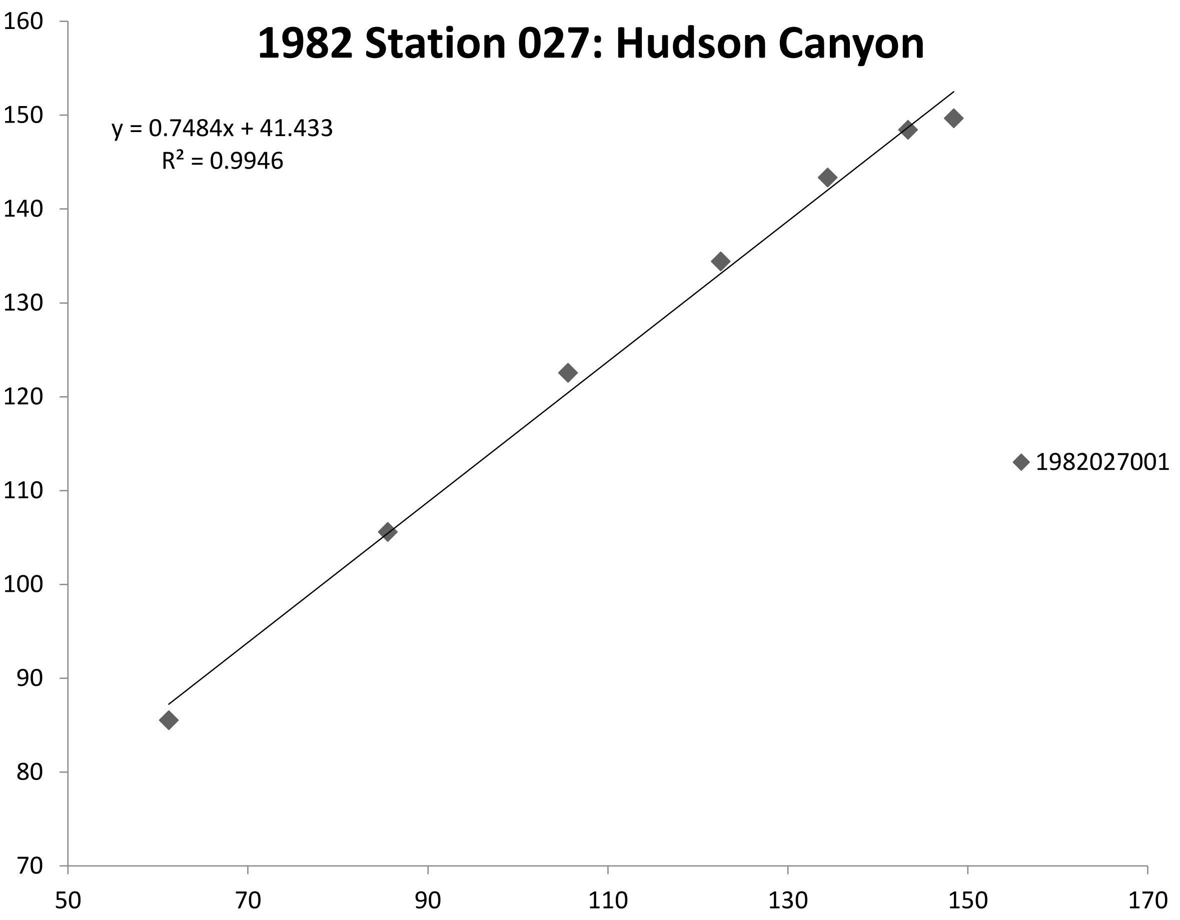
	1982	1988
k	0.36	0.37
Sdev	0.127	0.114
Linf	151.2	147.4
Sdev	14	16.1

