Another critical period: Physiological limits determine recruitment success during the post-larval stage of a temperate clupeid (*Sprattus sprattus* L.)

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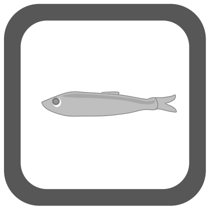
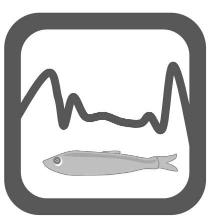
Outline



Life-cycle in the Baltic Sea, key studies

1-D growth model of seasonal cohorts

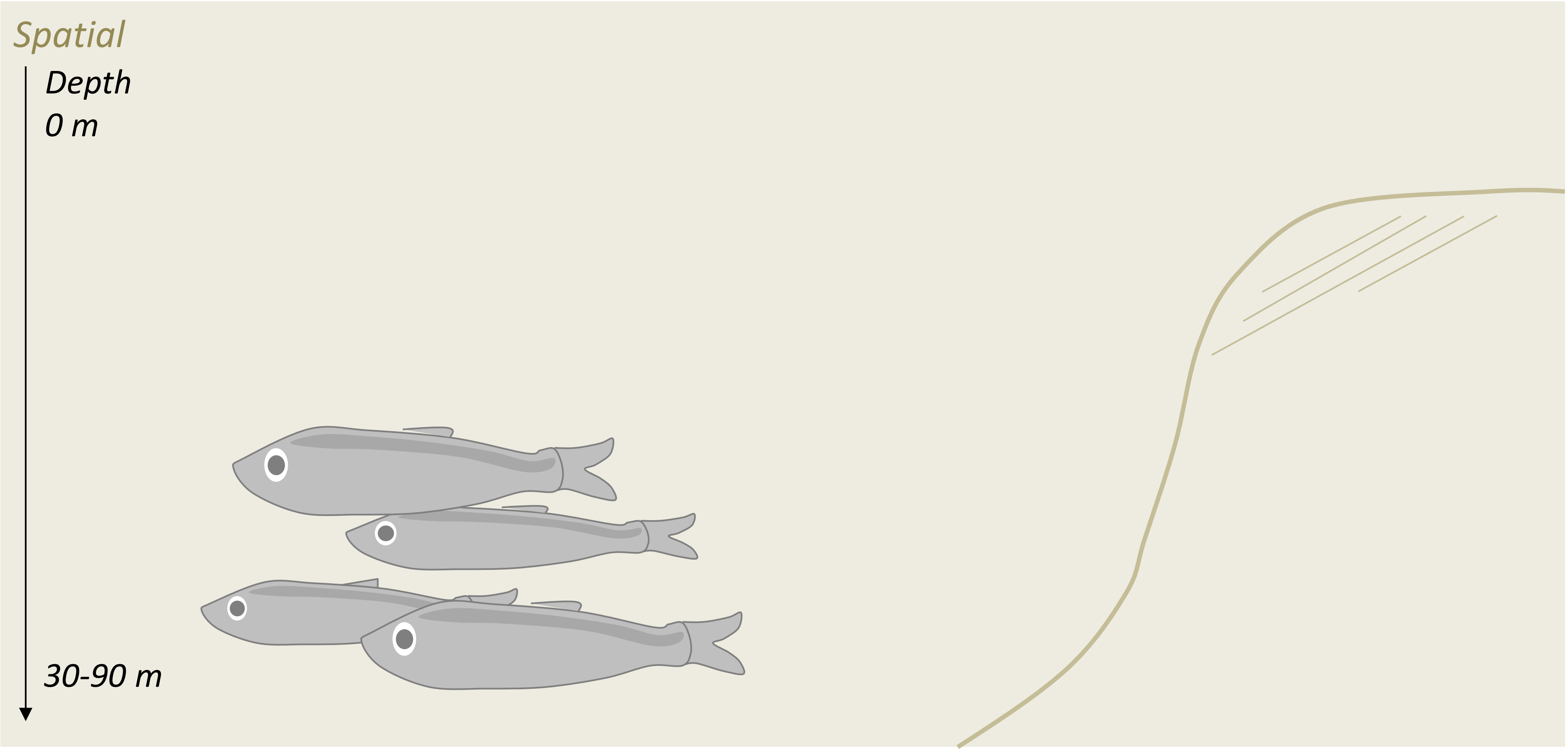
Growth performance in selected years

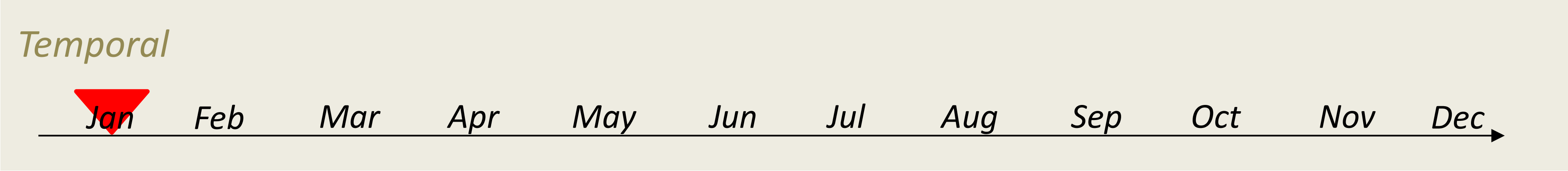


End-of-growing season condition & recruitment

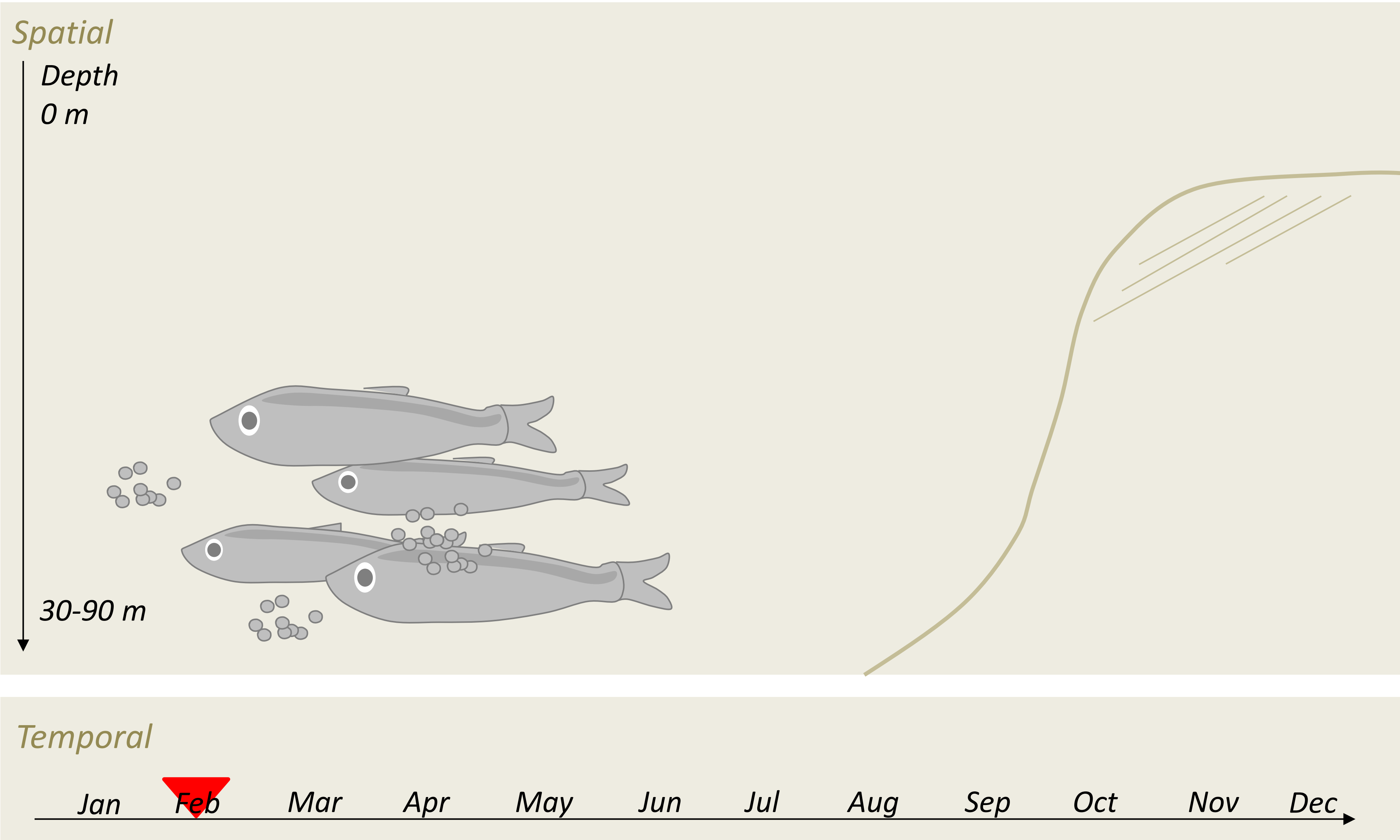
Sprat life-cycle in the Baltic Sea

Sprat life-cycle in the Baltic Sea

