

# Exploring temporal and spatial variation in growth rates of the scallop *Placopecten magellanicus*.

Scallop share day 2026

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<sup>1</sup>presenting author, all the errors are mine.

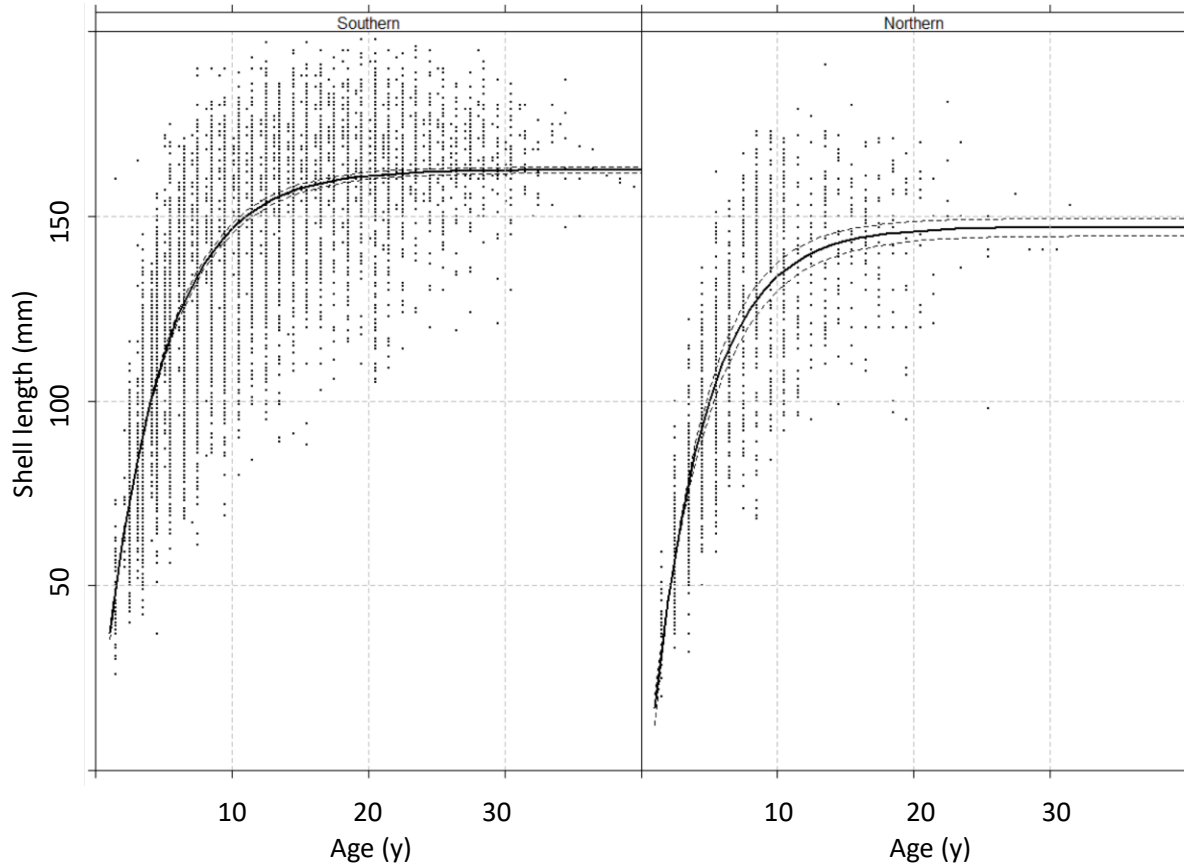
With additional thanks to the field crews who collected shells at sea.

# Why bother with growth rates?

- Recruitment, growth and mortality growth rates: the trifecta of stock management.
- Age based assessment requires rate estimates
- Spatial and temporal variation related to (?) environment, food, climate, biology (predation, parasites, disease, acidification) and more
- The question is posed at the whole stock level, then regional level, then.. how far can we go in dissecting time and space?
- I encourage you to examine data all the way down to the individual level because the data is actually very rich

An established approach to age at length relationship describing growth over time and space

NEFSC surf clam age and shell length data: 2014 assessment



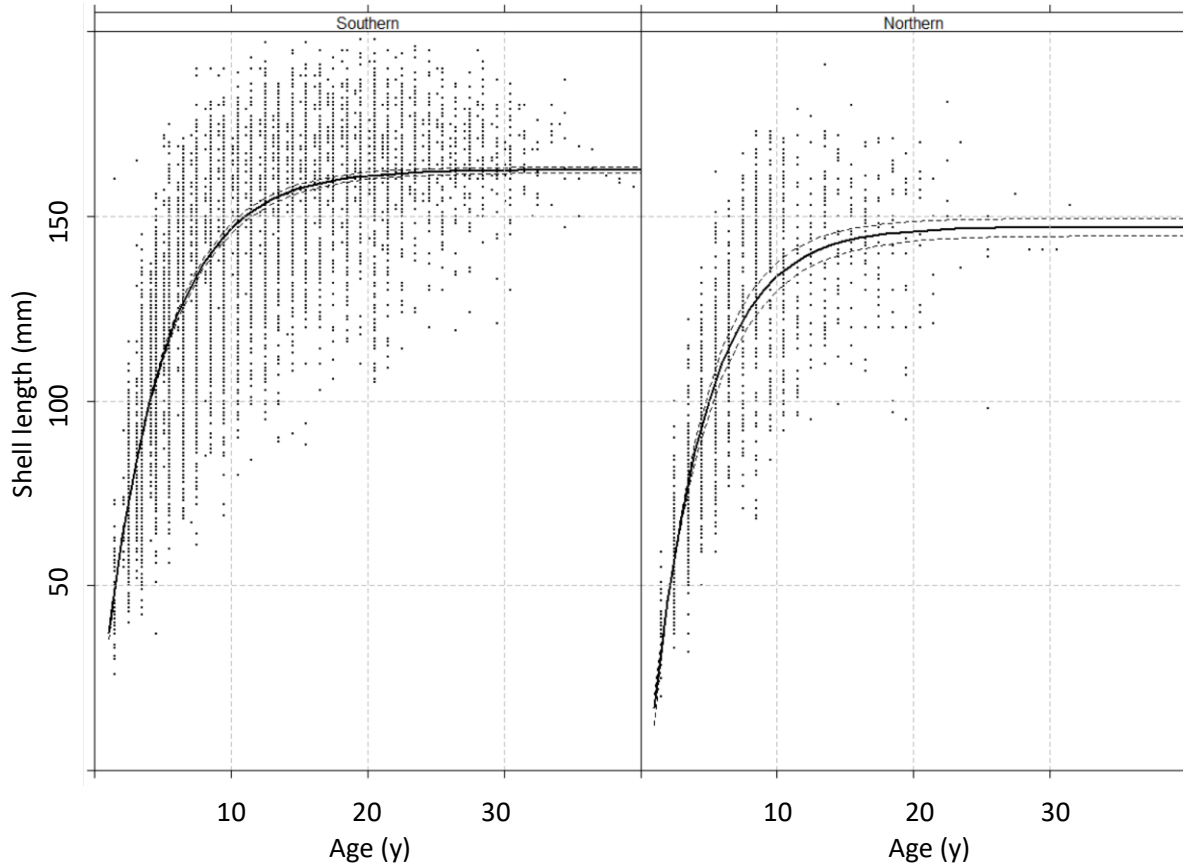
Von Bertalanffy growth equation

$$L_t = L_\infty [1 - e^{-k(t-t_0)}]$$

Consider the scatter in the data around the fitted line -  
What drives this? You lose so much information.

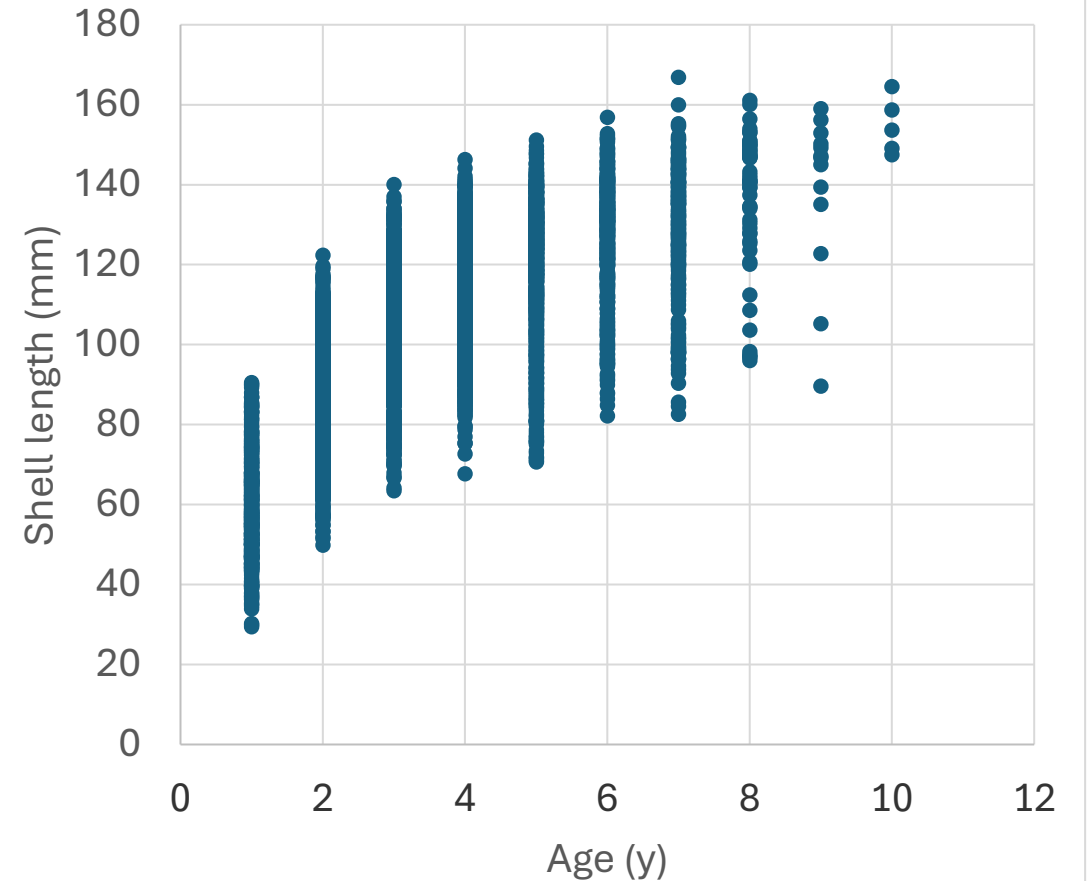
# Toady we are discussing age at length relationship in scallops

NEFSC surf clam age and shell length data: 2014 assessment



Consider the scatter in the data around the fitted line -  
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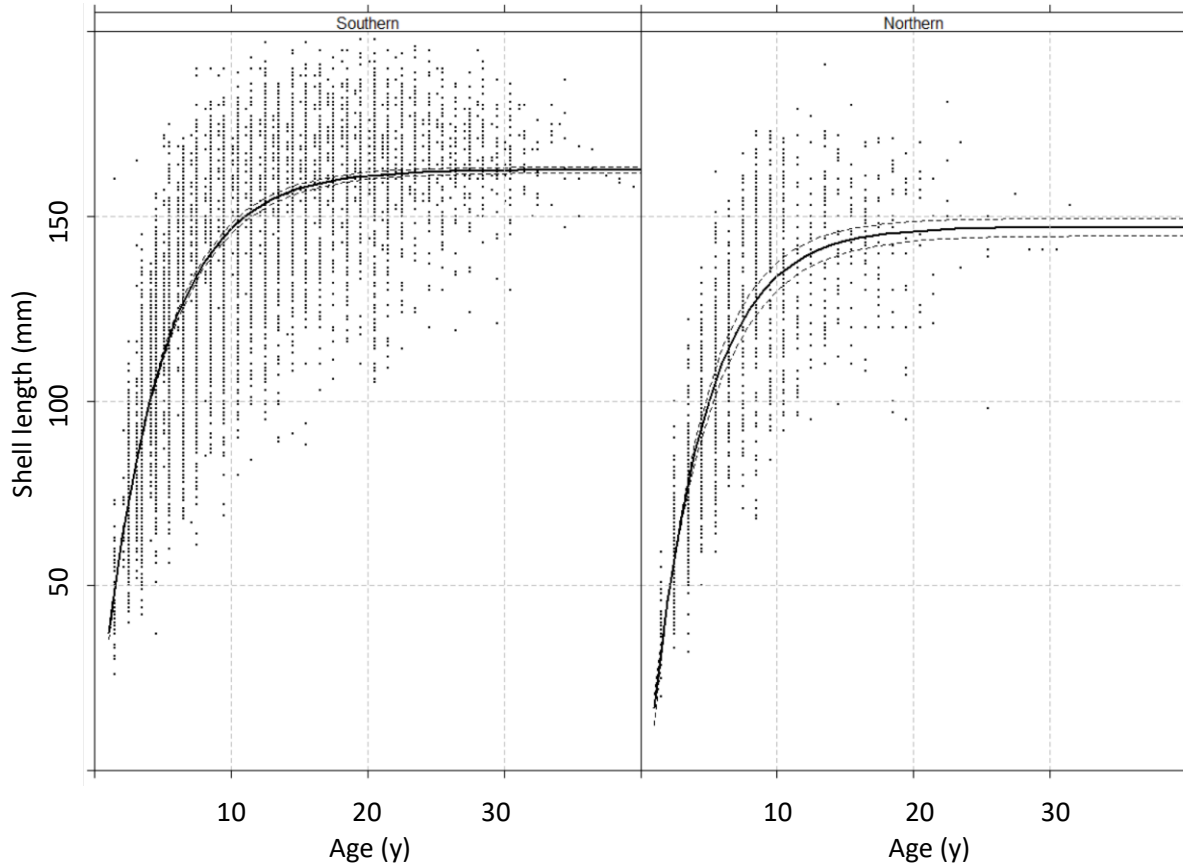
2018-2025 incl. n = 5437  
Age (y) v shell length (mm)



