UNIVERSITY OF MIAMI ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

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EARLY LIFE HISTORY AMERICAN FISHERIES SOCIETY

Environmental Effects on Larval Fish Ontogenetic Vertical Migration

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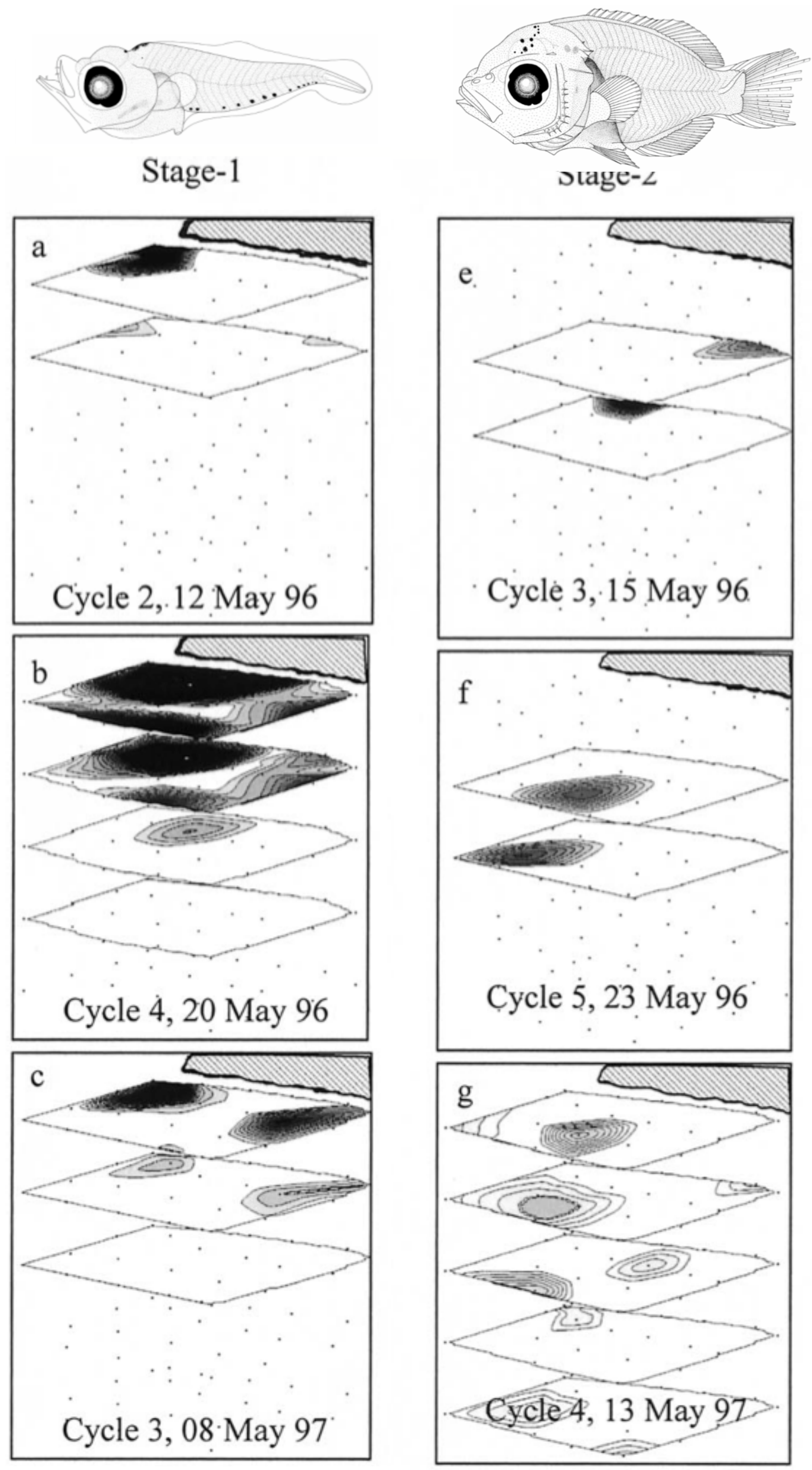
Motivation

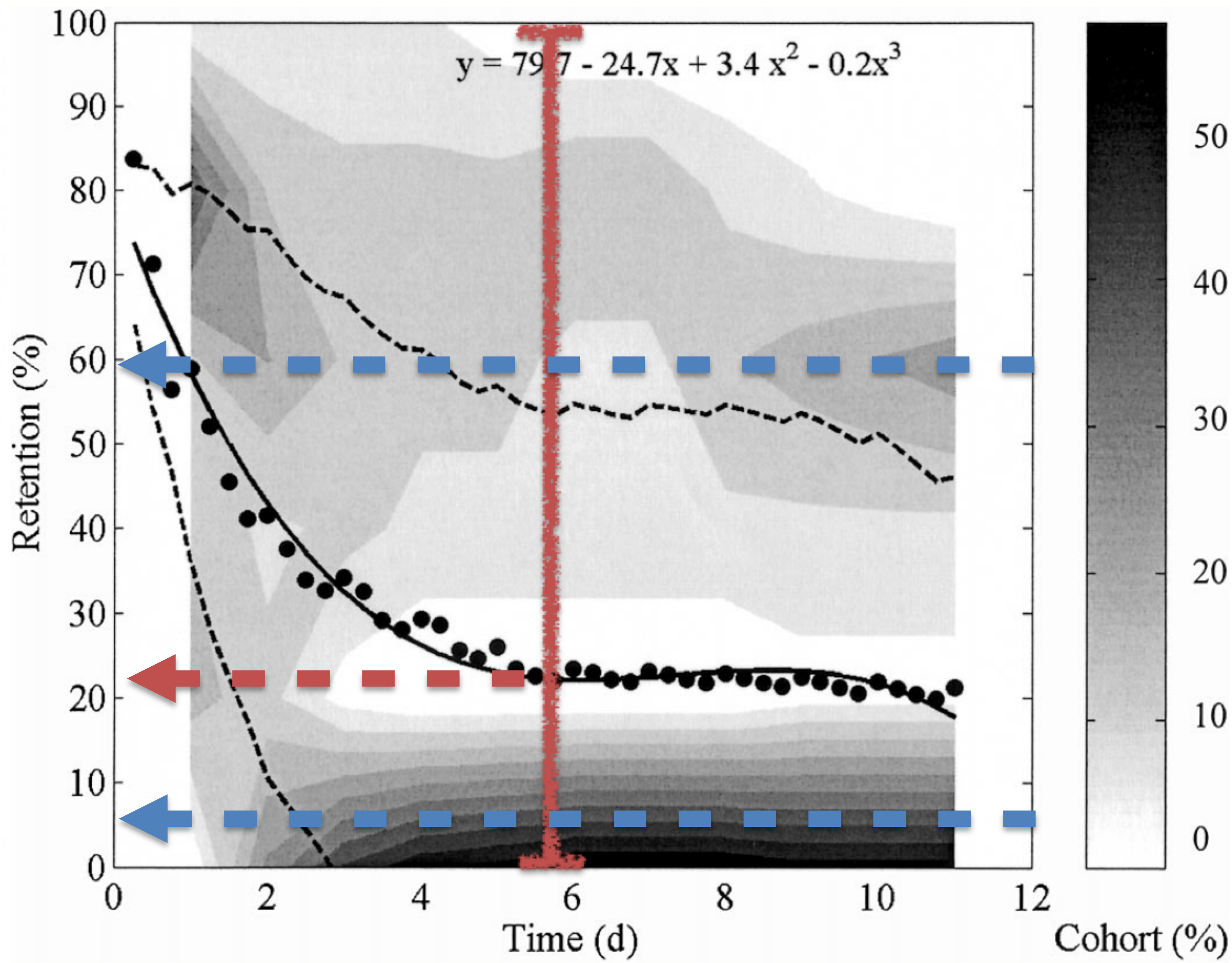
1. Ontogenetic Vertical Migration (OVM) is described by the changes in the depth center of mass between early pre-flexion and more developed post-flexion larval stages.
2. OVM is mainly driven by taxa and ontogeny, and is one of the prominent trait retaining larvae near their birth place [*Paris and Cowen 2004*].
3. OVM contributes to change the outcome of the dispersal within sheered flows, decreasing dispersal kernels and changing connectivity patterns [*Paris et al. 2007; Huebert et al. 2011*]
4. Only a few studies have reported the OVM of fishes [*Cha et al. 1994; Leis 2004; Paris and Cowen 2004; Hare et al. 2006; Irisson et al. 2008; Dalessandro et al. 2010*]
5. Even fewer studies that have focused on investigating environmental forcing mechanisms of vertical migration in larval fish [*Paris and Cowen 2004; Dalessandro et al. 2011; Huebert et al. 2011*]

Motivation
Ecological consequences of OVM - local retention

[Paris and Cowen 2004 *L&O;* Paris-Limouzy et al. 2005]



Stegastes partitus



Objectives & Methods

- **hypothesis**: fish larvae respond to changes in environmental conditions by modifying the center of mass and range of their vertical distribution in the water column

- We use an extensive ichthyoplankton survey around the island of Barbados (1996-1997) to demonstrate that OVM changes with water mass characteristics and clines