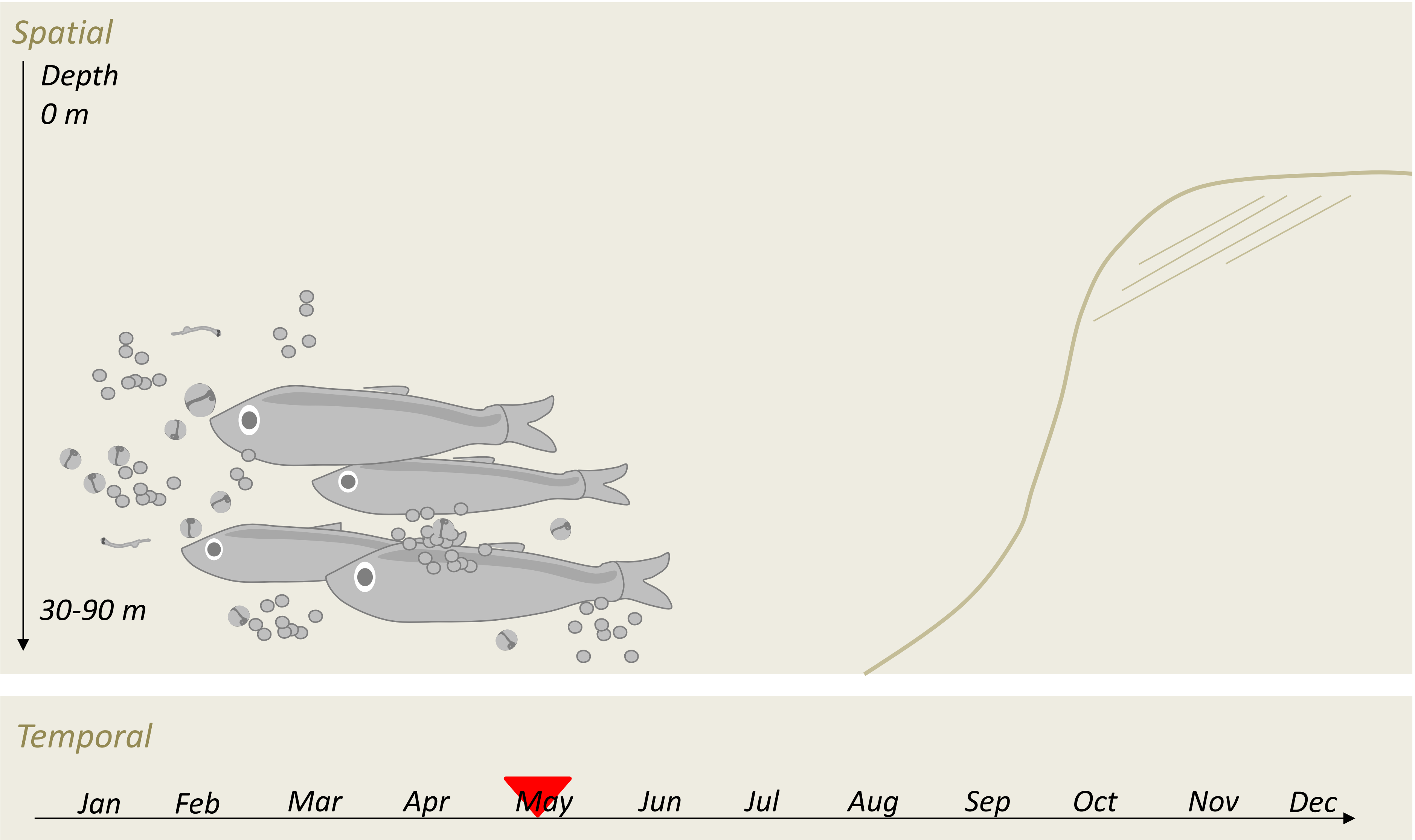




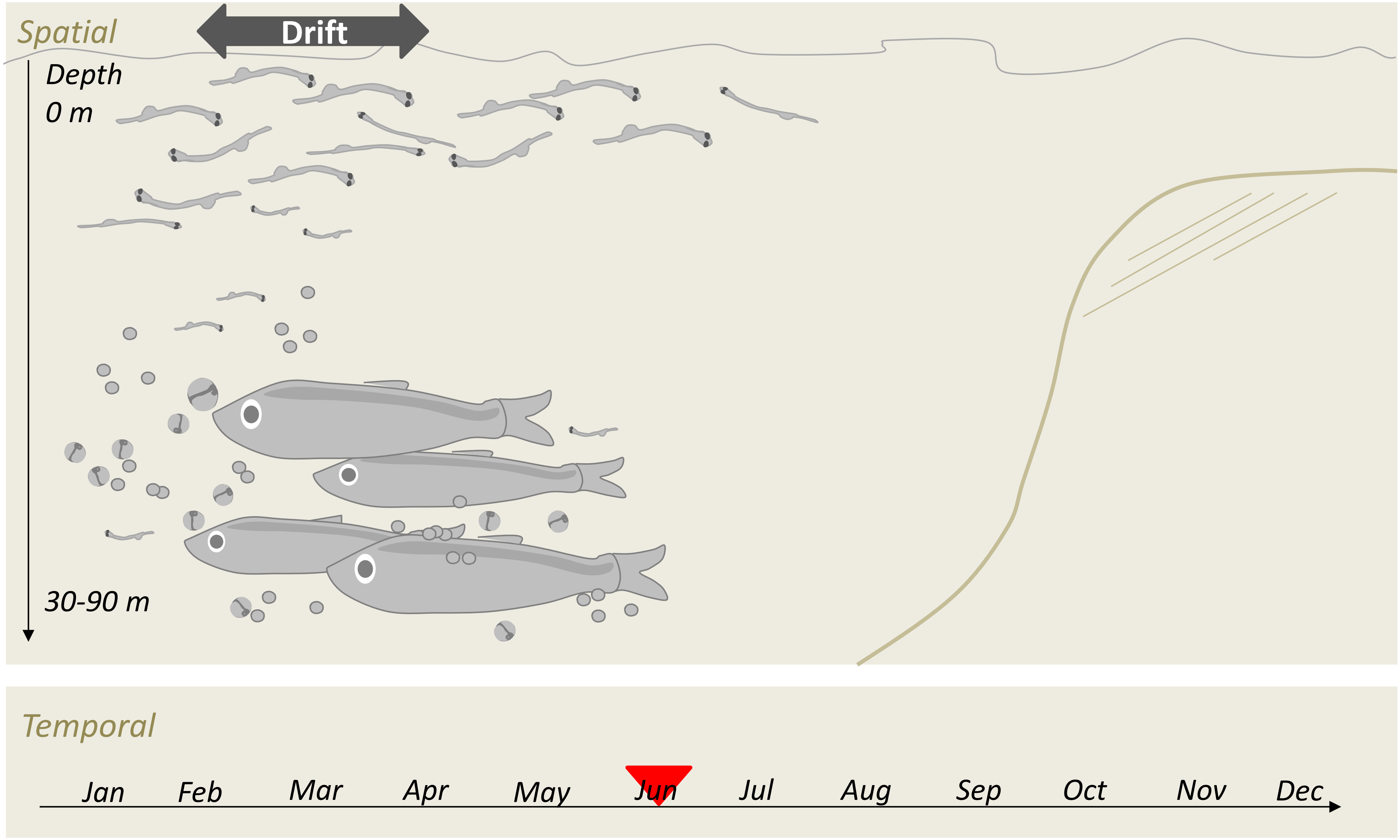
Sprat life-cycle in the Baltic Sea



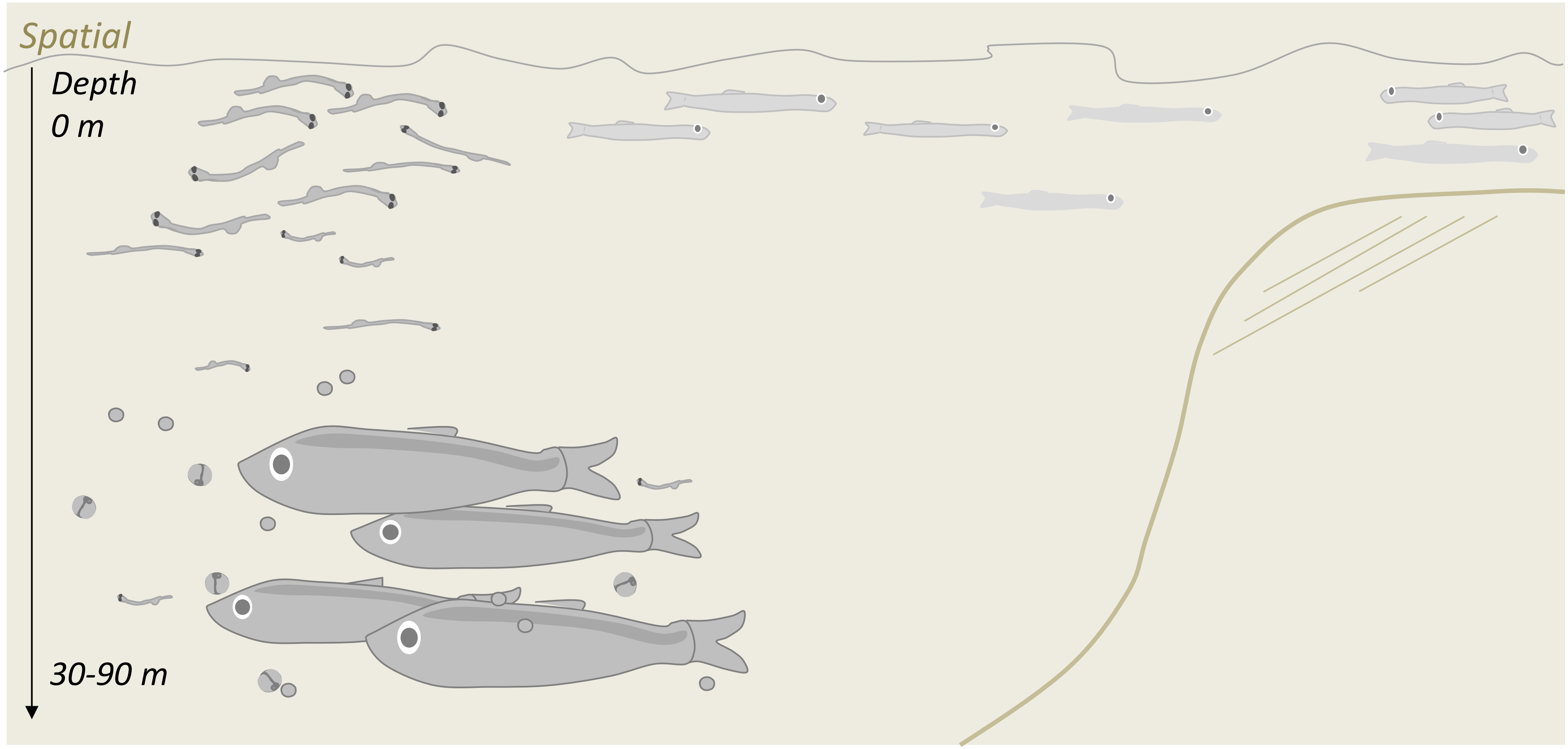
Sprat life-cycle in the Baltic Sea

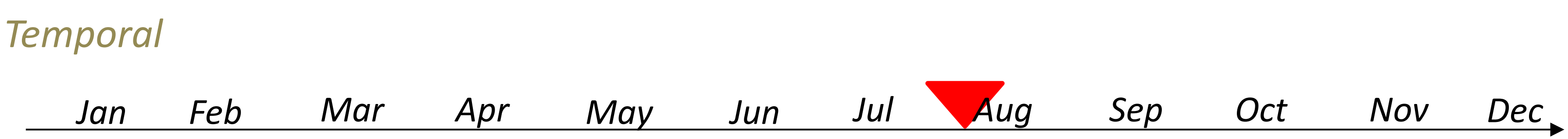


Sprat life-cycle in the Baltic Sea

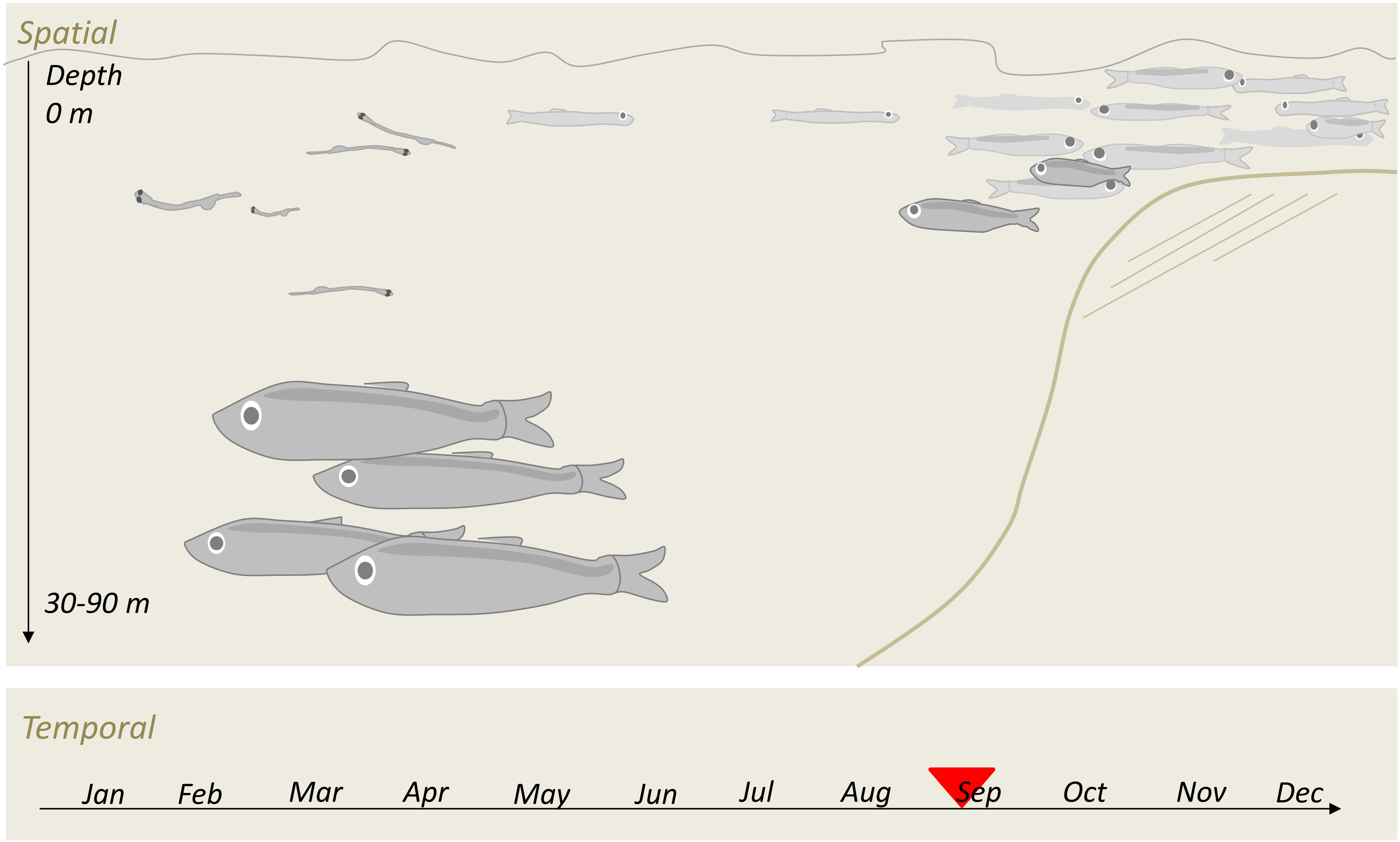


Sprat life-cycle in the Baltic Sea

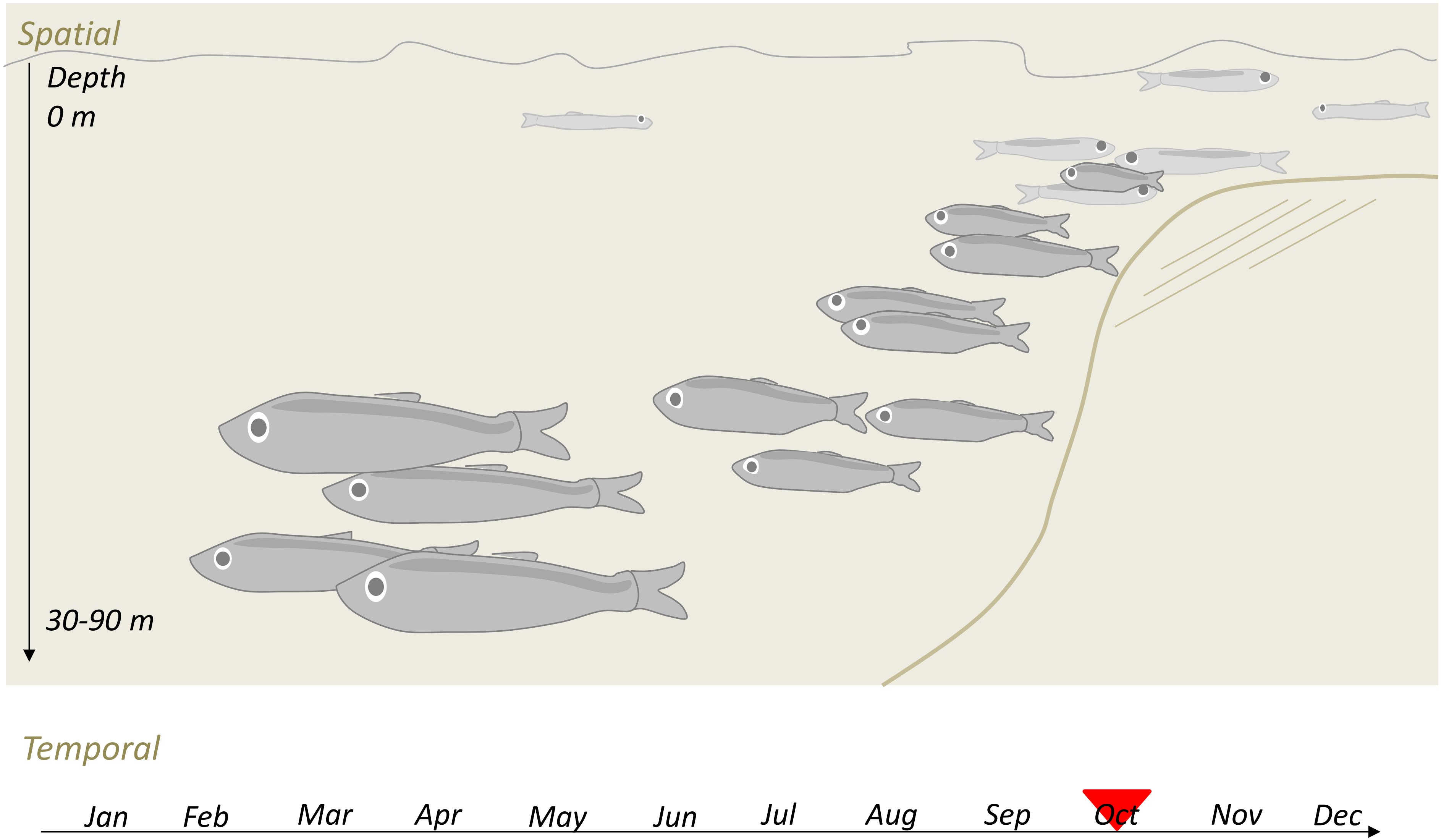




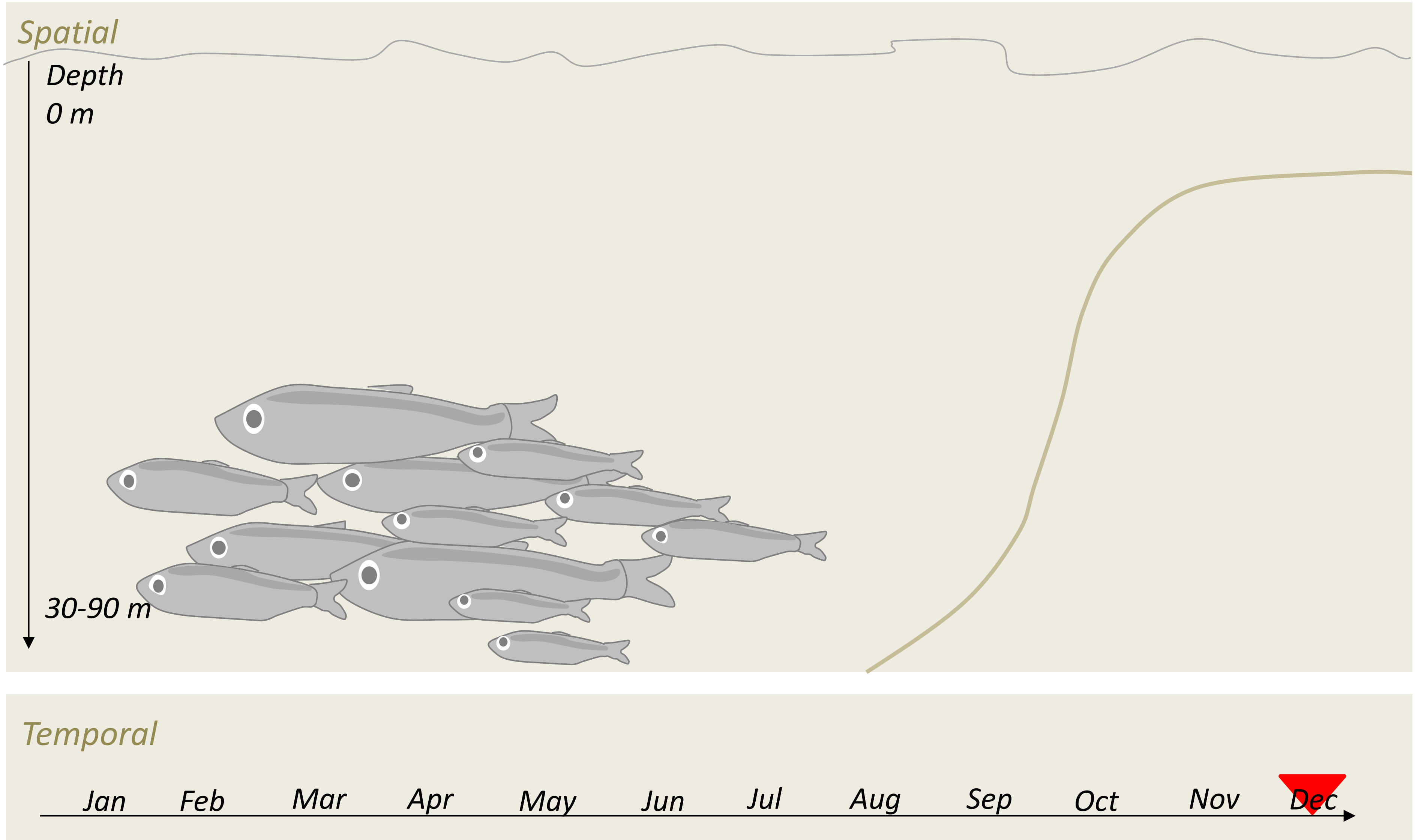
Sprat life-cycle in the Baltic Sea



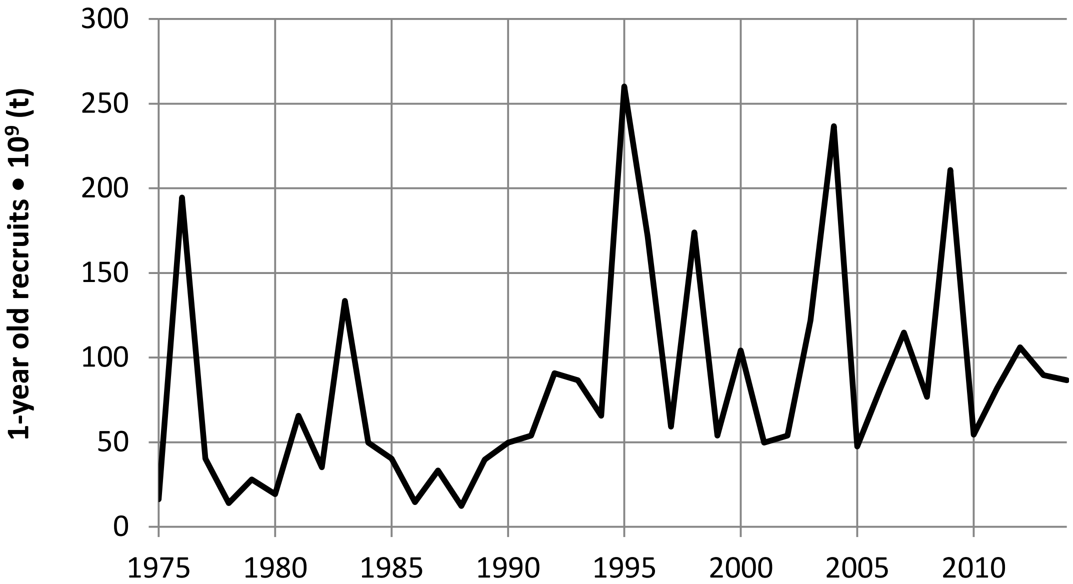
Sprat life-cycle in the Baltic Sea

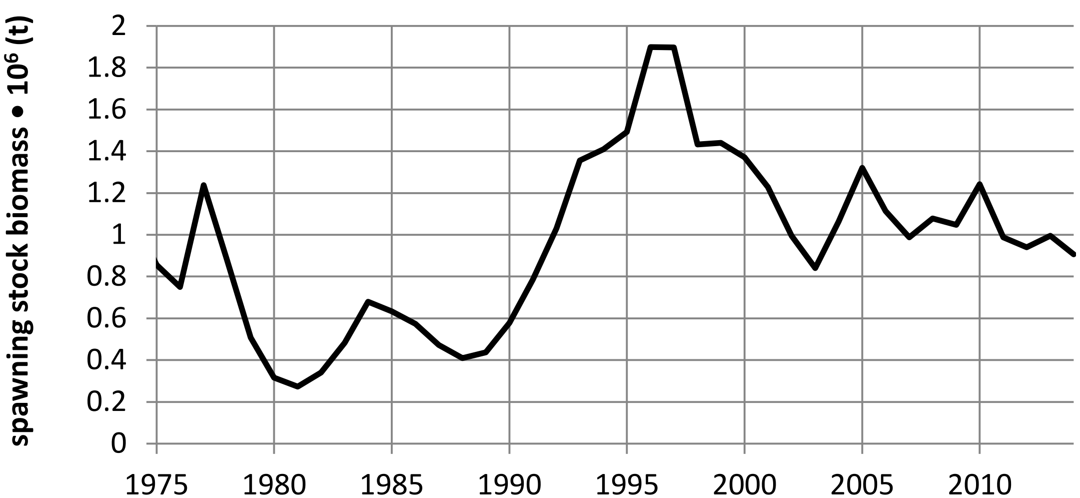


Sprat life-cycle in the Baltic Sea



Recruitment variability and critical life-stage