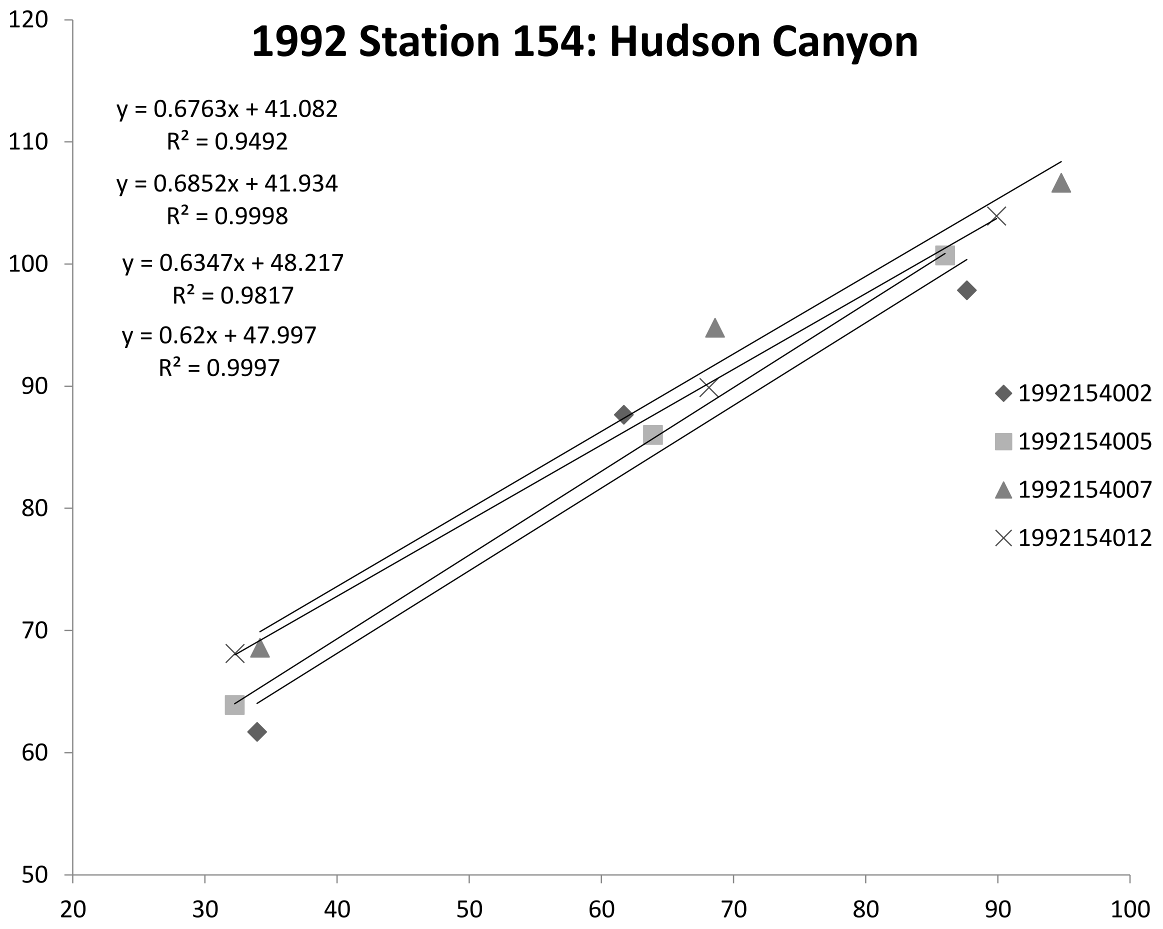




DelMarVa

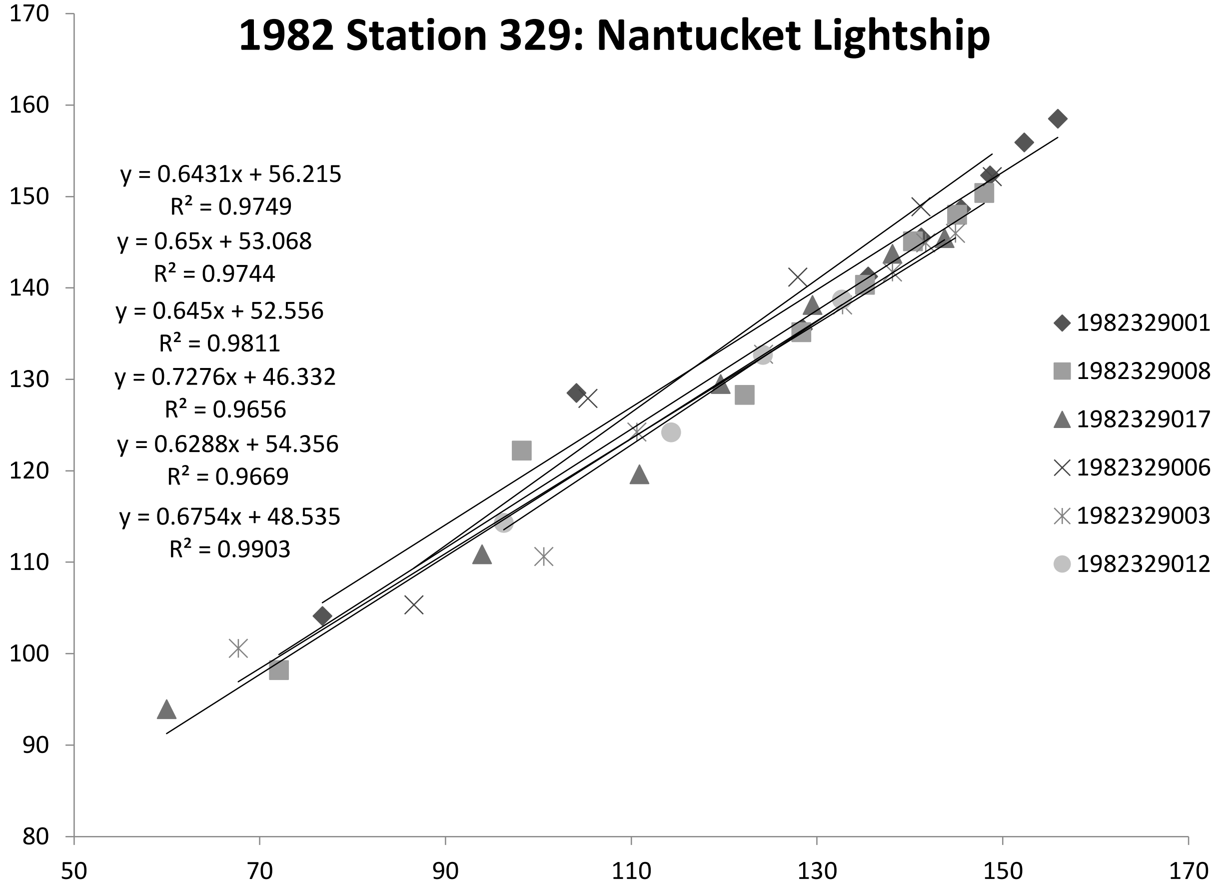
	1982	1992
k	0.55	0.52
Sdev	0.134	0.107
Linf	151.2	134.2
Sdev	14	7.6