Sampling strategy

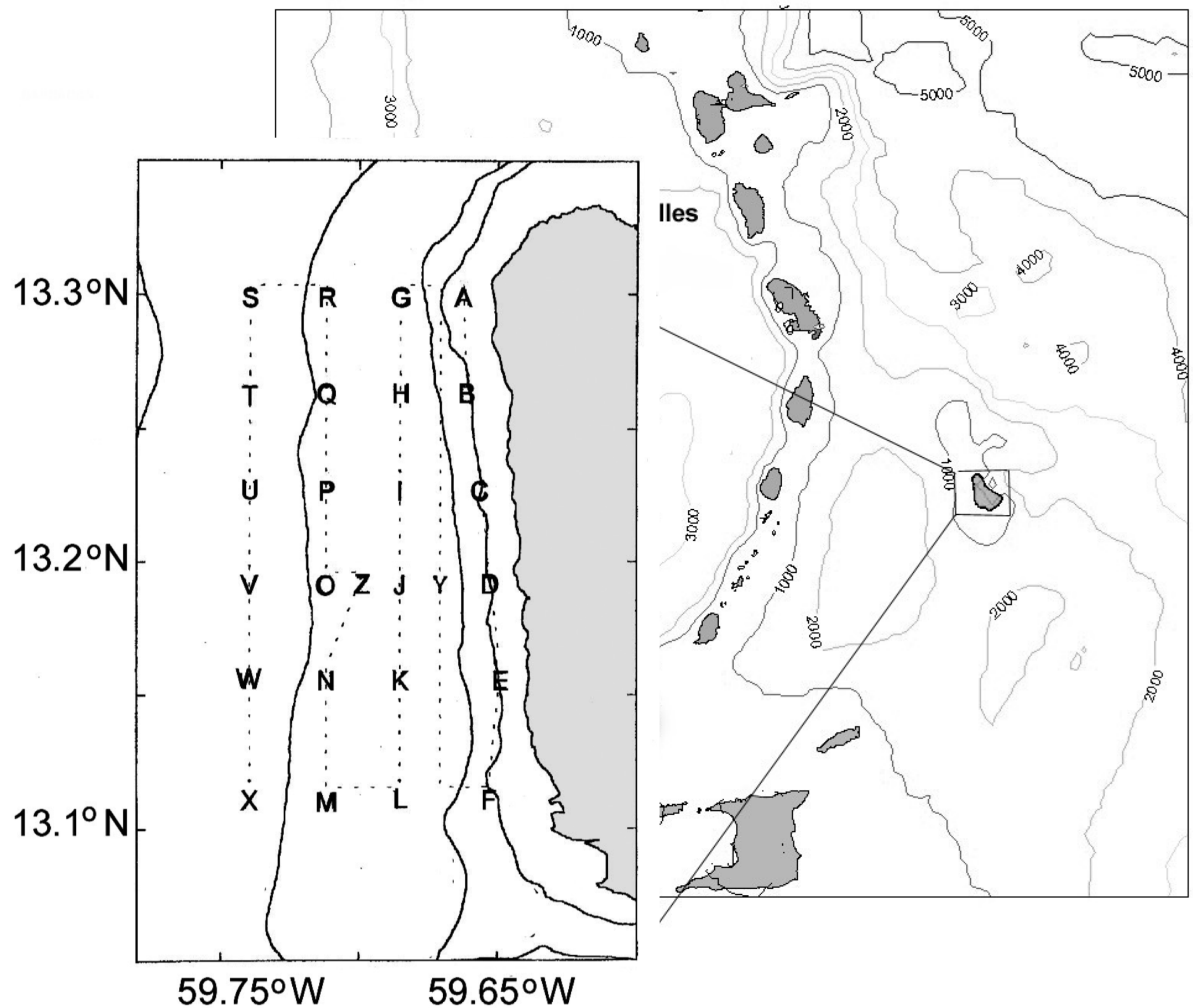
2 x 30-day sampling per year:
May 1996 & 1997

8 rotations x 3-day sampling x
26 stations (15 km x 20 km):

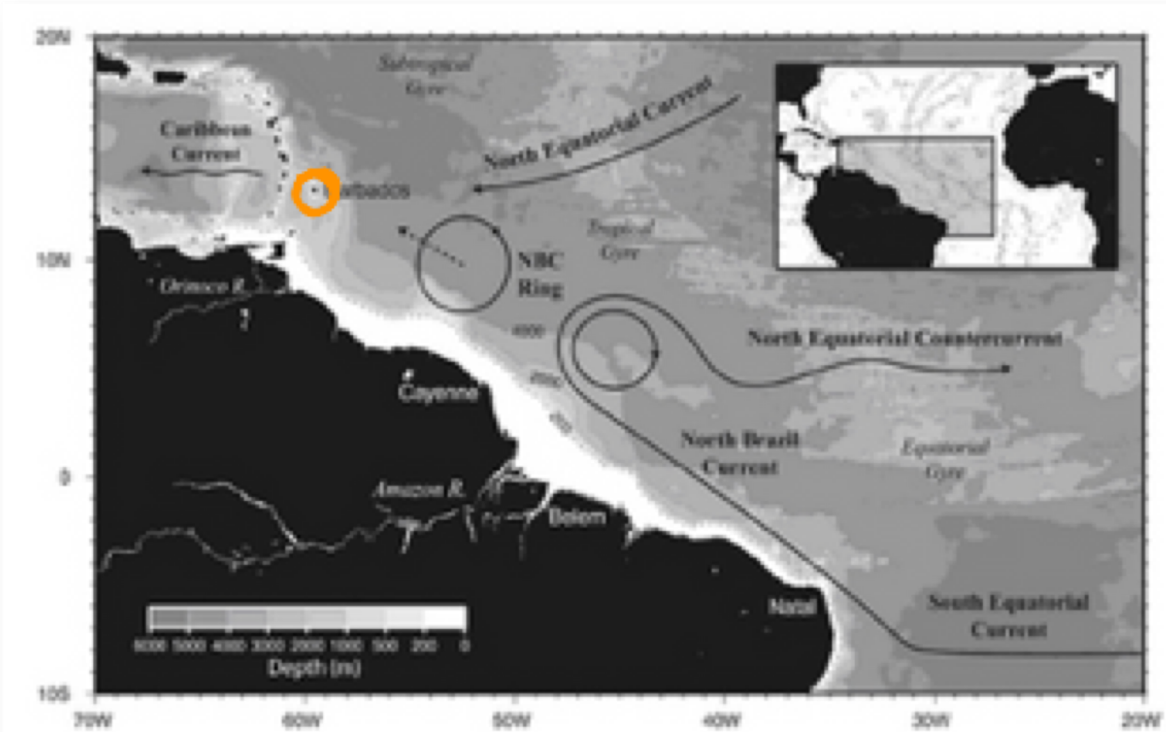
- day1 MOCNESS +CTD casts (depth, temperature, salinity transmission, fluorometry chlorophyll)
- day2 ADCP tracks
- day3 Argos Drifters

Depth range = 0-100 m
(1 net / 20 m bin = 5 nets)

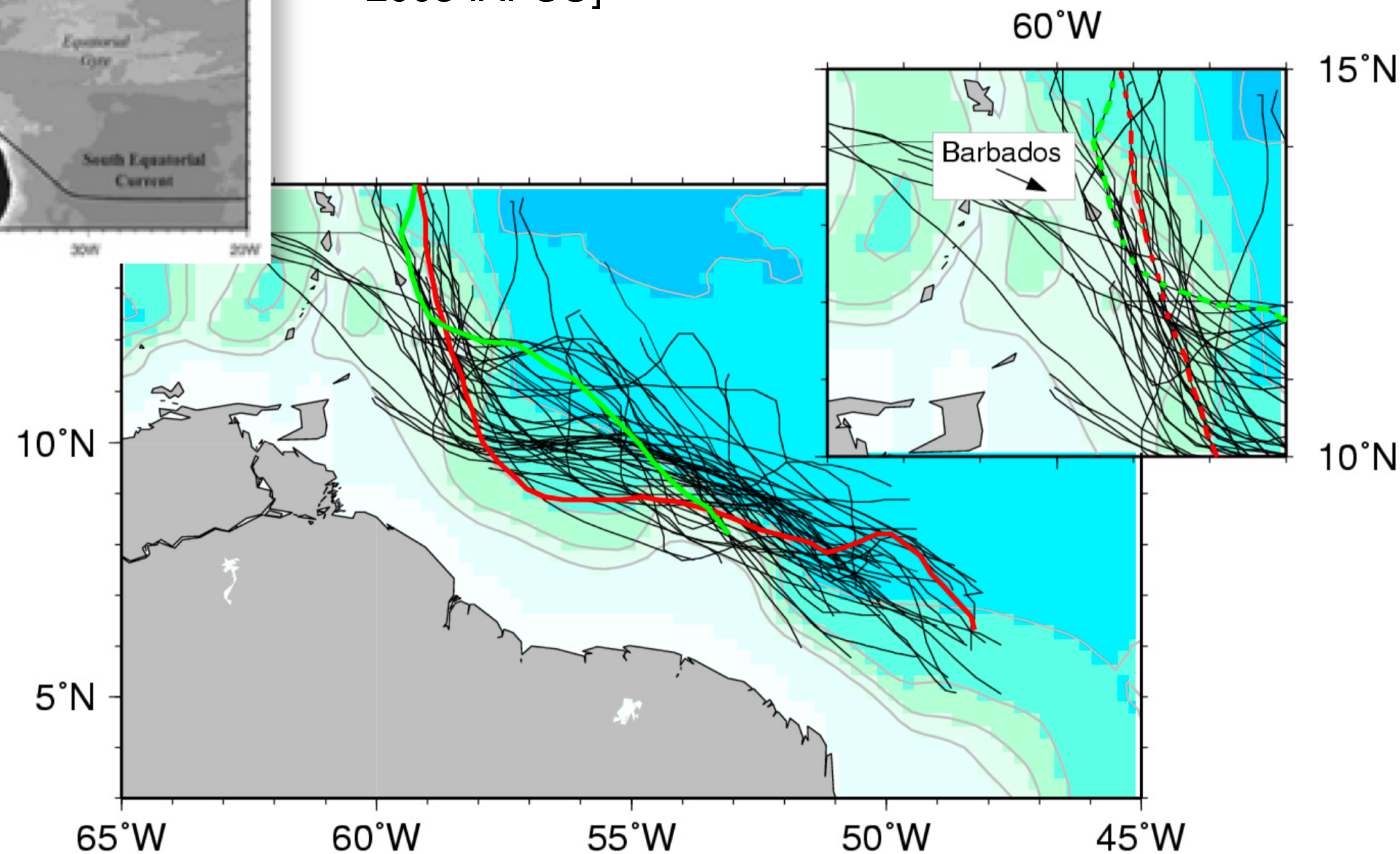
Total collected = *187,041*
fish larvae all stages