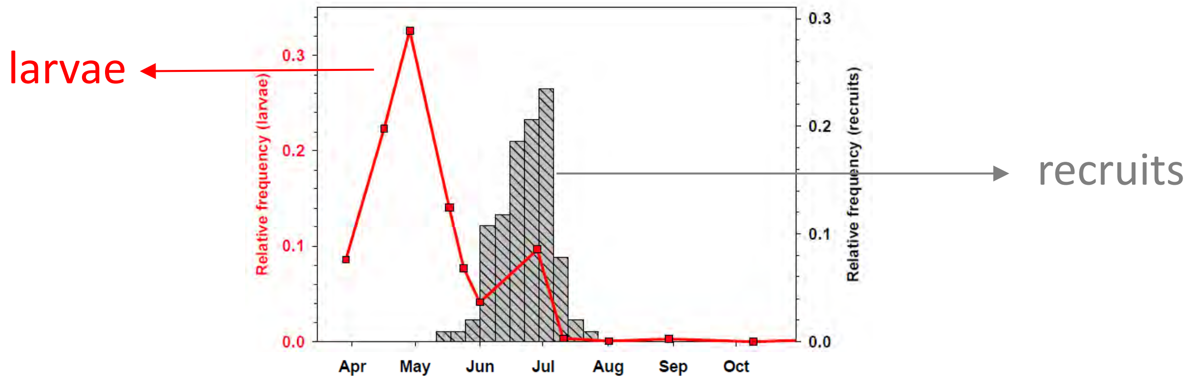
data from ICES WGBIFS 2015

Recruitment variability and critical life-stage

1a. Köster *et al*. 2003: **post-larval critical life-stage**

1b. Voss *et al*. 2012: **Act key mechanisms in coastal habitats of juveniles?**

2. Baumann *et al*. 2008: mismatch of peak spawning and peak origin of autumn-caught YoY/survivors:



Central Baltic Sea 2002

Recruitment variability and critical life-stage

1a. Köster *et al*. 2003: **post-larval critical life-stage**

1b. Voss *et al*. 2012: **Act key mechanisms in coastal habitats of juveniles?**

2. Baumann *et al*. 2008: **„summer over spring born"**

But why?

