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Modeling the impact of Climate Variability on Black Sea anchovy (*Engraulis encrasicolus ponticus*) recruitment and production

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INTRODUCTION

Research Area:

- INTRODUCTION
- OBJECTIVES
- METHODS
- RESULTS
- CONCLUSIVE REMARKS

Map of the Black Sea (http://en.wikipedia.org/wiki/Black_Sea)

FISHERIES OCEANOGRAPHY

FISHERIES OCEANOGRAPHY Fish. Oceanogr. 23:5, 436–457, 2014

Modeling the impact of climate variability on Black Sea anchovy recruitment and production

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INTRODUCTION

Many of the largest fisheries today in the world's oceans are based on small pelagic fish species such as anchovy and sardine. Anchovies are small saltwater

INTRODUCTION

Fig. 2 Black Sea anchovy (photo by Ezgi Şahin)

Fig. 3 Black Sea anchovy, Ali Hoca, Meltem, Serdar, (?), Ezgi

the Black Sea anchovy

(Engraulis encrasicolus ponticus)

- high consumption rates
    - basal metabolism
    - somatic growth
    - active reproduction
- opportunistic feeding on zooplankton prey
- high fecudity
- batch spawners
- protracted spawning season
- mature early
- schooling behavior
- strong swimmers
- active seasonal migration

INTRODUCTION

BACKGROUND

- Why studying Black Sea ecosystem?

From 1960's to 1990's its ecosystem has gone through a multi-staged environmental degredation due to:

- climate-induced effects
- severe eutrophication
- heavy exploitation of fish stocks
- introduction of alien species (*Mnemiopsis leidyi*)

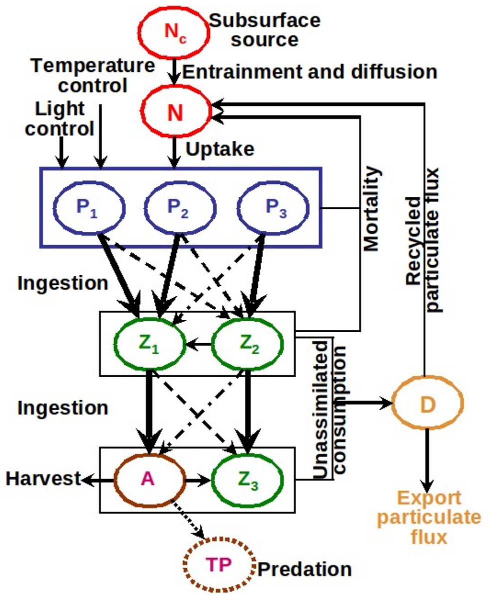
OBJECTIVES

The aim of this work is to investigate how the stochastic variations of temperature (T) and nutrient entrainment via vertical mixing (κ) affect anchovy spawning and recruitment stocks in the Black Sea.

METHODS

Ecosystem (NP3Z2) model:

Nitrate + 3 phytoplankton groups + 2 zooplankton groups



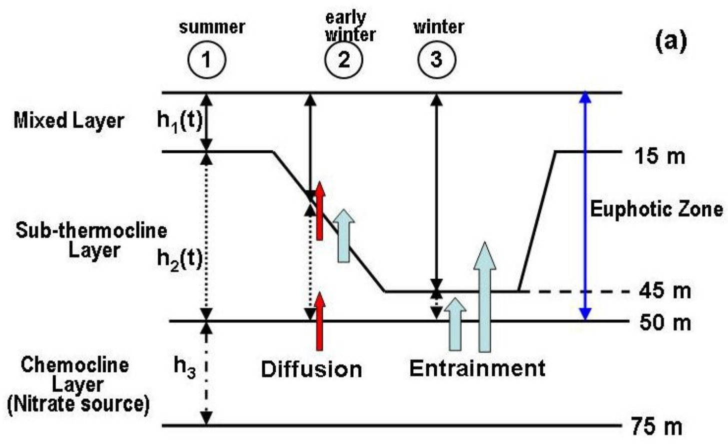
Anchovy life-cycle model:

