Spatial, environmental, and temporal constraints on fish distribution during early life history stages

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43rd Annual LARVAL FISH Conference

MAY 2019, PALMA DE MALLORCA

Oregon State University

College of Earth, Ocean, and Atmospheric Sciences

Outline

1. Are there habitat constraints in a species life cycle? If so,

2. Can we identify them?

3. When do they occur?

4. What determines these constraints?

5. What are the implications for species resilience and adaptability to climate change?

6. Watch for GitHub link:

https://github.com/lciannel/Larval-Fish-Conference

Branch: master ▾ | New pull request | Find File | Clone or download ▾

lciannel Arrowtooth flounder ··· Latest commit cf6600f 3 minutes ago

BeringDepth.txt	Add files via upload	an hour ago
GAM_Manual8.pdf	Add files via upload	20 hours ago
README.md	Update README.md	an hour ago
R_Script_Alaska_Plaice.R	Update R_Script_Alaska_Plaice.R	13 minutes ago
R_Script_Arrowtooth_Flounder.R	Arrowtooth flounder	3 minutes ago
akp_flatfile.csv	Add files via upload	an hour ago
akp_hauls.csv	Add files via upload	an hour ago
atf_cpue_upto2012_withPhi.csv	Arrowtooth flounder	3 minutes ago
atf_lengthcpue_sex_1992_2012.csv	Arrowtooth flounder	3 minutes ago

README.md

Larval-Fish-Conference

Here you will find R scripts and data files to reproduce some of the analyses shown at the Larval Fish Conference keynote lecture (also contained in this repository). The name of the file should be rather self-explanatory as to what the files does or is needed for. Youa re free to use, at your own risk, any of the data and Rscript files contained in this repository. If you have suggestions for how to improve thel suggest that for running these analyses you download all the files and script in the same directory. The script will call the data files contained in that directory.

The GAM Manual is a set of notes put together for GAM courses that I taught at my home institution (OSU). There you will find examples of Variable Coefficients Models, analyses with Zero Inflated Data, both of which are shown in the presentation. There are other things in the GAM Manual.

Habitat constraints

Monarch butterfly

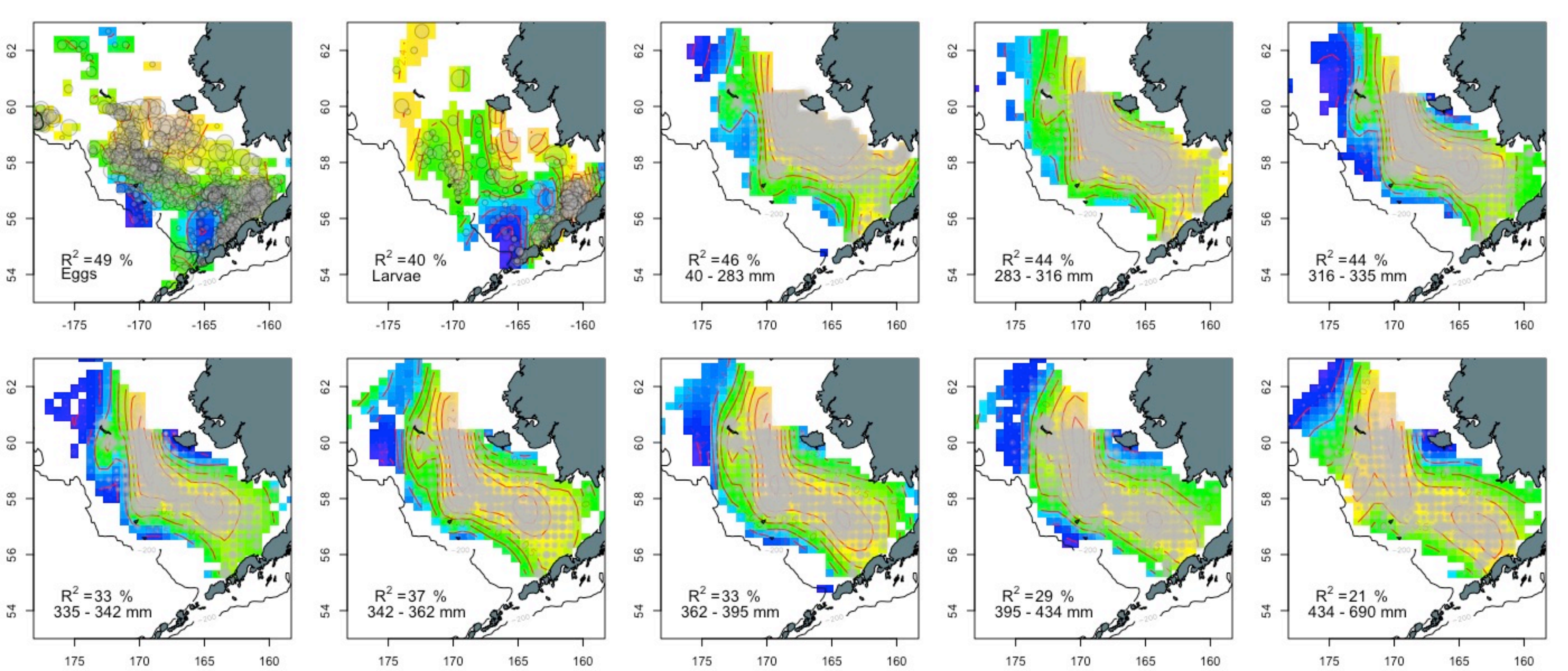
Sea turtles

Pacific salmon

Habitat constraint:
a small portion of the species range consistently used over time by a life history stage

Habitat constraint across life stages

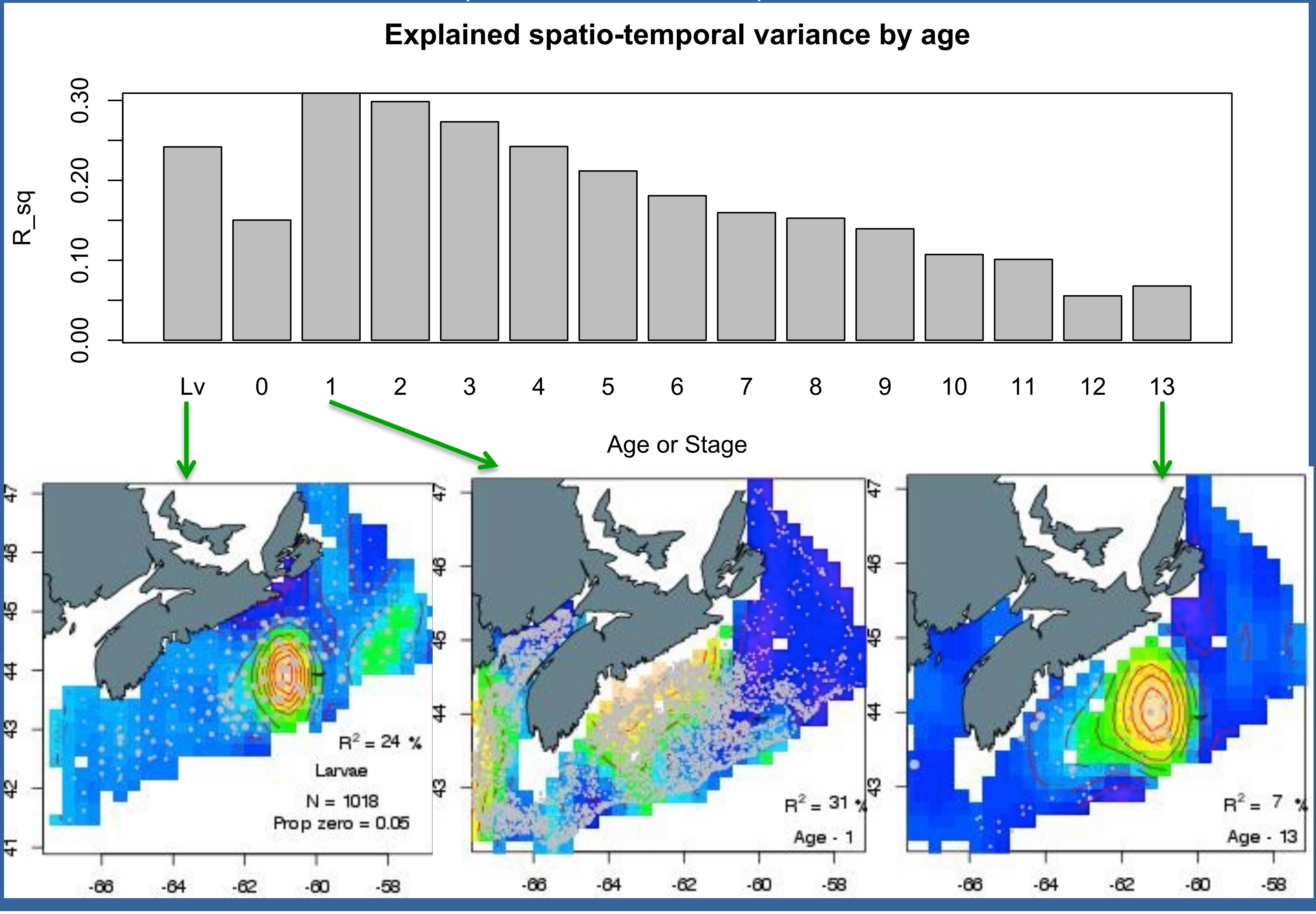
Alaska Plaice (*Pleuronectes quadrituberculatus)* in the Bering Sea