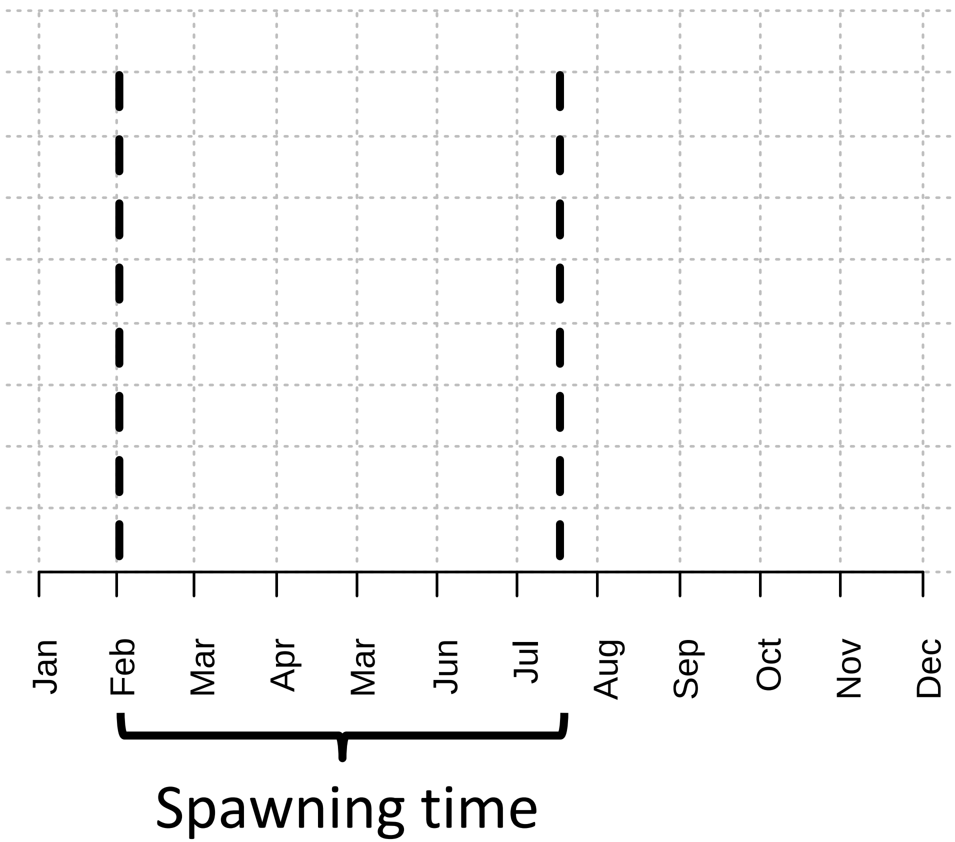
Our working hypotheses:

(1) recruitment strength is **bottom-up** regulated

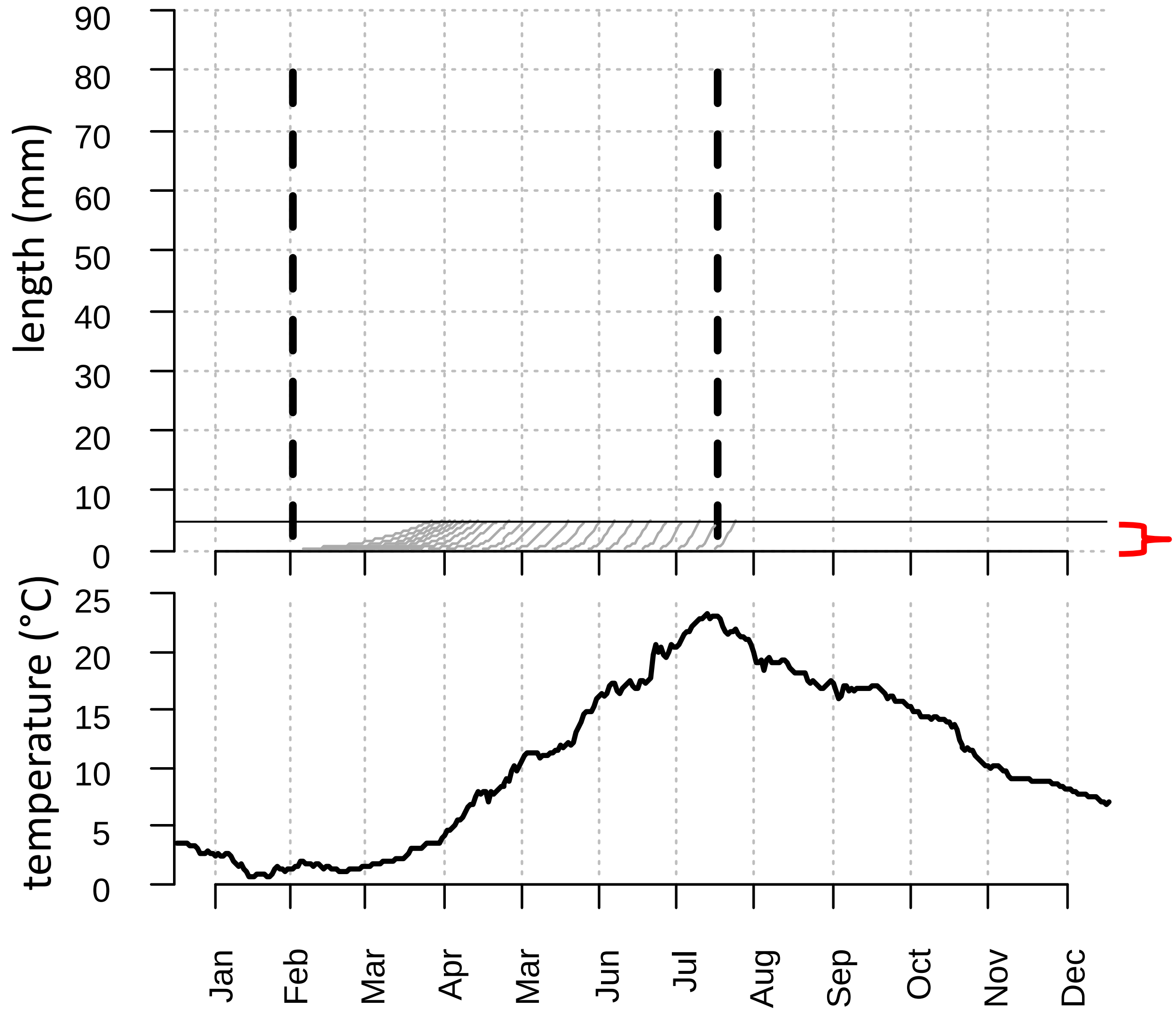
(2) survival is the result of **temperature * food** interaction in the post-larval stage defining a sucessful **„starting time"**

(3) **growth performance** in the post-larval stage **modulates survival** and **survival determines year-class strength**

Growth model of seasonal cohorts

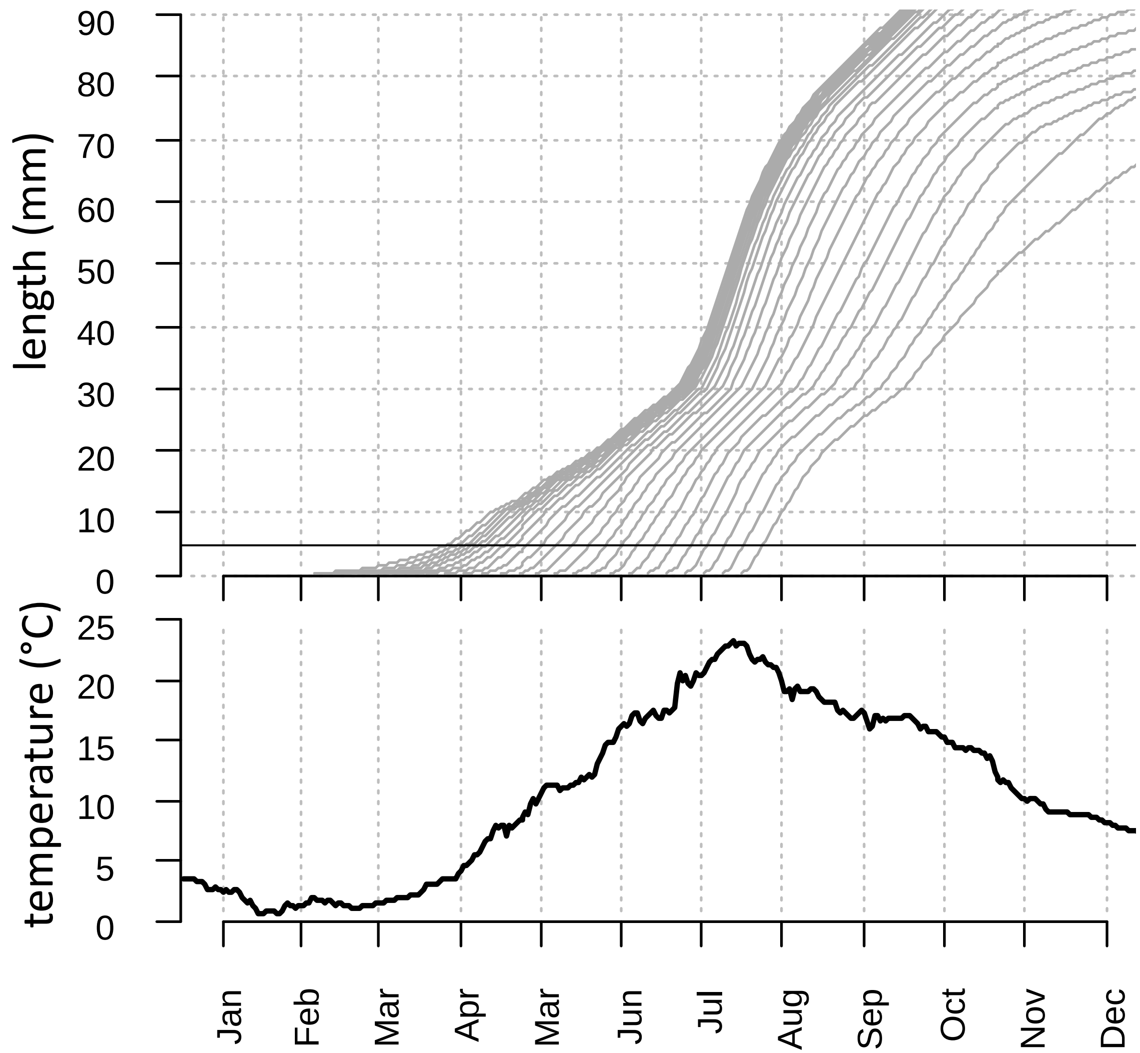


Growth model of seasonal cohorts



Temperature dependent development of egg & yolk sac larvae (Petereit *et al.* 2008)

Growth model of seasonal cohorts

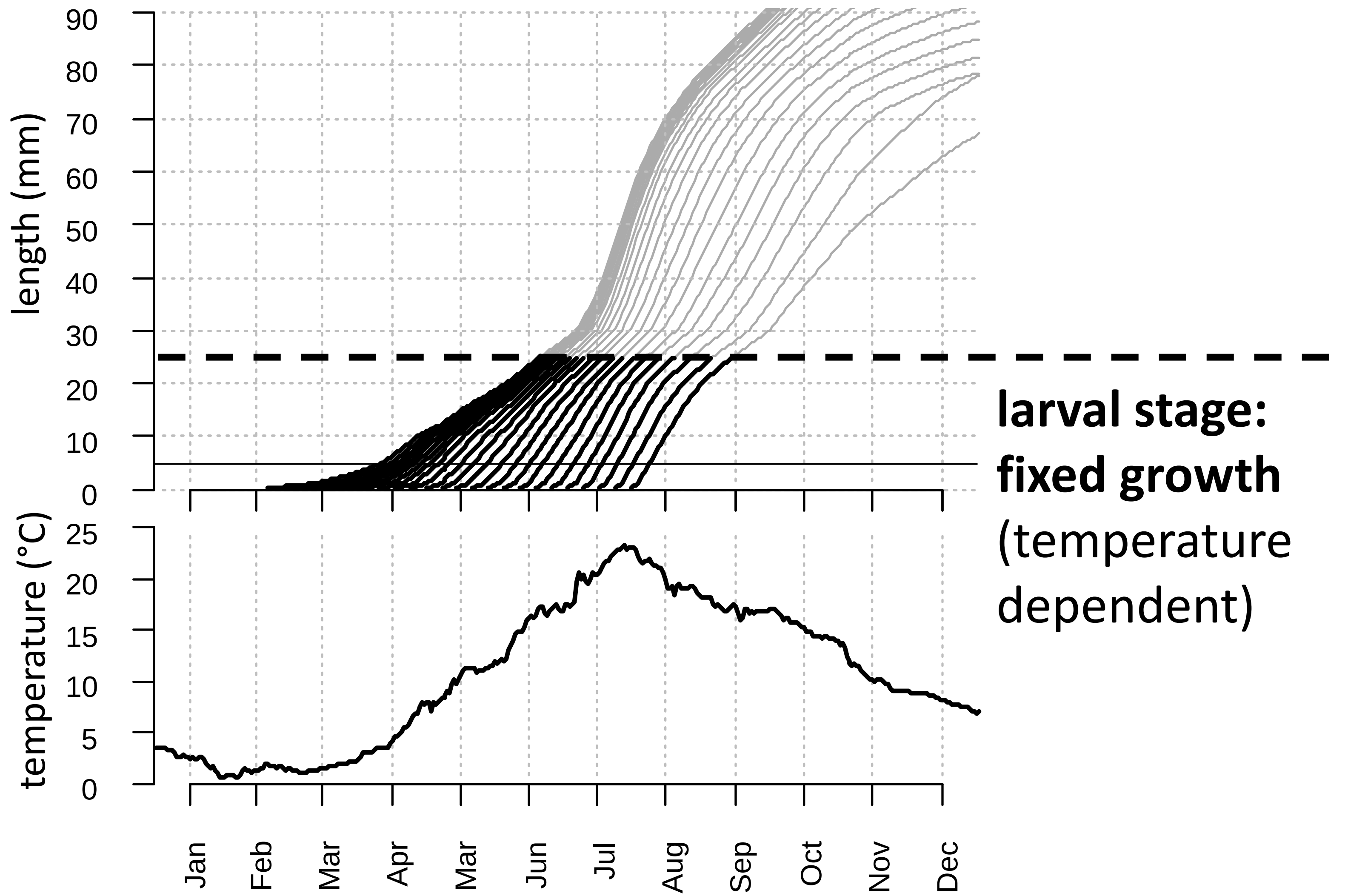


Temperature dependent length growth starting with 5 mm (first feeding)