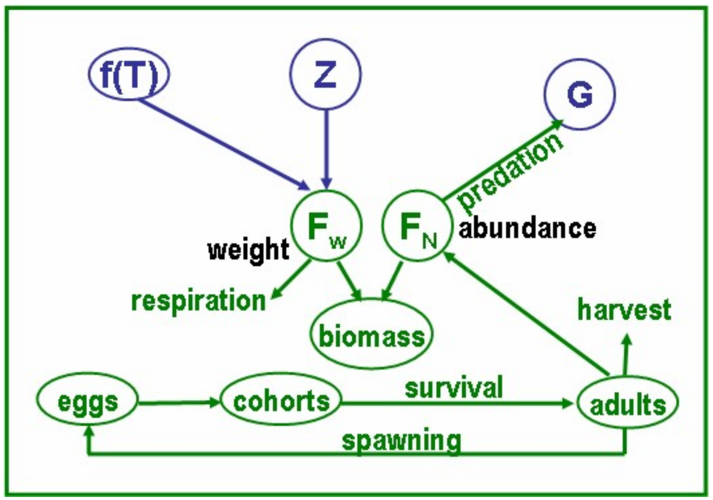
Bioenergetics based model with 90 cohorts, spawning takes place from June to August (90 days).

Model year starts from June 1st.

Vertical resolution:

2 layer system: Euphotic zone is divided into mixed layer and sub-thermocline





(Oğuz et al., 2008a)

METHODS

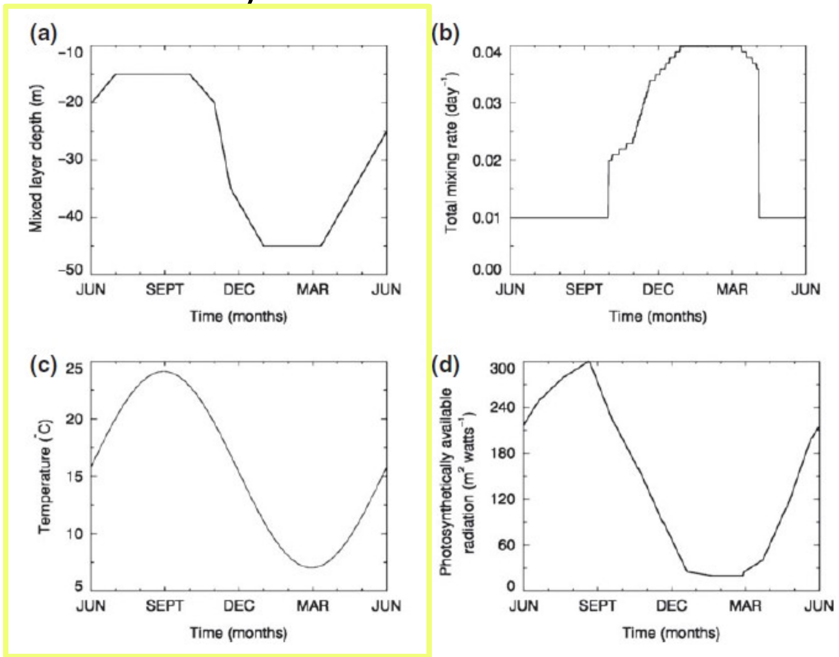
- a 1D coupled ecosystem model of lower trophic level (NP3Z3) and anchovy life-cycle (Oğuz et al., 2008a) is run with
- 50 year long daily temperature and total mixing rates time series data
- Daily values for each 360 day of year are generated by stochastically assigning three coefficients (α_0,α_1,α_2) to a regression equation that was fit to the mean climatological cycles of the Black Sea:

  For example, for temperature

$$T = \alpha_0 - \alpha_1 \cos(0.01745 day) - \alpha_2 \sin(0.01745 day)$$

Model Input

Black Sea mean climatology (baseline simulation)



Annual cycle for daily (a) mixed layer depths (m), (b) total mixing rates (day-1),(c) mixed layer temperatures (^{0}C) and photosynthetically available radiation (PAR; W m-2).