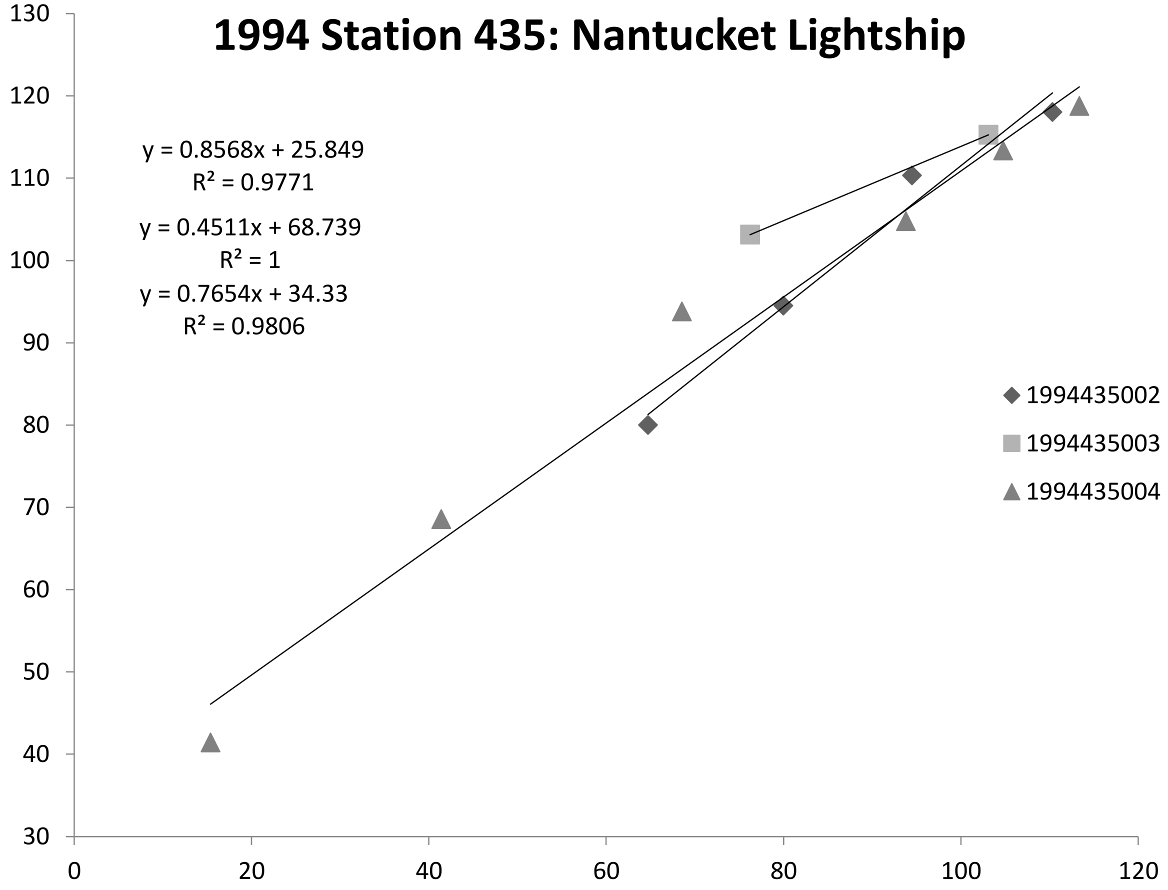




Hudson Canyon

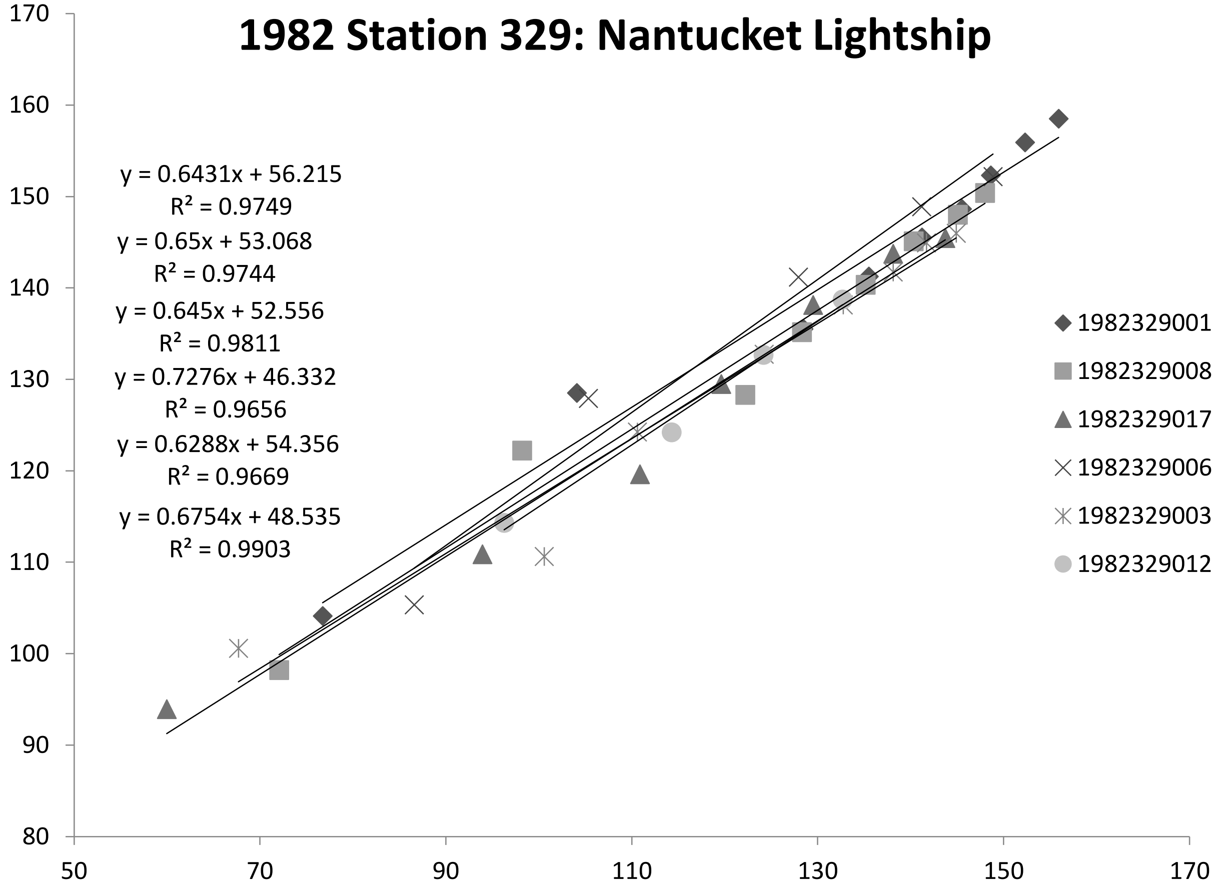
	1982	1992
k	0.29	0.426
Sdev	N/A	0.049
Linf	164.7	129.6
Sdev	N/A	3.5