(back-calculated length growth from otoliths of YoY-survivors, n > 400)

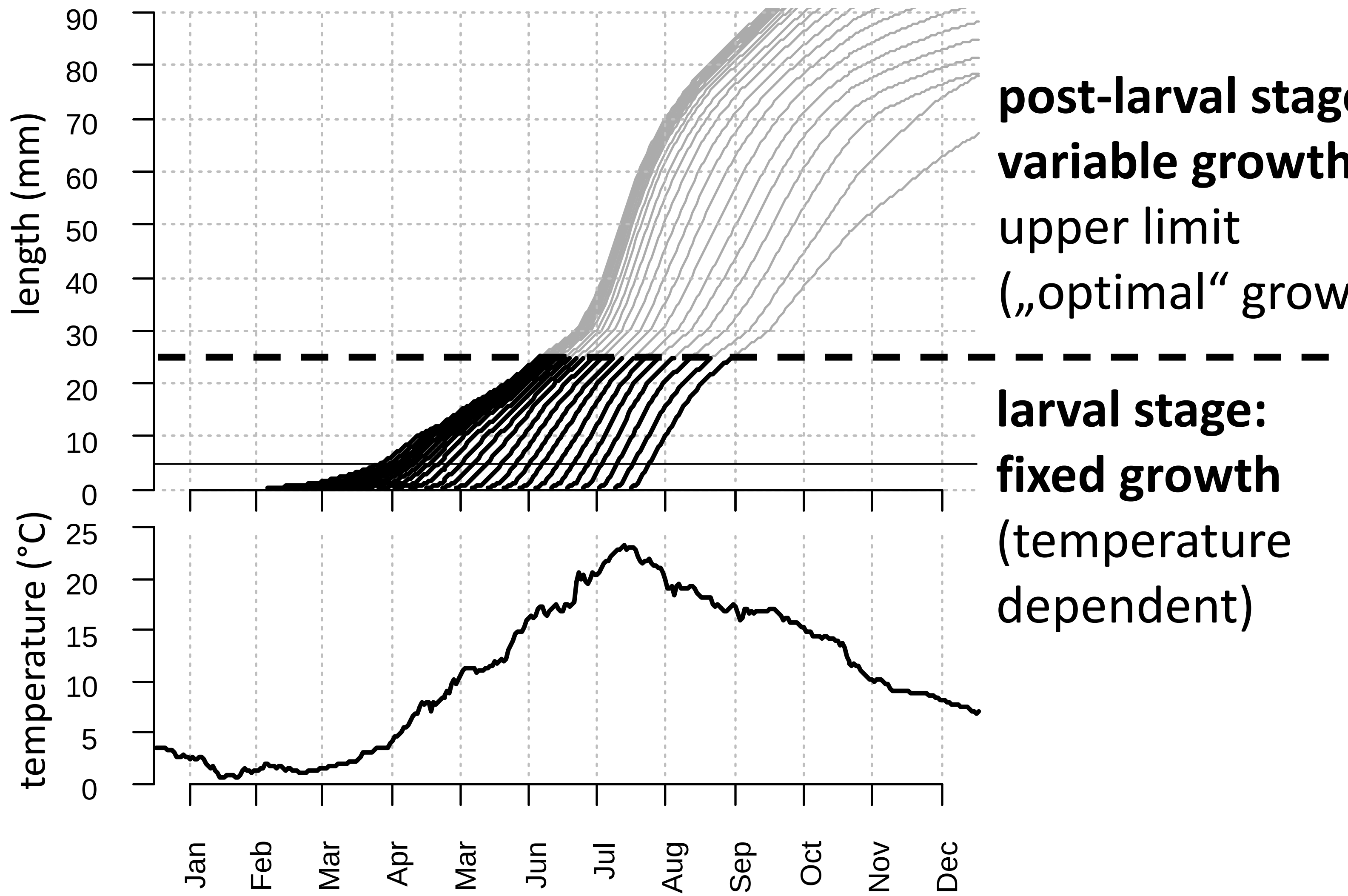
Baumann *et al.* 2008, Günther *et al.* 2012

Growth model of seasonal cohorts



larval stage: fixed growth (temperature dependent)

Growth model of seasonal cohorts



post-larval stage: variable growth
upper limit („optimal“ growth)

larval stage: fixed growth
(temperature dependent)

Post-larval growth per day

Length

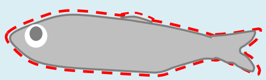
Functional response	Routine metabolism	Swimming performance
Brachvogel *et al.* 2013 Brachvogel *et al.* in prep	Meskendahl *et al.* 2010	Meskendahl *et al.* in prep
f (length, T, daylength, prey concentration & type)	*f* (length, T)	*f* (length, T, daylength, prey concentration)
C [Joule]	$R_{Routine}$ [Joule]	$R_{Feeding\ activity}$ & $R_{Swimming}$ [Joule]

$$G = C - (R_{routine} + R_{Feeding\ Activity} + R_{swimming} + \underbrace{R_{SDA} + F + E}_{0.3*C})$$

Post-larval growth – energy allocation

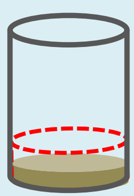
1.

$G < 0$



no growth

\+

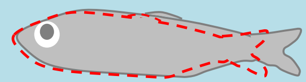


reduction of energy reserves

2.

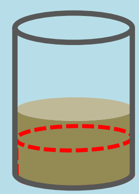
$G > 0$

$G - E_{min} < 0$



(reduced) growth

\+

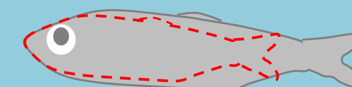


small increase of energy reserves

3.

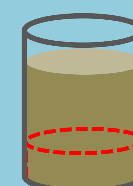
$G > 0$

$G - E_{min} > 0$



(optimal) growth

\+

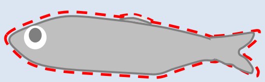


increase of energy reserves

Growth model of seasonal cohorts

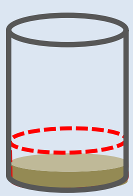
Test run:

Const. **zero** prey concentration



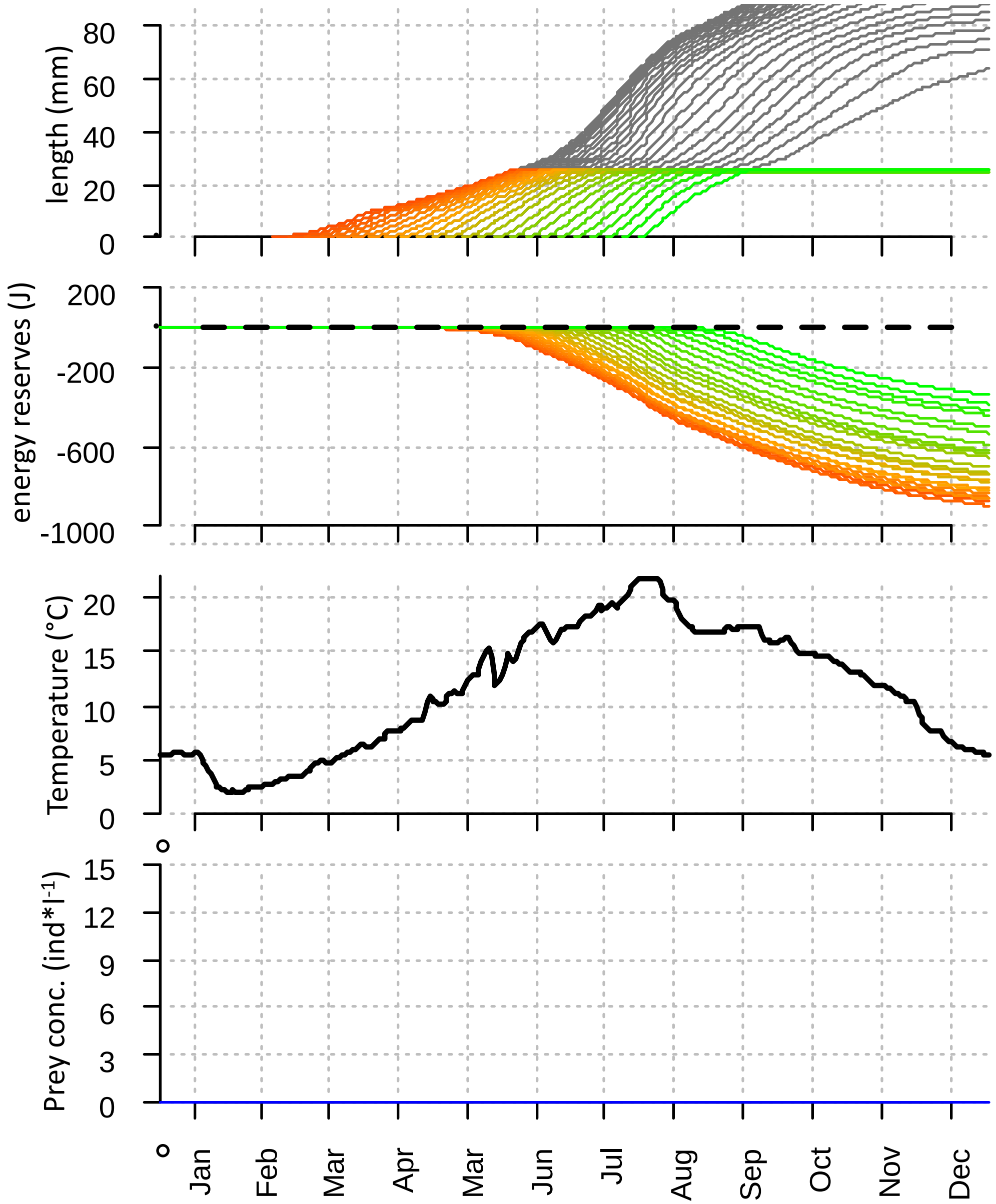
no growth

+



reduction of e-reserves

prey



no plankton

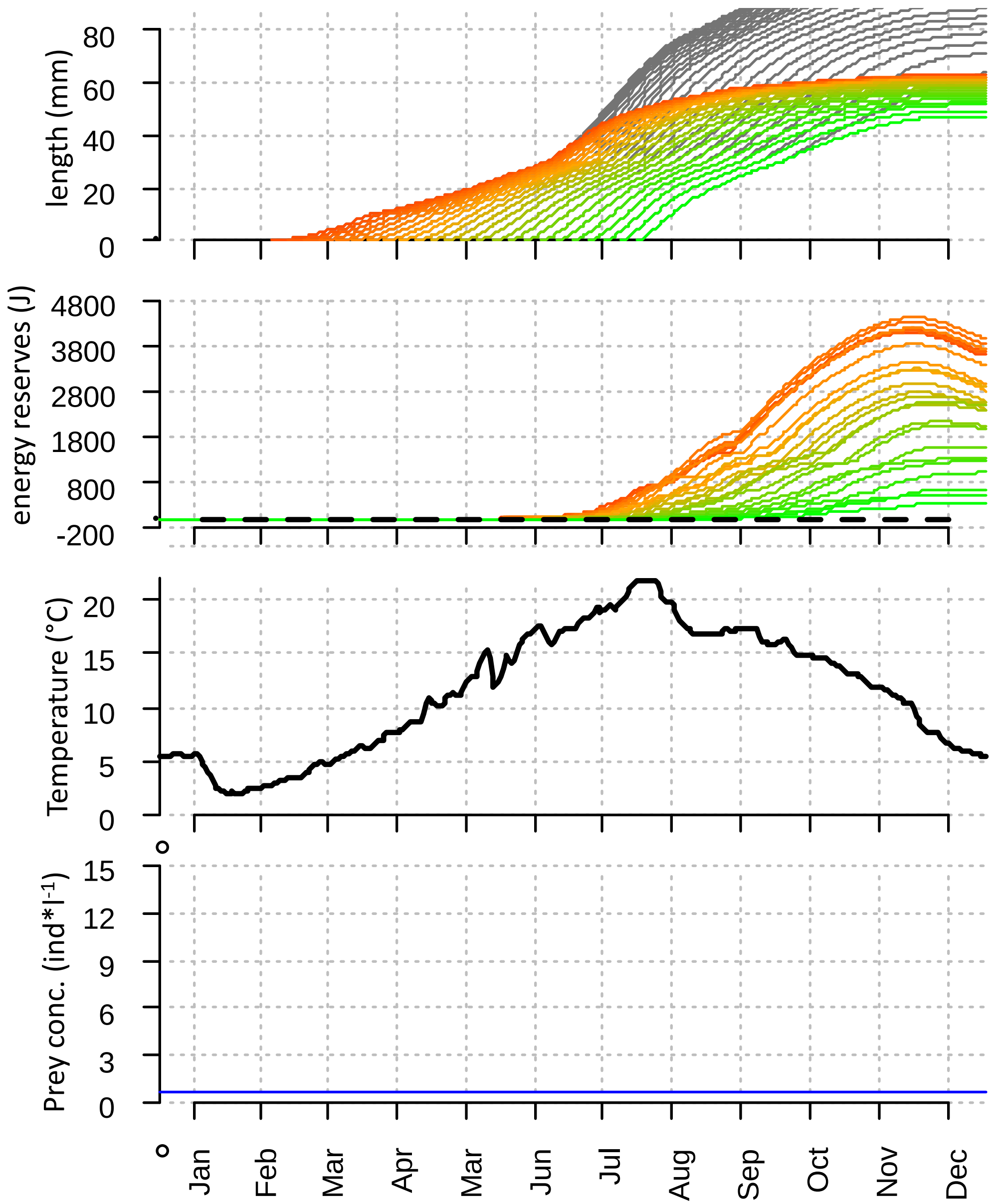
no growth, energy loss

all cohorts die

Growth model of seasonal cohorts

Const. prey concentration
0.6 ind*l^{-1}

reduced growth
+
small increase of e-reserves



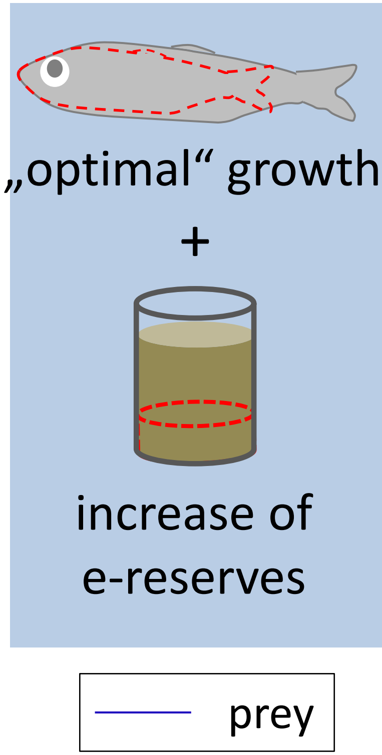
Low prey concentration

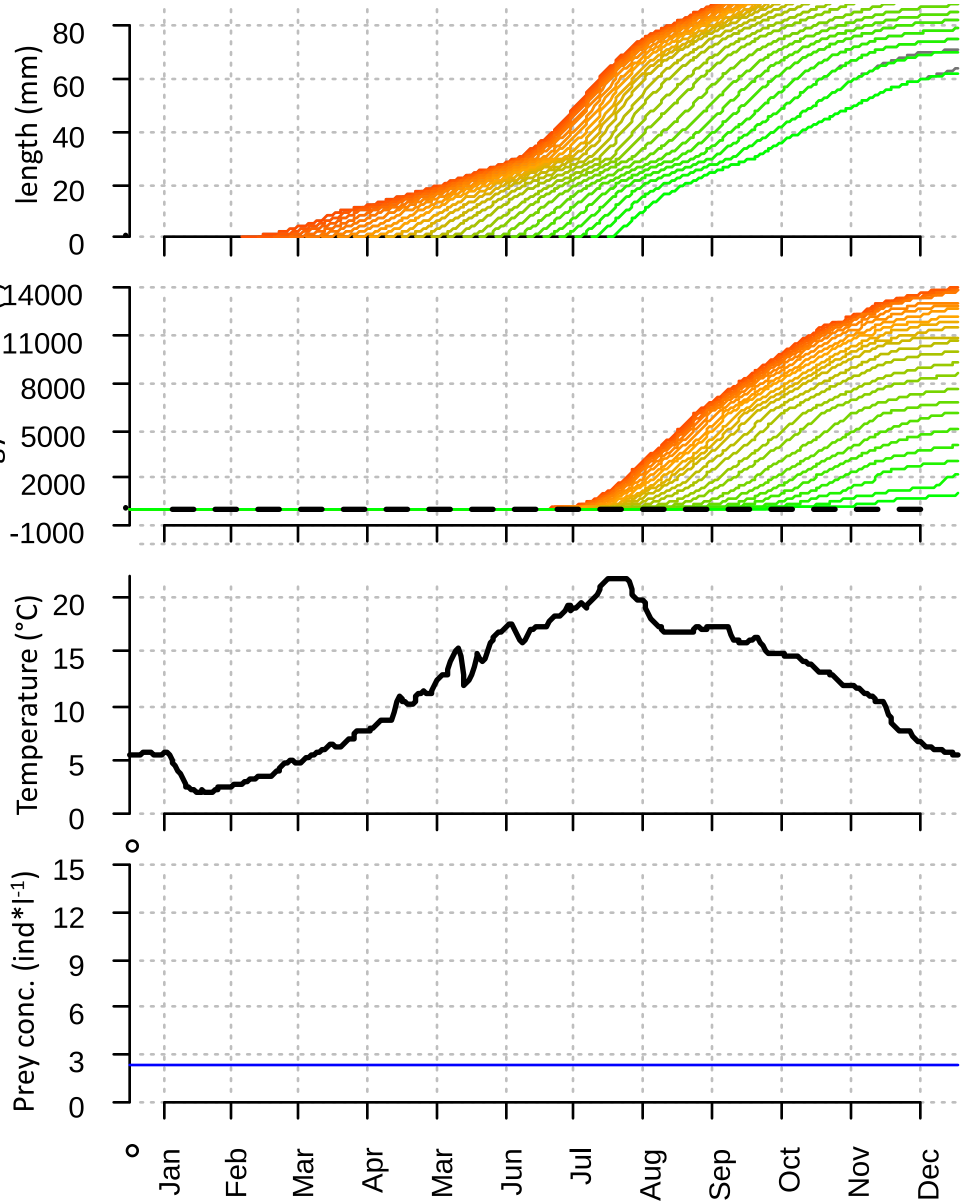
Growth (below „optimal“) and energy storage

Growth model of seasonal cohorts

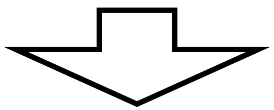
Const. prey concentration

2.4 ind*l^{-1}





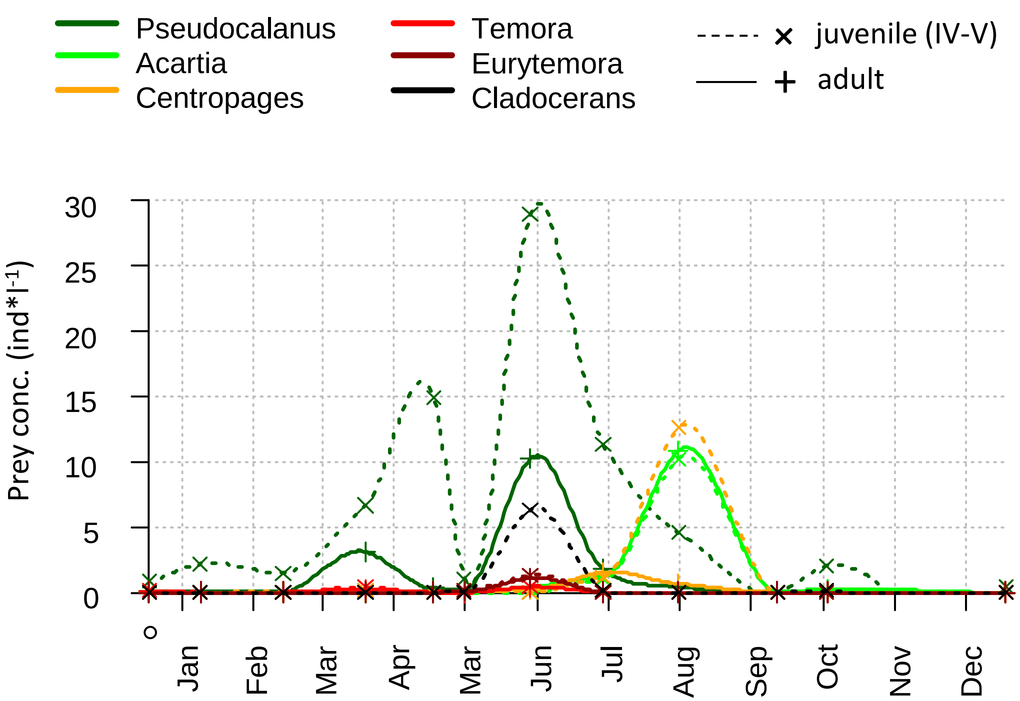
High prey concentration

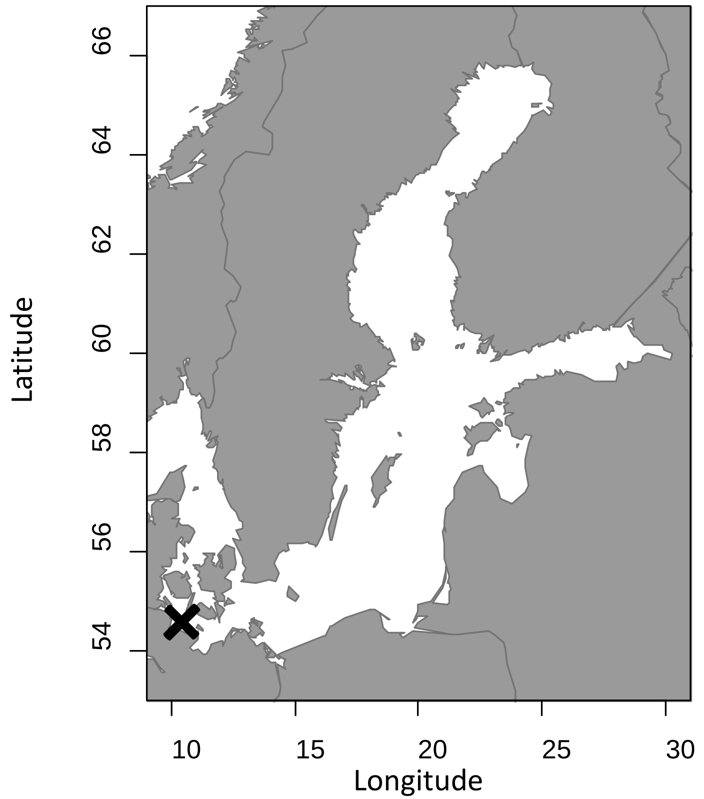


Optimal growth and energy storage

Seasonal plankton time series

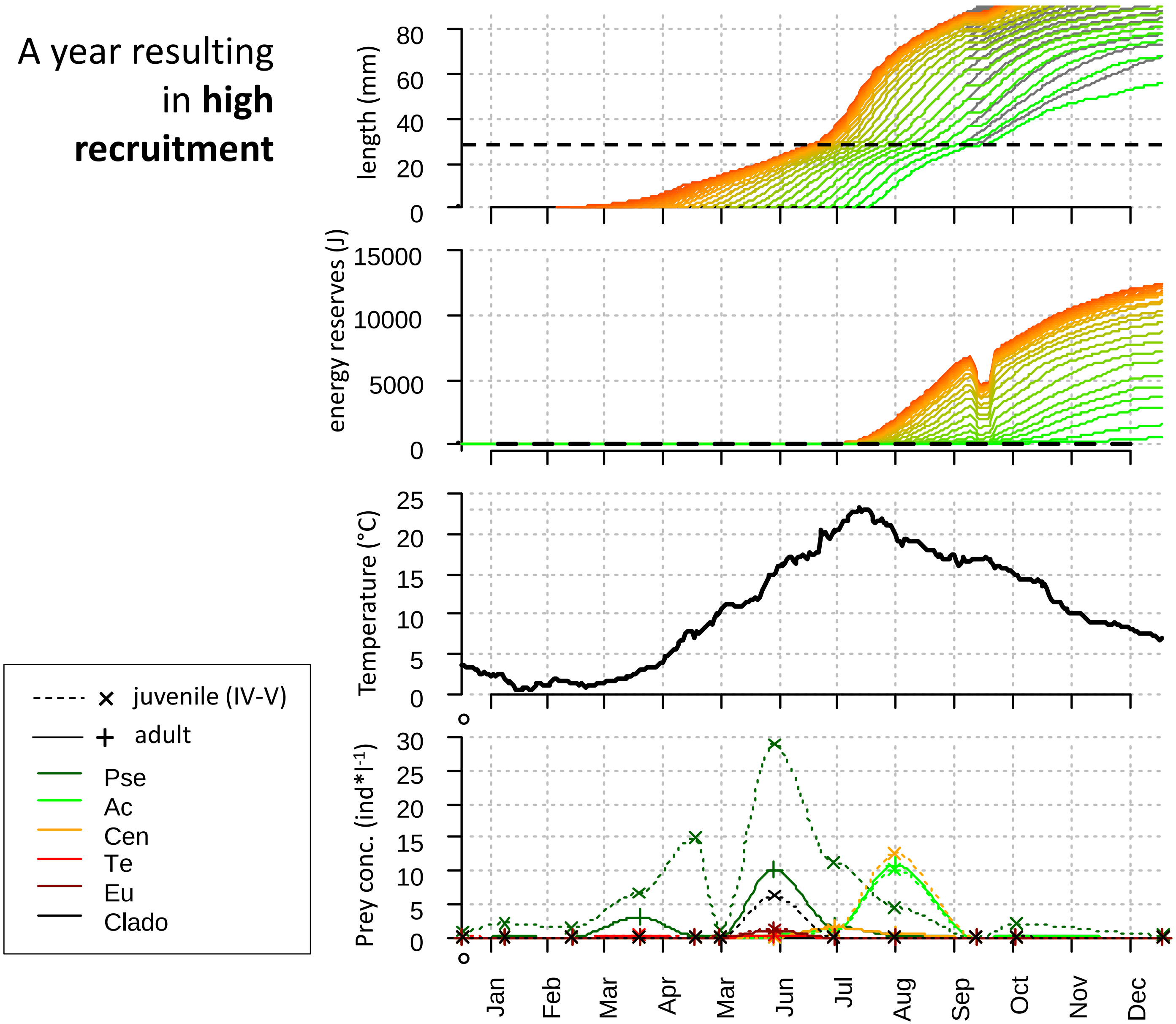
- coastal near location, vertical WP2 hauls (10-49 samples year^{-1})
- 2005 – 2015
- different energy contents per species and stage
- different capture success per species and stage