50 year high frequency temperature and total mixing rate variations

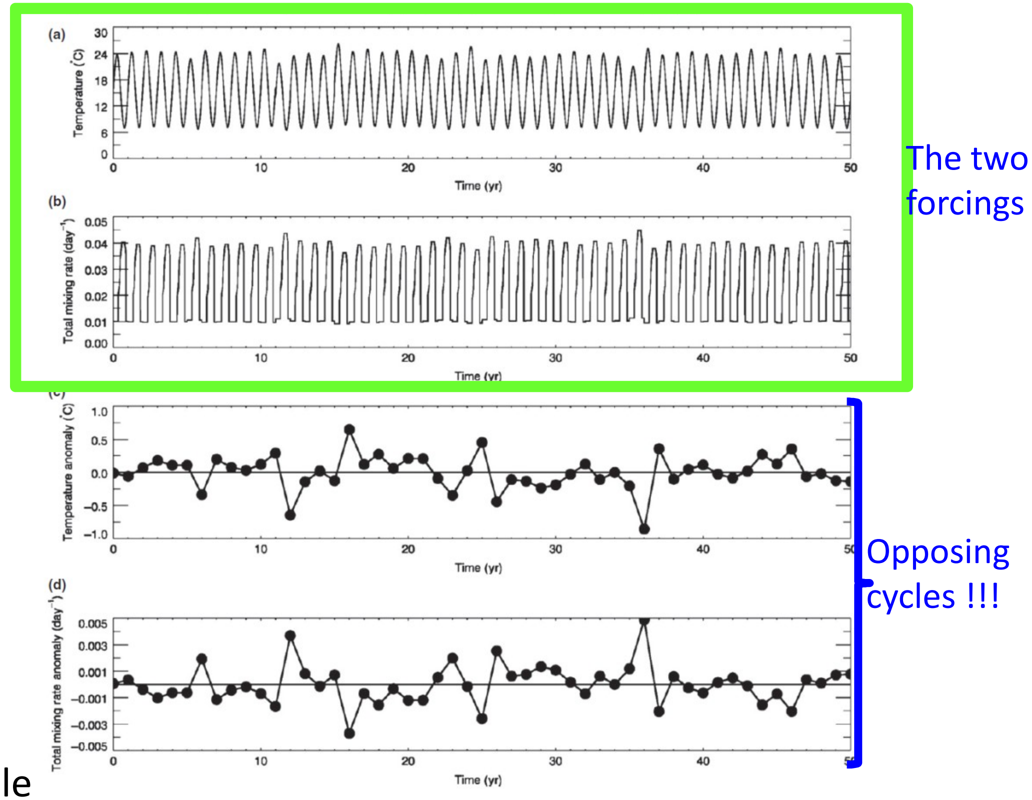
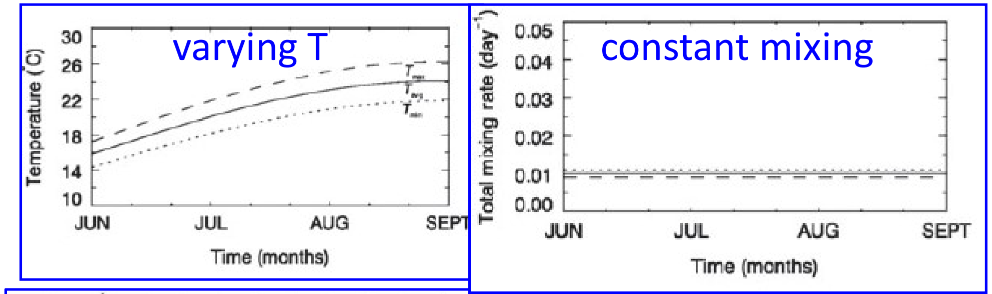
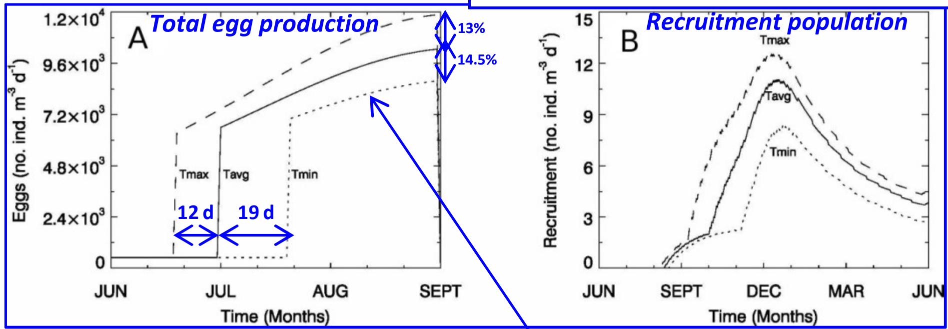