$$X_{s,lat,lon,y} = a_{s,y} + s(lat,lon) + e_{s,lat,lon,y}$$

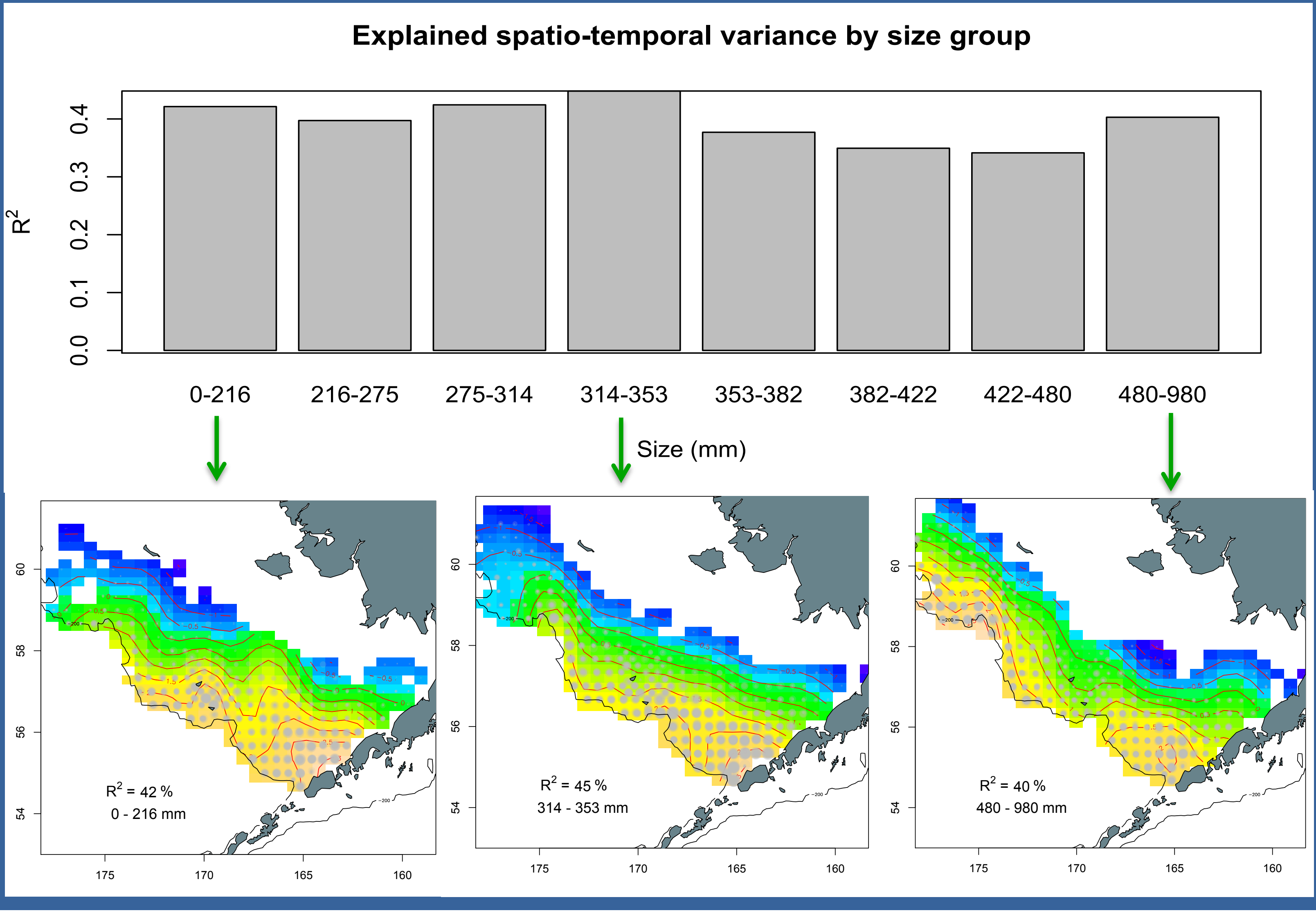
Habitat constraint across life stages

Silver hake (*Merluccius bilinearis)* in the Scotian shelf

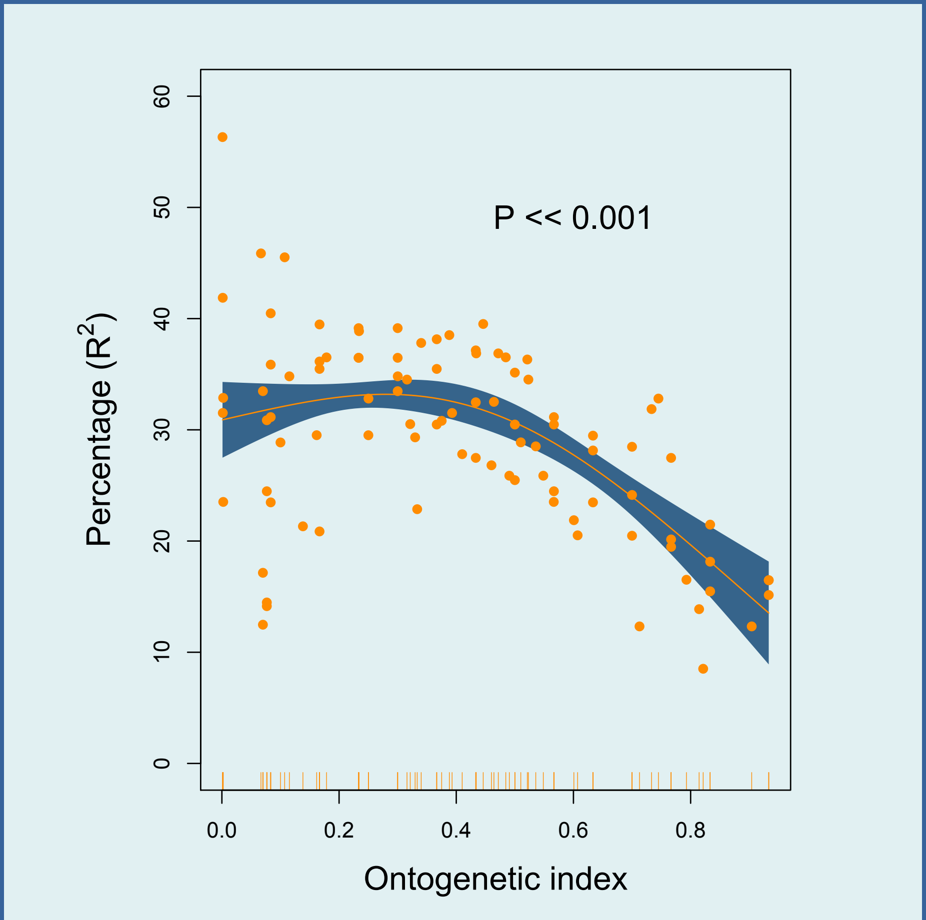


Habitat constraint across life stages

Arrowtooth flounder (*Atheresthes stomias)* in the Bering Sea



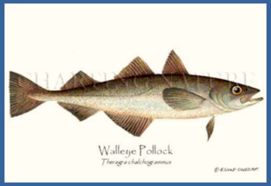
Habitat constraint across life stages



- Spatial constraint decreases with ontogeny
- There is significant species to species variability:
  - *sd(species)* = 6.75
  - *sd(residual)* = 7.23
- **Does life history of the species correlate with this variability?**

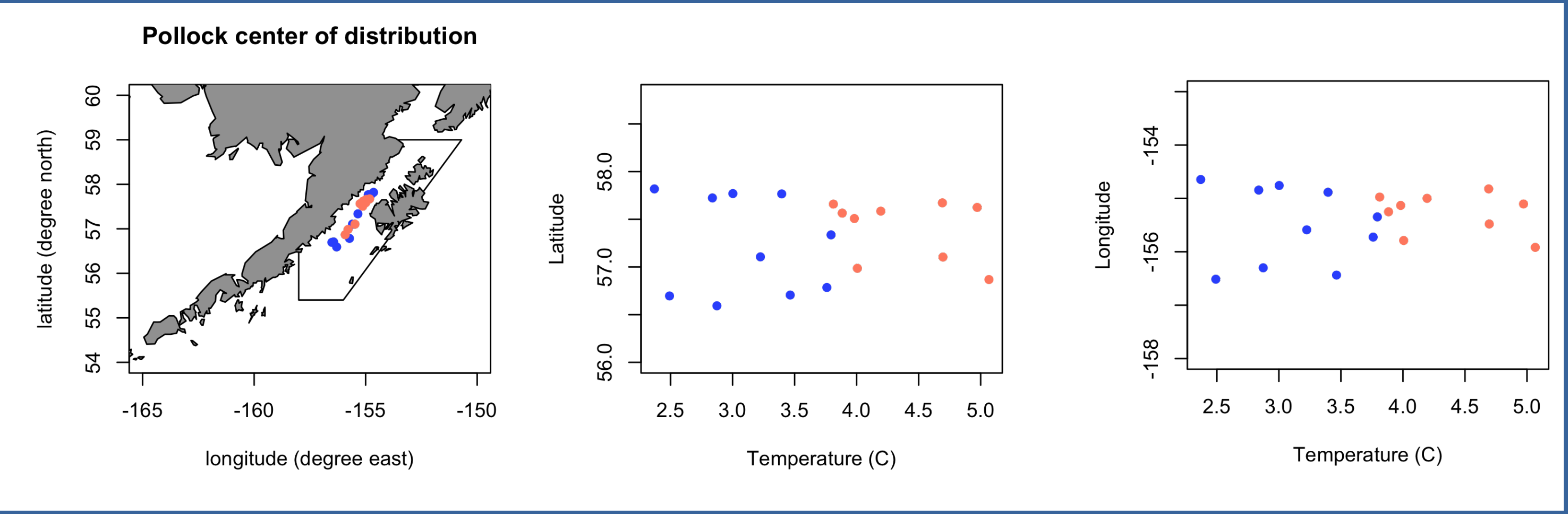
•**Ontogenetic index**: *target age/max age* or