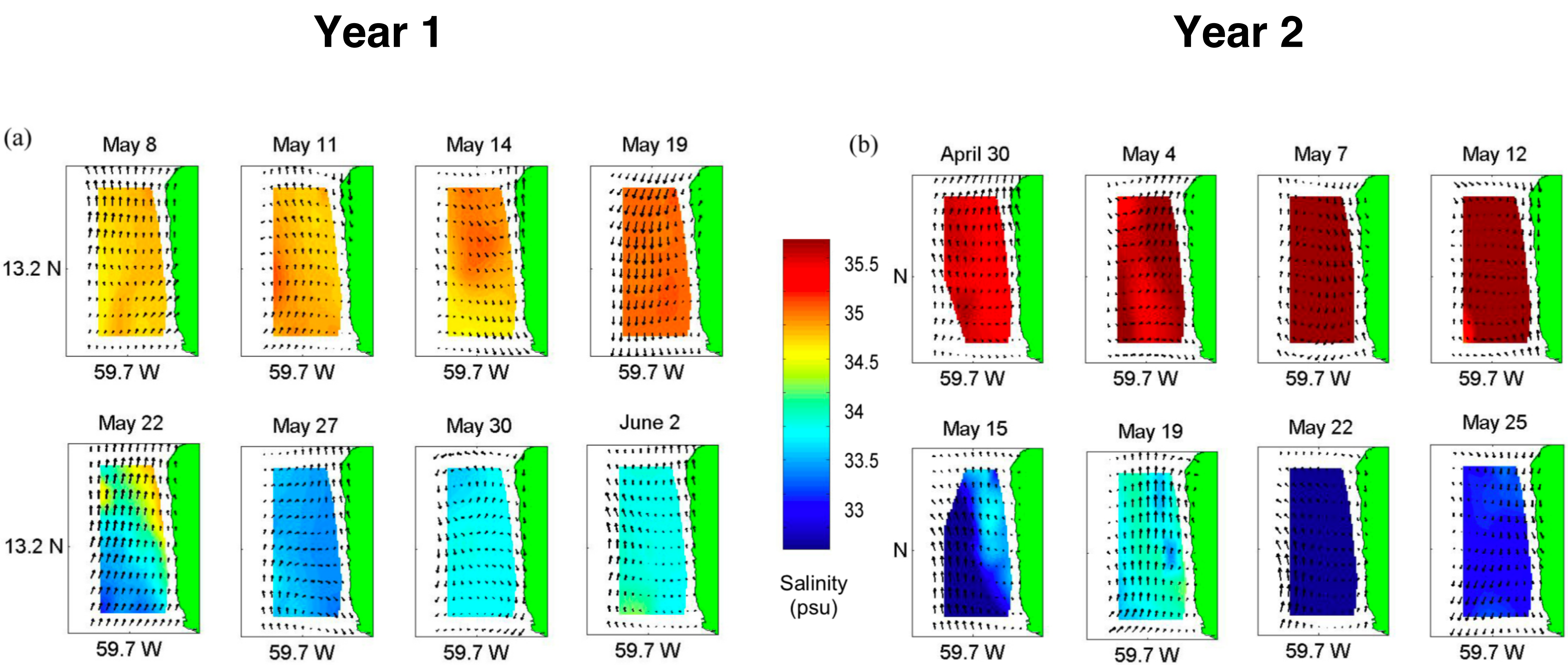
Influence of North Brazil Current Rings (NBCRs)



[Garraffo, Johns, Chassignet, Goni, 2003 IAPSO; Cowen, Paris, Sponaugle, Fortuna, Lwiza, Dorsey, 2003 IAPSO]



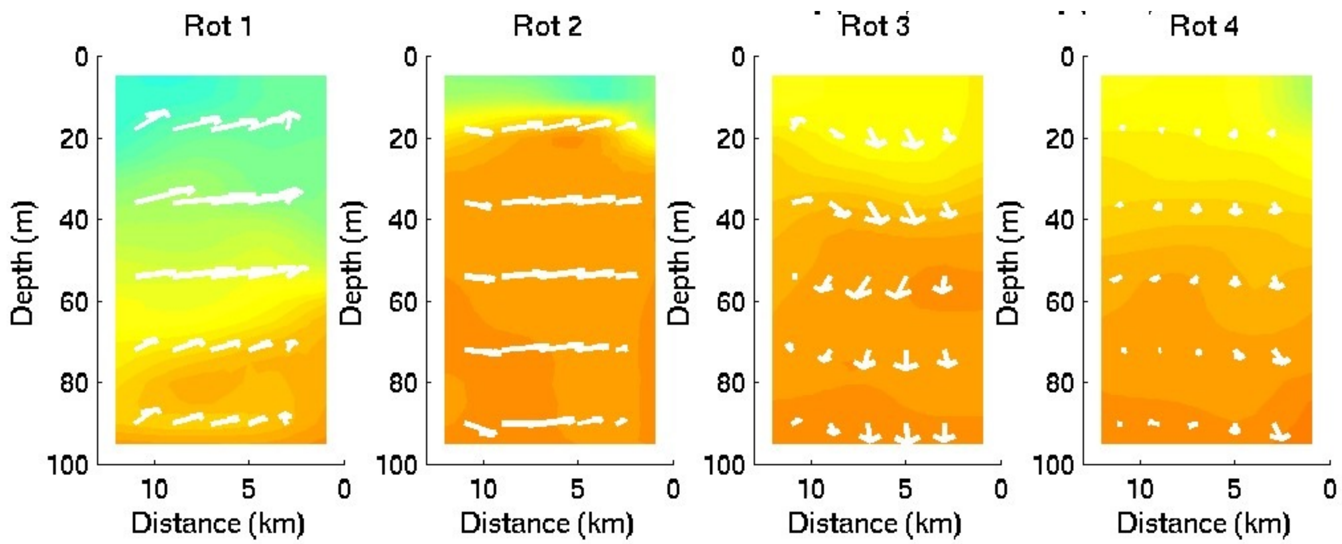
Oceanography: NBCR & low salinity intrusion



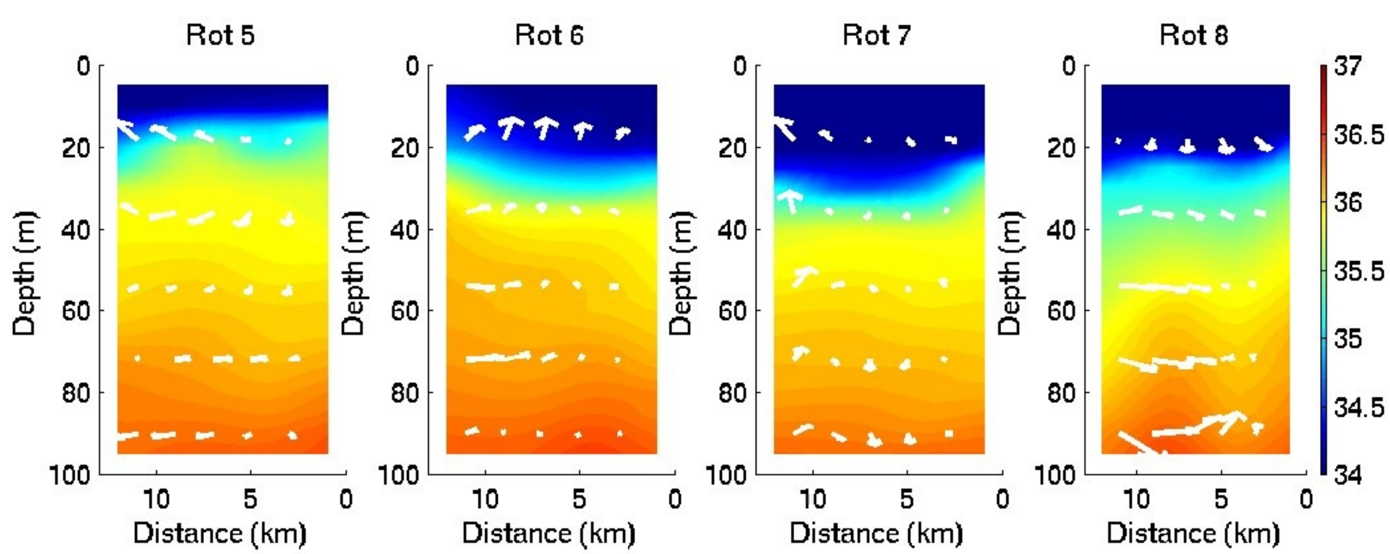
[Paris et al. 2002 *DSR*]