Figure 2. Stochastic 50-yr time series of (a) temperature and (b) total mixing rate (day-1) serving as model forcing For longterm simulations, (c) winter temperature anomaly (^{0}C) and (d) total mixing rate anomaly (day-1).

RESULTS – Seasonal Variations

Temperature simulation:





EGGS

- Temperature has a strong control on egg production through regulation of onset of spawning activity, daily survival rates and egg abundance.
- Each 2ºC increase in spawning season temperature, caused a shift in onset of spawning by 19 and 12 days earlier, relative to minimum temperature simulation (dotted line).

RECRUITMENT

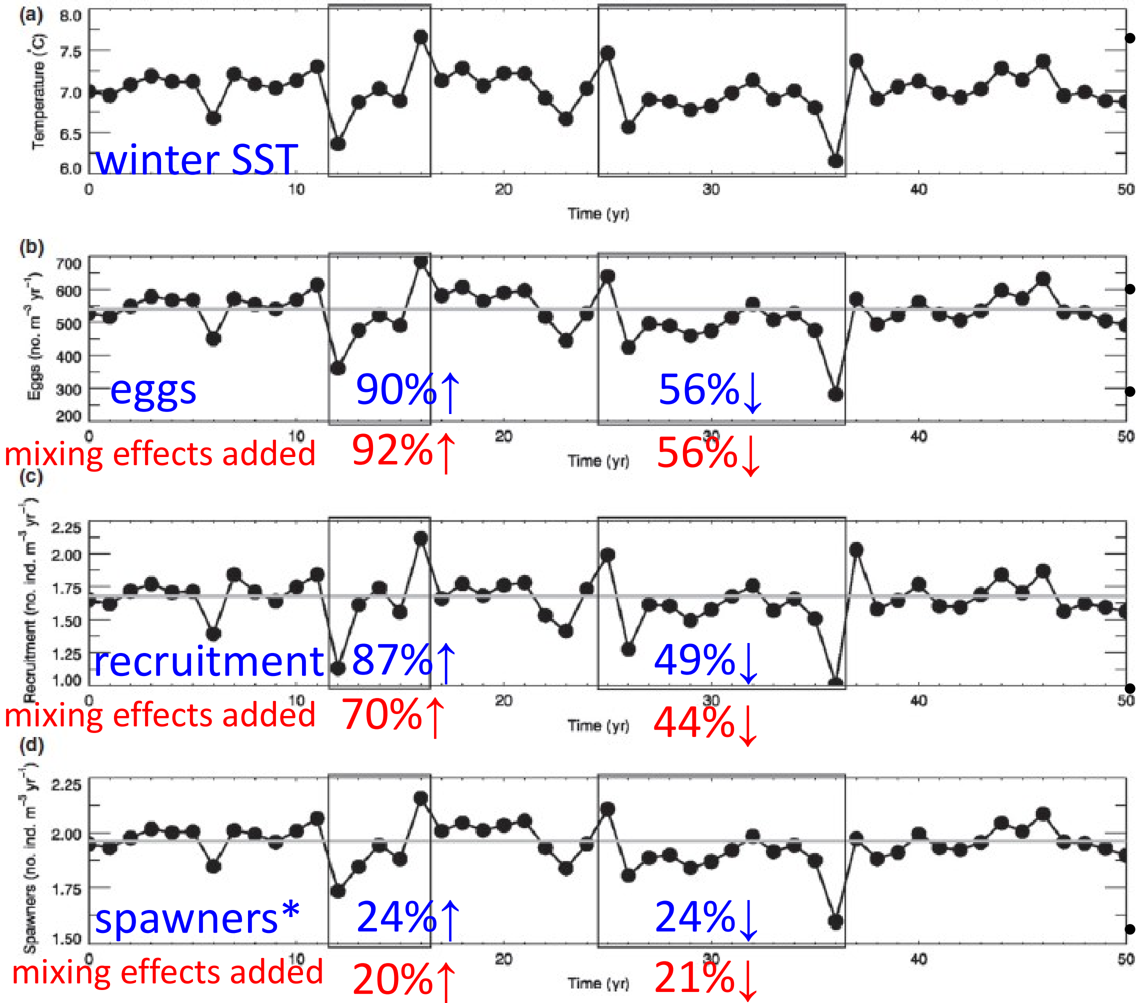
- Higher summer temperatures increased both recruitment numbers and timing of their appearance.
- High availability of recruitment in December is due to availability of mesozooplankton at that time.
- The inclusion of varying mixing has an influence on the early developmental stages of anchovy. From November to March, it slightly increases/decreases food availability for anchovy during the time of cold/warm years.
- The assumption of 2ºC temperature variability is in line with observations of natural variability in SST in the Black Sea due to climatic teleconnections, i.e., North Atlantic Oscillation (NAO).
- From 1980 – 1995 a total of ~1.8ºC decrease in the basin averaged winter (December-March) mean SST was observed, which coincided with the strong positive phase NAO (Oguz, 2005b).