The scallop data – consider the spread in the data

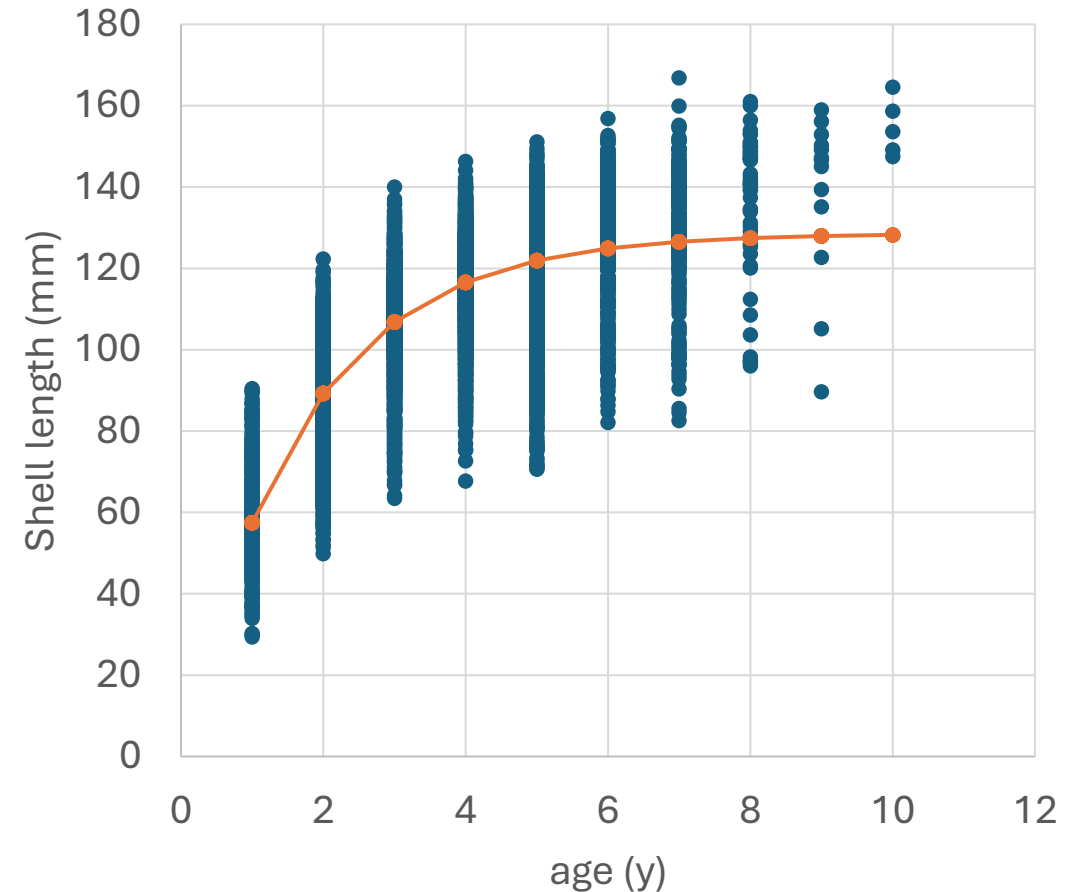
# Toady we are discussing age at length relationship in scallops

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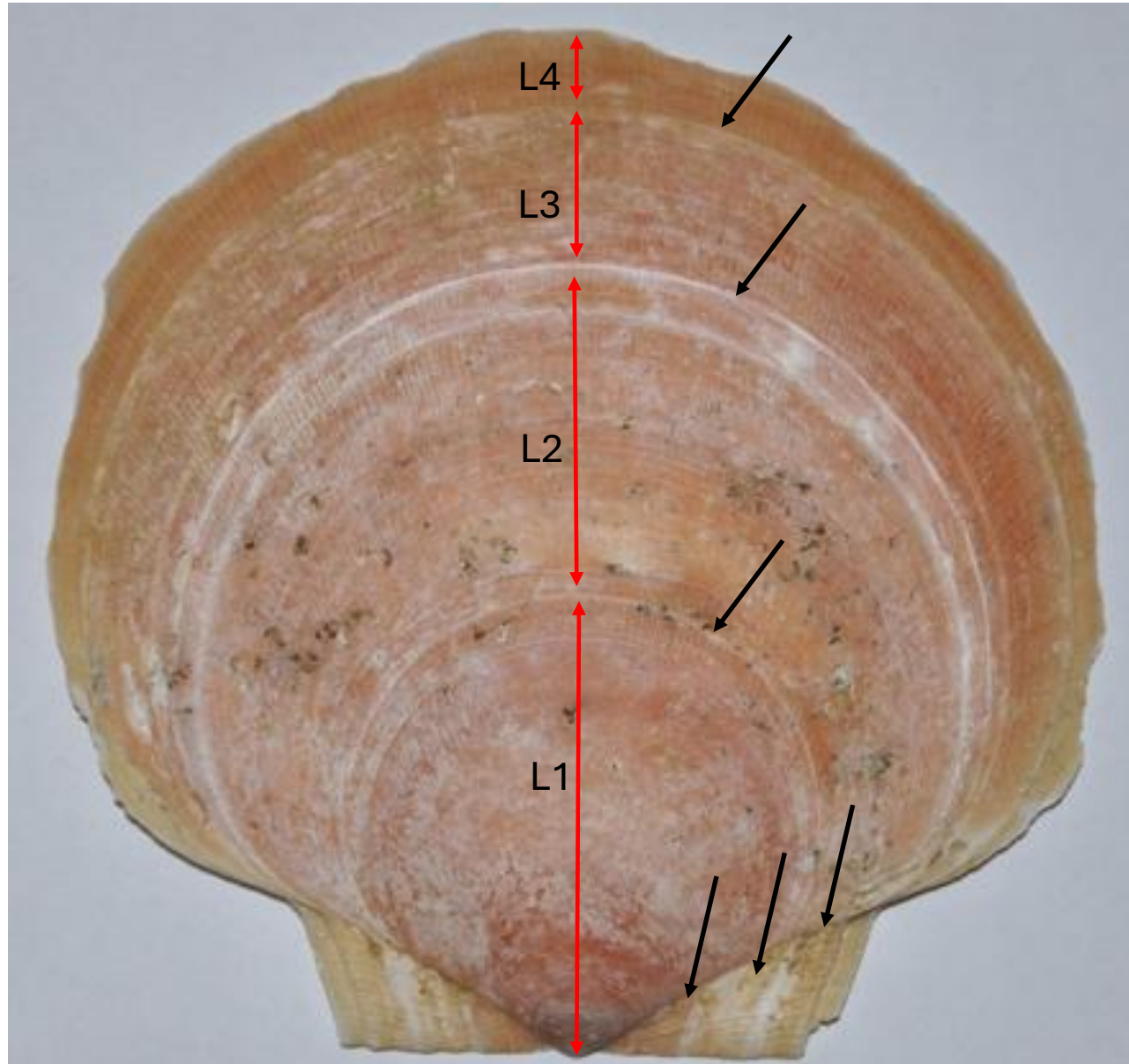


The scallop data – consider the spread in the data,  
and how it looks when we fit a von Bert ....

## How do we estimate age?

Consider an approach that includes a focus on growth increments – so larger scallops give more data.

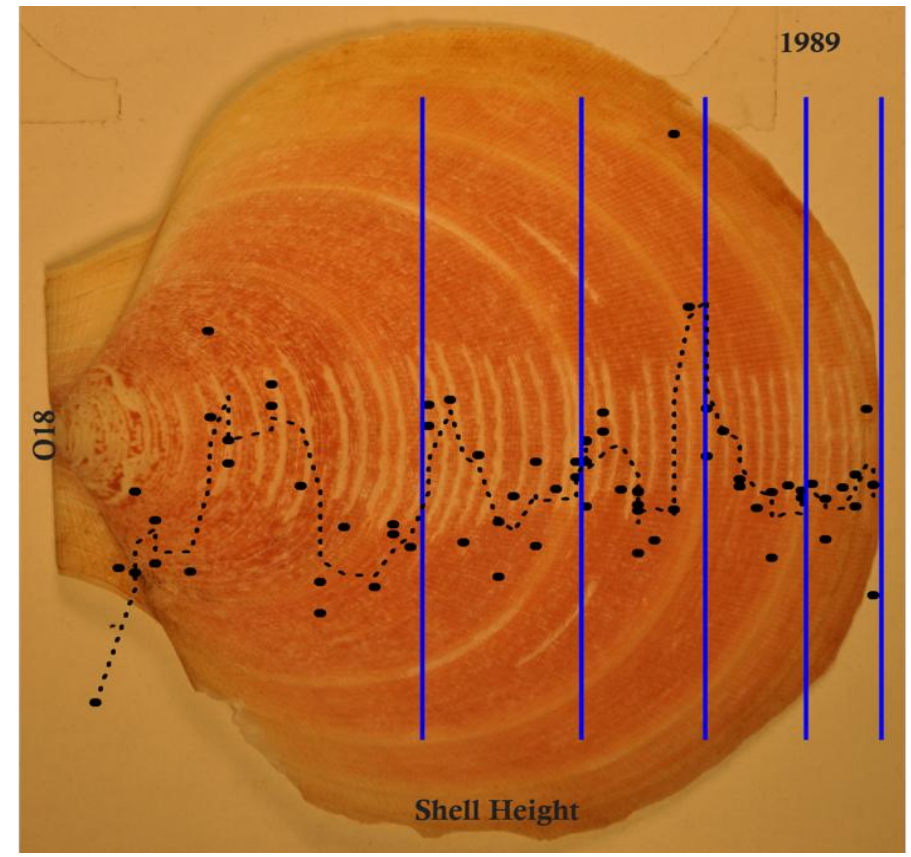
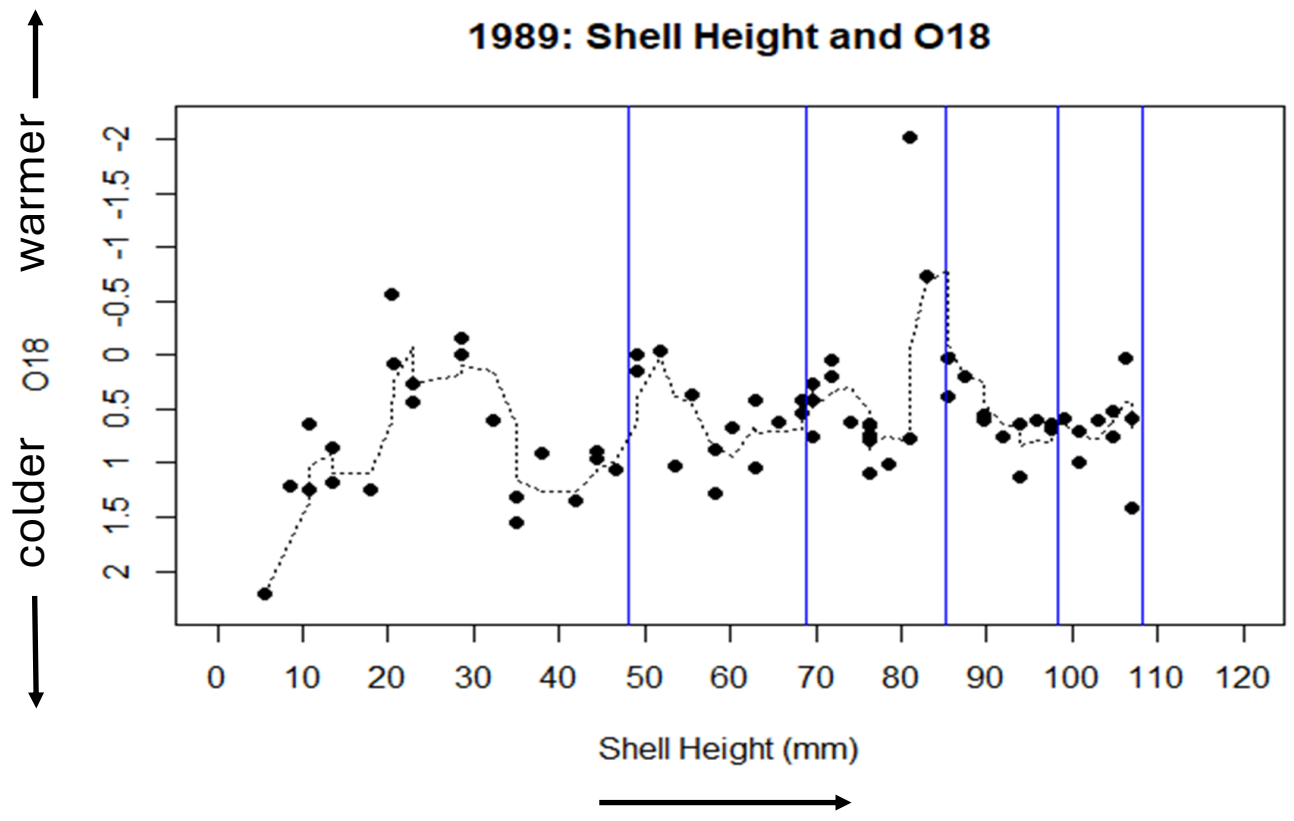
Note we ignore the first line because it is <1 year. This has some later impacts