target size/max size



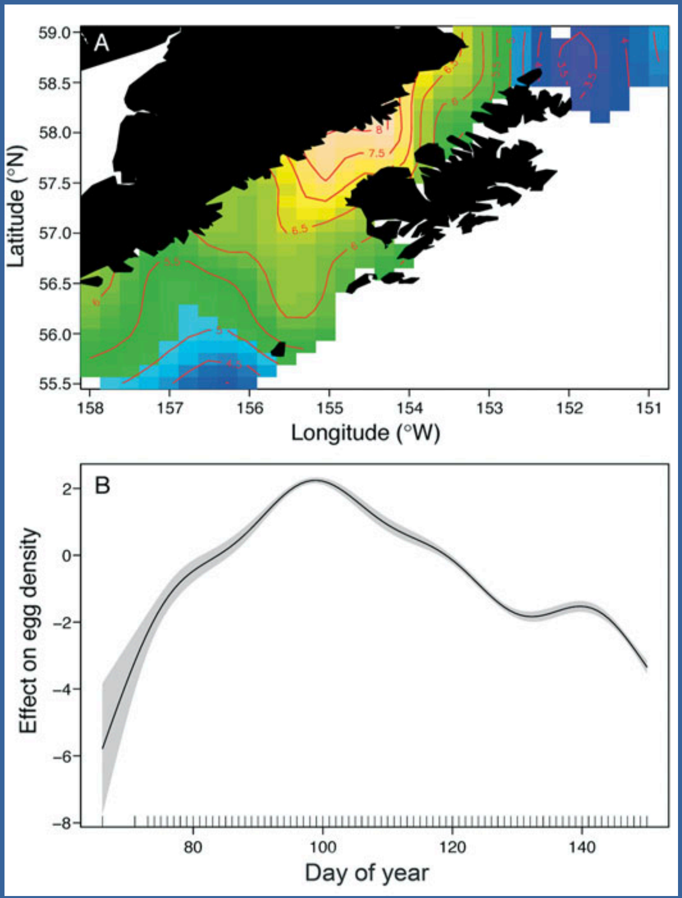
Alaska pollock

Gadus chalcogrammus



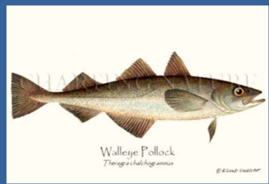
Alaska pollock

Gadus chalcogrammus



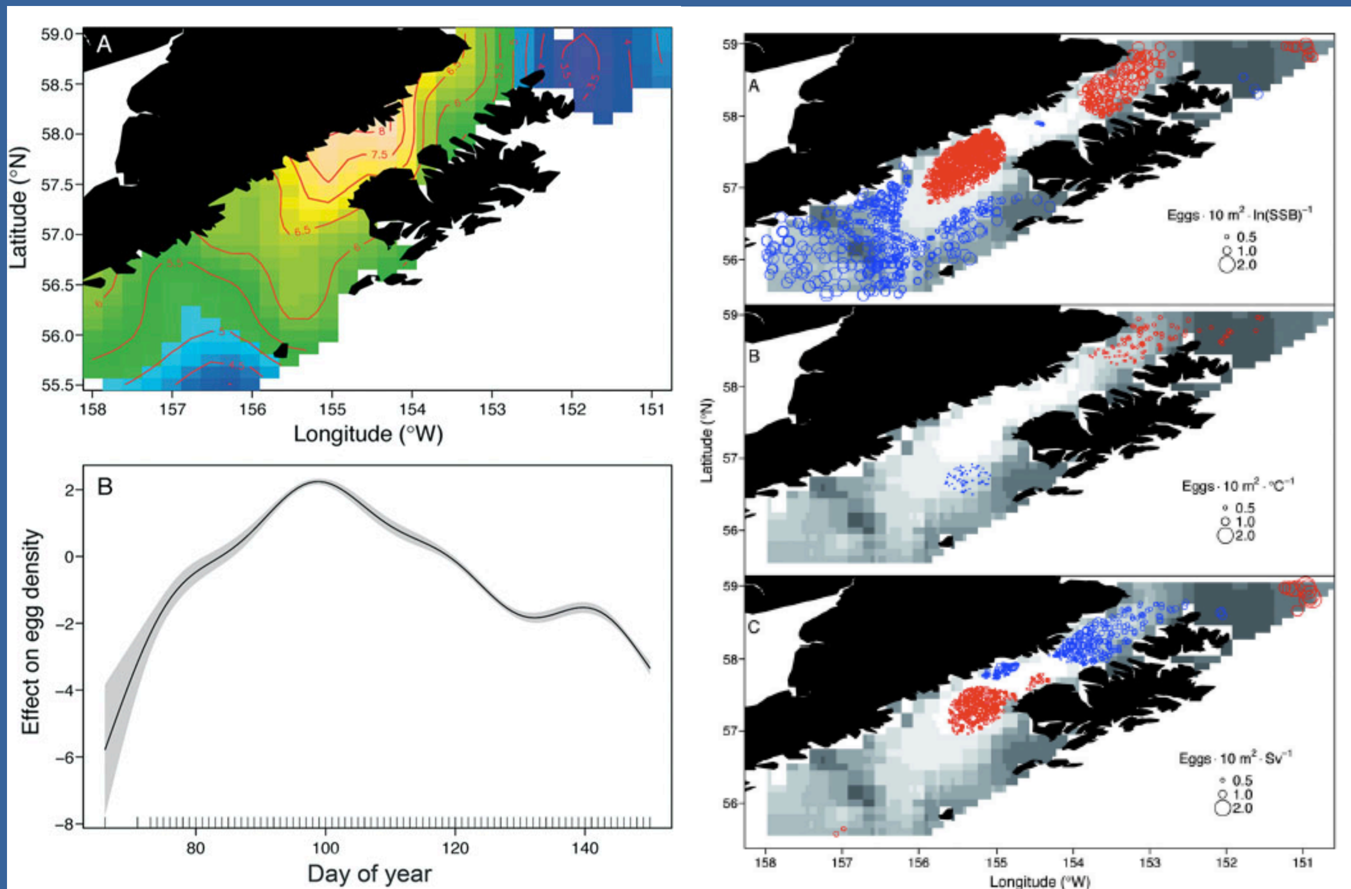
$$y_{(y,\phi,\lambda,t)} = s(\phi,\lambda) + s(t) + s(z) +$$
$$s(\phi,\lambda)\cdot B_y + s(\phi,\lambda)\cdot T_{(y,\phi,\lambda)} + s(\phi,\lambda)\cdot Sv_{(y,\phi,\lambda)} + e_{(y,\phi,\lambda)}$$

Bacheler et al. (2009) MEPS



Alaska pollock

Gadus chalcogrammus



Biomass
(*B*)

SST
(*T*)

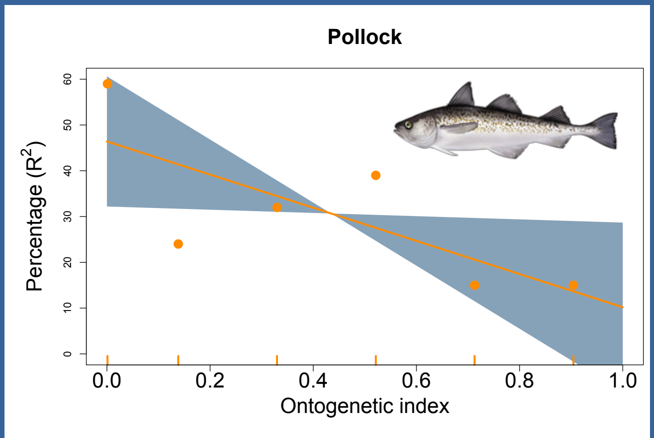
Transport
(*Sv*)

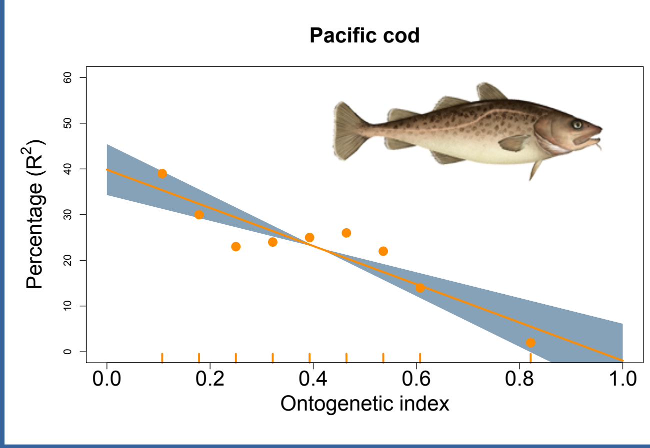
$$y_{(y,\phi,\lambda,t)} = s(\phi,\lambda) + s(t) + s(z) +$$

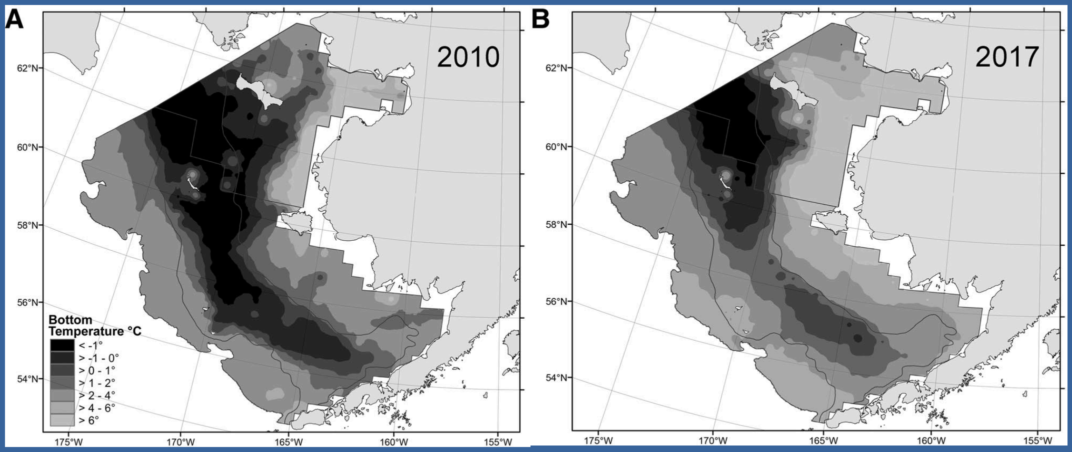
$$s(\phi,\lambda)\cdot B_y + s(\phi,\lambda)\cdot T_{(y,\phi,\lambda)} + s(\phi,\lambda)\cdot Sv_{(y,\phi,\lambda)} + e_{(y,\phi,\lambda)}$$