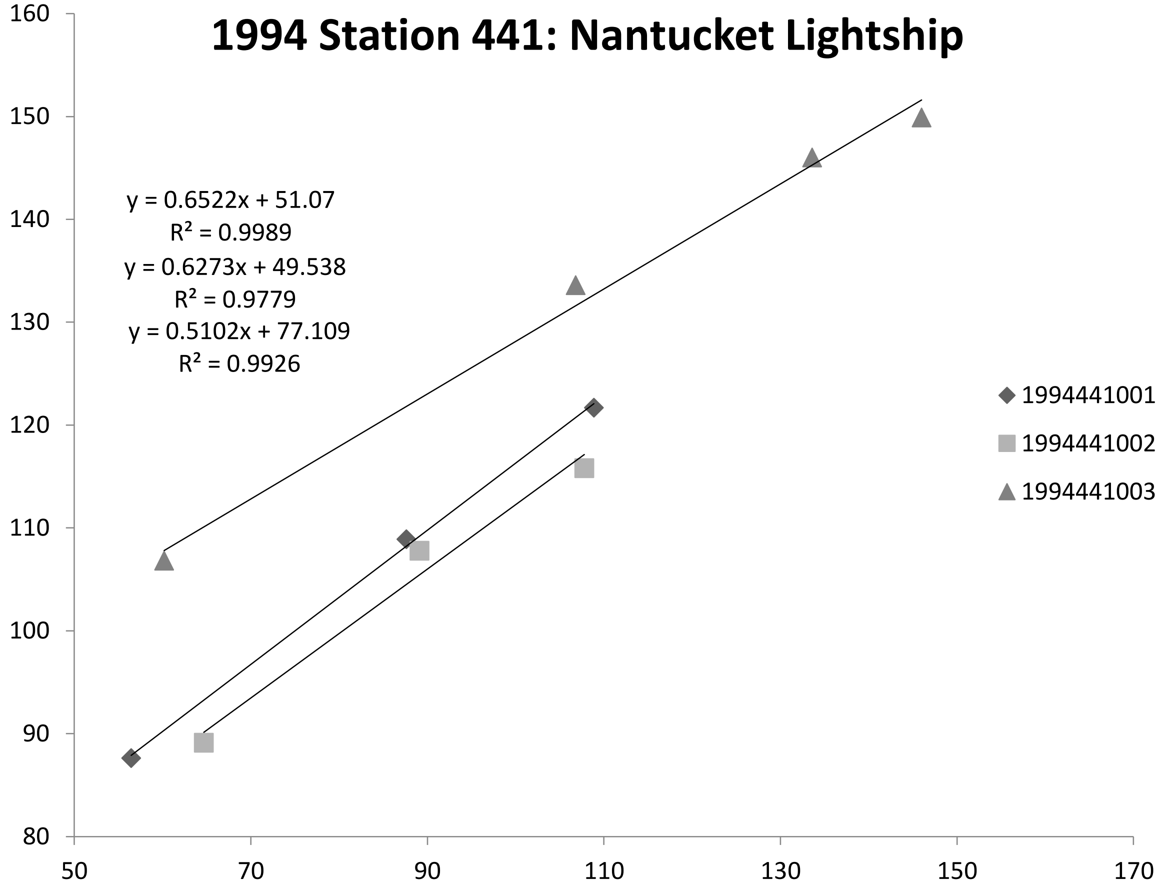




Nantucket Lightship

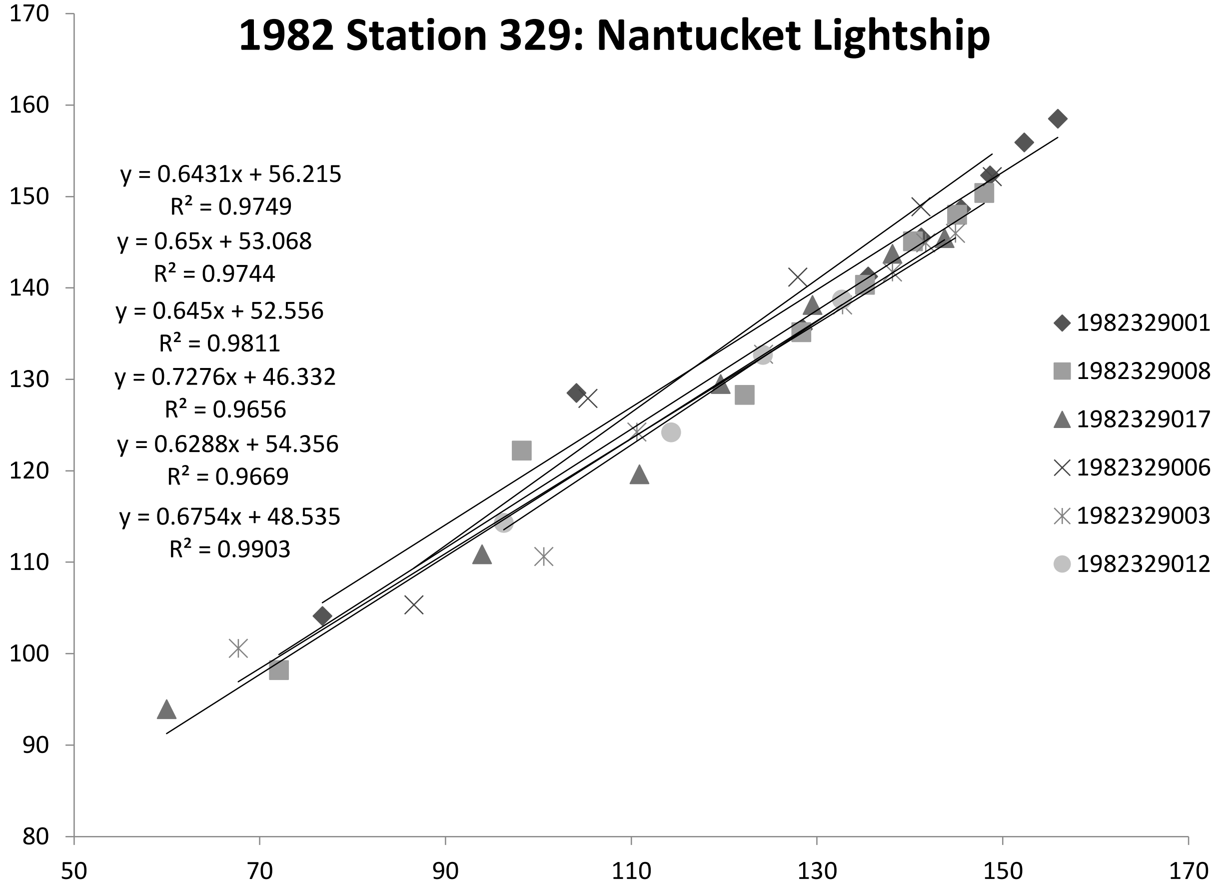
	1982	1994
k	0.41	0.41
Sdev	0.053	0.343
Linf	153.9	150.7
Sdev	8.8	27.9