### Negatives:

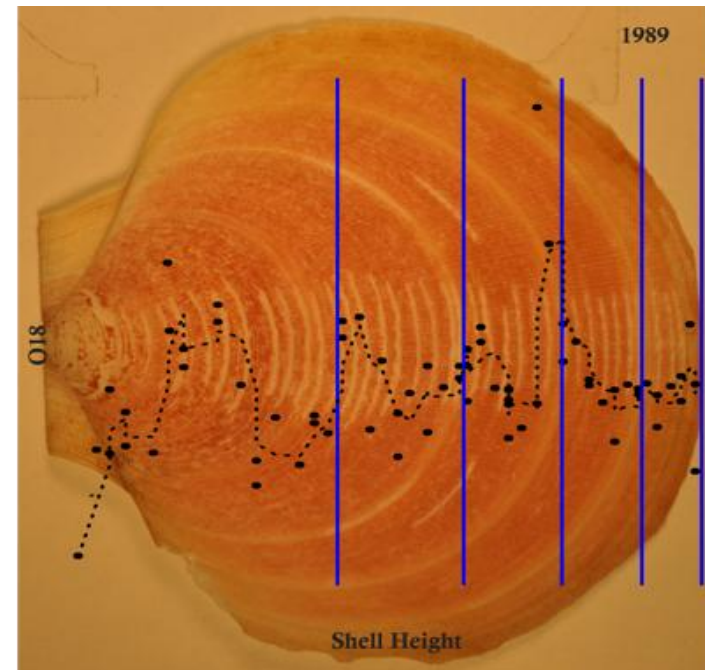
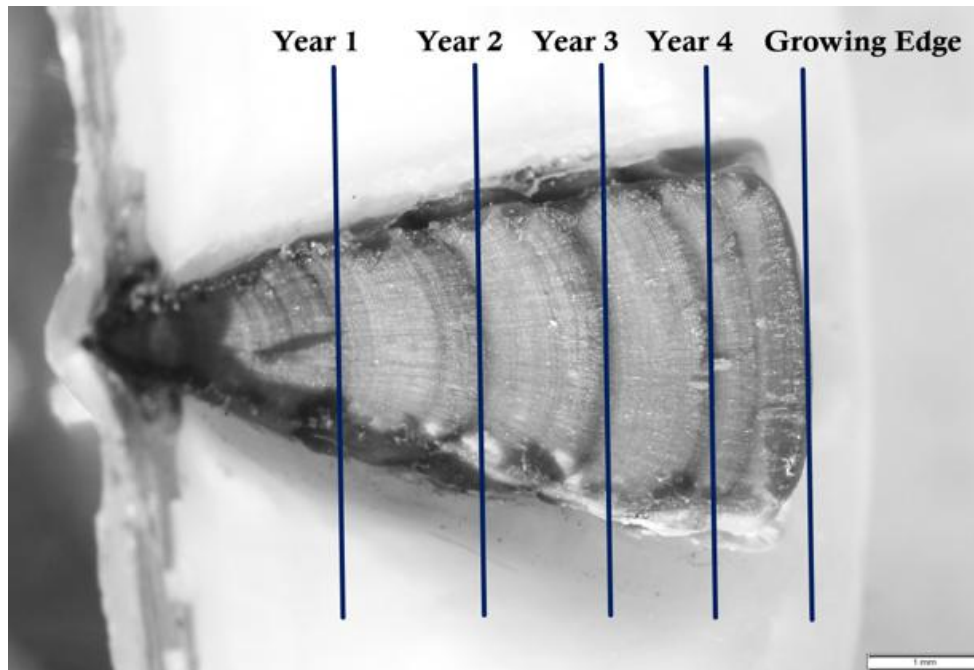
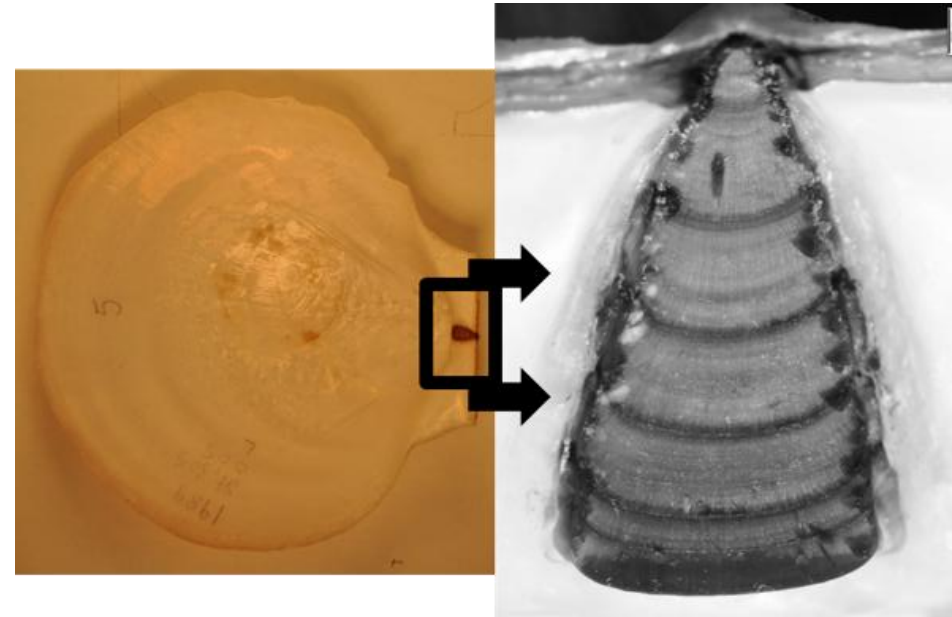
- Some scallops are too abraded to give clear increments on the external surface.
- Smaller scallops give little information.

**Isotope verification:** Blue lines indicate the location of the external growth rings (annuli). Growth rings form in summer at the temperature maximum.



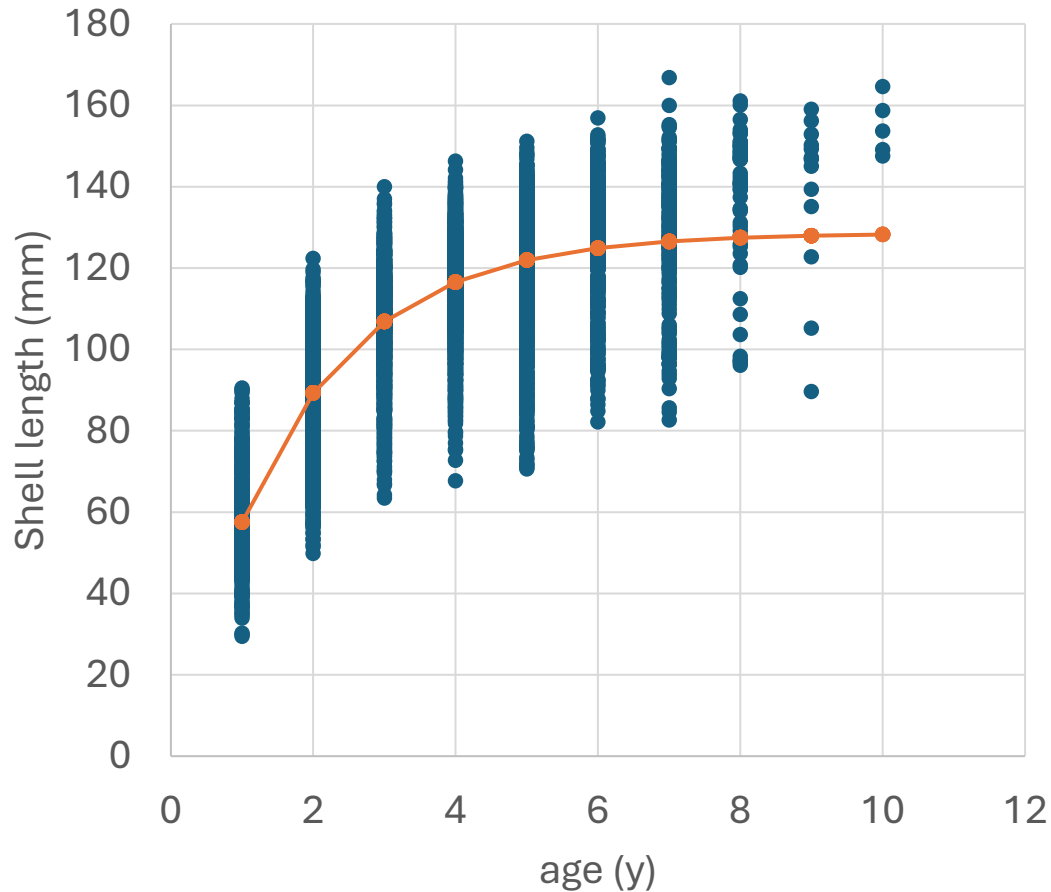
And there are internal signatures that can be used:  
scallop hinges and the **resilium**

- These are not exposed to abrasion.
- Note spacing of signatures on the resilium
- # Annuli match (as per Merrill et al)
- Equally efficient to process large numbers.
- Quite easy to read



# Data source for this presentation: 2018-2025 VIMS cruises

2018-2025 incl. n = 5437  
Age (y) v shell length (mm).

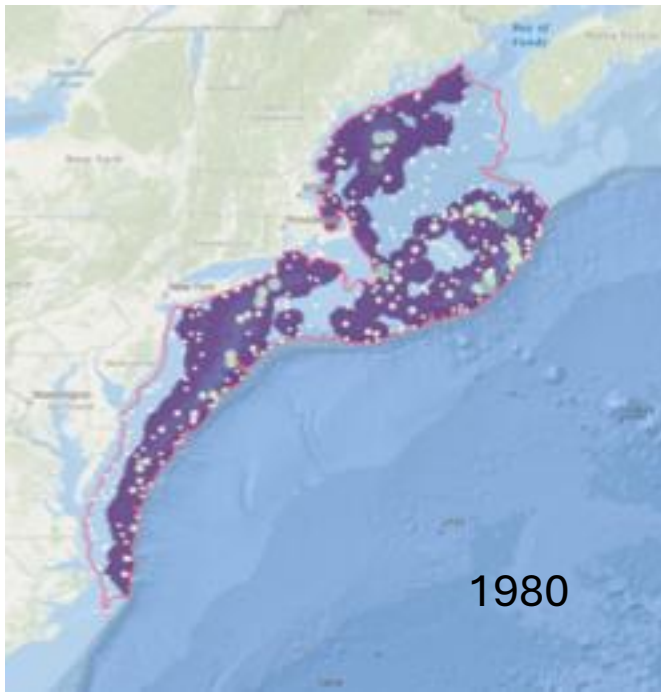


**All scallops in plots have matching age-length estimates by annuli and resilium, and we have every increment measure.**

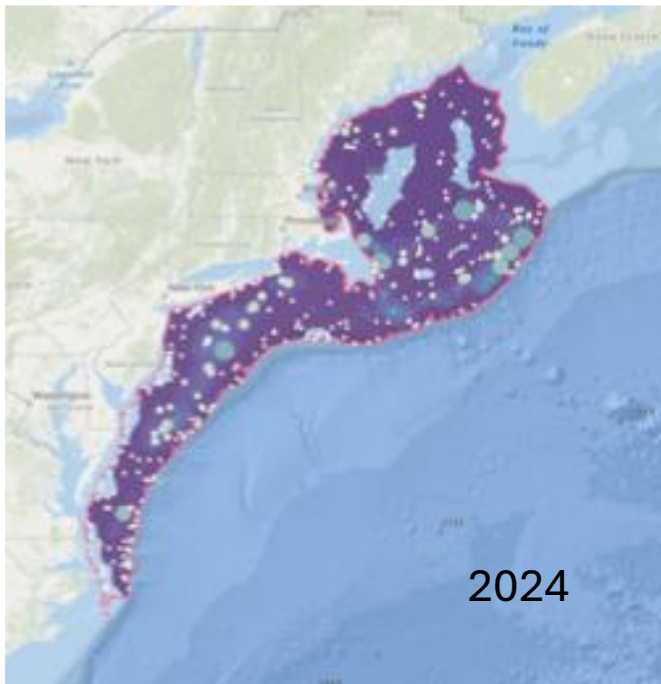
Total n scallops examined: 8535  
Total measured: 6243  
Total included in these plots: 5437  
Total cruises: 29

year	cruises	n	range of mean depths
2018:	4	48	51-87m
2019:	4	1427	47-80 m
2020:	4	955	49-87 m
2021:	4	905	52-83 m
2022:	3	831	51-76 m
2023:	4	532	55-82 m
2024:	3	406	38-54 m
2025:	3	333	38-55 m

**Q: Is there temporal and spatial variation in the age versus length relationship?**



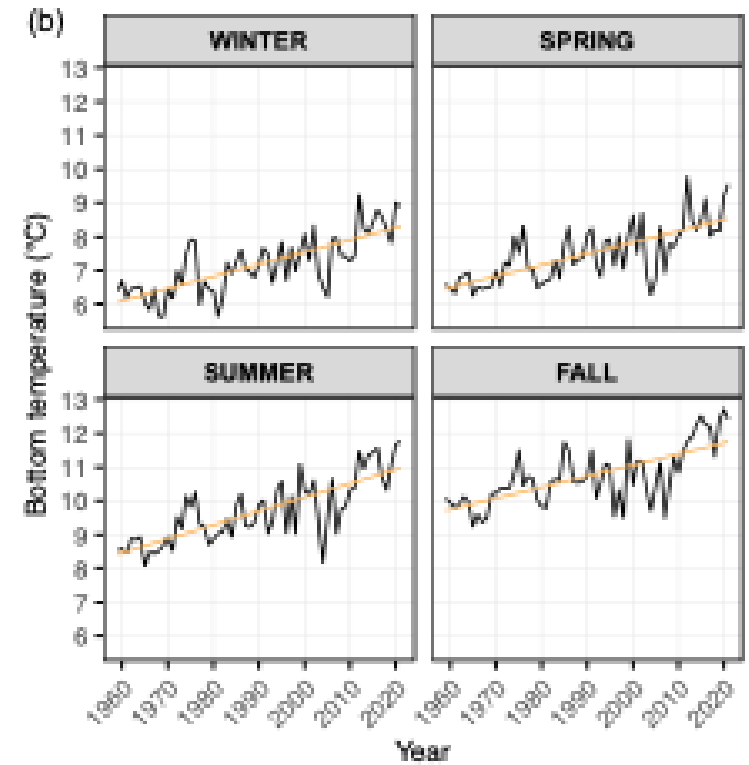
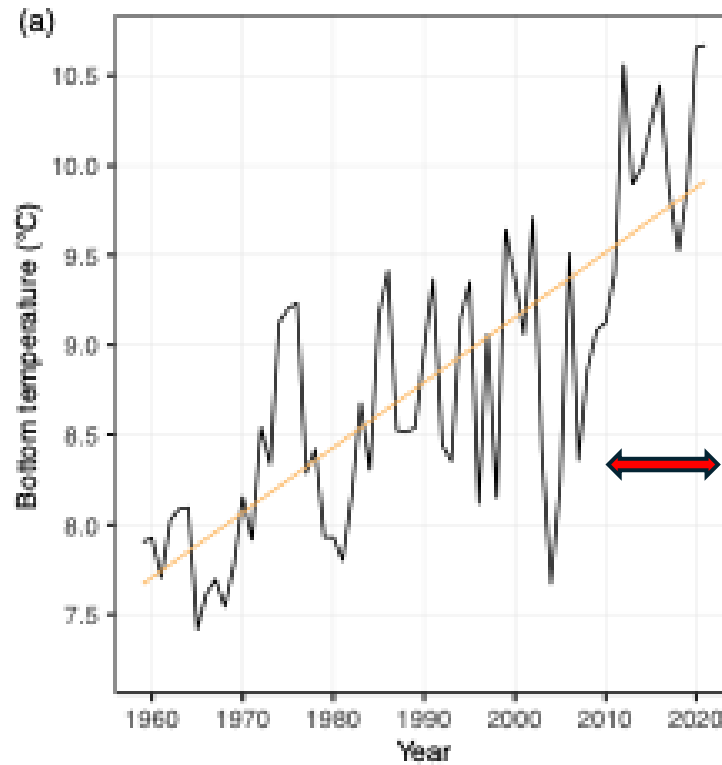
1980