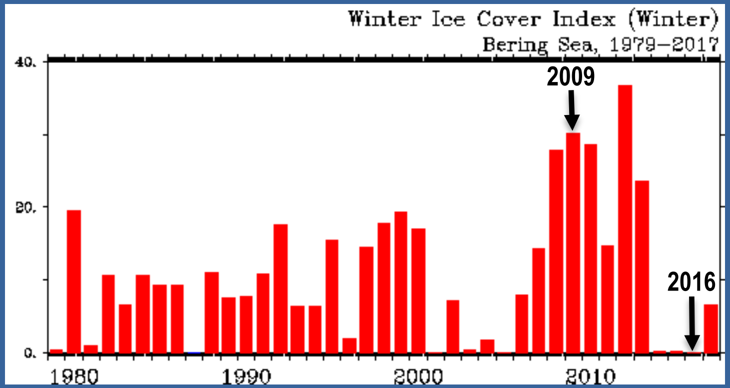
Bacheler et al. (2009) MEPS

Implications for population resilience



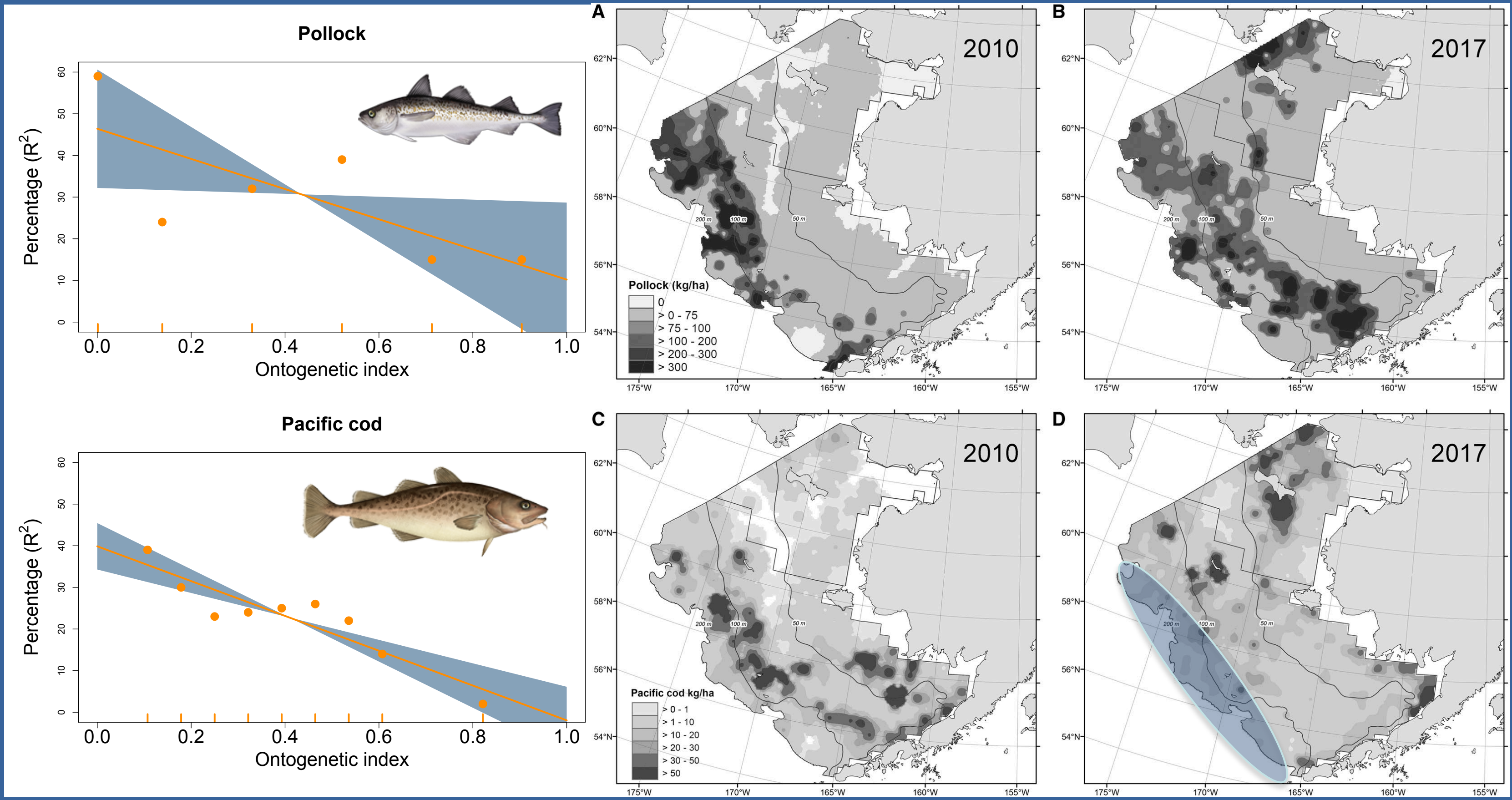






Stevenson and Lauth 2018

Implications for population resilience



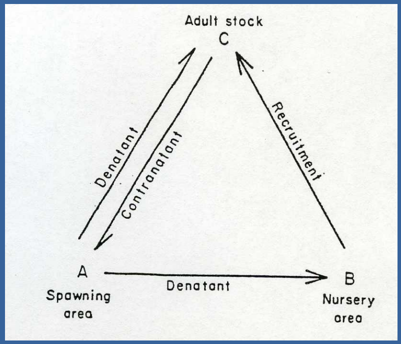
Stevenson and Lauth 2018

Summary

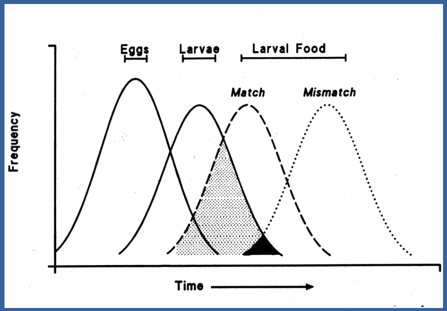
1. Temperature <u>does not</u> always matter
2. Different <u>life history stages</u> have different responses to temperature: more sensitivity for older stages
3. <u>Early life stages</u> are more constrained in space
4. <u>Life histories</u> can predict patterns of habitat use through ontogeny
5. The presence of <u>constrained</u> and <u>unconstrained</u> habitats through a species life cycle may limit their resilience to climate change

What constrains fish spawning habitats?

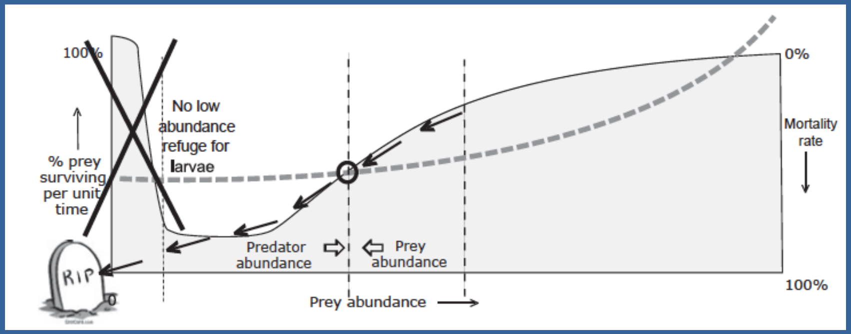
Spatially close life-cycle



Increase feeding



Reduce predation



What constrains fish spawning habitats?

Spatially close life-cycle

Follana Berna et al. THE EFFECT OF BEHAVIOURALLY MEDIATED FISH VULNERABILITY ON EARLY-LIFE PRODUCTION AND DISPERSAL. TU 17:00-17:15

Stock et al. 3-D ADVECTION, DIFFUSION, AND MORTALITY OF EGGS AND LARVAE DISPERSING FROM A NASSAU GROUPER (*Epinephelus striatus*) SPAWNING AGGREGATION OBSERVED WITH A NOVEL PLANKTON IMAGING SYSTEM. TU 17:45-18:00

Guerreiro et al. IMPORTANCE OF NURSERIES AREAS FOR EARLY LIFE STAGES OF FISH AT CENTRAL COAST OF PORTUGAL. WE 15:00-15:15

Orenes et al. LARVAL DISPERSAL PATTERNS IN THE DUSKY GROUPER (*Epinephelis marginatus*, LOWE 1834) BETWEEN MARINE PROTECTED AREAS ALONG THE SOUTHEASTERN IBERIAN COAST. Poster

Russo et al. CHARACTERIZATION OF THE LARVAL HABITAT OF TUNA SPECIES IN THE CENTRAL MEDITERRANEAN SEA. Poster

Increase feeding

Axler et al. VARIABILITY IN ICHTHYOPLANKTON DISTRIBUTIONS, FITNESS, AND TROPHODYNAMICS ACROSS RIVER PLUMES IN THE NORTHERN GULF OF MEXICO . TU 11:30-11:45

Swieca et al. IMPLICATIONS OF A TIDALLY MODULATED RIVER PLUME ON FINE-SCALE LARVAL FISH TROPHIC INTERACTIONS. TU 12:00-12:15

Gleiber et al. FOOD WEB CONSTRAINTS ON LARVAL GROWTH IN SUBTROPICAL CORAL REEF AND PELAGIC FISHES. TU 15:00-15:15

Burns et al. INTERANNUAL VARIABILITY OF TROPHODYNAMICS OF LARVAL DEEPWATER REDFISH, *Sebastes mantella*, IN THE GULF OF ST. LAWARENCE. TU 16:15-16:30

Shropshir et al. ESTIMATES OF FOOD LIMITATION EXPERIENCED BY PELAGIC FISH LARVAE IN THE GULF OF MEXICO. TU 14:45-1500

Mir et al. FEEDING ECOLOGY OF BLUE WHITING (*Micromesistius poutassou*) LARVAE IN THE NORTHWESTERN MEDITERRANEAN SEA. Poster

Reduce predation

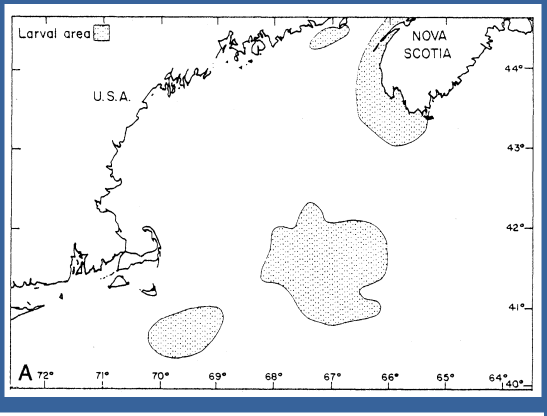
Fennie Hamilton et al. COHO SALMON PREDATION ON PELAGIC JUVENILE ROCKFISH: DO EARLY LIFE HISTORY TRAITS PLAY A ROLE? WE 11:45-12:00

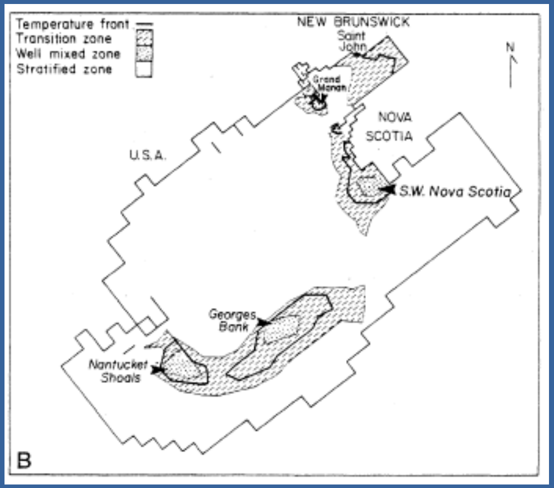
Ottmann et al. ARE EPHYRAE OF *Pelagia noctiluca* IMPORTANT PREDATORS OF LARVAL TUNA? WE 12:00-12:15

Randall et al. OCCURRENCE OF ICHTHYOPLANKTON IN AUTUMN HERRING DIETS OF EASTERN NEWFOUNDLAND IMPORTANCE OF THE SPATIOTEMPORAL PREDATOR WE 12:15-12:30

Strategies for life-cycle closure

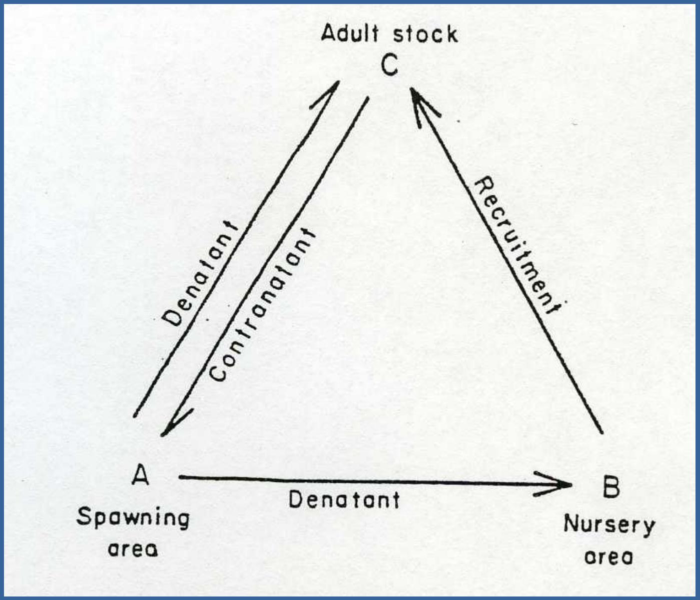
Iles and Sinclair (1982): member vagrant





- Geographically stable larval retention areas
- Limited home range
- Homing based on geographic clues