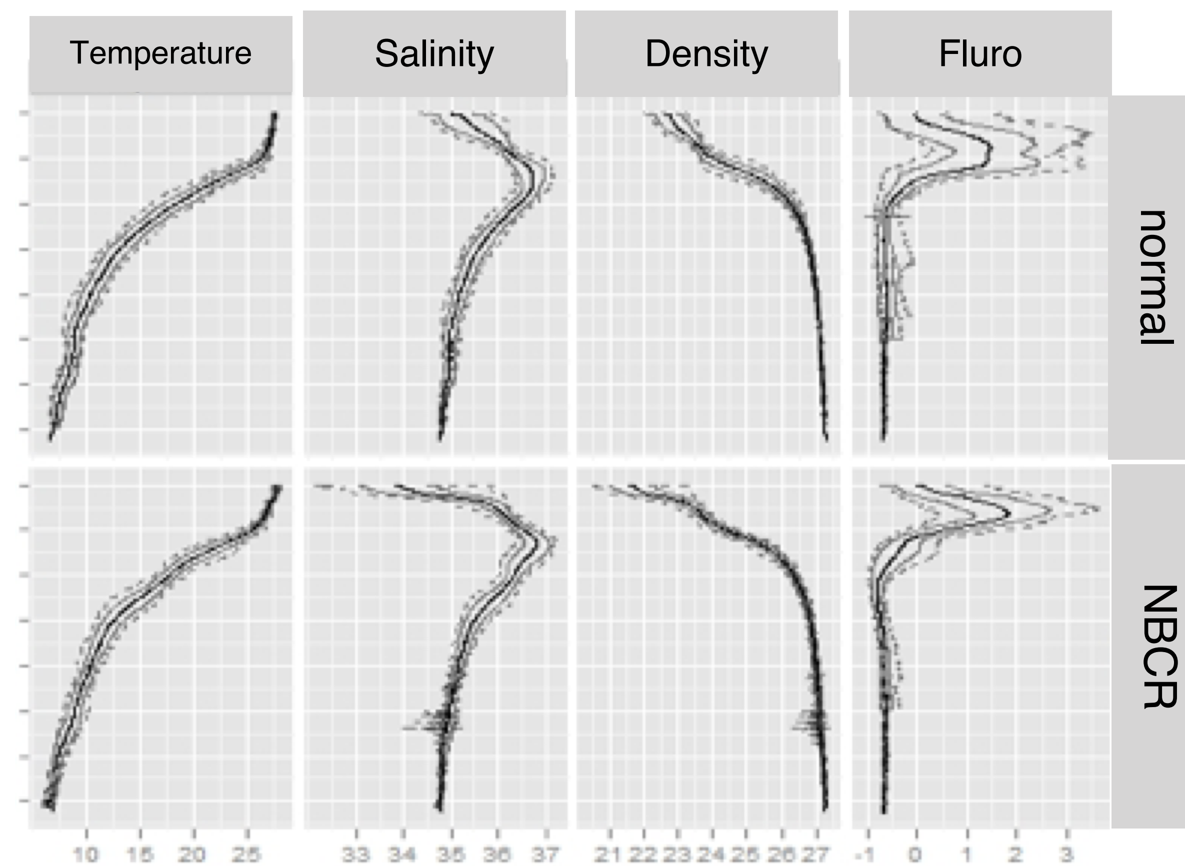
Barbados oceanography in the upper 100 m

Rotation 1-4, year 2

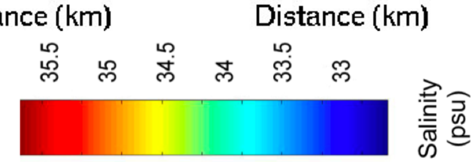


Rotation 5-8, year 2





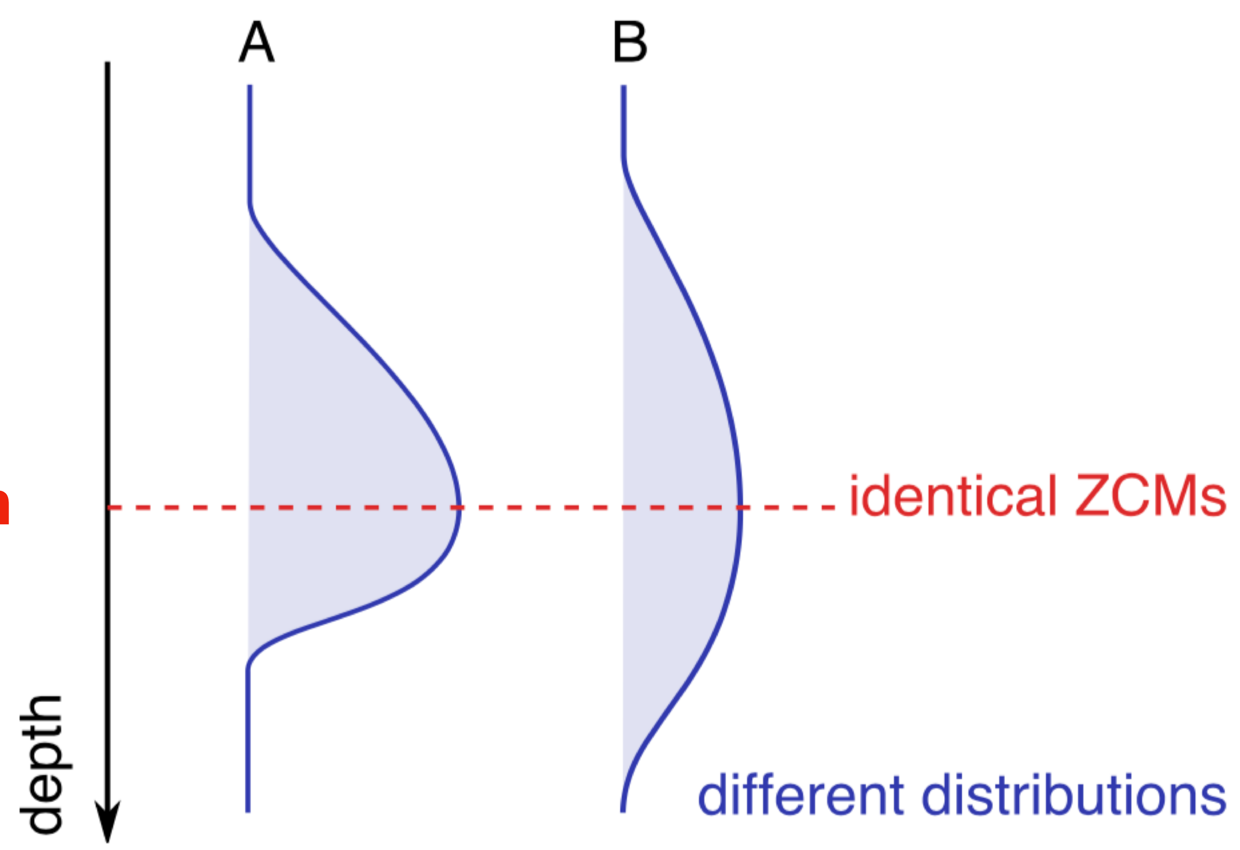
[Paris et al. 2002 *DSR*]



Analytical methods

Zcm = **depth of center of mass** - average of all the nets depths at each sampling station weighted by the proportion of larvae caught (i = 0-100 m)

$$z_{cm} = \bar{z}_w = \sum_i \frac{a_i}{\sum a_i} z_i$$



Univariate approach

Multivariate approach

Analytical methods

For each Zcm, we extract values of the following variables:

Spatio-temporal year, rotation, station, latitude, longitude, time: day or night

Physical depths of thermocline, halocline, pycnocline, and chlorophyll maxi- mum

Taxonomic family, genus

Ontogeny stage: pre or post-flexion

We test the statistical differences of the *Zcm* variance and median:

- **Taxonomic Vertical Migration (TVM)**- between taxa (Shapiro, Fligner-Killeen, Kruskal-Wallis, Wilcoxon signed-rank)
- **Diel Vertical Migration (DVM)**- between the day and the night (Shapiro, Fligner-Killeen, Wilcoxon signed-rank)
- **Ontogenetic Vertical Migration (OVM)** - between developmental stages (Shapiro, Fligner-Killeen, Kruskal-Wallis, Wilcoxon signed-rank, Kolgomorov)

Regression Tree on Zcm **-** estimated from stations and families against the taxonomy, ontogeny and oceanography