2024

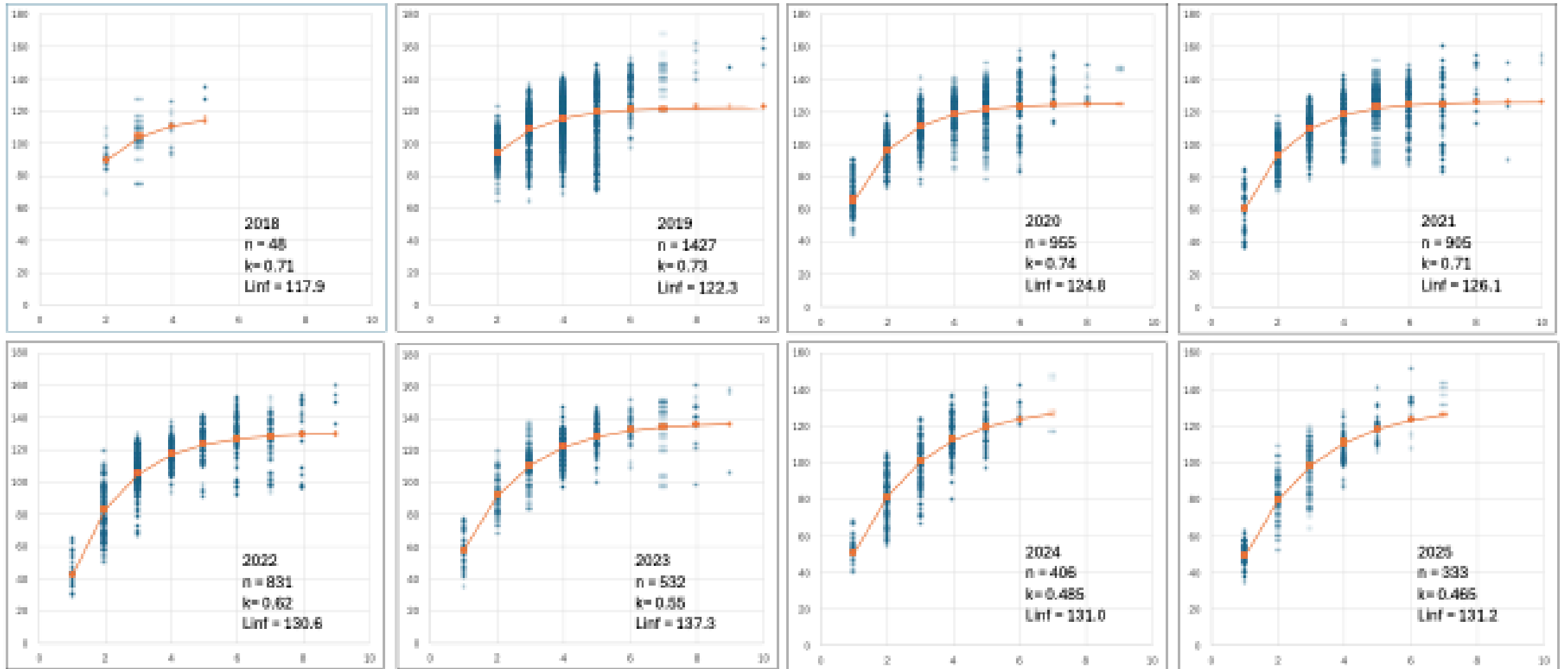
The data cover a large area in a limited time frame –  
Scallop distribution: DisMap portal, NEFSC surveys

Regional warming: duPontavice et al (2023)  
[doi.org/10.1016/j.pocean.2022.102948](https://doi.org/10.1016/j.pocean.2022.102948)

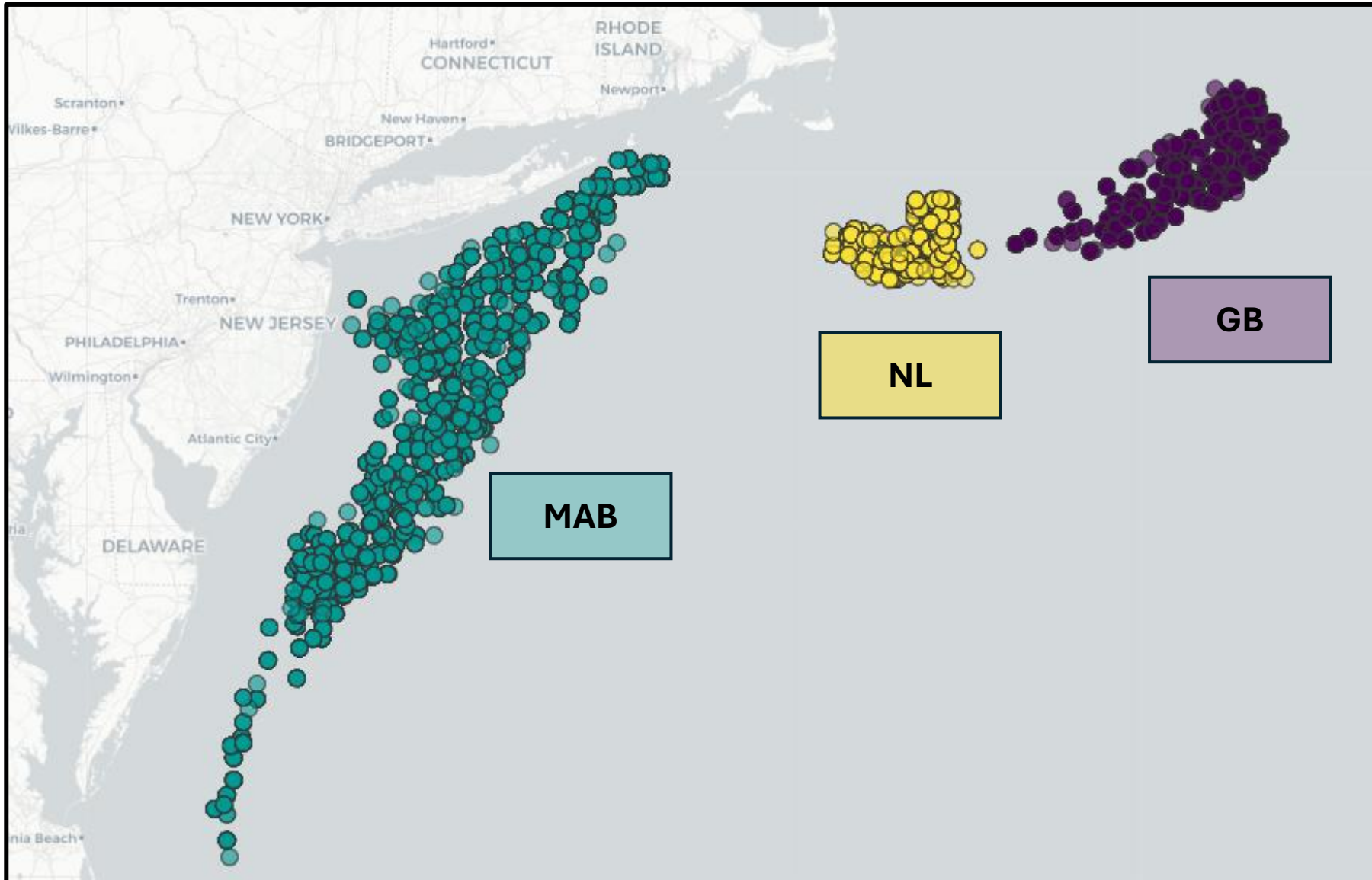


Birth years (BY) for our data cover the period **~2009-2024 (15 years)**

Individual age at length values, **by year, all cruises**, with n values, von Bert k and Linf

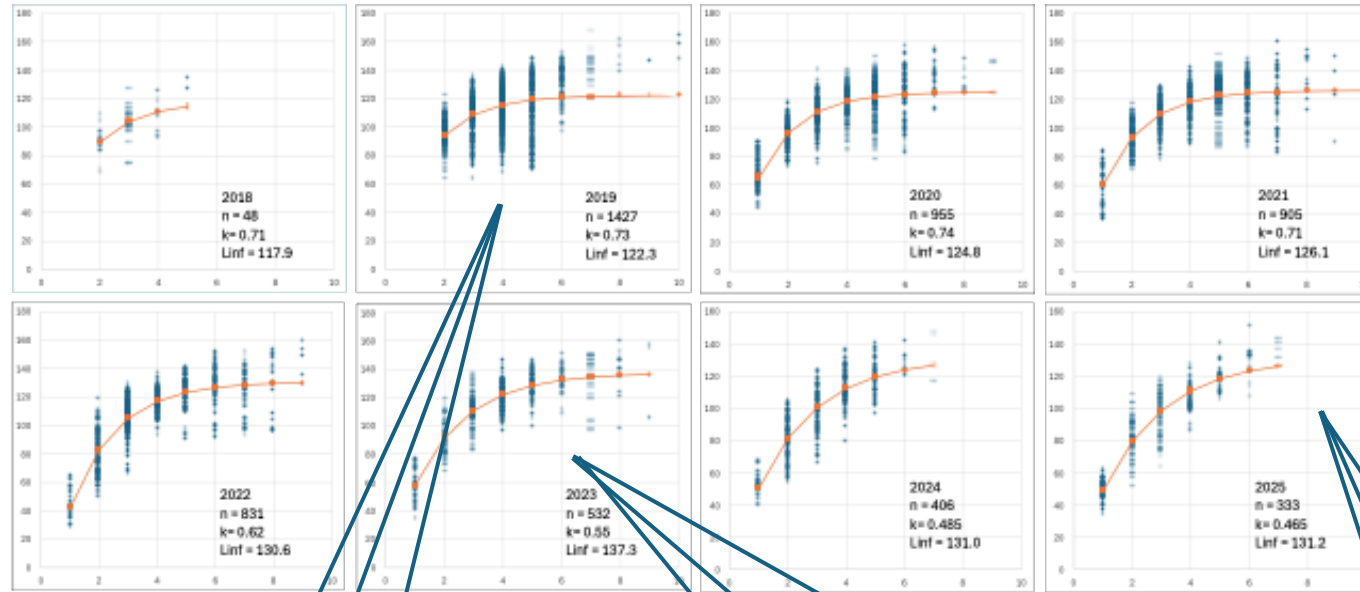


Some notable differences among these plots, and still a lot of variation around the fit.



We could consider data by three spatial strata:  
MAB: Mid Atlantic  
NL: Nantucket Lightship  
GB: Georges Bank.  
This would be justified by the physical oceanography

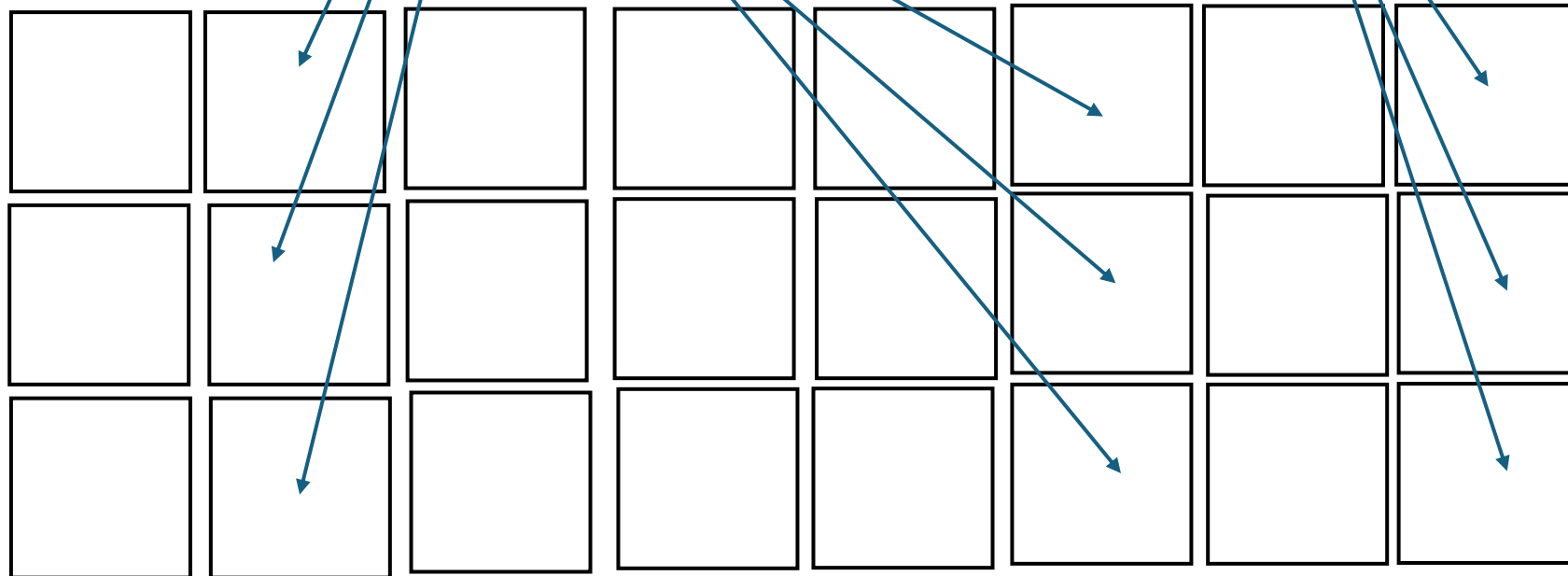
Make a matrix of plots with year and area Bert k and Linf values, then compare, BUT this remains one data point per scallop