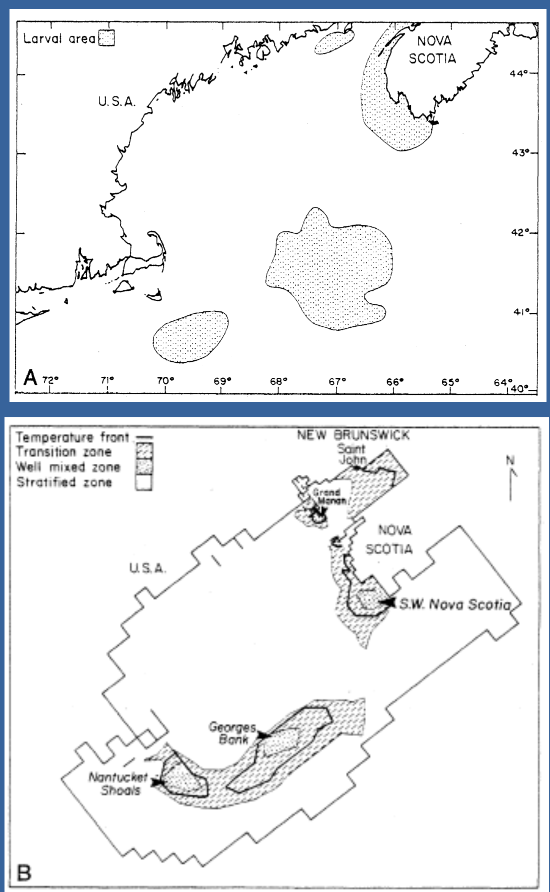
Harden Jones (1968): migration triangle



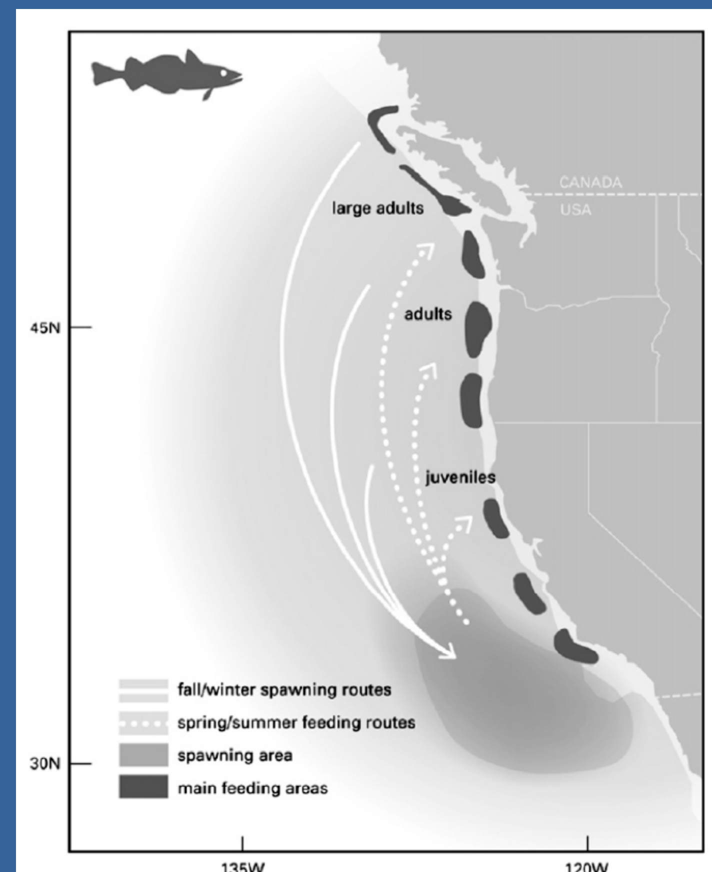
- Environmentally based drift pathways
- Migratory
- Homing based on geographic clues + environmental cues

Strategies for life-cycle closure

Iles and Sinclair (1982): member vagrant



Harden Jones (1968): migration triangle



- Geographically stable larval retention areas
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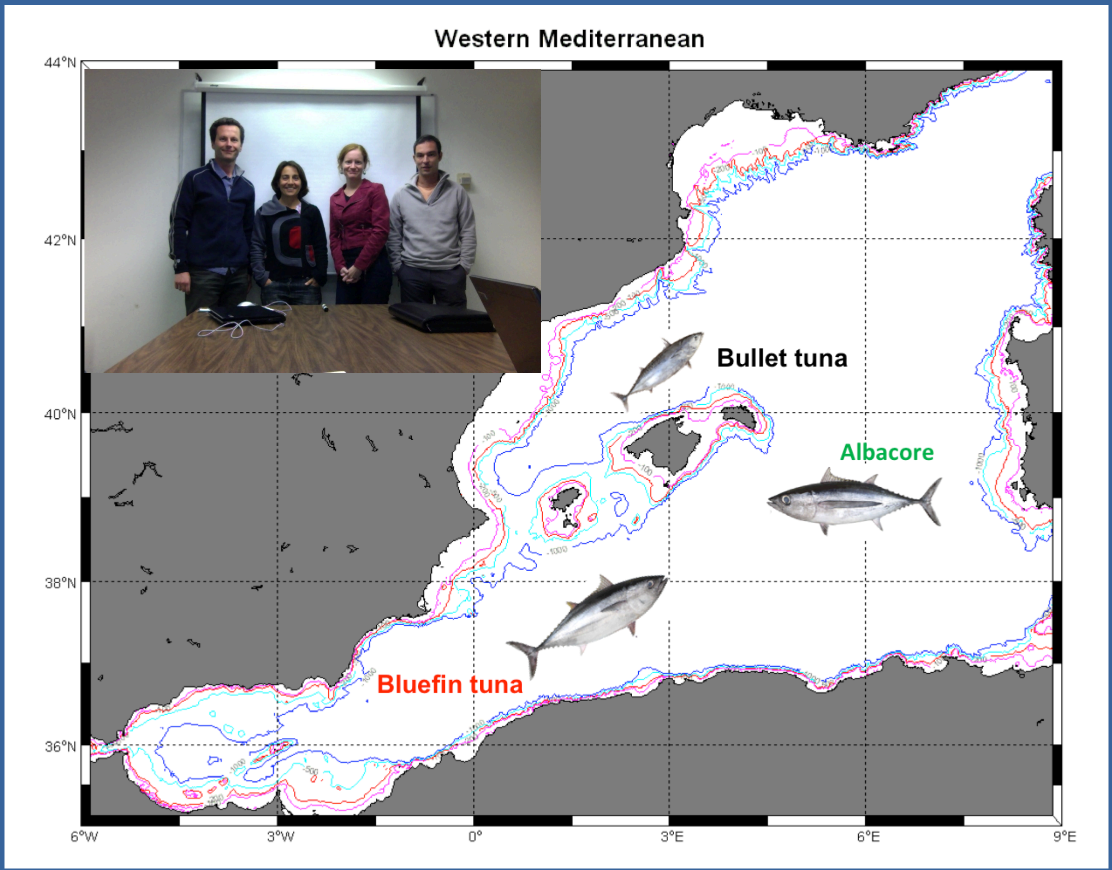
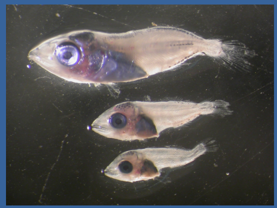
- Environmentally based drift pathways
- Migratory
- Homing based on geographic clues + environmental cues

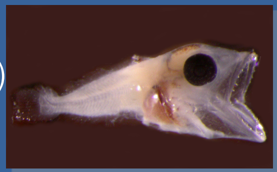
Tuna spawning distribution in the western Mediterranean



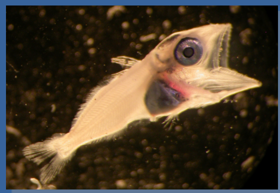
Bullet tuna
(*Auxis rochei)*
Small body-size (3-4 kg)
Mediterranean resident
Coastal year-round



Albacore tuna
(*Thynnus alalunga*)
Medium body-size (20-30kg)
Mediterranean resident
East-west migration



Bluefin tuna
(*Thynnus thunnus*)
Large body-size (>500 kg)
Med + Atlantic
Long migration



Reglero et al. 2012. MEPS

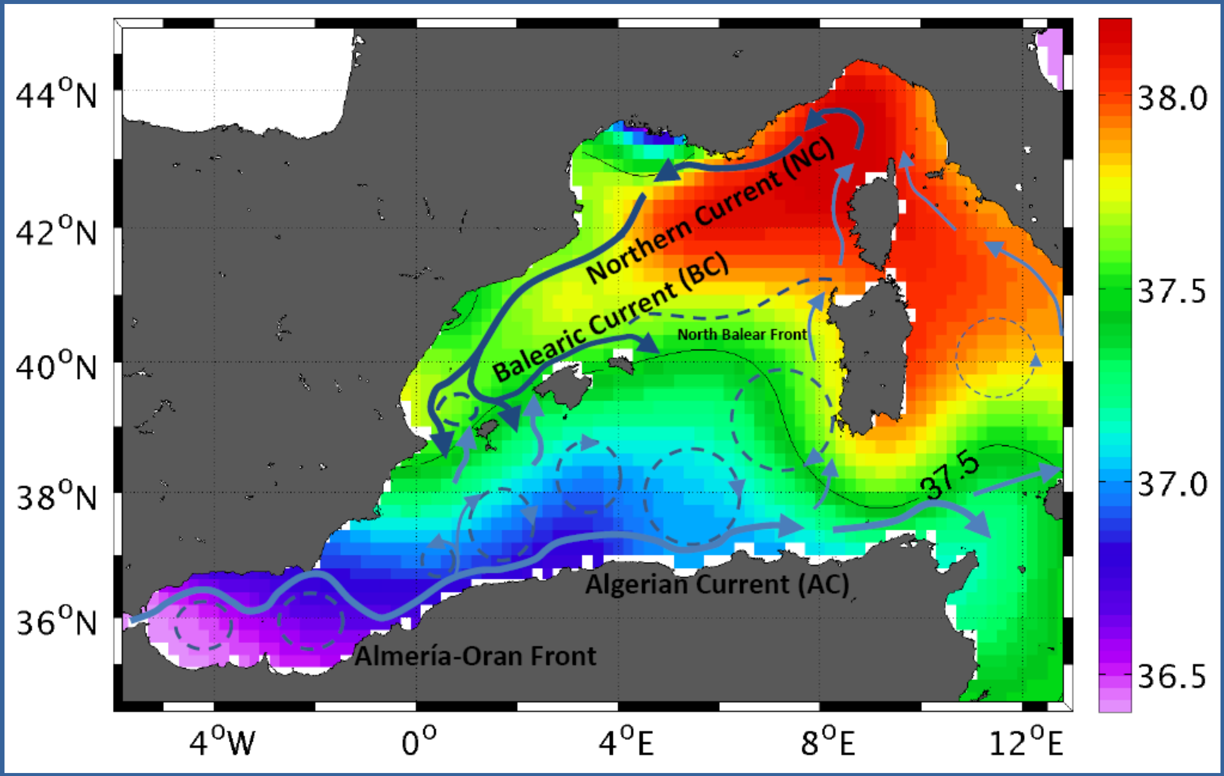
	Home range	
Short	→	*Long*
	Homing strategy	
Geographic	→	*Environmental*