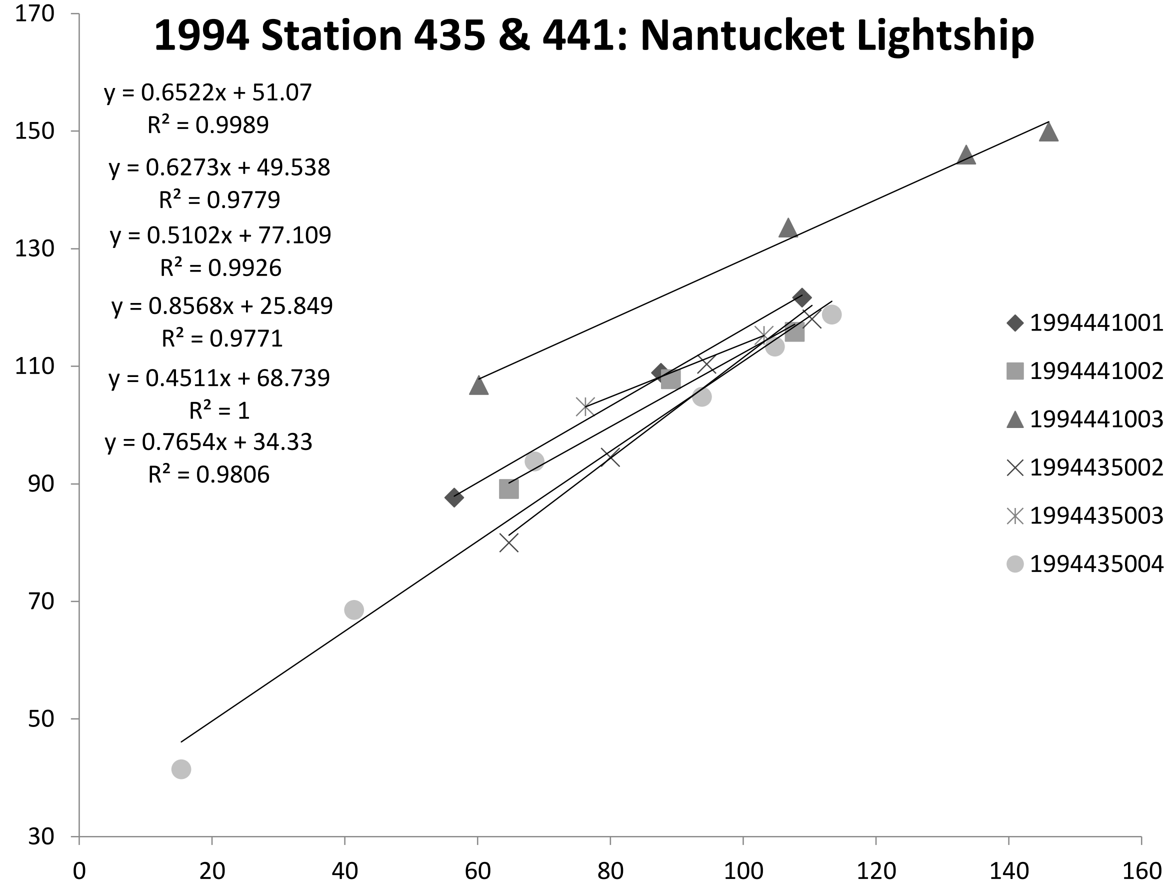




Nantucket Lightship

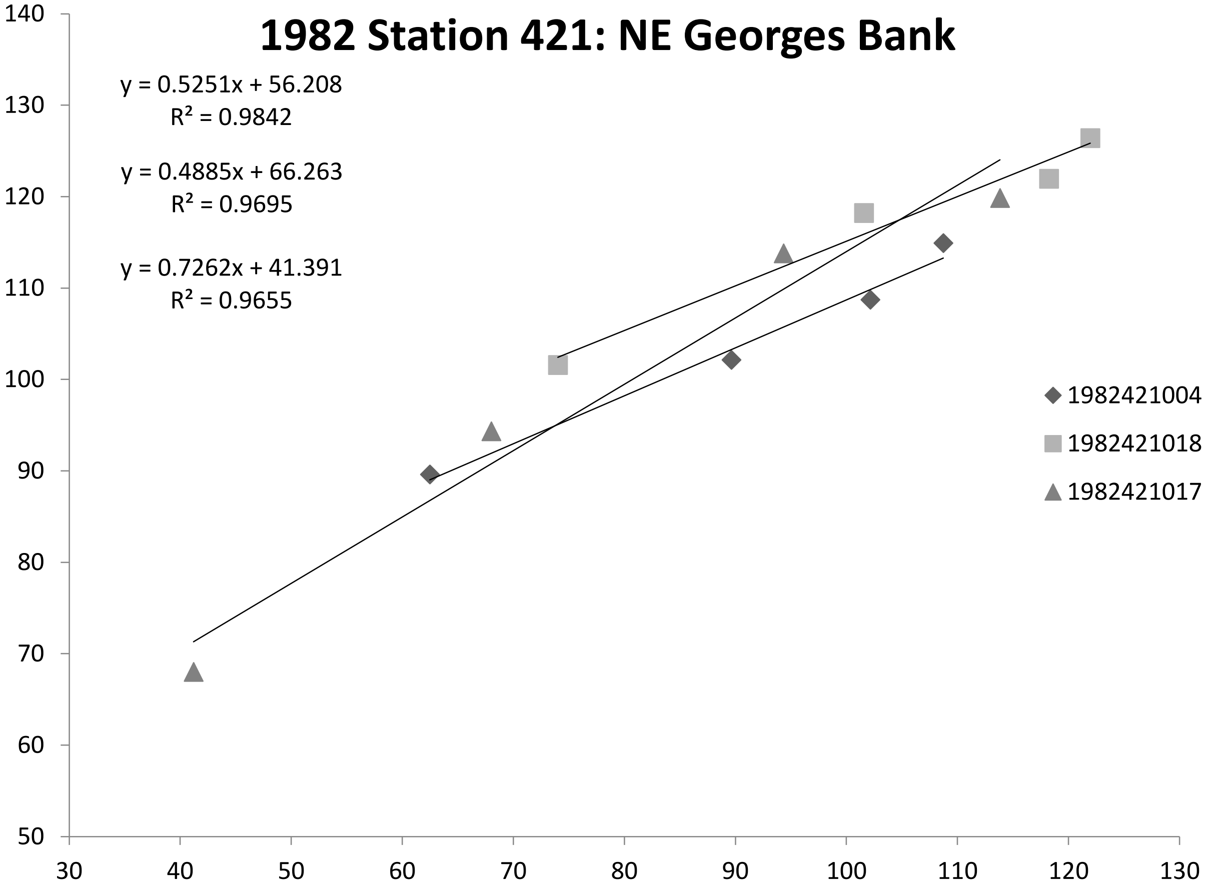
	1982	1994
k	0.41	0.52
Sdev	0.053	0.132
Linf	153.9	145.7
Sdev	8.8	12.3