MAB

NL

GB



## How many data points are we considering?

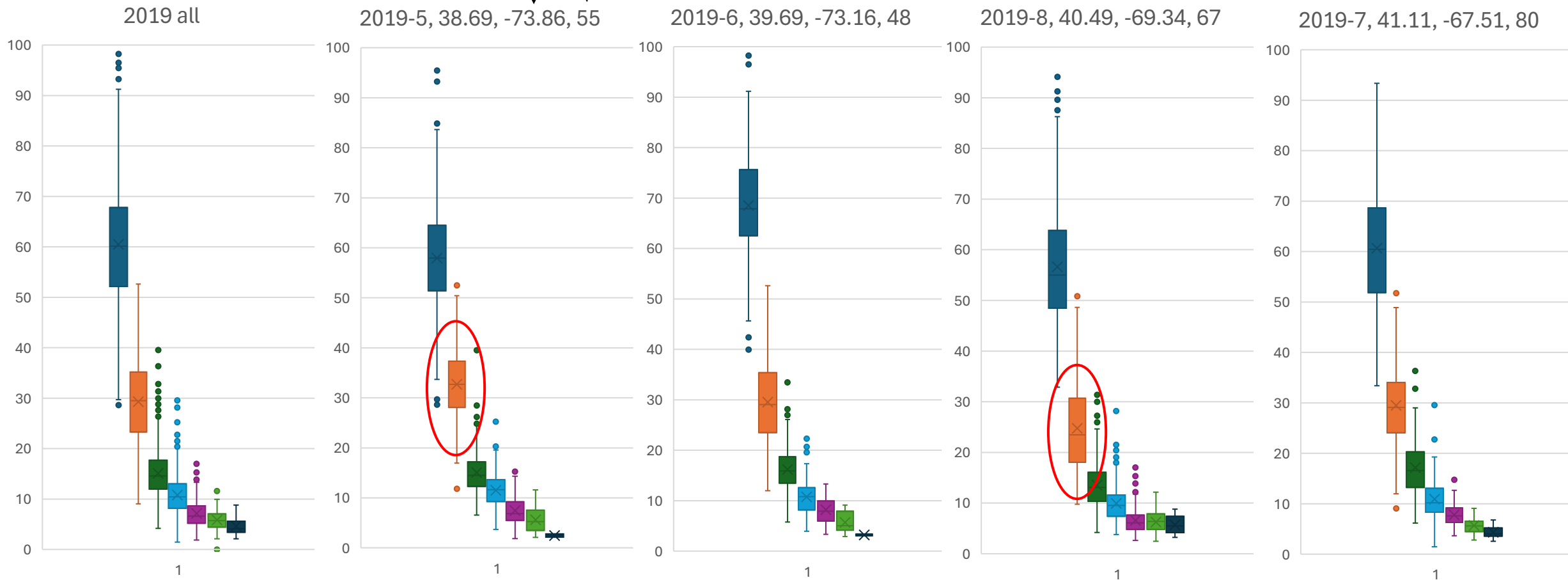
	2018	2019	2020	2021	2022	2023	2024	2025	TOTAL	
# scallops	1		118	42	25	37	37	78	337	
	2	14	210	142	158	153	63	101	68	909
	3	24	271	173	172	251	116	97	80	1184
	4	8	548	183	159	144	158	102	55	1357
	5	2	274	221	178	110	82	58	33	958
	6		97	85	136	69	34	9	15	445
	7		18	25	44	57	27	2	4	177
	8		5	6	10	18	13			52
	9		1	2	4	4	2			13
	10		3		2					5
TOTAL	48	1427	955	905	831	532	406	333	5437	
# increments	1		118	42	25	37	37	78	337	
	2	28	420	284	316	306	126	202	136	1818
	3	72	813	519	516	753	348	291	240	3552
	4	32	2192	732	636	576	632	408	220	5428
	5	10	1370	1105	890	550	410	290	165	4790
	6		582	510	816	414	204	54	90	2670
	7		126	175	308	399	189	14	28	1239
	8		40	48	80	144	104			416
	9		9	18	36	36	18			117
	10		30		20					50
TOTAL	142	5582	3509	3660	3203	2068	1296	957	20417	

	2018	2019	2020	2021	2022	2023	2024	2025	TOTAL	
# scallops	1		118	42	25	37	37	78	337	
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	7		18	25	44	57	27	2	4	177
	8		5	6	10	18	13			52
	9		1	2	4	4	2			13
	10		3		2					5
	TOTAL	48	1427	955	905	831	532	406	333	5437
	eliminate first increment, then									
	curves 5 points		445							
	curves 6 point		177							
	curves 7 points		52							
	curves 8 points		13							
	TOTAL		687							

Subsumed within this data set is 687 individual level plots with 5 or more points!

# Annual growth increments over space within a year: 2019, n = 1496

Cruise #, LAT, LONG, Depth(m)



Southwest  Northeast

# Annual growth increments over space within a year: 2020, n= 1093

Cruise #, LAT, LONG, Depth(m)

↓ ↓ ↓ ↓

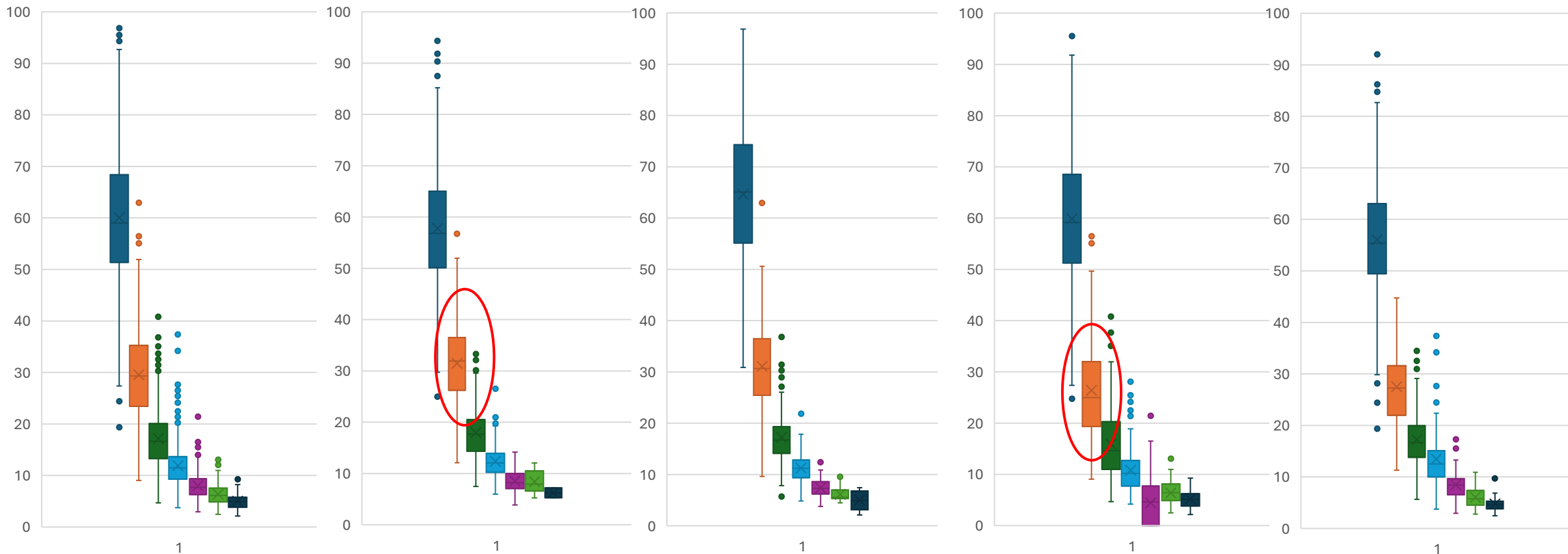
2020 all

2020-3, 38.72, -73.67, 58

2020-4, 40.09, -72.75, 49

2020-6, 40.78, -69.33, 68

2020-5, 41.09, -67.42, 49

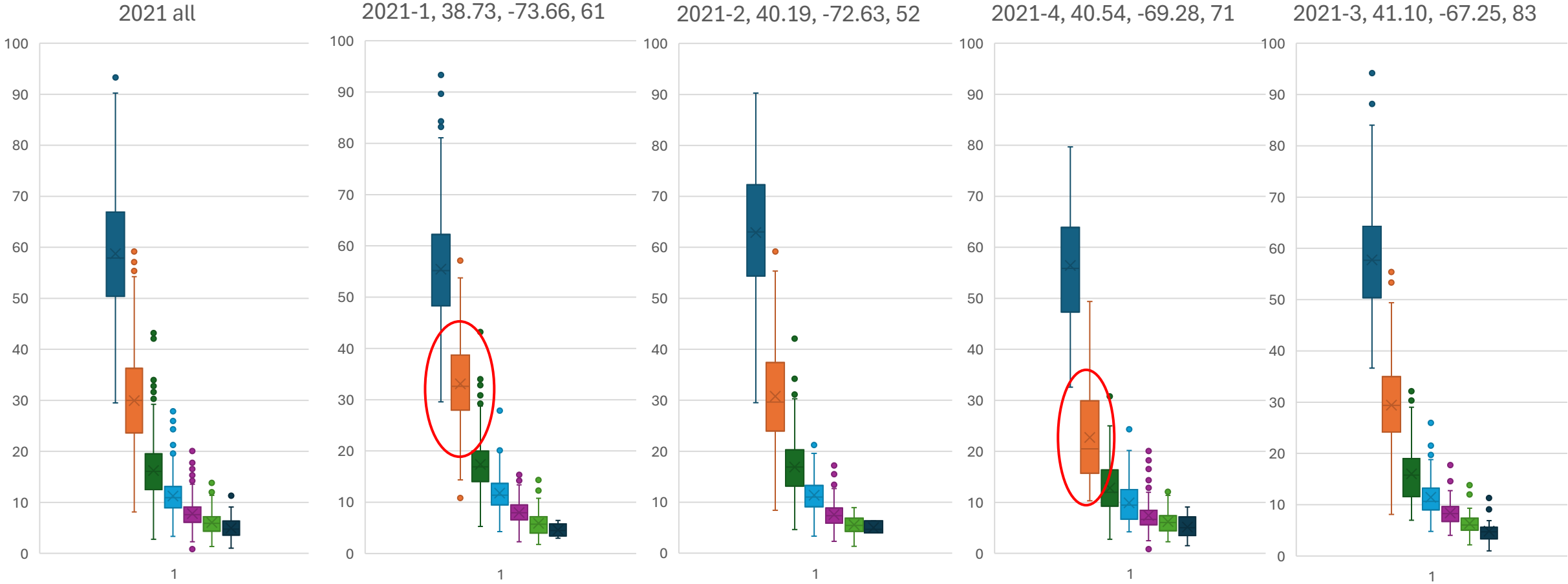


Southwest  Northeast

# Annual growth increments over space within a year: 2021, n = 935

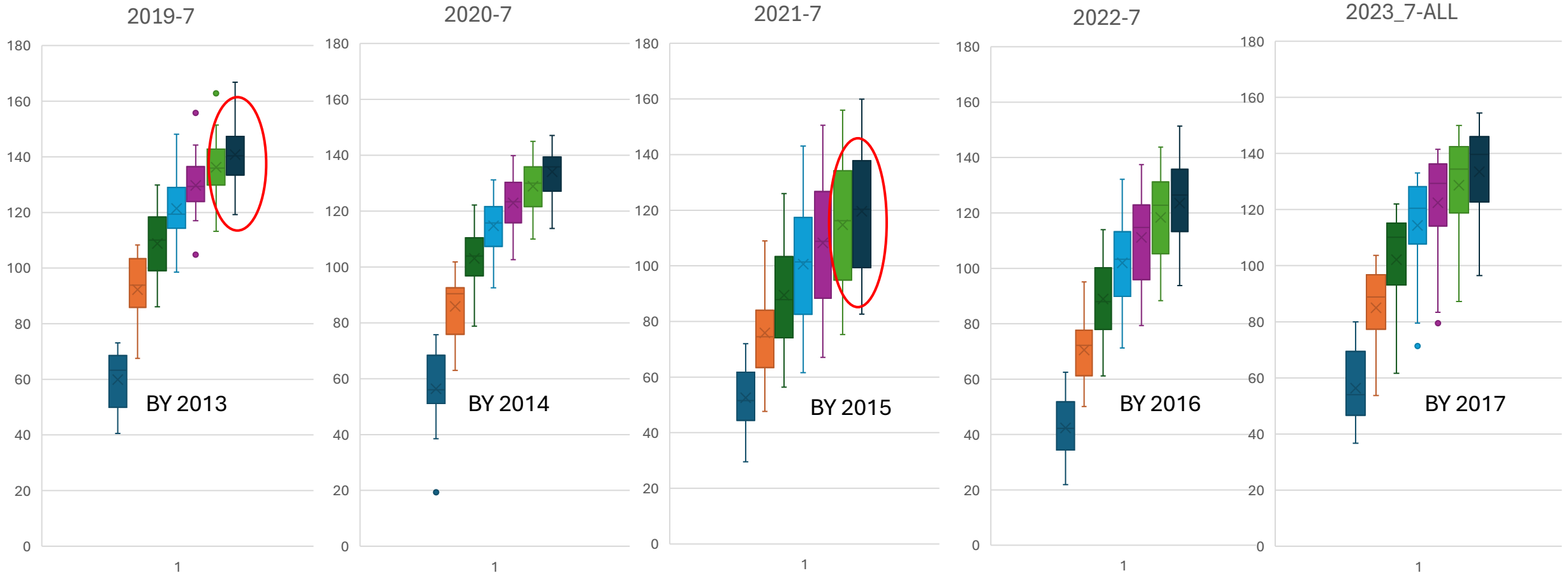
Cruise #, LAT, LONG, Depth(m)