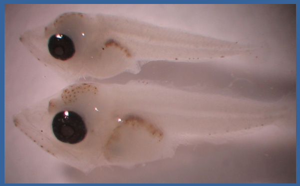
INSTITUTO ESPAÑOL DE OCEANOGRAFÍA

Oceanography in the western Mediterranean

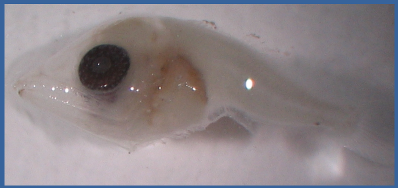
Tetrapturus belone

Coryphaena hippurus



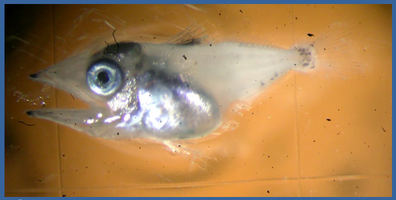


Euthynnus alleteratus

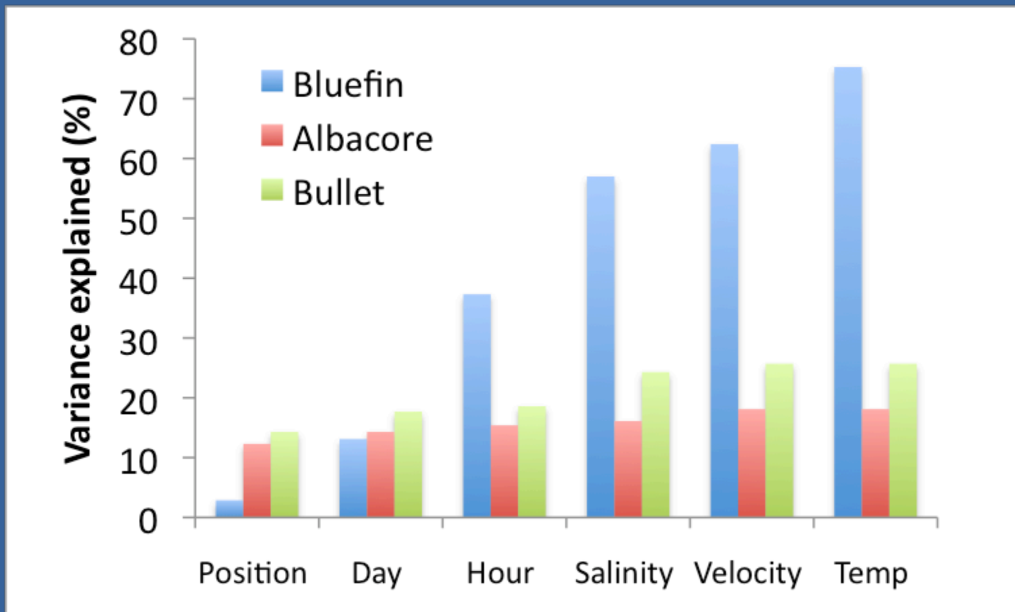


Katsuwonus pelamis

Xiphias gladius



Sarda sarda



Geo

Geo + Env

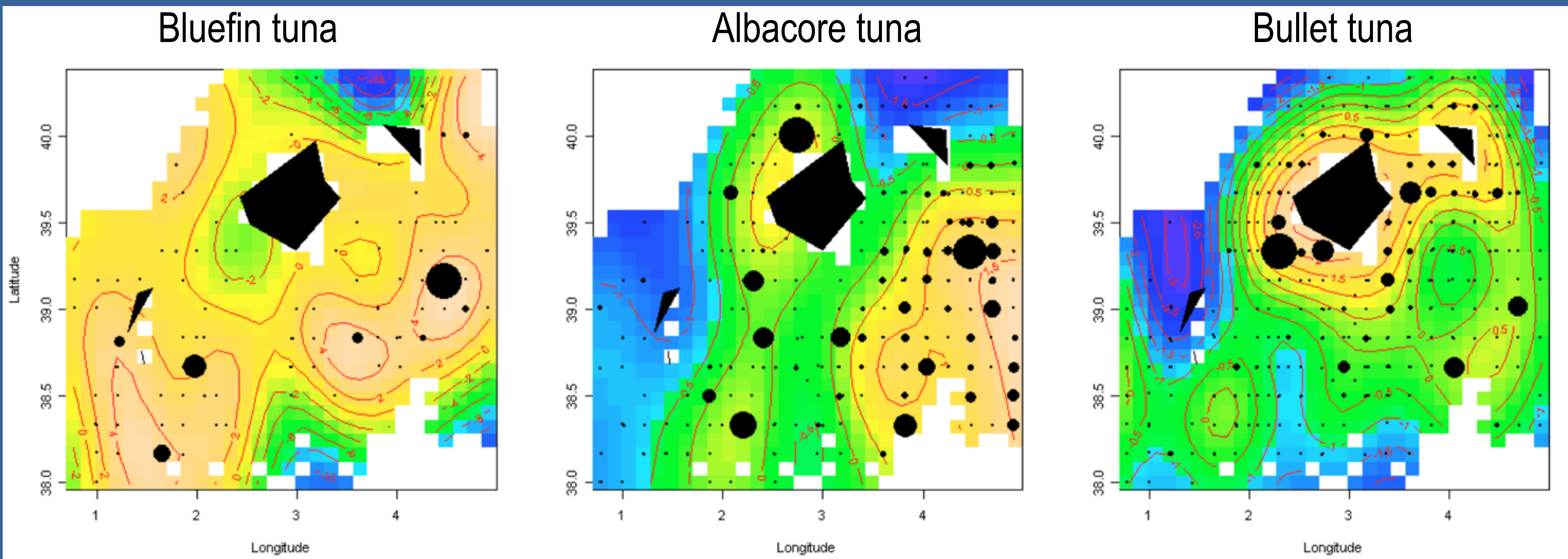
- Bluefin tuna larvae:
  - -geography alone has limited effect
  - -half of the explained variance is captured by hydrography

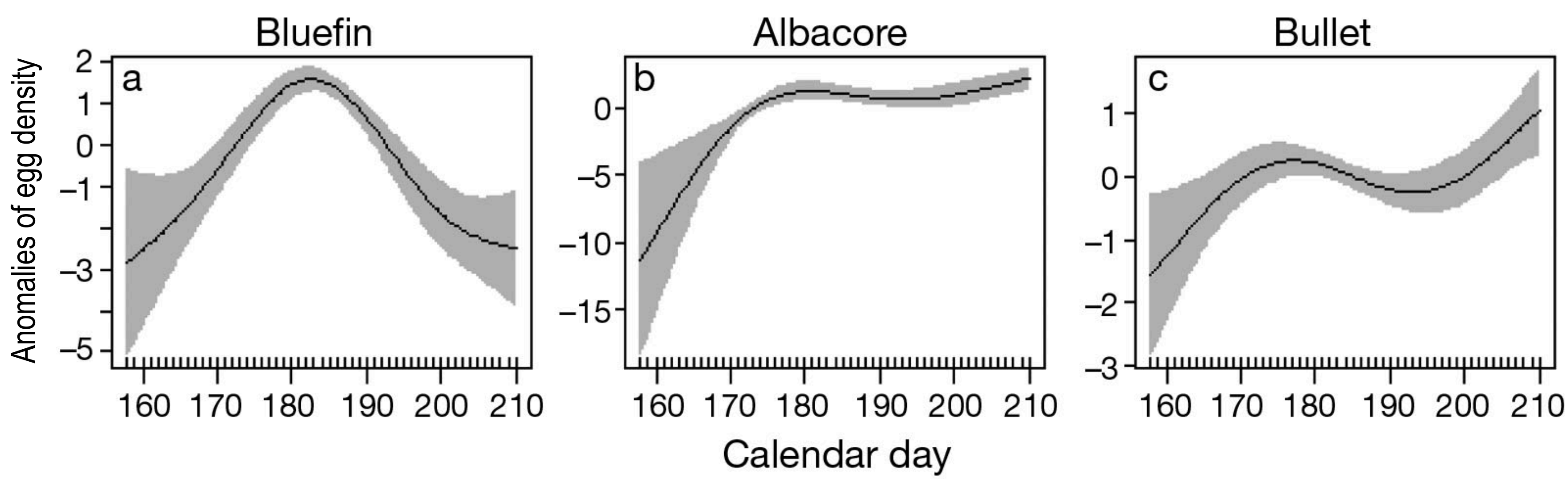
- Albacore & bullet larvae:
  - -different areas
  - -nearly all explained variance is captured by geography

Geo + Environmental

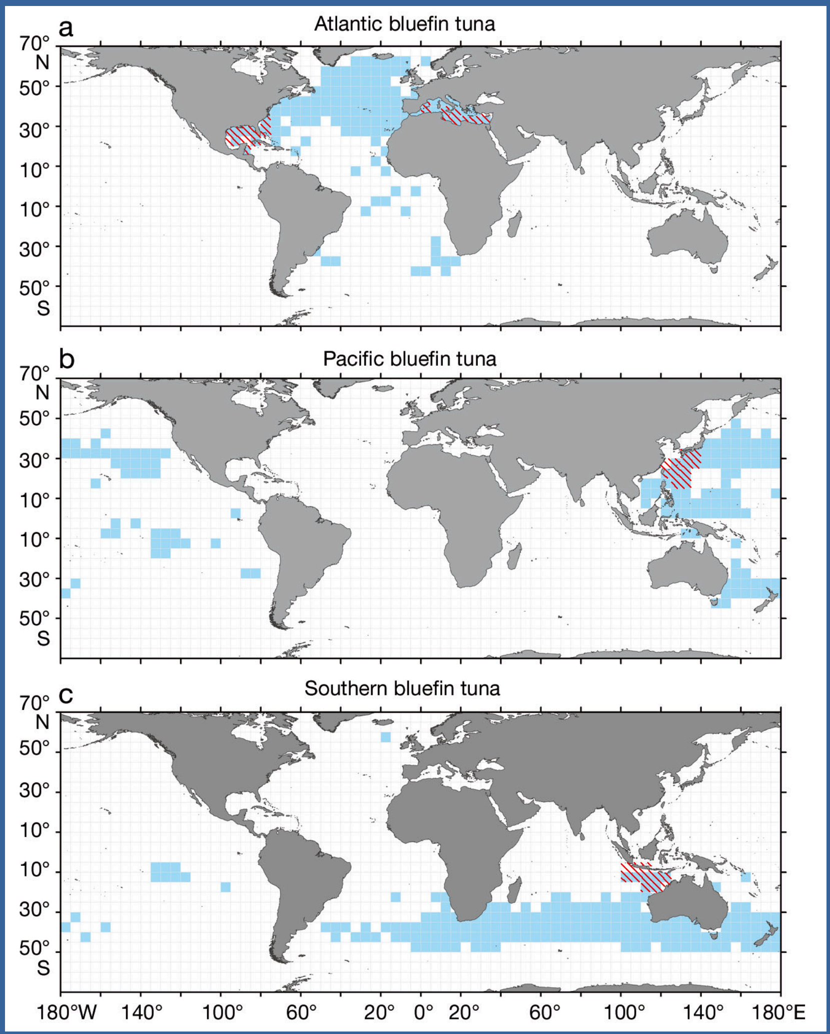
Geo

Covariate	Bluefin	Albacore	Bullet
Position	2.88	12.3	14.3
Day	13.1	14.3	17.7
Hour	37.3	15.4	18.6
Salinity	57.0	16.1	24.3
Velocity	62.4	18.1	25.7
Temp	75.3	-	-


Bluefin tuna
Albacore tuna
Bullet tuna
Latitude
Longitude
Longitude
Longitude


Bluefin
Albacore
Bullet
a
b
c
Anomalies of egg density
Calendar day

Tuna spawning distribution

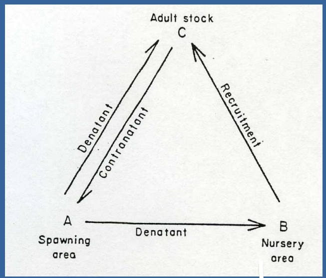


Reglero et al. 2014, MEPS

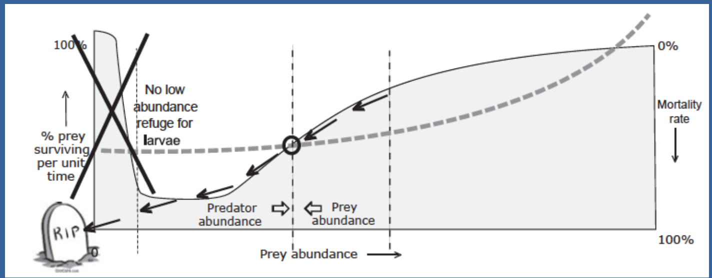
- Reglero et al (2014) conducted metanalysis of tuna spawning activity worldwide: presence/absence of tuna larvae
- At this large scale, the primary drivers of tuna spawning habitats are: SST + Eddy Kinetic Energy (EKE)
- The spawning distribution range of bluefin tunas is typically limited to Western Boundaries systems which have higher SST and intermediate EKE
- The observed bluefin tuna spawning range is much more restricted than the one predicted from model covariates

What constrains fish spawning habitats?