Real plankton data 2006

A year resulting in **high recruitment**

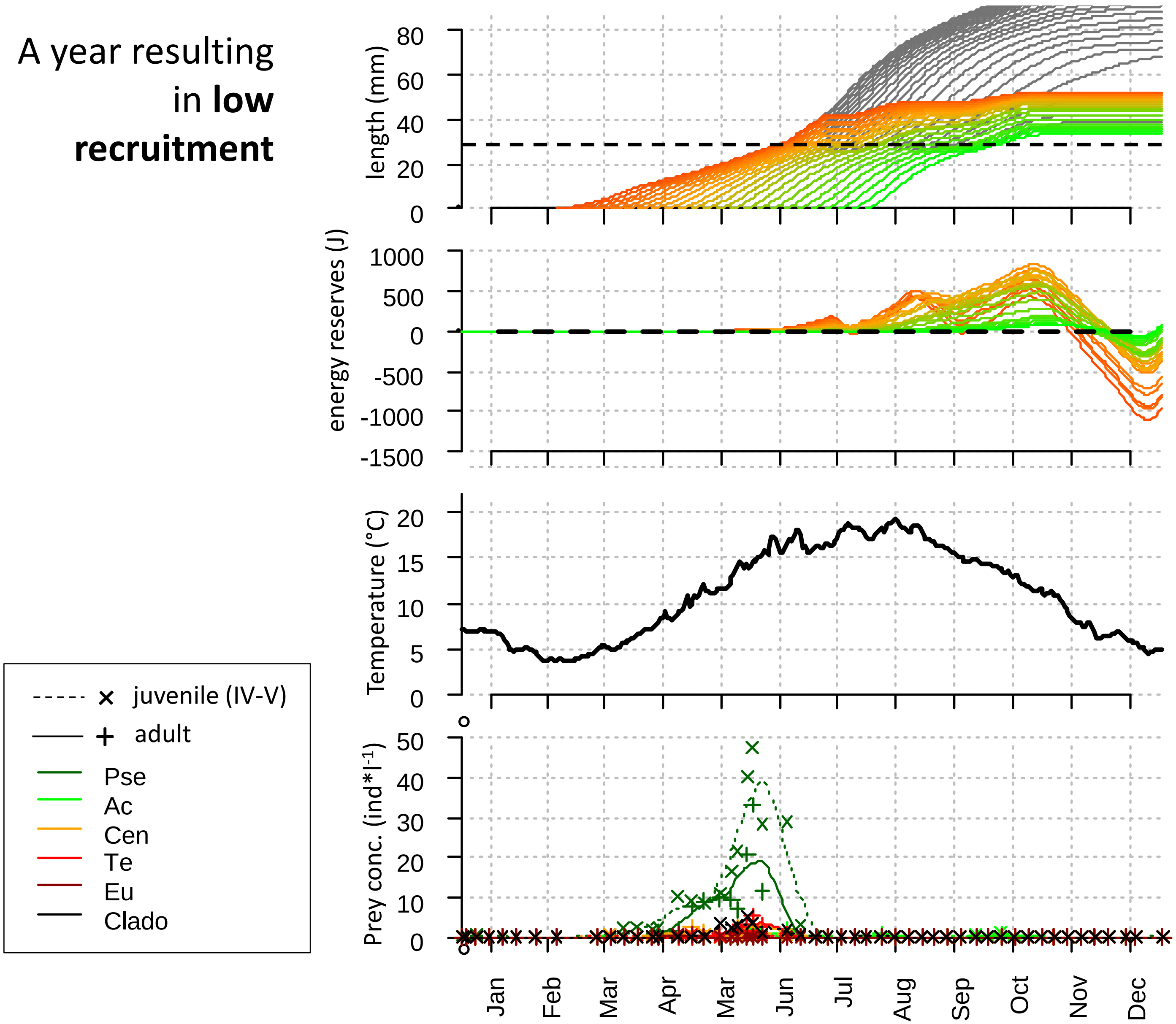


„optimal“ until September & strong increase of energy reserve

all cohorts survive

Real plankton data 2007

A year resulting in **low recruitment**



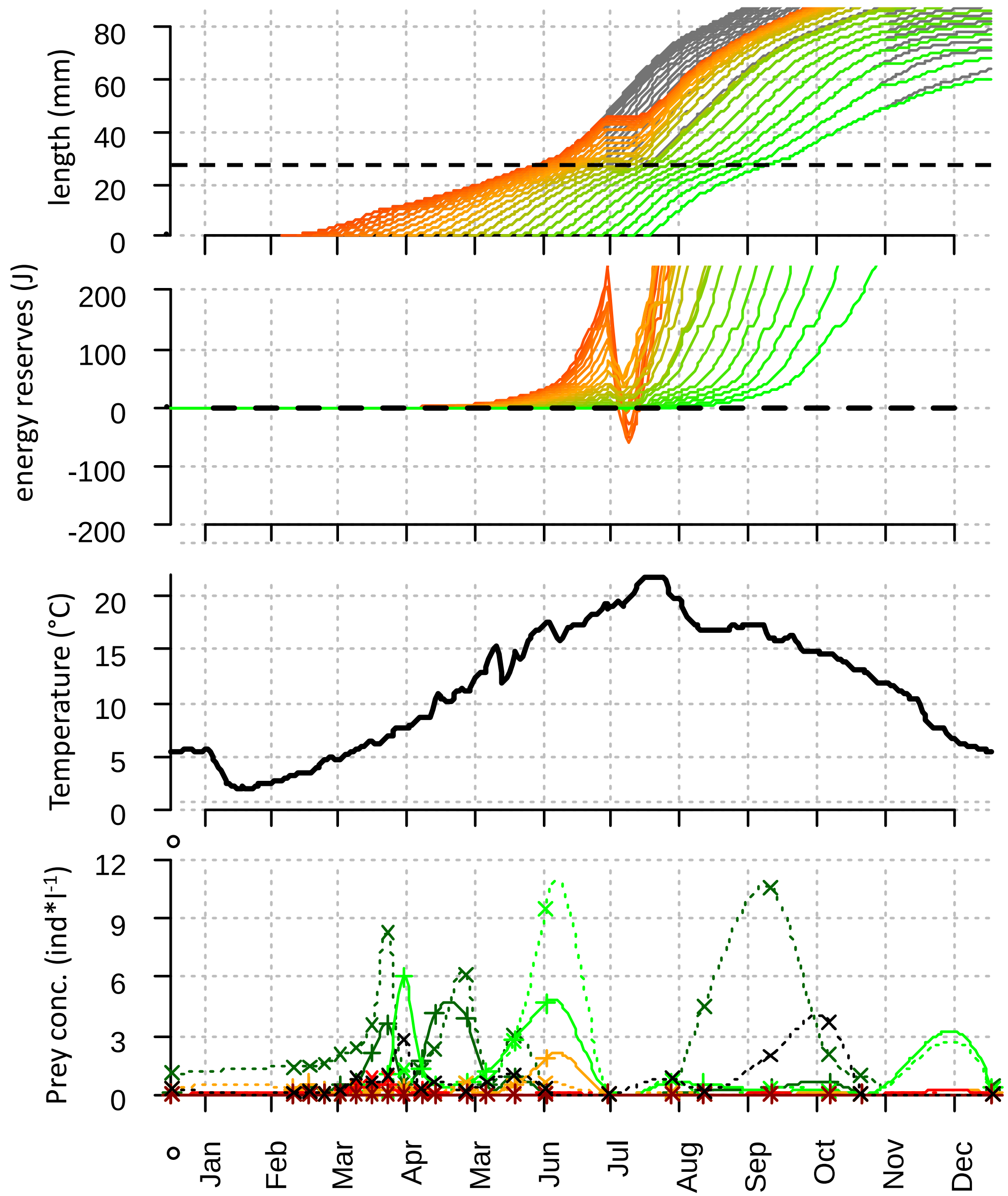
overall low length growth

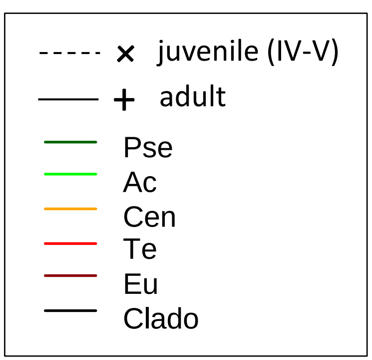
depletion of energy reserves until all cohorts die

largest = earliest cohorts die first

Real plankton data 2014

A year resulting in **high recruitment**



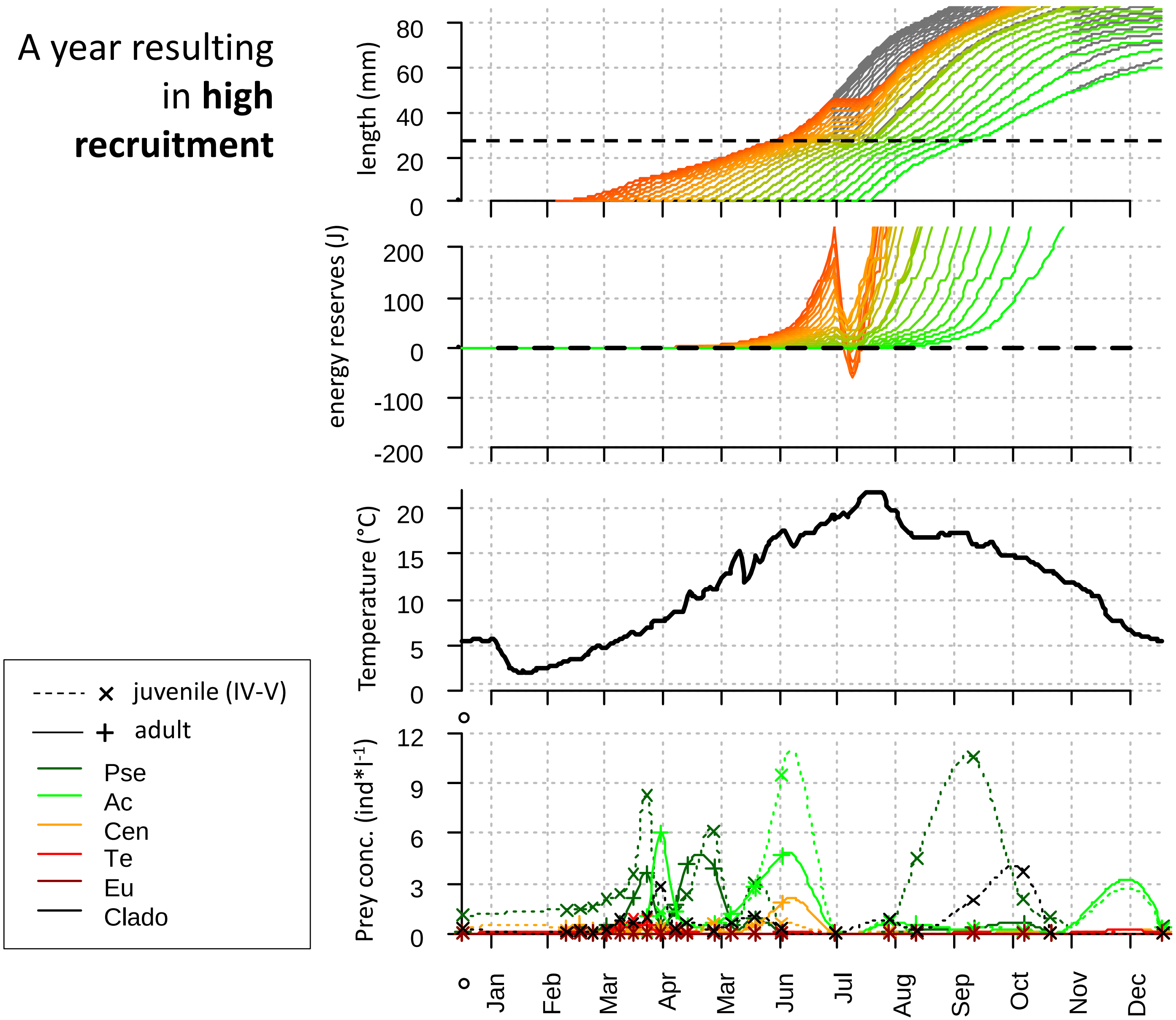


no „optimal“ growth, for early cohorts

early cohorts die, due to larger size & higher metabolic demand at high temperatures