↓ ↓ ↓ ↓



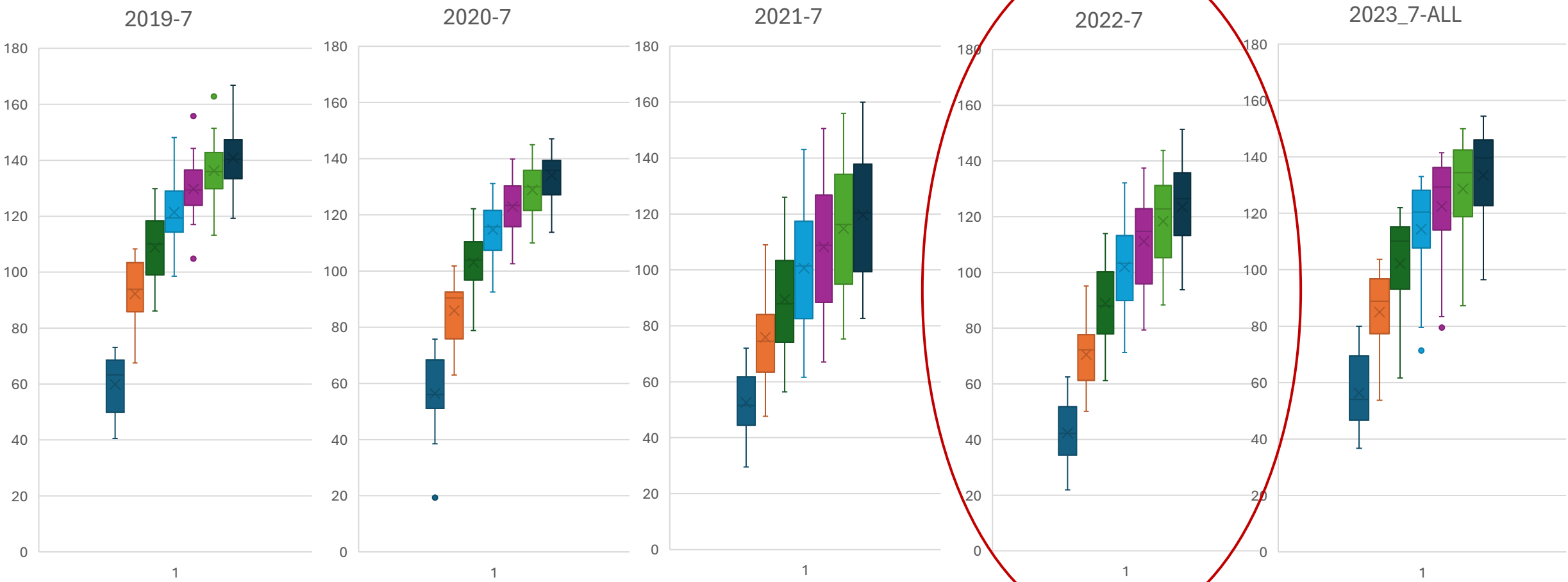
Southwest  Northeast

But there is also information within the year class data - consider the length with age records in the 7-year old by year all cruises



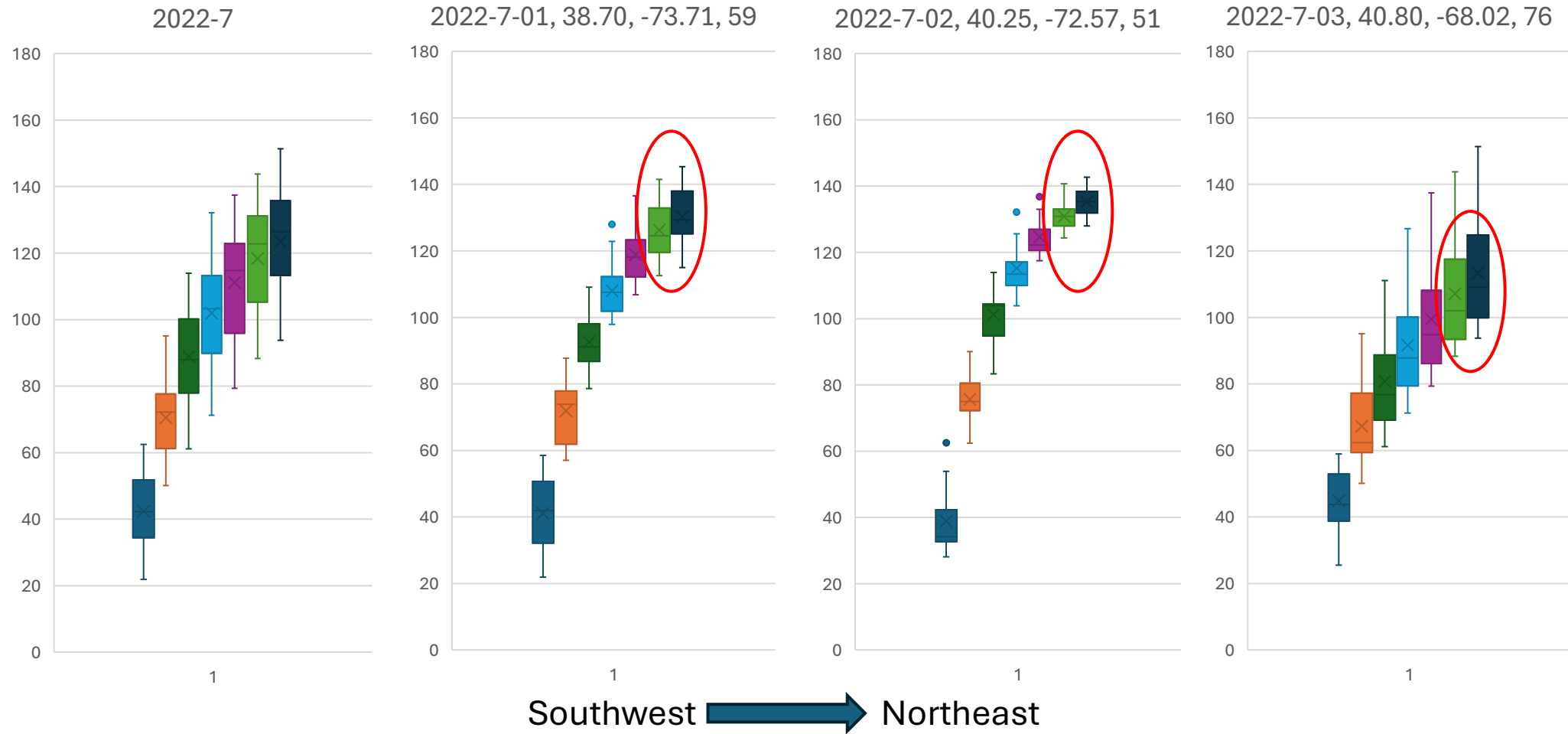
Each individual archives of multiple year's worth of data, plots suggest variation over time.

But there is also information within in the year class data - consider the length with age records in the 7-year olds by year all cruises



Let's explore a single year in more detail

# There is structure within 7-year olds (BY 2016) in 2022 collections across space



**Let's explore increments** with something other than von Bertalanffy....

With kudos here to our colleague **Challen Hyman**

A Gompertz curve with an inflexion early in the curve.

$$L_a = L_\infty \exp\left(-\exp\left(-K(a - a_{\text{inf}})\right)\right)$$

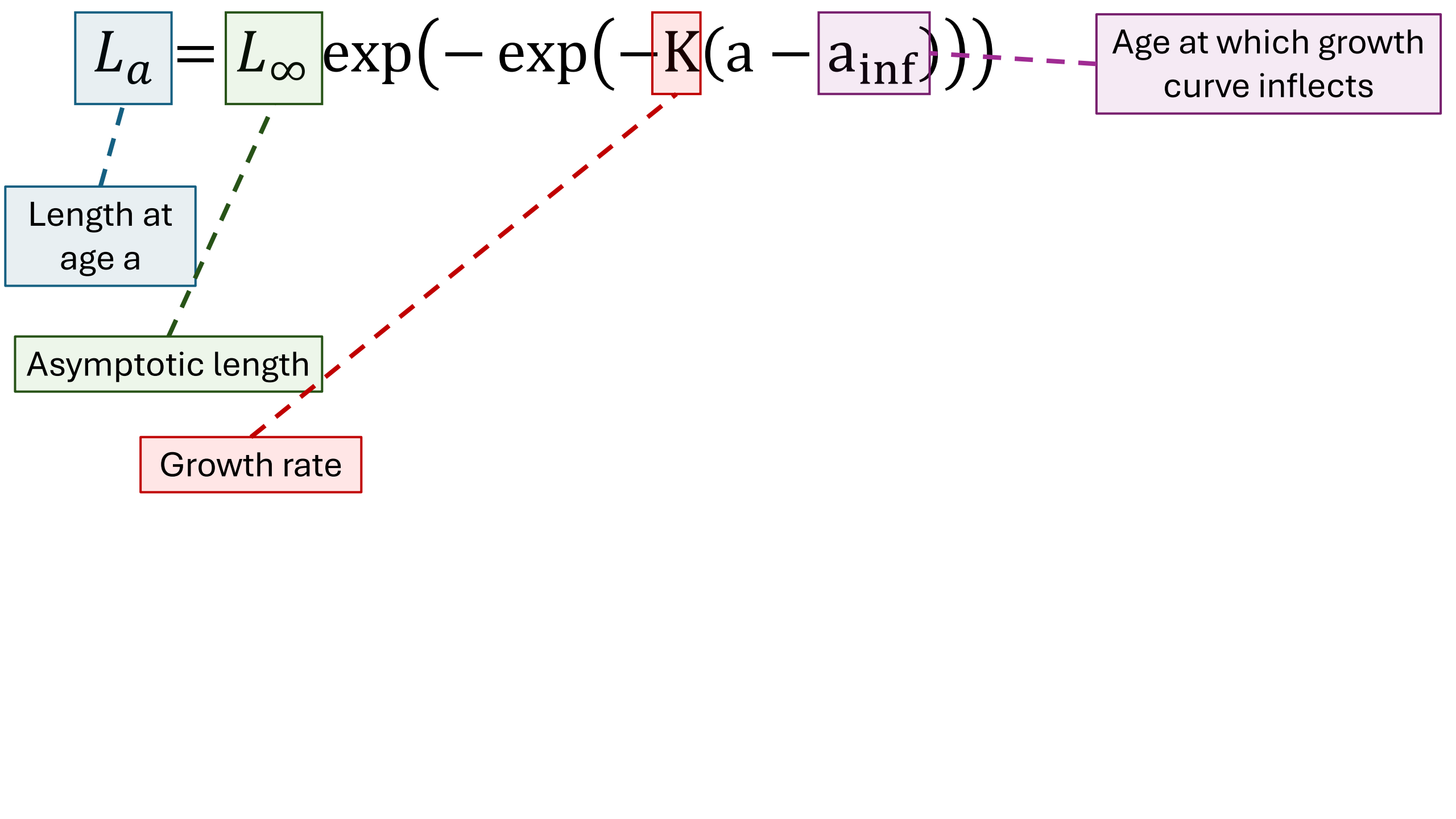
$$L_a = L_\infty \exp(-\exp(-K(a - a_{\text{inf}})))$$

Age at which growth curve inflects

Length at age a

Asymptotic length

Growth rate



$$L_a = L_\infty \exp\left(-\exp\left(-K(a - a_{\text{inf}})\right)\right)$$

$L_a$  =  $L_\infty$   $\exp\left(-\exp\left(-\right.$   $K$   $\left.(a - \right.$   $a_{\text{inf}}$   $\left.)\right)\right)$

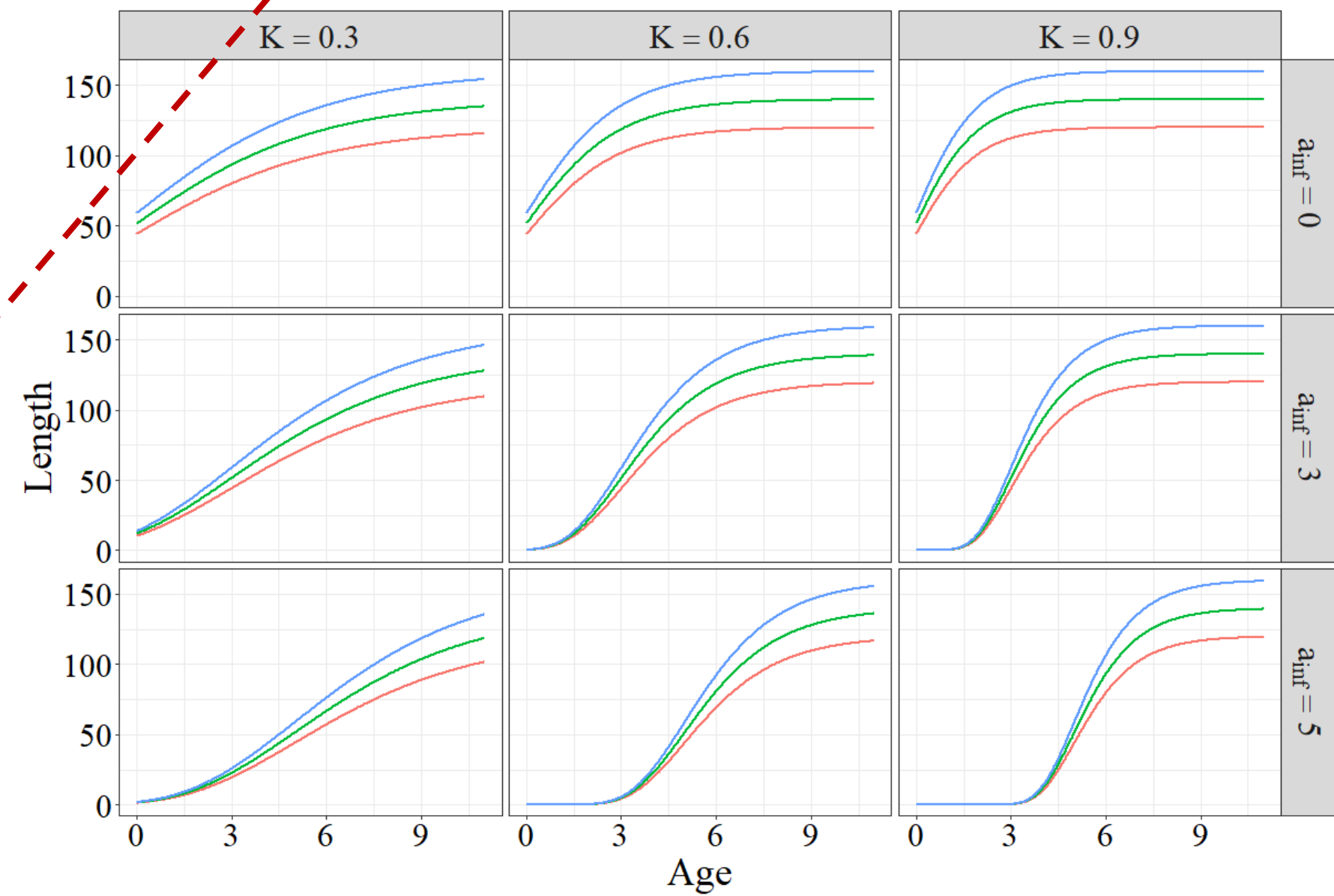
Age at which growth curve inflects

$L_{\text{inf}}$  — 120 — 140 — 160

Length at age a

Asymptotic length

Growth rate



$$L_a = L_\infty \exp\left(-\exp\left(-K(a - a_{inf})\right)\right)$$

$$\ln L_\infty = \beta_0 + \tau_{W_\infty}$$

$$\ln K = \alpha_0 + \tau_K$$

$$\ln a_{inf} = \gamma_0 + \tau_{a_{inf}}$$

Log-scale  
estimation  
keeps  
parameters  
positive

Population-level  
average value

Individual-specific  
random deviation

For multiple measurements per individual,  
include individual-specific random effects  
for each growth parameter to account for  
variation in biology