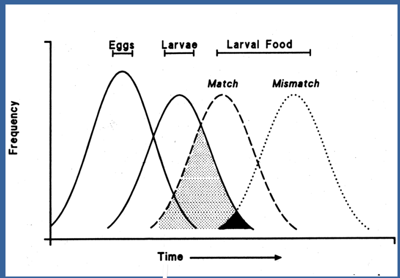
Close life-cycle



Reduce predation



Increase feeding

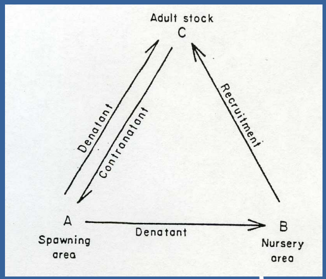


Driven by surroundings (ecology)

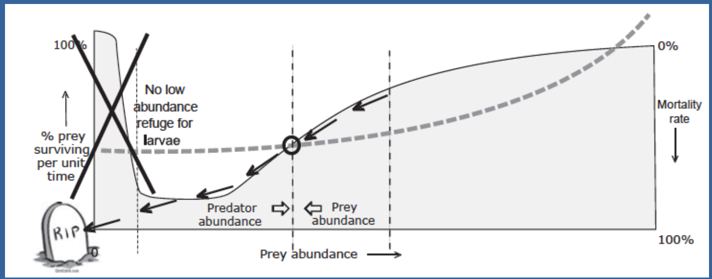
- Why does bluefin tuna only spawn in Med and GOM?

What constrains fish spawning habitats?

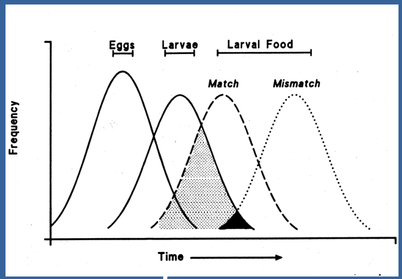
Close life-cycle



Reduce predation



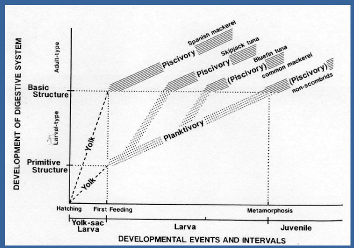
Increase feeding



Driven by surroundings (ecology)