RESULTS – Interannual Variations

Case 1: Temperature simulation

Case 2: Temperature and mixing simulation (now shown here)

Direct temperature increase of 1.3 ºC | Abrupt temperature decrease of 1.3ºC



*females comprising 50% of adult stock

- Egg production is sensitive to temperature.
- Mixing has no effect on egg production and indirectly influences egg production through slightly increasing spawner numbers.
- Anchovy recruitment respond strongly to changes in temperature.
- The addition of mixing counteracts the temperature effects, resulting in decreased recruitment variability that follows temperature but with a weaker signal.
- Spawners are mainly affected by temperature. The effect of temperaure slightly diminishes when mixing effects are included. But not as much as in the case of recruits.
- Spawner stock include adults of 1+, 2+, 3+ year classes that carry the temperature signal of previous years.

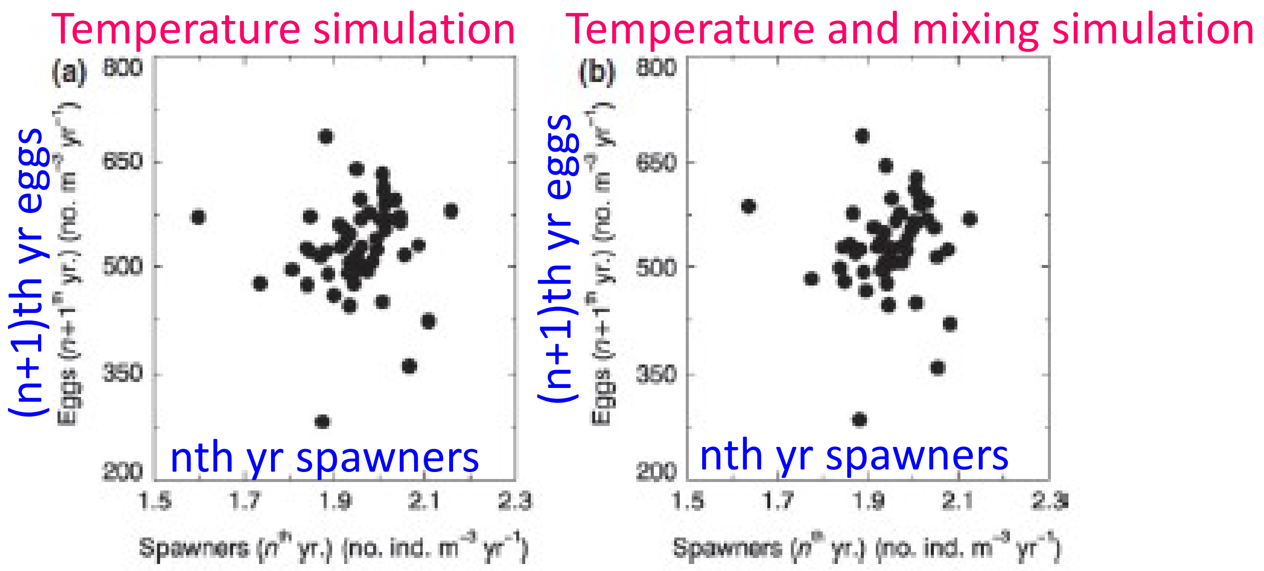
RESULTS – Interannual Variations

Comparison with other regions

- Similarly, Pethybridge et al.(2013) found temperature to be the major influence on anchovy growth and fecundity in the North-western Mediterranean Sea.
- A similar trend was observed in the Baltic Sea, where a close link between sprat recruitment and 45-yr climate variations have been observed (MacKenzie and Köster, 2004).

RESULTS – Interannual Variations Regression Analysis

Is there any relationship exists between this year's (nth yr.) spawners and next year's (n+1th yr.) egg production?

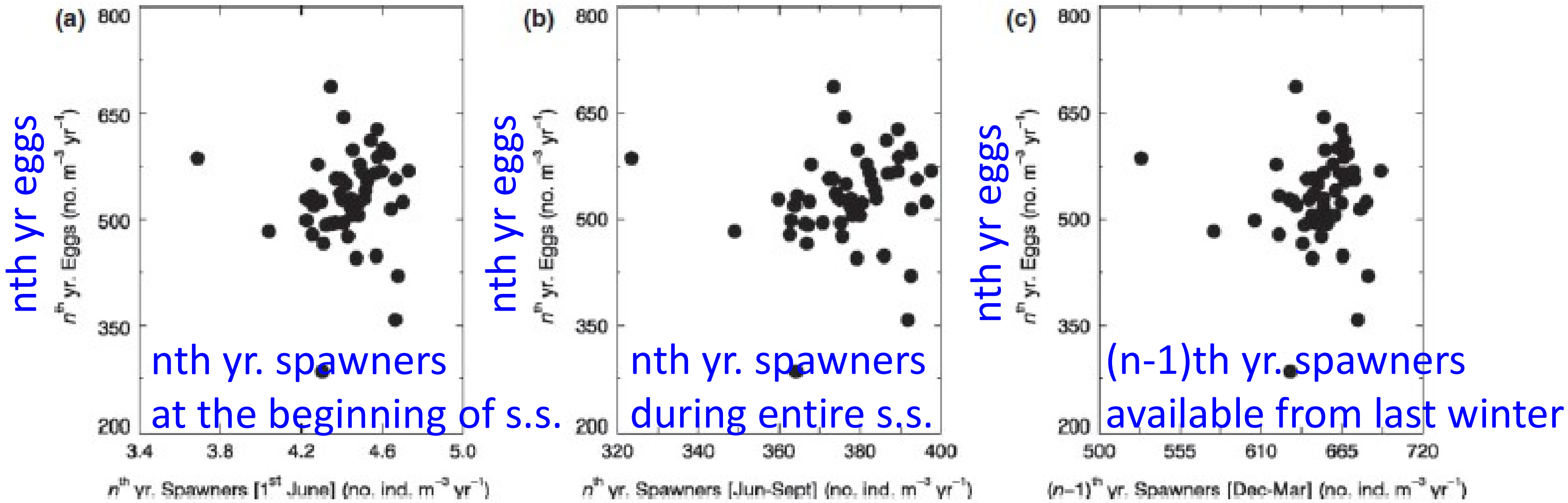


- ➢No relationship exists

RESULTS – Interannual Variations

Do the spawners have a control over the seasonal egg production?