$$L_a = L_\infty \exp\left(-\exp\left(-K(a - a_{inf})\right)\right)$$

$$\ln L_\infty = \beta_0 + \beta_1 x + \tau_{W_\infty}$$

$$\ln K = \alpha_0 + \alpha_1 x + \tau_K$$

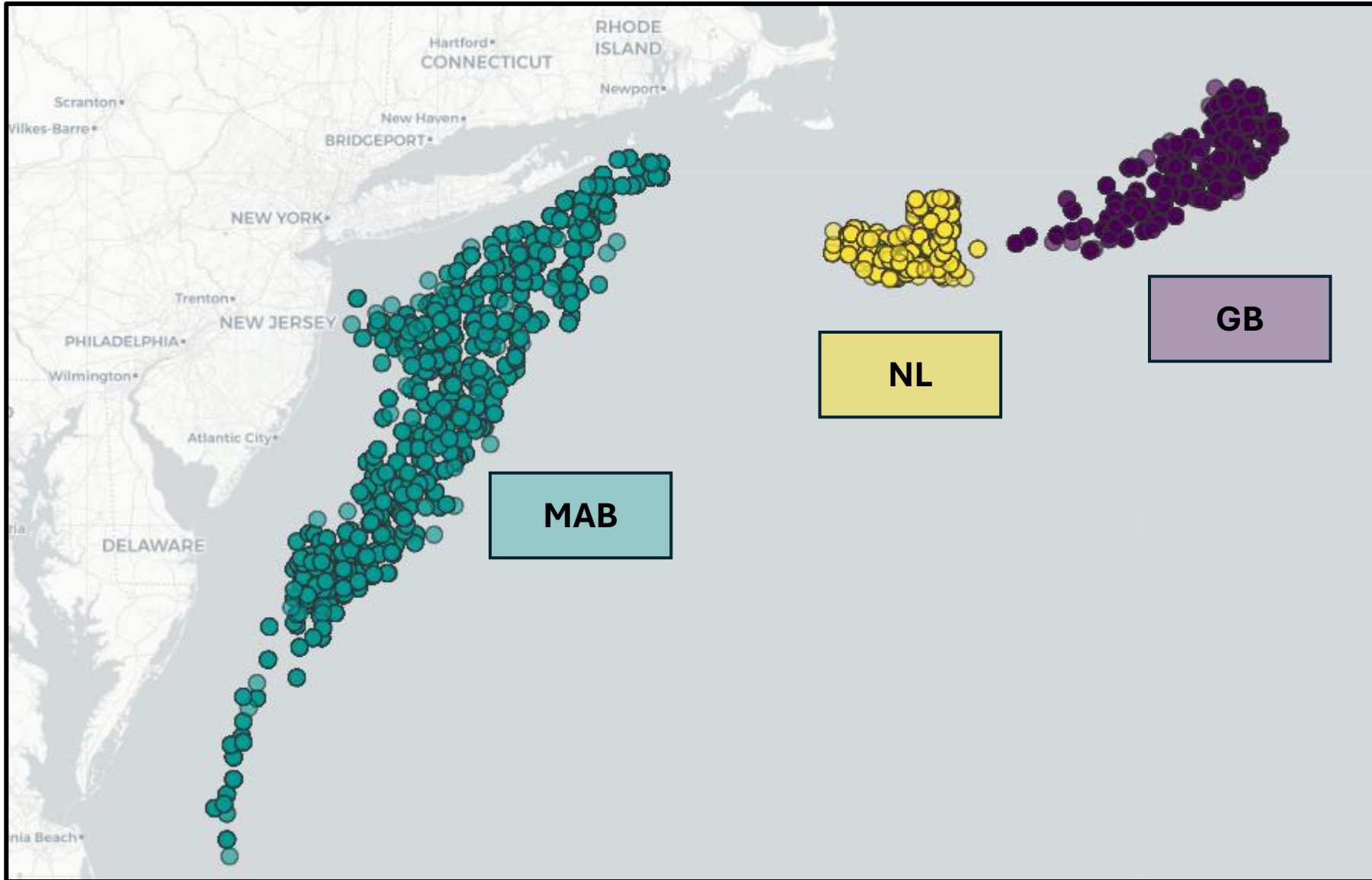
In addition to individual biology, models can be easily augmented to include environmental components

$$\ln a_{inf} = \gamma_0 + \gamma_1 x + \tau_{a_{inf}}$$

Population-level average value

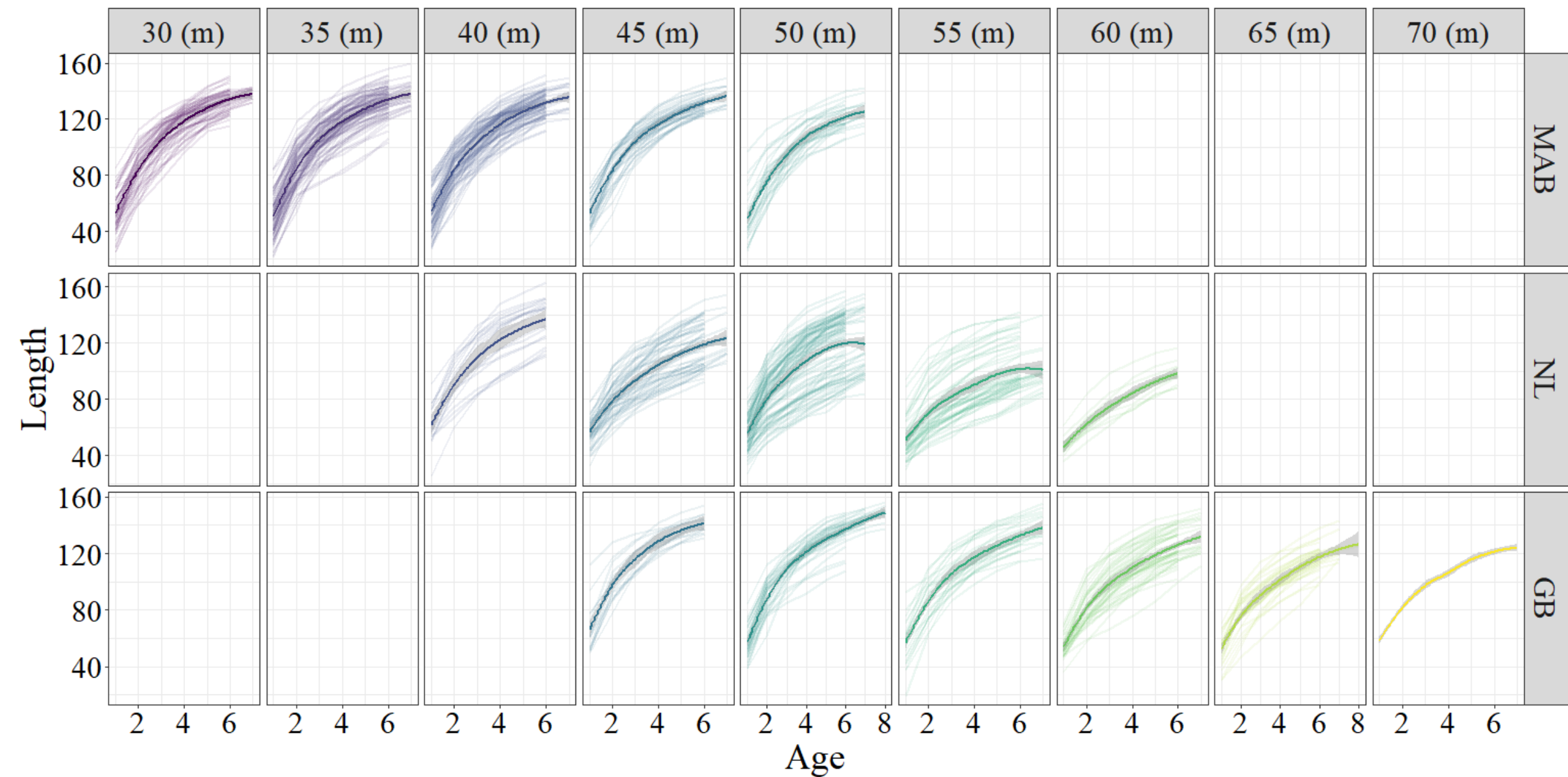
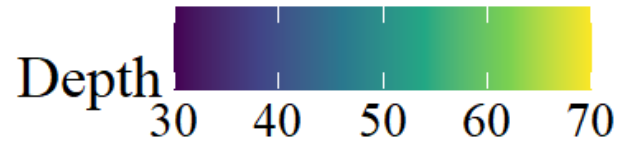
Individual-specific random deviation

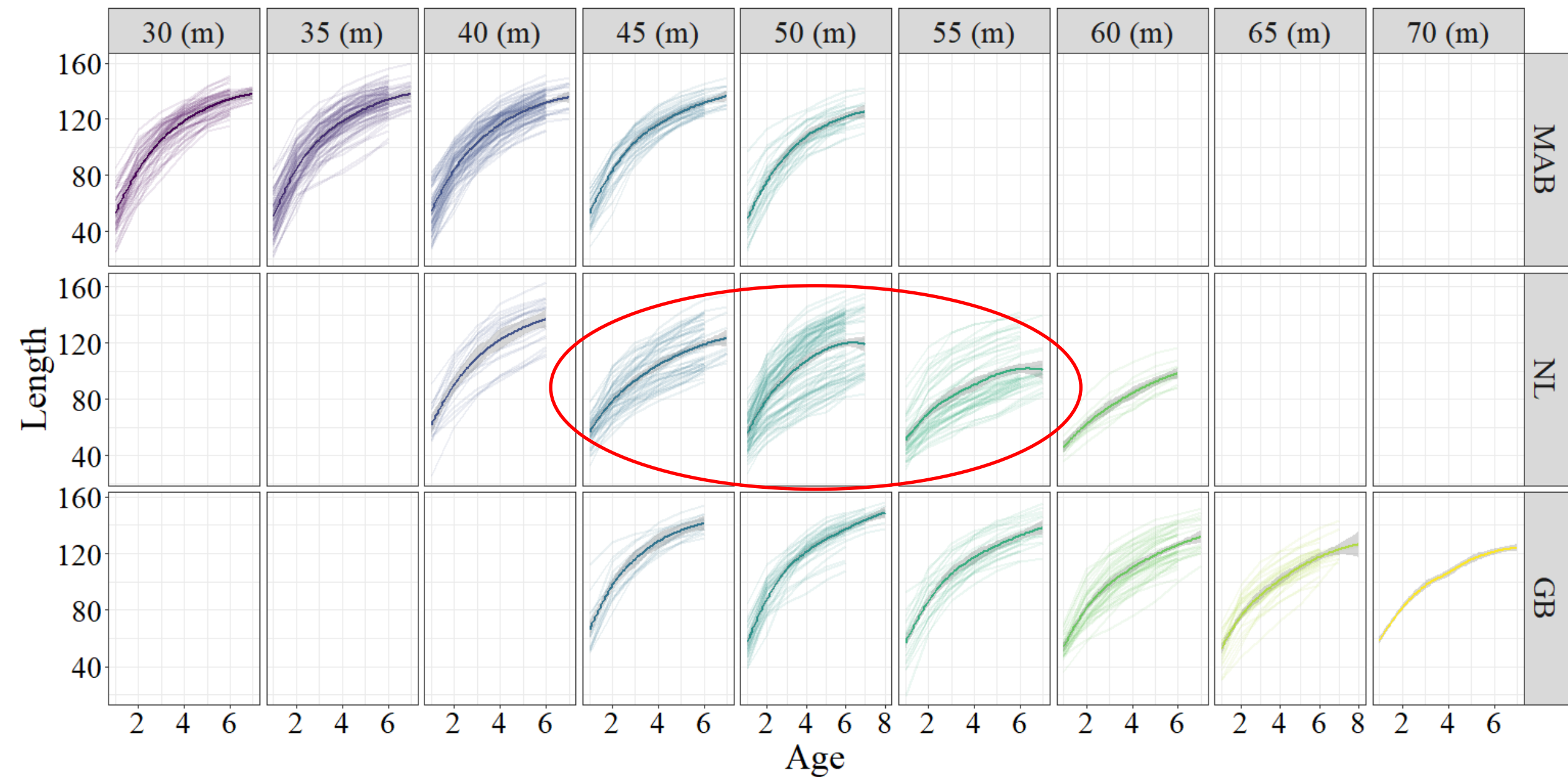
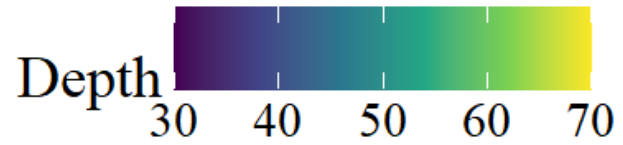
Environmental effect



Stratified individual scallops by three spatial strata  
MAB: Mid Atlantic  
NL: Nantucket Lightship  
GB: Georges Bank

NB: the time frame of scallop BY is small 2009-2024 (15 years).