Development

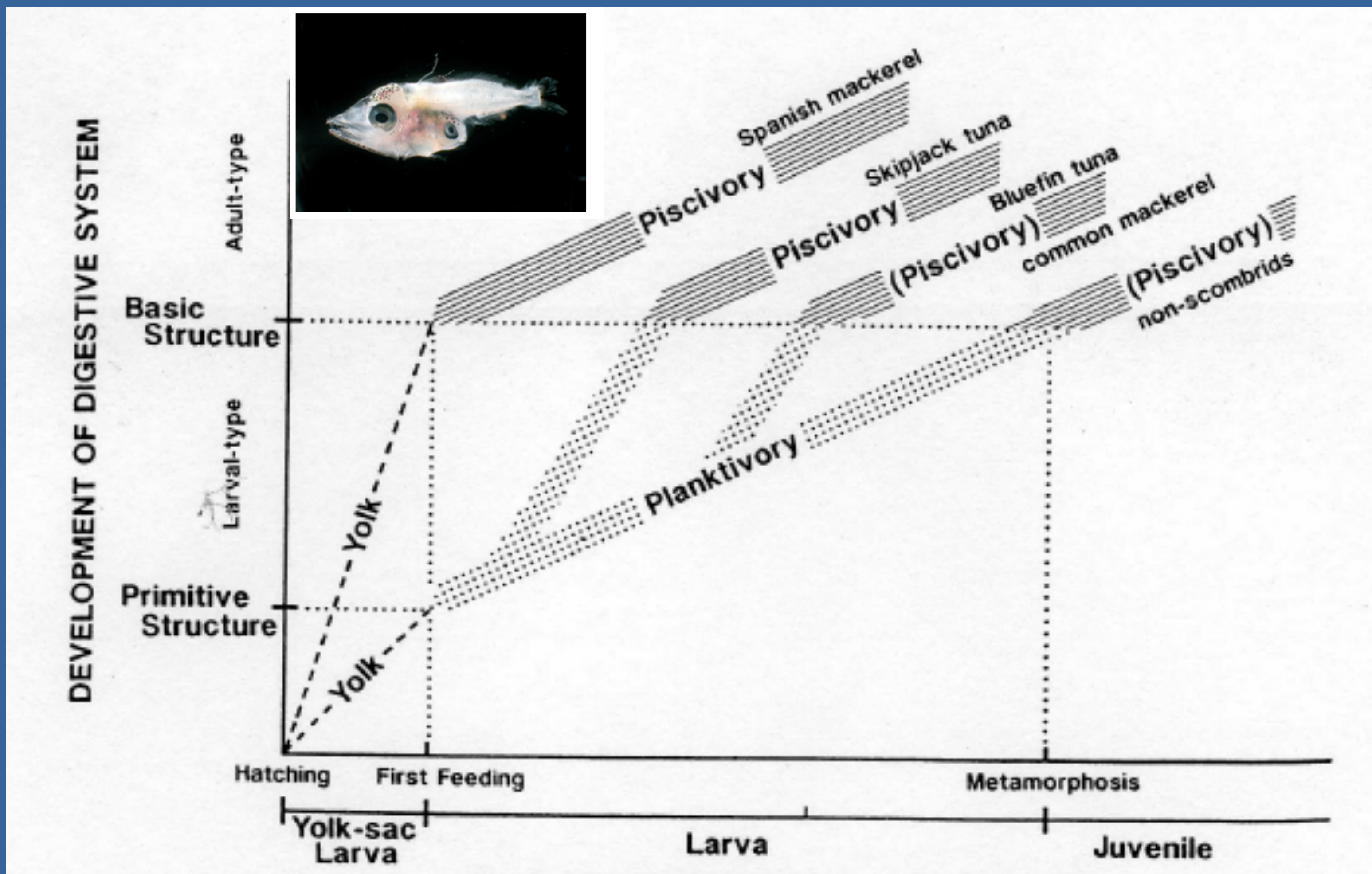
Physiology



Encountering mates

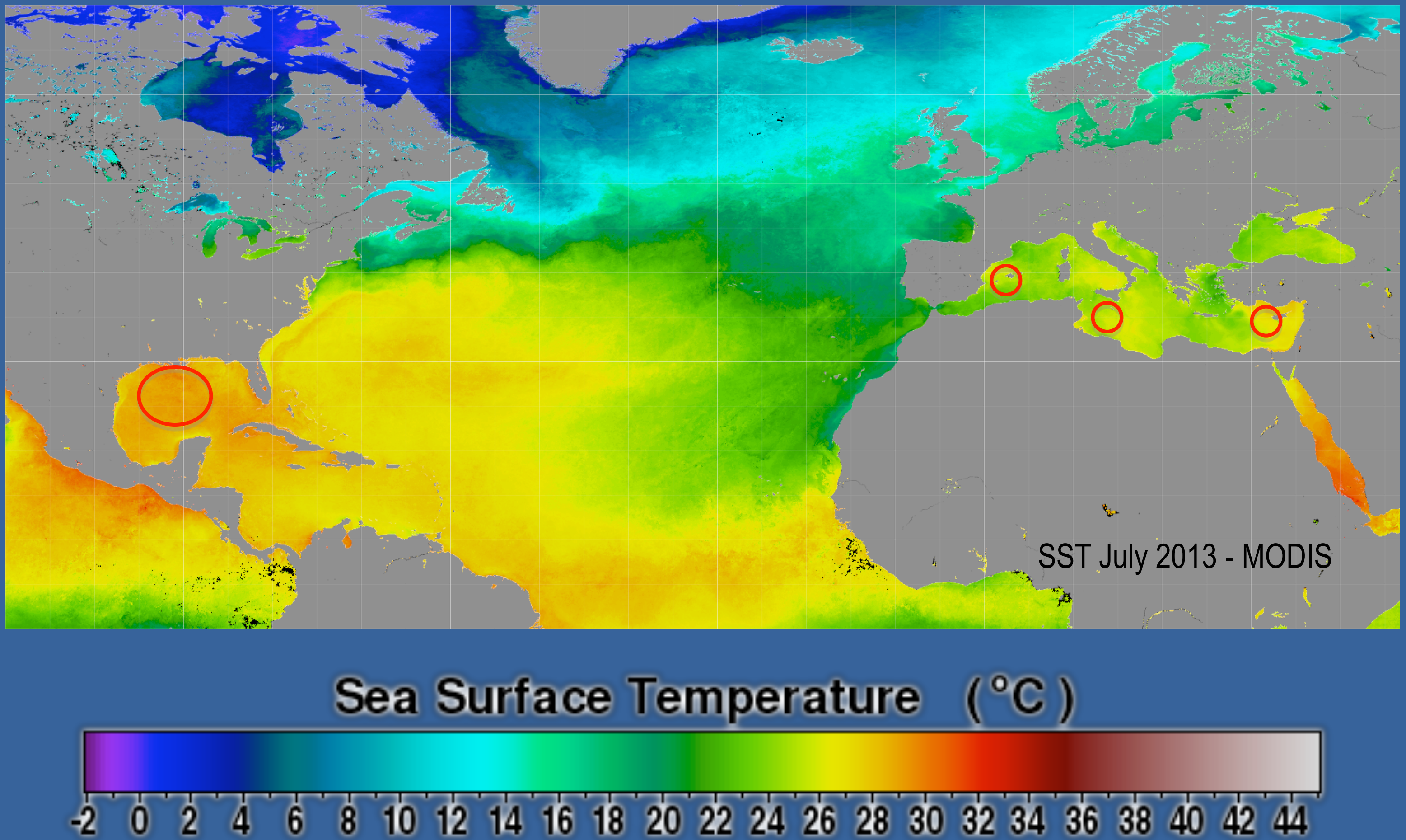
Driven by evolutionary history

Physiological constraints



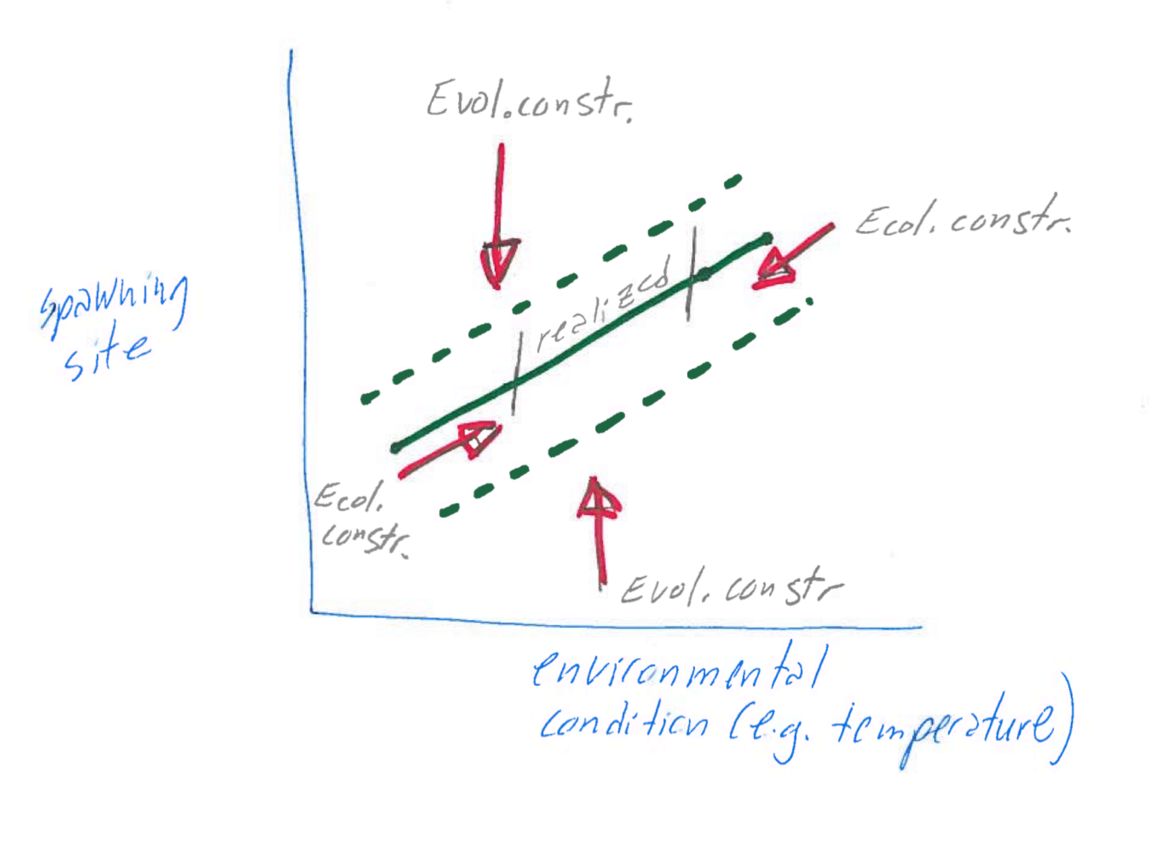
Tanaka et al. 1996

2. Physiological constraints



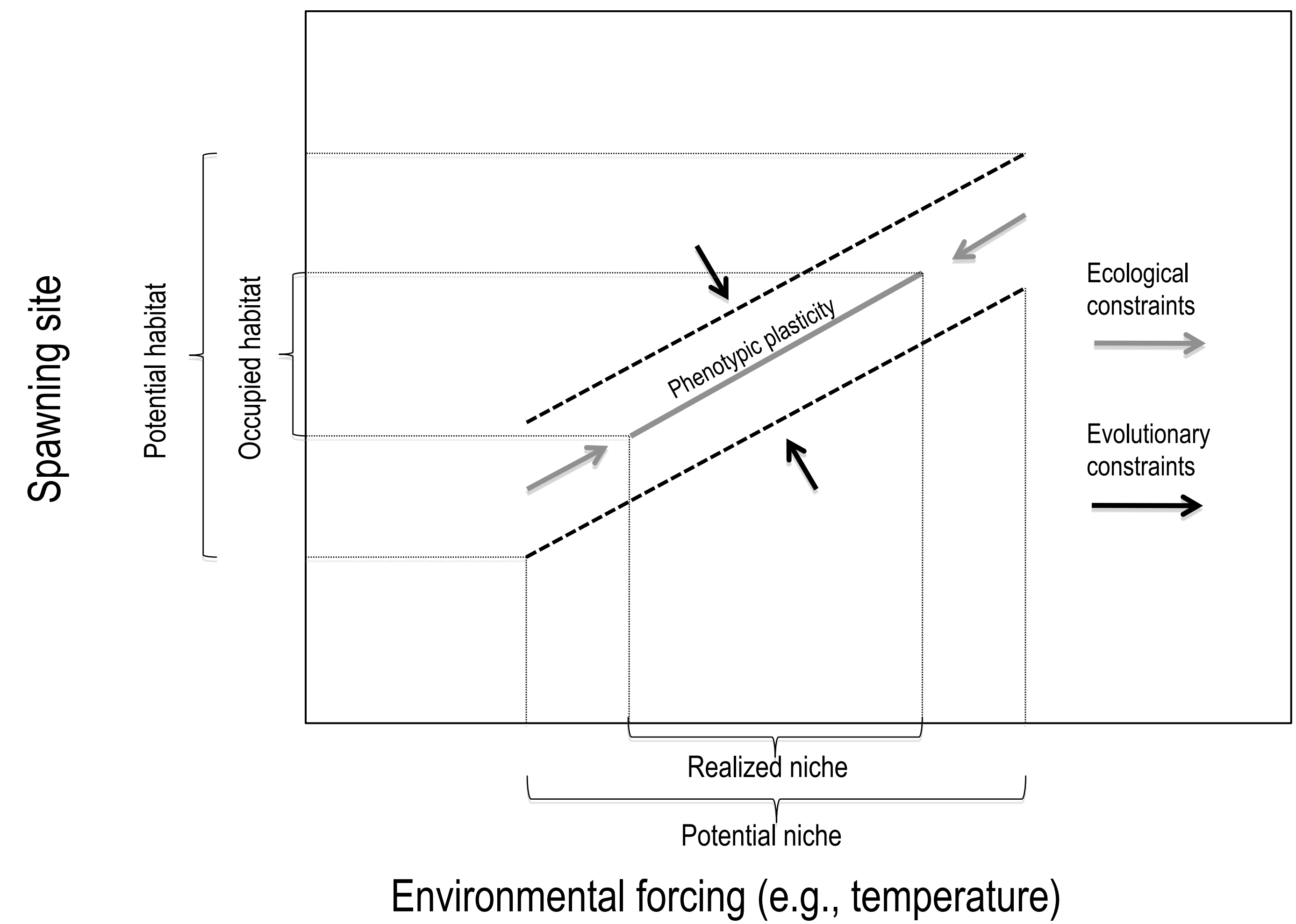
How adaptable are spawning sites?

How adaptable are spawning sites?



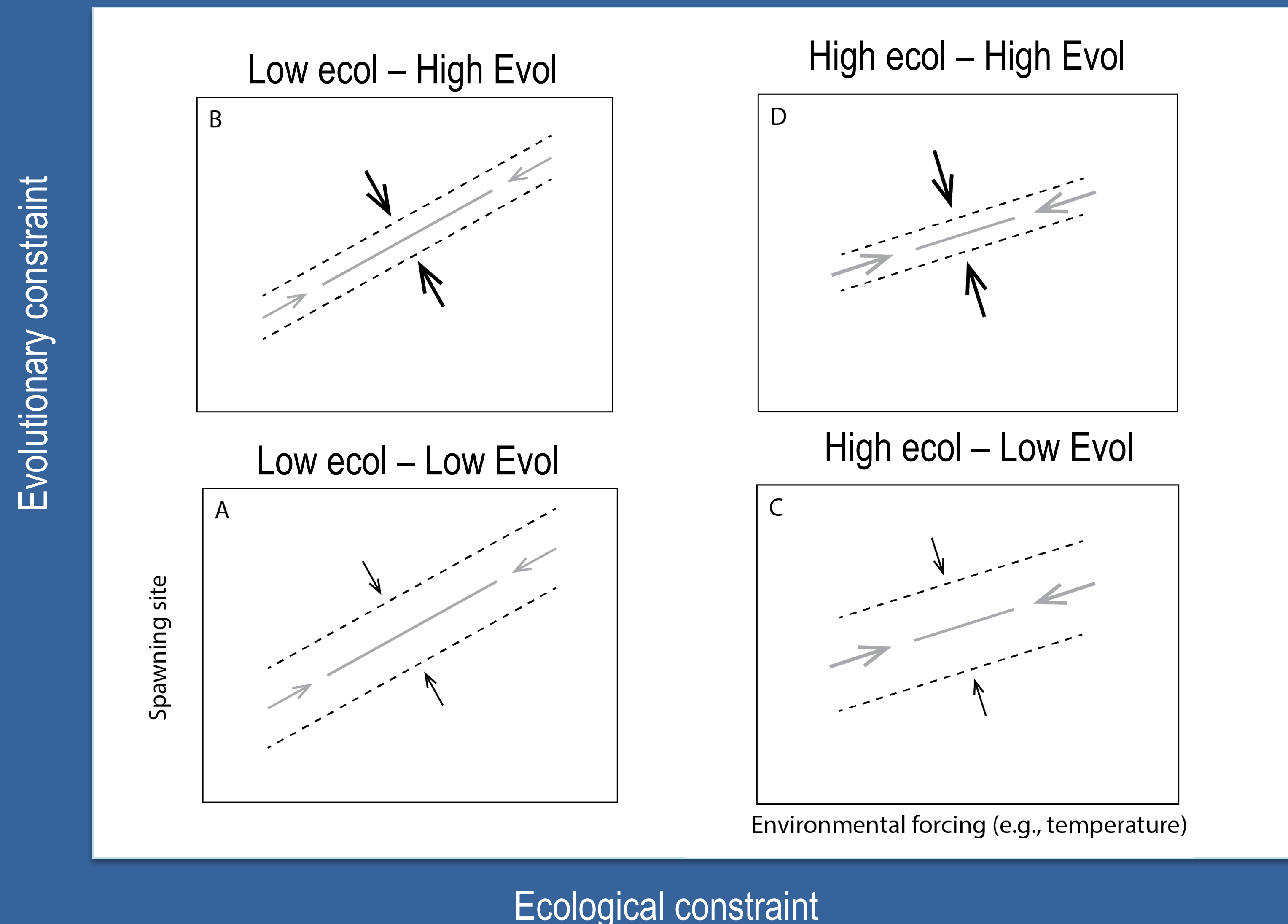
Drawing by Esben Moland Olsen *(after a beer, or 2)*

How adaptable are spawning sites?



Ciannelli et al. 2015

How adaptable are spawning sites?



Ciannelli et al. 2015

How adaptable are spawning sites?

Evolutionary constraint

Low ecol – High Evol

Short term: high
Long term: low
Large pelagics

High ecol – High Evol

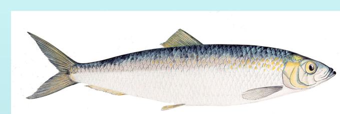
Least adaptable
Slope-spawning flatfish

Low ecol – Low Evol

Most adaptable
Small pelagics

High ecol – Low Evol

Short term: low
Long term: high
Gadids, herring



Ecological constraint

Ciannelli et al. 2015

Conclusions

1. Habitat constraints: occur primarily during early life history stages
2. Species with spatially constrained and unconstrained stages may be unable to spatially close the life cycle
3. Spawning habitats are affected by both ecological and evolutionary processes
4. Combining plastic and evolutionary responses to better predict species distribution and adaptability to future climate scenarios