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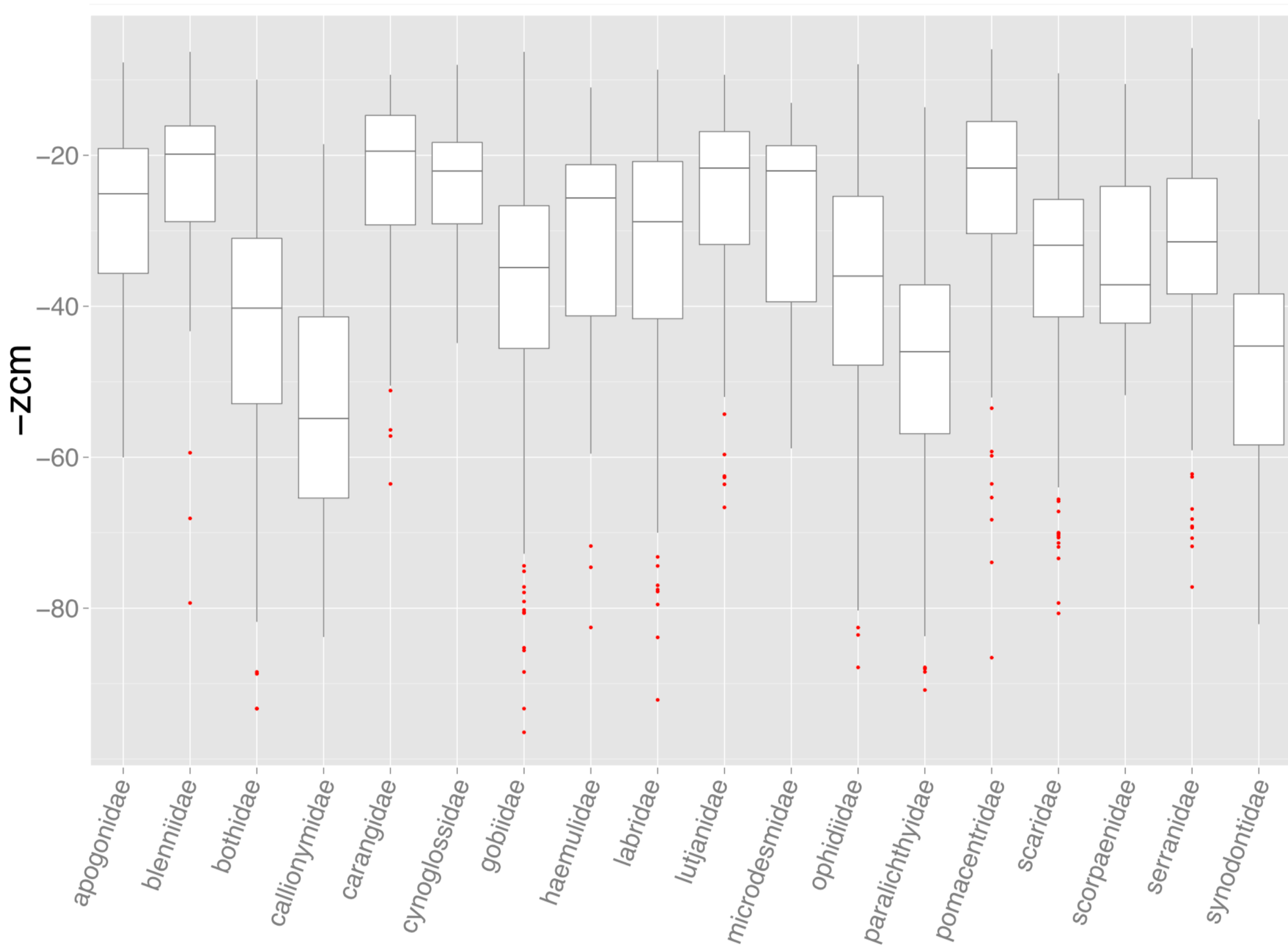
Analytical methods: oceanographic variables

Influence of NBCRs on vertical distribution

Thermocline depth	Mean salinity below halocline	Mean temperature below thermolcine	Mean Fluro std below maxChloro depth
Halocline depth	Mean salinity below picnocline	Mean temperature below picnocline	Mean Fluro std below mixed bottom
Maximum Chlorophyl depth	Mean salinity below mixed bottom	Mean temperature below mixed bottom	Mean Fluro std below picnocline
Mixed bottom depth	Minimum of salinity	Minimum of temperature	Minimum of Fluro std
Pycnocline depth	Maximum of salinity	Maximum of temperature	Maximum of Fluro std
			Fluro std at max chloro depth


RESULTS

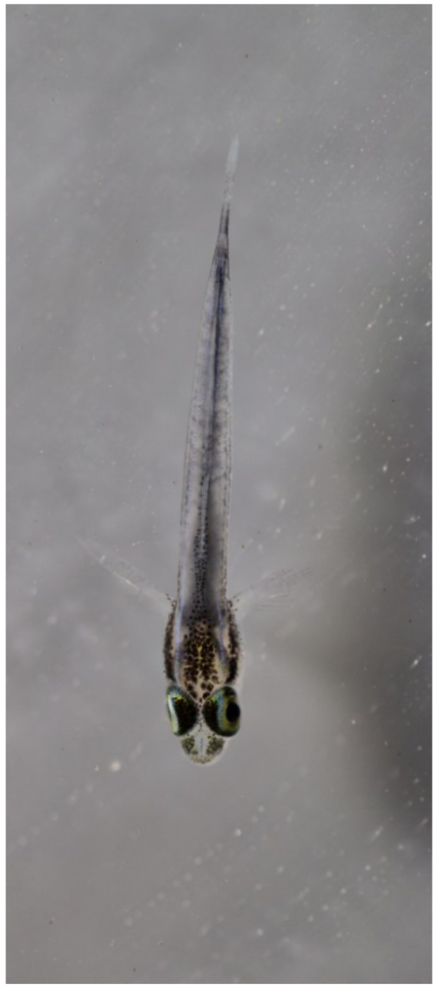
Taxonomic analysis (family): distribution of Zcm



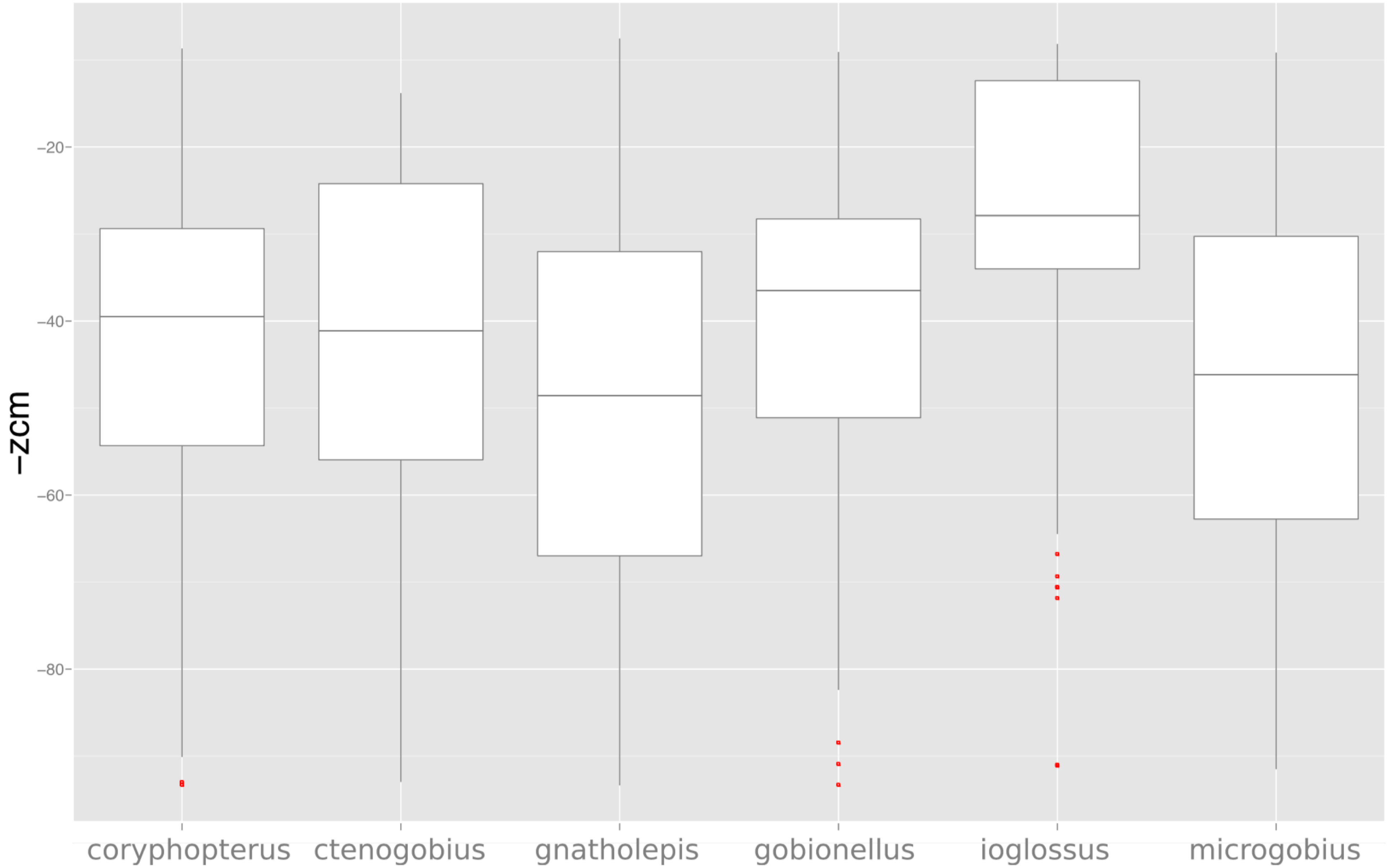
Kruskal-Wallis test: $\chi^2 = 788.1258$, df = 17, $p < 2.2.10^{-16}$