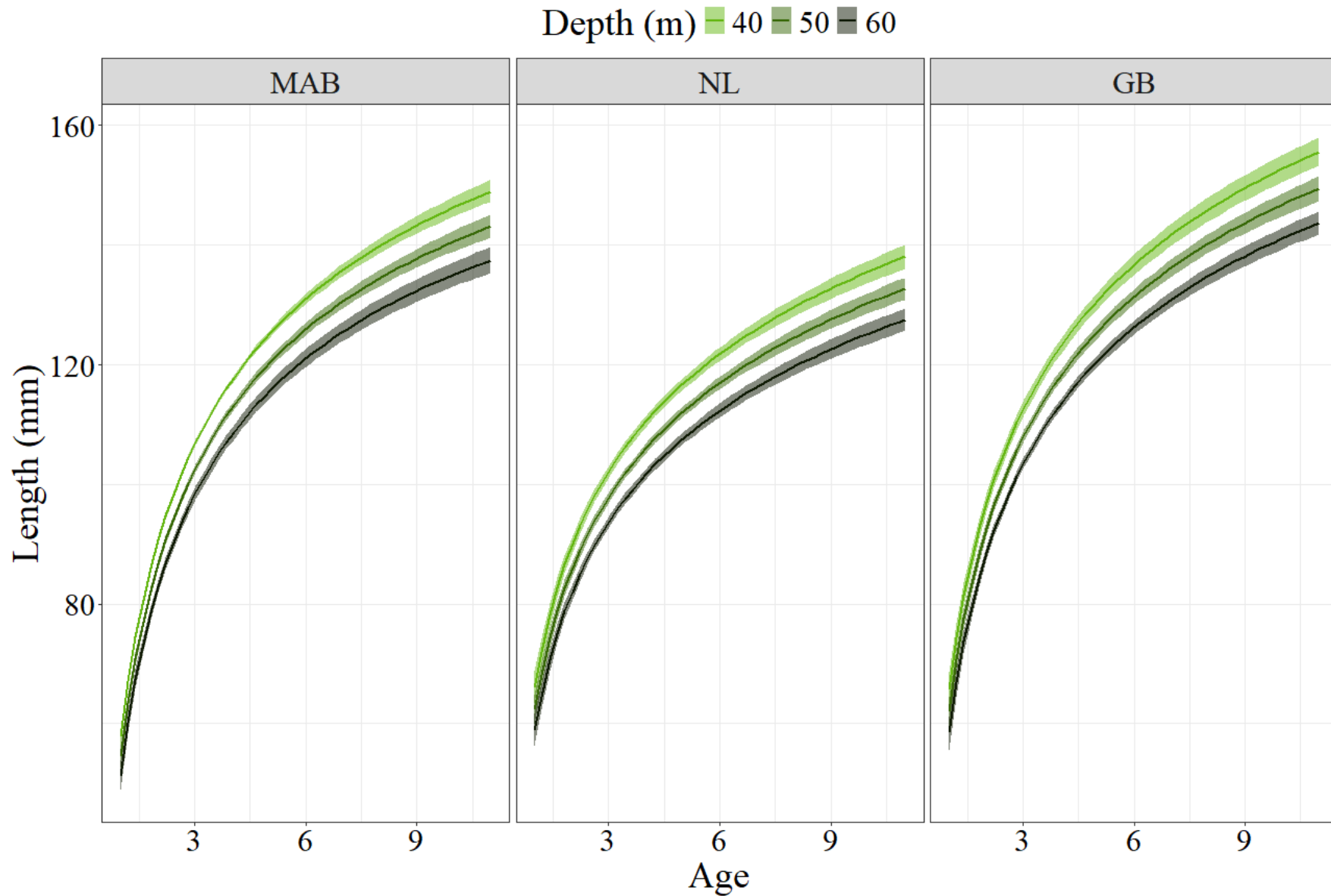




# Model framework

- Response variable: length at age
- $L_{\infty}$  and  $K$  modeled as function of depth and region
- $L_{\infty}$ ,  $K$ , and  $a_{\text{inf}}$  specified to vary due to individual-specific physiology

# Results

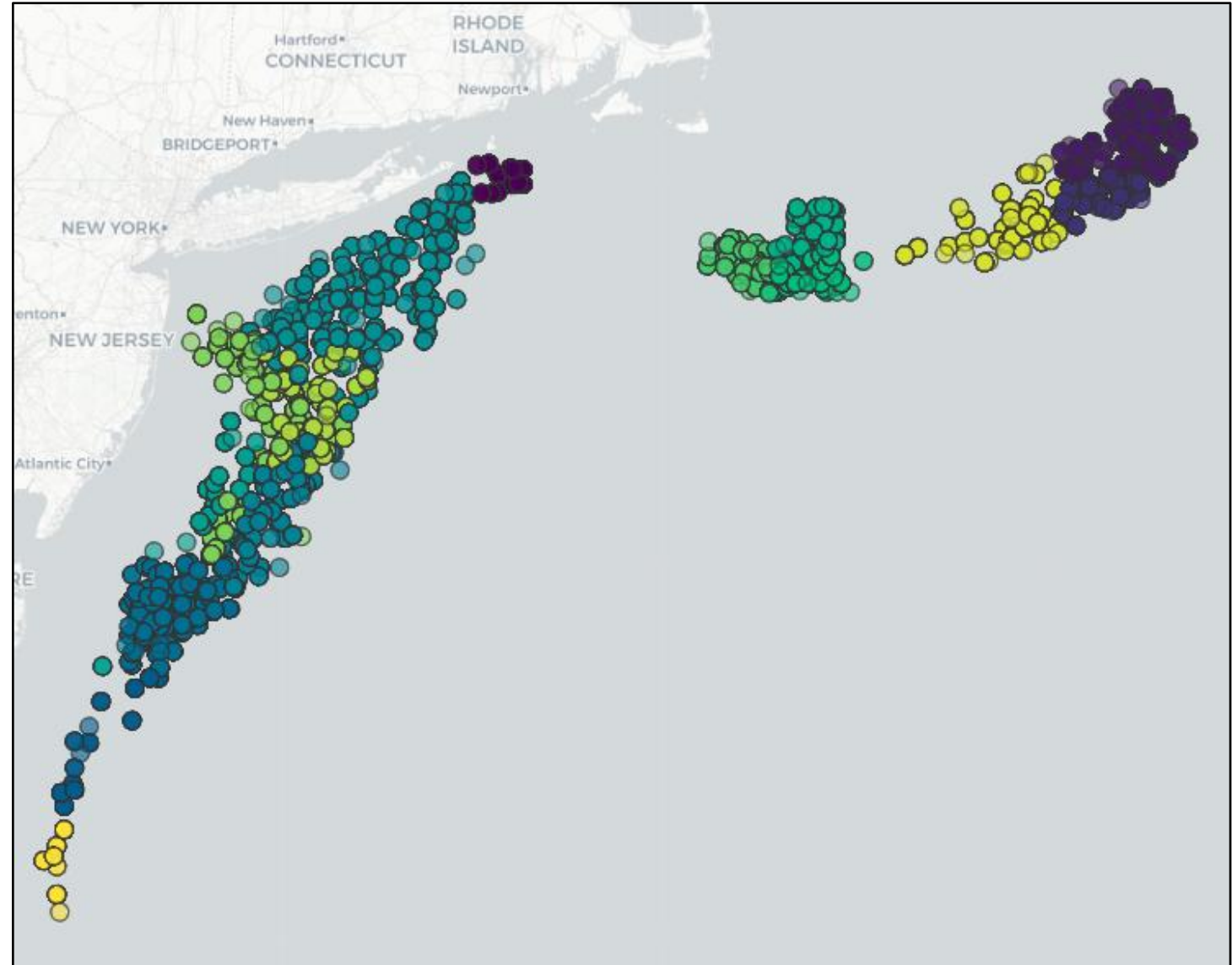


Both region and depth meaningfully affected scallop growth curves

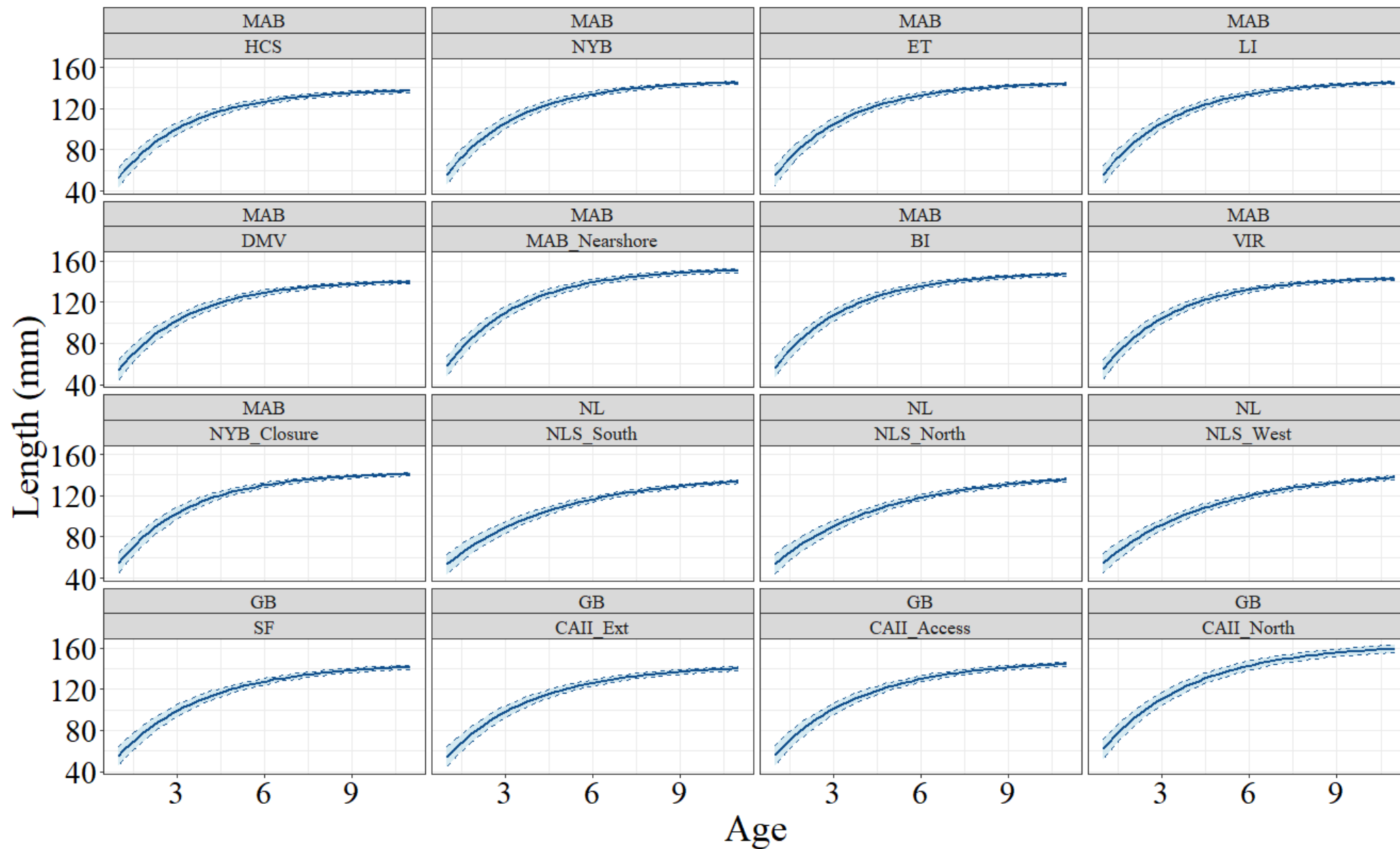
# Prediction framework using SAMS\* area where data is available

- For each management area:
  - Predict average growth curve based on
    1. Region
    2. Average depth

\*SAMS: Scallop Area Management Simulator  
7 in MAB, 12 on Georges Bank, 5 in Gulf of Maine



# Prediction framework using SAMS\* area: age v length for average depth



# Summary thoughts:

Field samples cost a lot of money to collect, we should ask how much data we can glean from them and then use all of it.

Original Q: focus - temporal and spatial variation in growth rates

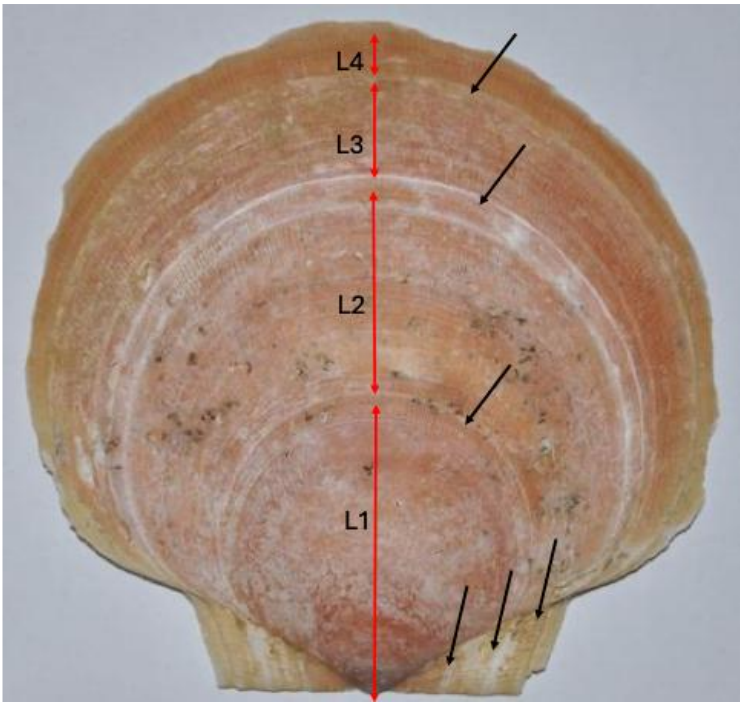
Q: Is there variation in age at length in the scallop population over time and space?

A: Yes, both space and depth (maybe need longer time series for time, but we can explore the environmental drivers)

Q: Can we describe this variation in quantitative terms?

A: Yes, we can von Bert at whole population or “regional” cruise level, but the abundance of increment data at the individual level allows more.

Q: Can we collect both age v length and increment data on a continuing basis?



Age estimation in surfclams from hinge sections.  
Image acquisition: Miguel Montalvo, VIMS  
Analysis: Heng Lian & Yi He, W&M Data Science