Real plankton data 2014

A year resulting in **high recruitment**



no „optimal" growth, for early cohorts

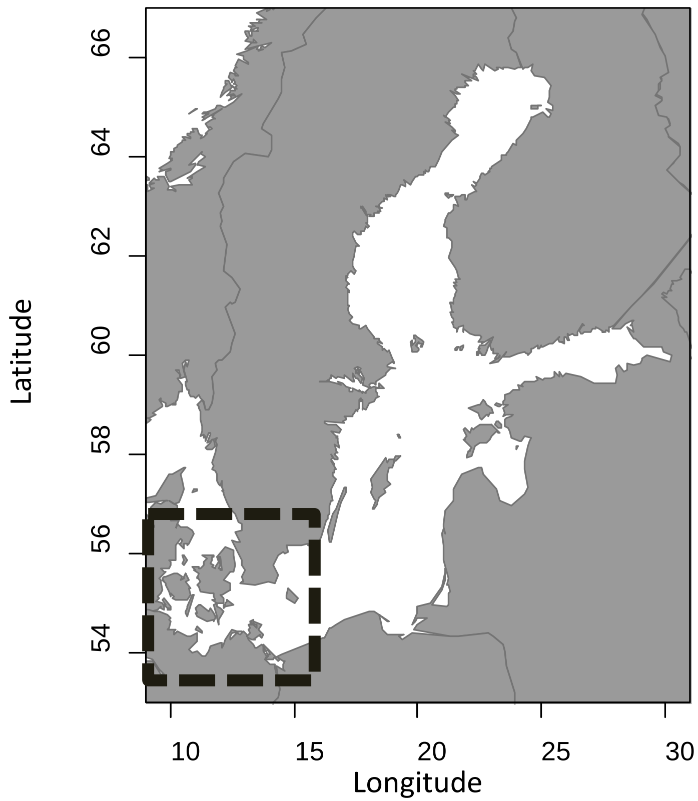
early cohorts die, due to larger size & higher metabolic demand at high temperatures

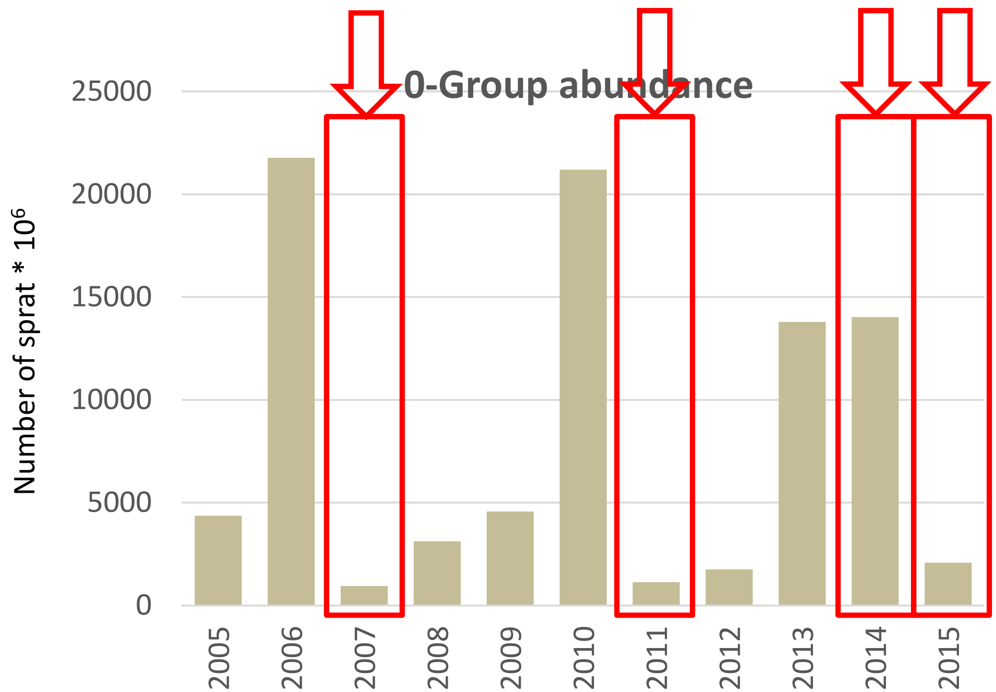
Bigger is better is not always true!

Recruitment variability

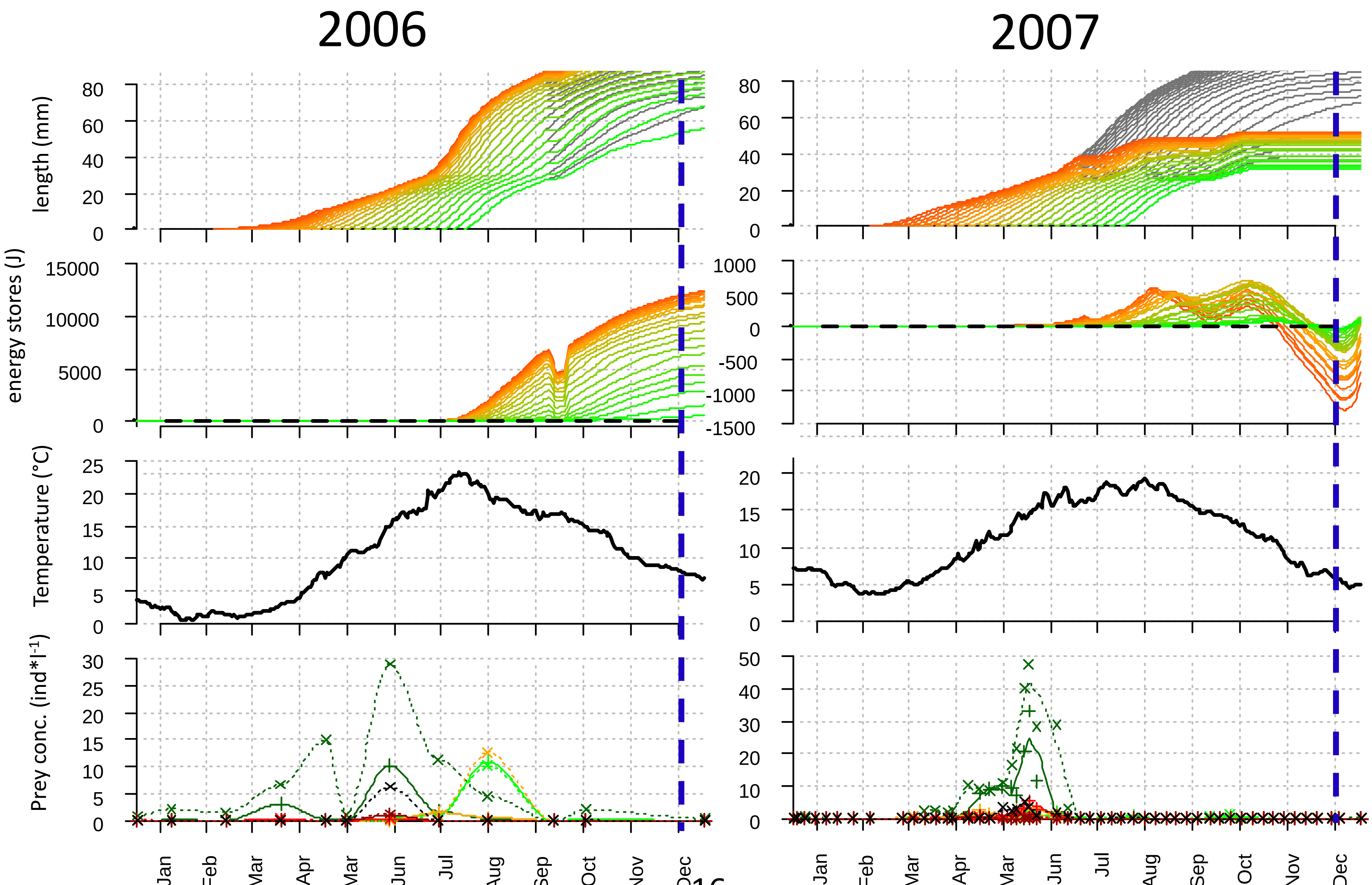
Recruitment proxy: annual hydroacoustic survey from the Western Baltic Sea

early cohorts „suffer“





Recruitment variability and growth

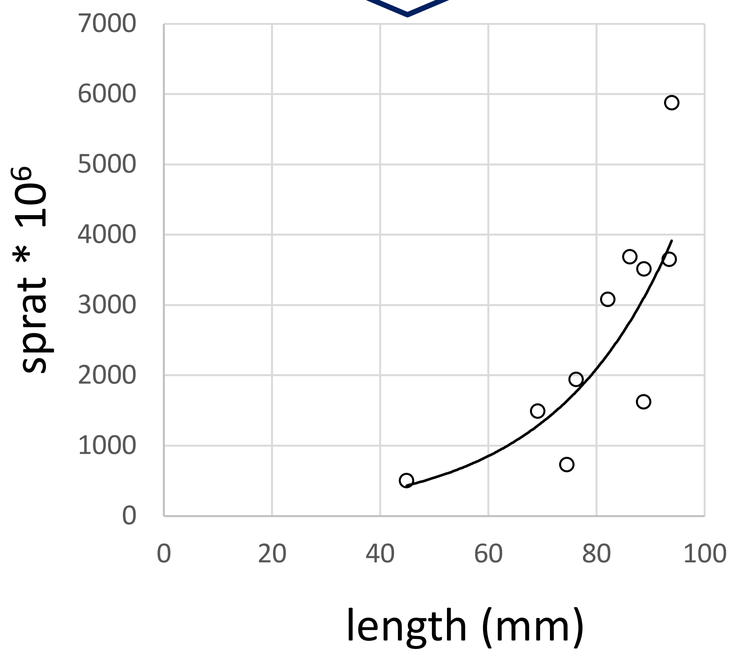


Recruitment variability and growth

Year-class strength vs **length** (Dec)

$$\text{no. sprat} = a * e^{b*\text{length}}$$

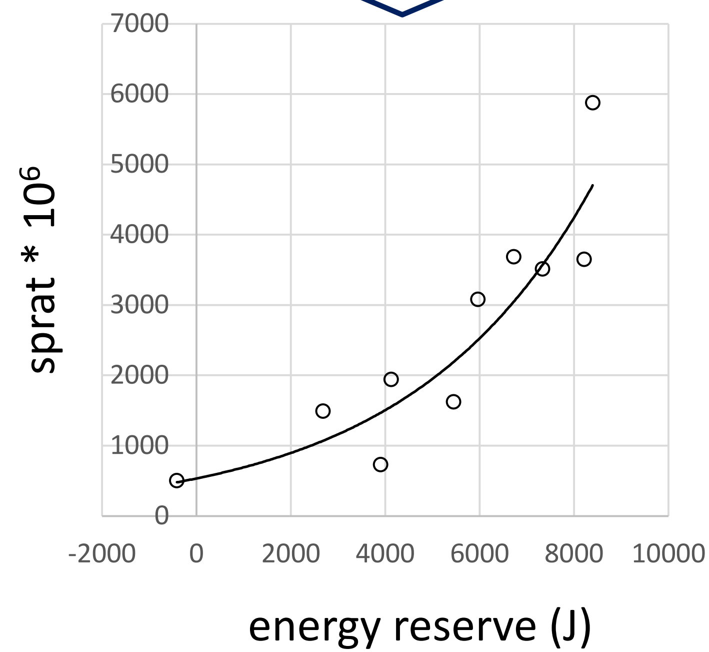
	a	**b**	r^2
0-group	62	0.06	0.56
1-group	57	0.05	0.73



Year-class strength vs **e-reserves** (Dec)

$$\text{no. sprat} = a * e^{b*\text{e-reserve}}$$

	a	**b**	r^2
0-group	1229	0.0003	0.59
1-group	533	0.0003	0.83



Summary and conclusions

Our working hypotheses:

(1) recruitment strength is **bottom-up** regulated

TRUE

(2) survival is the result of **temperature * food** interaction in the post-larval stage defining a sucessful **„starting time“**

TRUE ⇨ early cohorts suffer at low summer plankton conc. as their large body has high demands in summer temperatures

(3) **growth performance** in the post-larval stage **modulates survival** and **survival determines year-class strength**

FALSE ⇨ survival of spring cohorts is not crucial for year-class strength

TRUE ⇨ **growth performance in the post-larval stage determines year-class strength**