Taxonomic analysis (genus): distribution of Zcm

Gobiidae

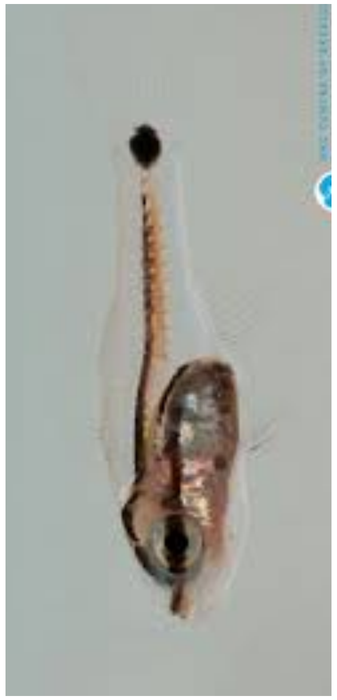


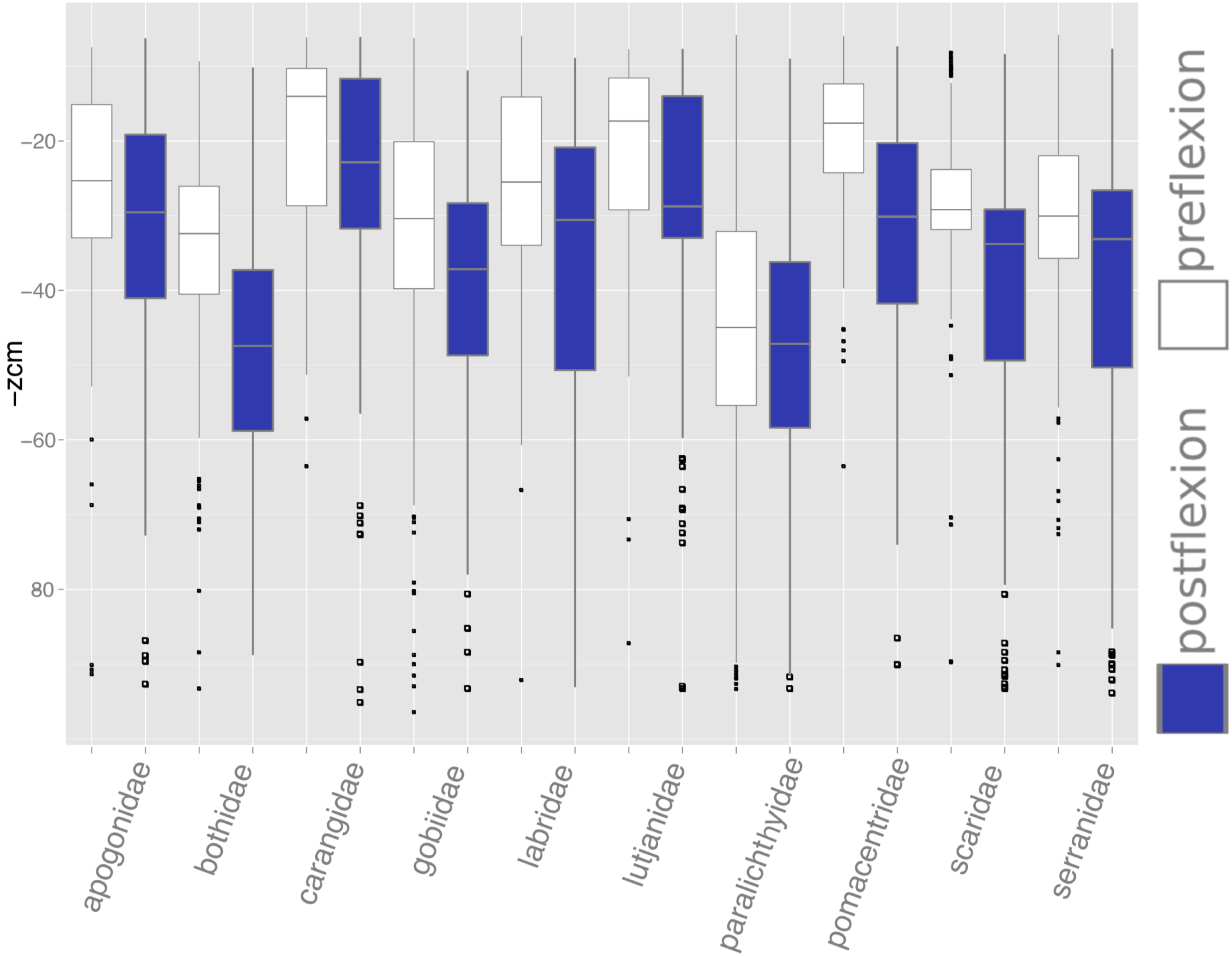
Credit: R. Chaput



Kruskal-Wallis test: $\chi^2 = 99.0494$, df = 5, $p < 2.2.\ 10^{-16}$

Ontogenetic analysis (family): distribution of Zcm

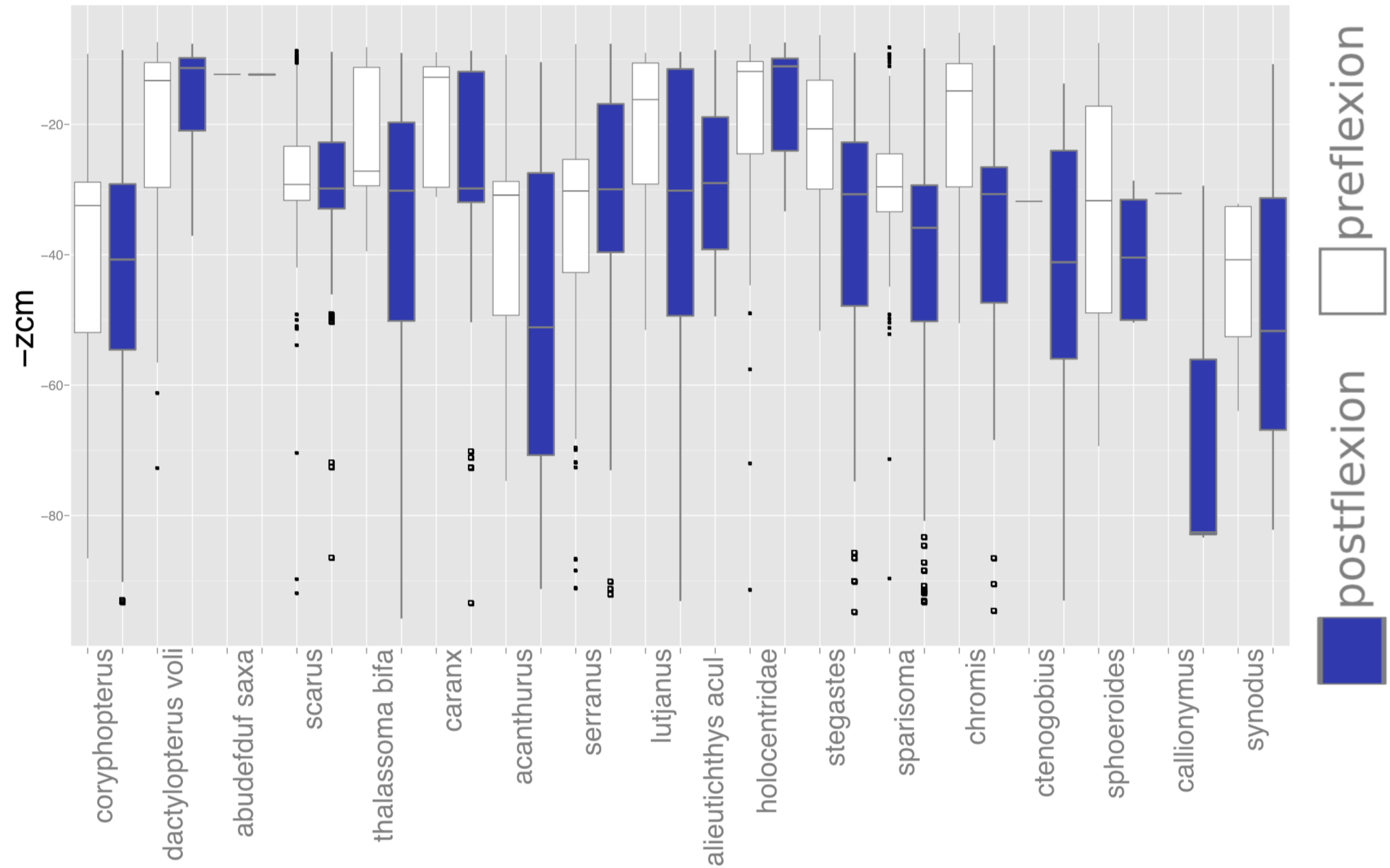




Apogonidae p=0.023, Bothidae p=2.10^{-16}, Gobiidae p=4.10^{-9}, Labridae p=$3.5.10^{-5}$, Lutjanidae p=0.0009,