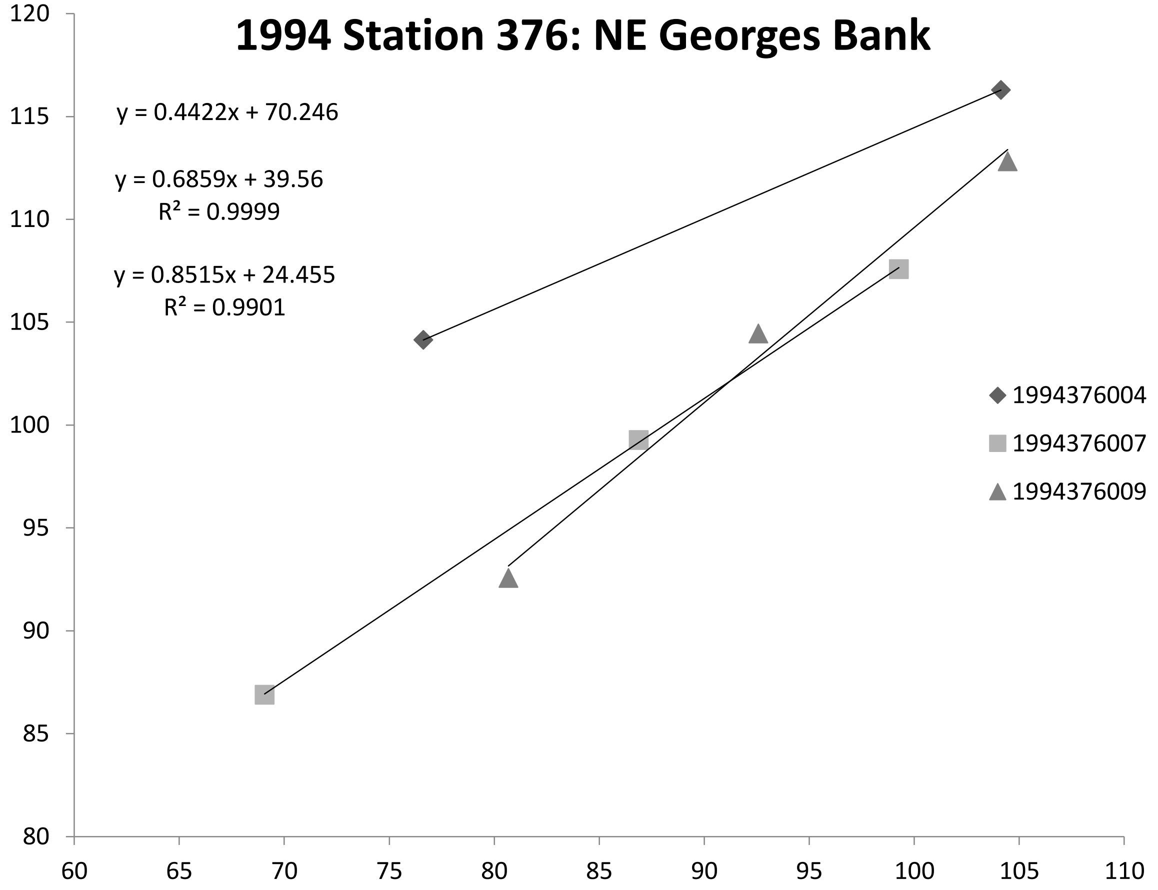




Nantucket Lightship

	1982	1994
k	0.41	0.46
Sdev	0.053	0.241
Linf	153.9	148.2
Sdev	8.8	19.5

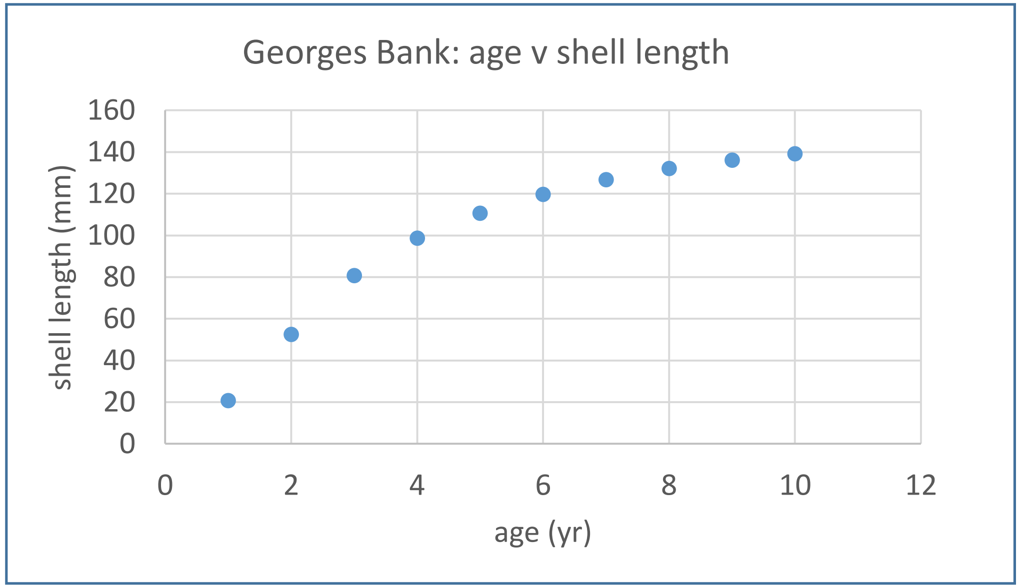




NE Georges Bank

	1982	1994
k	0.56	0.451
Sdev	0.211	0.334
Linf	133	138.8
Sdev	16.7	22.4

So we have an abundance of Lt v Lt+1 plots, and from these we generate estimates of k (how fast scallops grow), and Linf (how big scallops grow). But we still have not shown you an independent method to insure the rings we measure are annual. Well, we have two such methods: internal hinge structure and isotopes…