Temperature and mixing simulation:



50-yr model output of available spawners during different time periods,

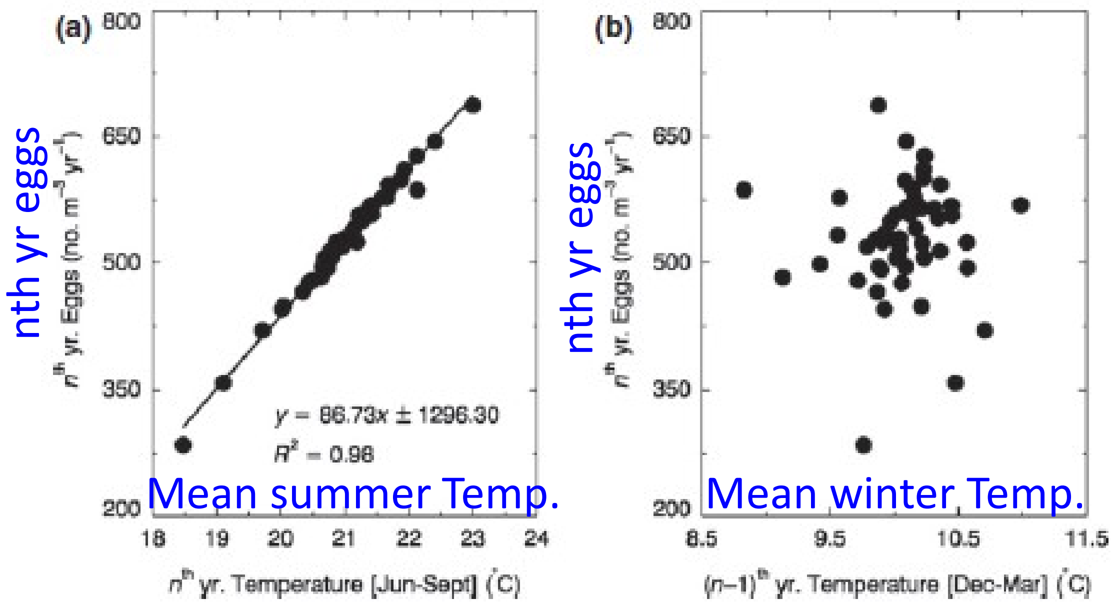
(a) at the beginning of spawning season (June 1st),
(b) during the entire spawning season (June- September),
(c) during last winter (December-March) were correlated with the total number of eggs produced during the present (n) year spawning season.

- No correlation for any of the selected time intervals.

RESULTS – Interannual Variations

Is there any relation explaining the variation of eggs with the mean (a) summer (nth yr.) and/or (b) winter (n-1th yr.) temperatures?

Temperature and mixing simulation:



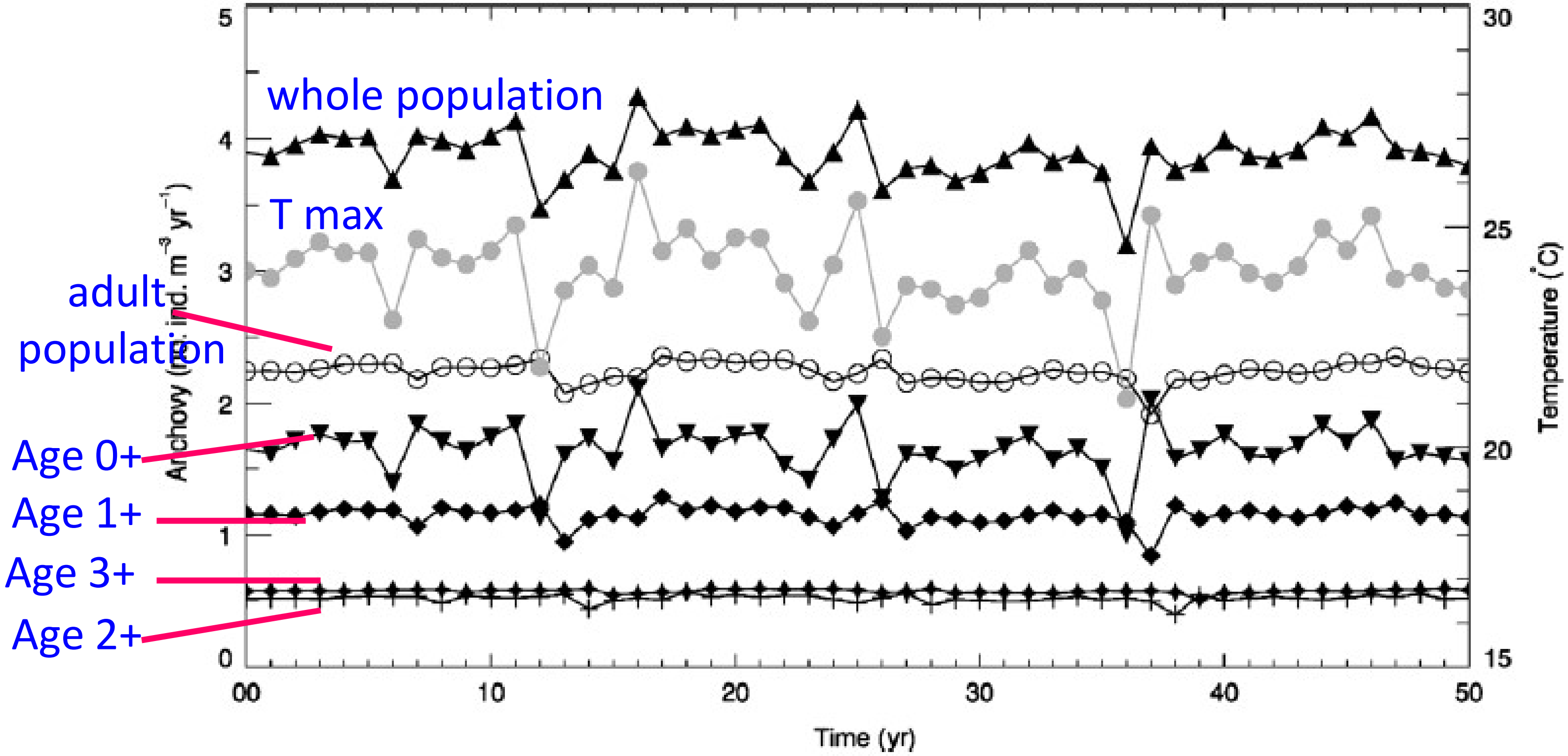
- ➢High correlation 98% between mean summer temperatures and egg production.
- ➢No such correlation found for mean winter temperatures.

- ➢This indicates that egg production intensity in a given year is not dependent on the available stock of anchovy, but rather on the prevailing temperature conditions during the spawning season of that year.
- ➢This is in contrast to an earlier theory that relates recruitment succes to the number of available spawners (Cushing, 1996).

RESULTS – Interannual Variations

Comparison of temperature variability (●) with variability within the age classes

Temperature simulation:



- ➢Recruitment (age 0+) (▼) variability directly matches the T max signal of the same year.
- ➢For older age classes, the temperature signal can still be tracked in the stock, but there is a delay timing.
- ➢For example, Age 1 year class (♦) carries the temperature signal of the previous (n-1)th year.
- ➢The same applies to the following age classes. Each age class match the temperature signal they are subjected to when they were in the recruitment stage.

RESULTS – Interannual Variations

- Anchovy recruitment were seen to be more sensitive to environmental conditions than the older age classes, which have been influenced by the environmental conditions of the previous years.
- This is also shown for anchovy in the North-west Mediterranean Sea (Pethybridge et al., 2013). It supports the theory that the earlier life stages were more vulnerable to climate change effects than the older age classes (Rijnsdorp et al., 2009).

CONCLUSIVE REMARKS

- Anchovy are more sensitive to temperature variations in their early life stages (eggs, larvae and recruitment).
- Temperature variability is the main cause in varying recruitment.
- The temperature signal can be tracked in the anchovy stock through age classes from year to year. However, overall effect on the entire stock is hard to resolve at once, by traditional and current management based approaches.
- Under such circumstances, future yield estimations can be anticipated considering individual anchovy age groups, with the time lag it requires for environmental to propagate to a certain age.
- In conclusion, considering intense fisheries pressure, today's management strategies should aim to develop approaches integrating both the ecosystem processes and the variability in the environmental conditions (Hofmann & Powell, 1998).

Thank you! ☺