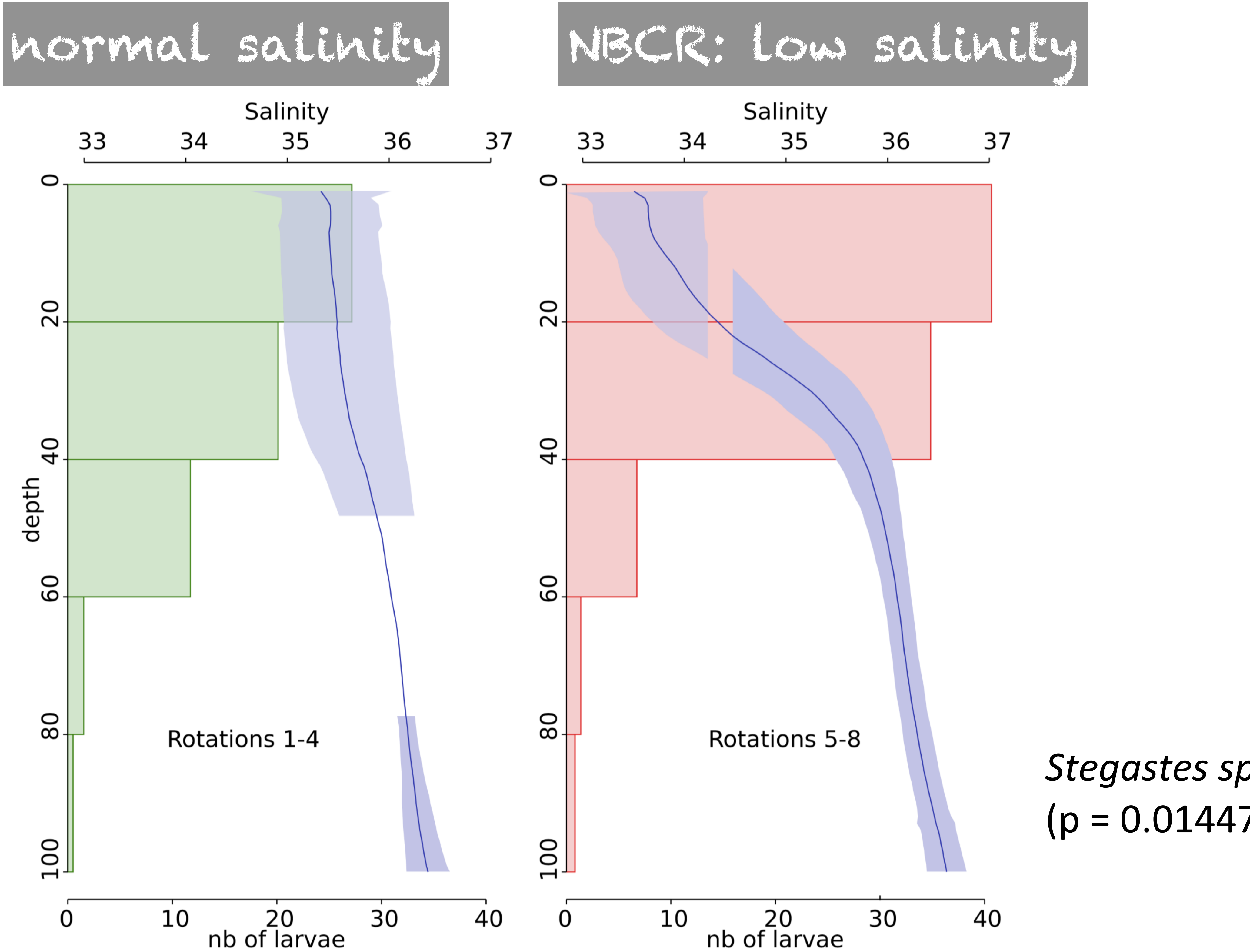
Pomacentridae p=4.10^{-16}, Scaridae p=3.10^{-10}

Ontogenetic analysis (genus): distribution of Zcm



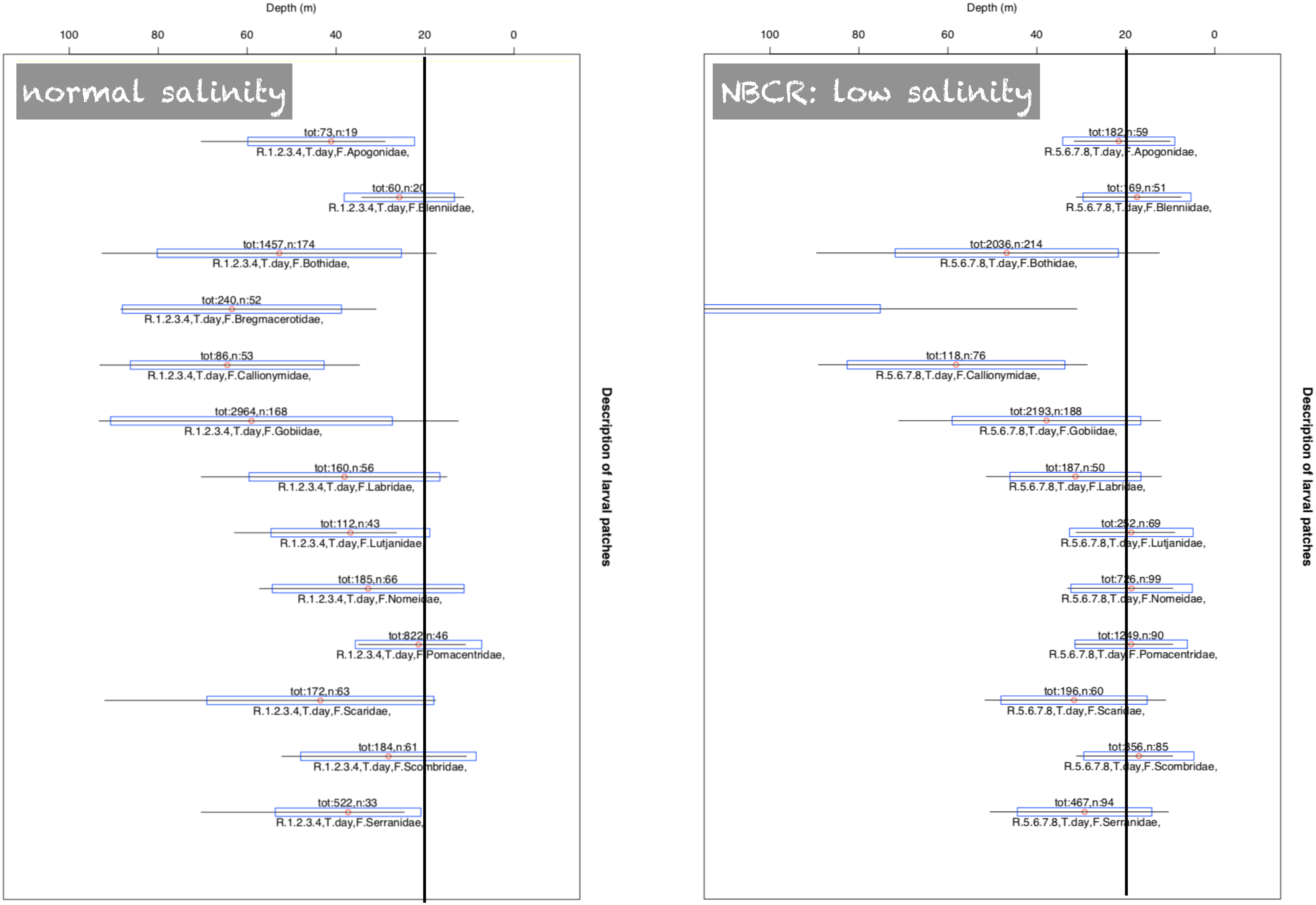
In most cases post-flexion larvae are deeper than pre-flexion larvae

Environmental effect on vertical distribution

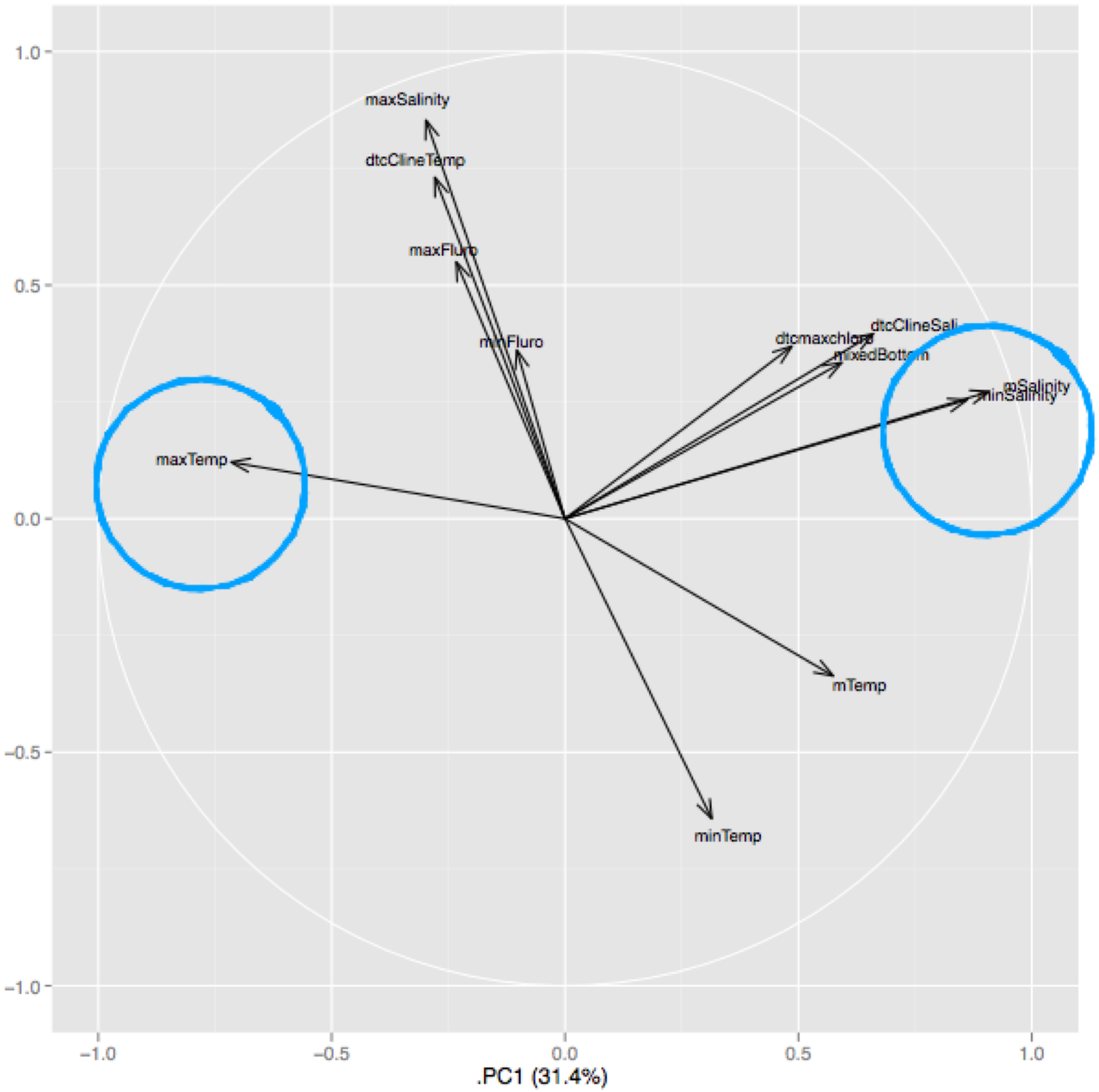


Stegastes spp.
($p = 0.01447$)