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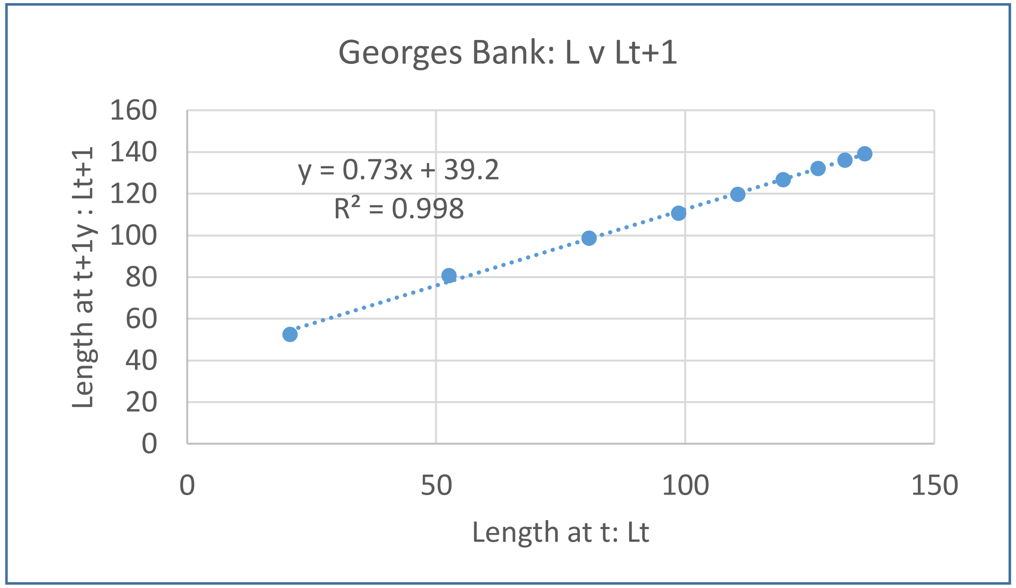


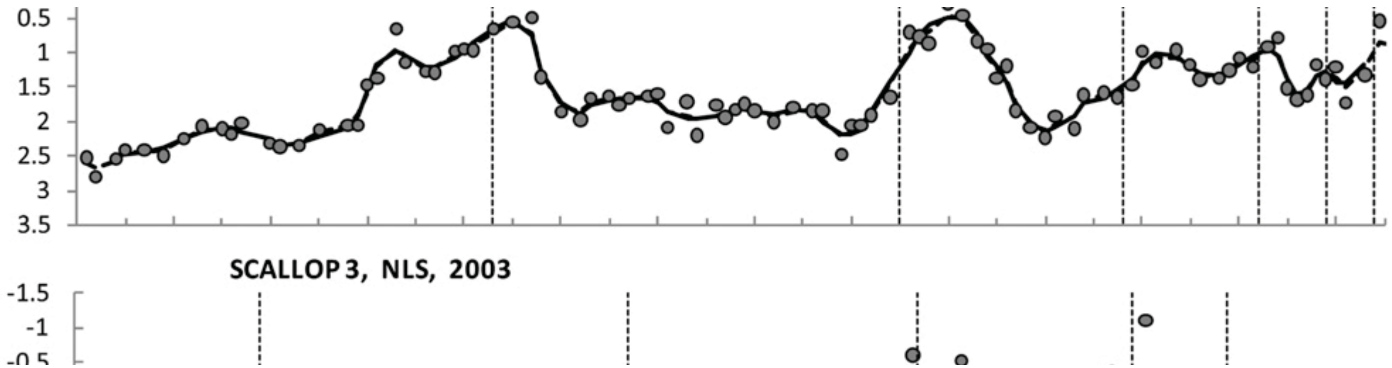
Hinge = [ligament + resilium] and cross sections. Merrill and co-authors (1977) suggested number of resilium lines = estimated age….recall how the lines are spaced proportionately across the shell, they are similarly spaced across the resilium….. And we are currently examining them as blind estimates of age in our archived scallops.

Isotopes do not lie….(Howard Spero, Professor Emeritus, U California Davis).

$CaCO_3$

^{18}O ^{16}O

$CO_2 + H_20 = H^+ + HCO_3^- = 2H^+ + CO_3^{--}$ then $Ca^{++} + CO_3^{--} = CaCO_3$



Source: Chute et al 2012

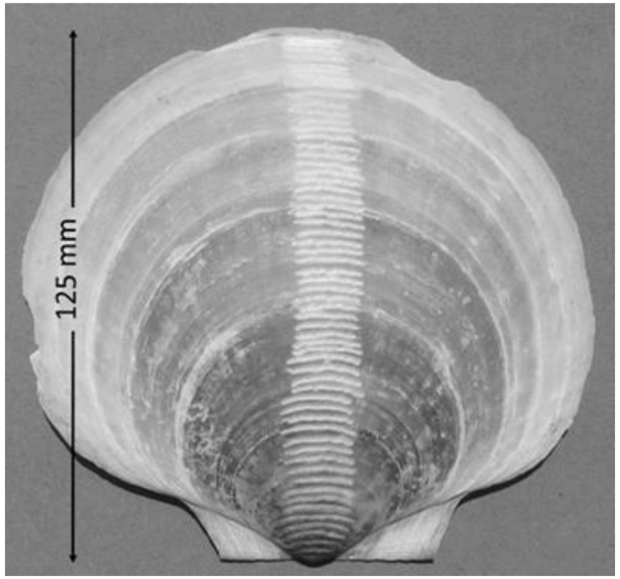


Figure 2. Photograph of a scallop shell from this study (scallop 1, from closed area II) showing the size and placement of drilled samples.

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Still left to be completed

- Age estimates from external signatures from remaining archive samples (2 years of stations left); shells from 2014-2016 (N-S and with depth); NLS slow growth shells; Rudders mark & recapture (2016 ongoing).
- Conclude “blind” reading of external lines (week of 5/15/2017).
- Select individuals for resilium and isotope work (week of 5/15/2017).
- Complete data collection analyses summer 2017.
- Write report Fall 2017.