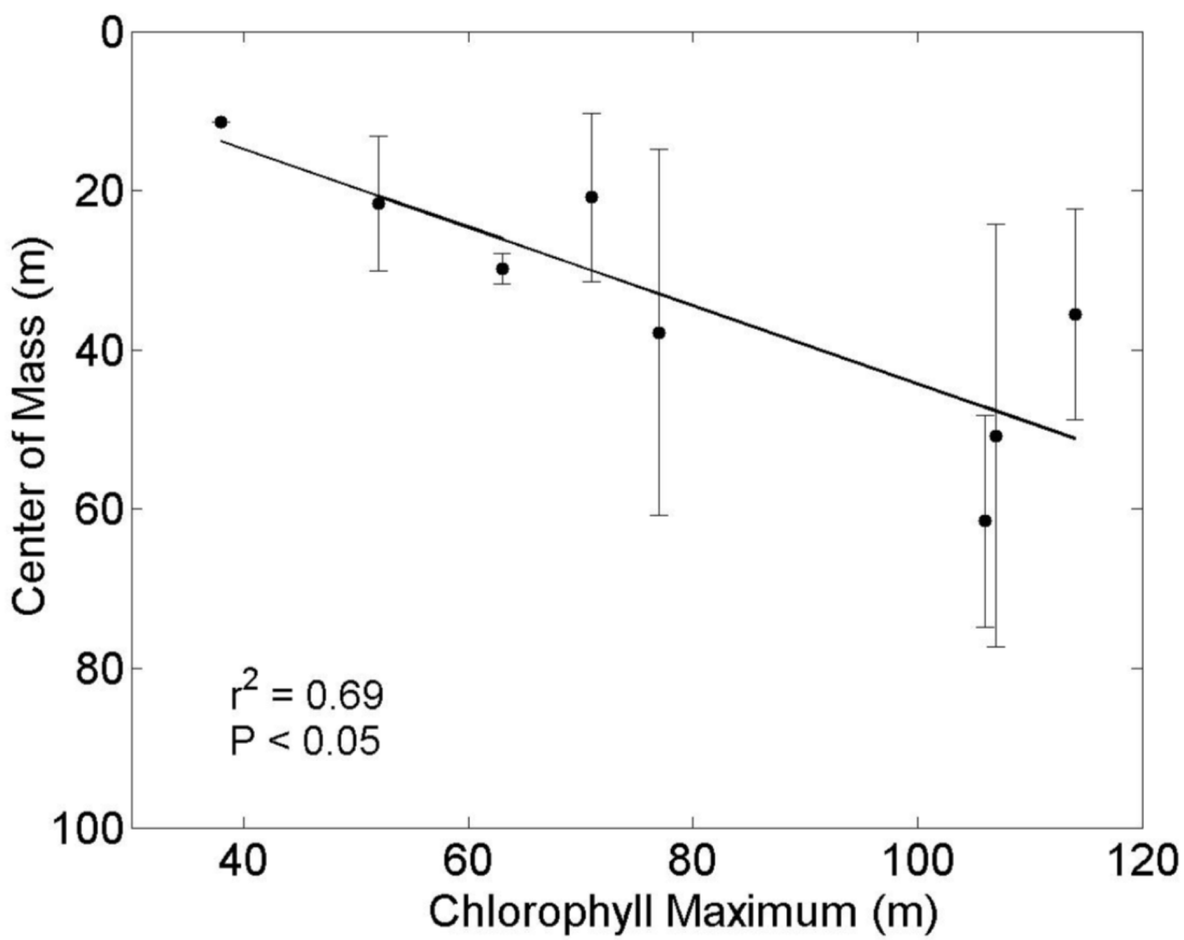
NBCR effect on larval patches



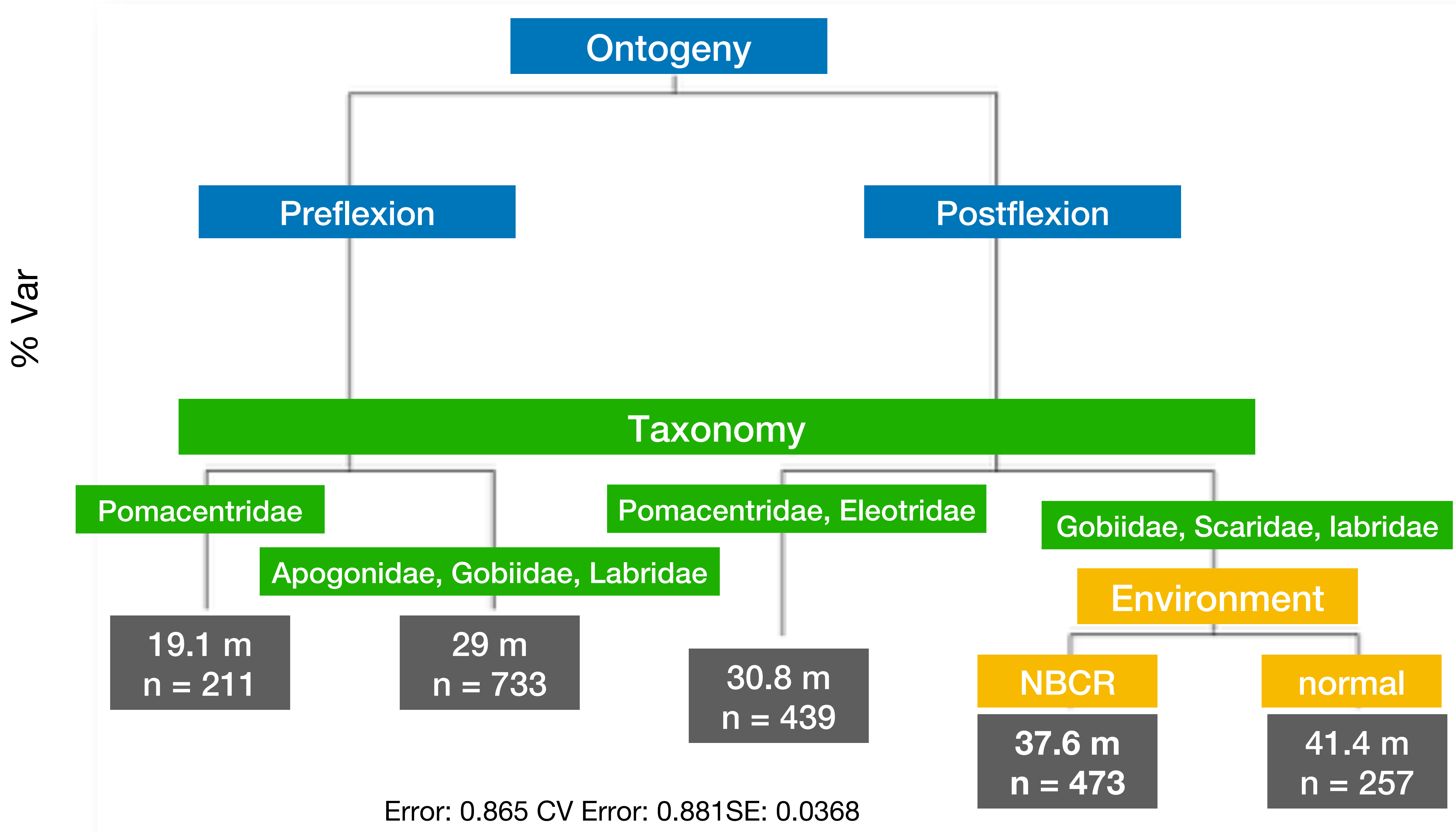
PCA Environmental VAR & Chl. max effect on Zcm



Thalassoma bifasciatum



Results: regression tree on Zcm



Analysis on the 6 more abundant families

Summary and future work

- *Significant TVM* at the family and genus level
  - ✓ Pomancentridae are more compact and shallower than other families Zcm ~ 20-30 m
  - ✓ Gobiidae are more widely spread with Zcm ~ 40m
- Non-significant DVM - potentially due to small temperature changes throughout the day
- *Significant OVM* - post-flexion are deeper and more spread than pre-flexion stages
- ***Significant environmental effects on OVM***
  - ✓ Most coral reef fish taxa tend to rise in the water column during low salinity intrusions and increased stratification from NBCRs
  - ✓ chlorophyll maximum, halocline, and thermocline are the major signals for changes in Zcm —with variable consequences among taxa
- **Changes in water mass characteristics and in clines may influence the dispersion and migration of fish larvae**
  - ✓ Basis for evaluating expected OVM and dispersal changes in a changing ocean
  - ✓ What is the influence of the NBCRs in particular? What are the consequences of the two regimes in terms of advection?
  - ✓ How important are local conditions compared to the advection process?
  - ✓ Integration of environmental response of OVM in biophysical models

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