Gastric evacuation rate of European sardine and Atlantic chub mackerel: the effects of different diets and the application of the results to predation estimates

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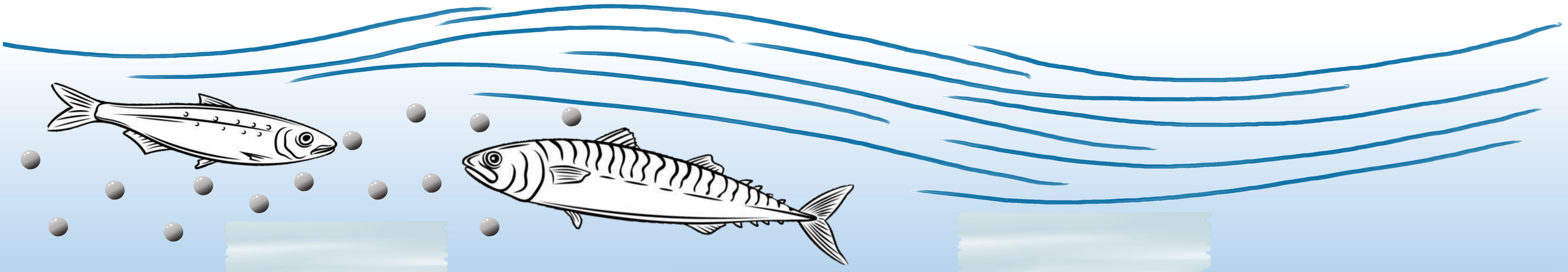


INTRODUCTION

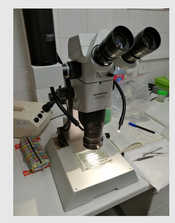
- Cannibalism and Intraguild predation of fish eggs are frequently observed in small pelagic fish and can be an important cause of mortality.
- The European sardine and the Atlantic chub mackerel have been identified as the major predators of fish eggs in Atlantic Iberian waters (Garrido *et al.*, 2008, 2015 and Fonseca *et al.*, 2022).
- Daily egg mortality due to predation is generally estimated by removing the number of eggs consumed in one day (daily ration) from the total number of eggs produced by the population in one day.
- However, these estimations rely on a number of parameters that are usually assumed as equal to other predators or areas. These assumptions can severely affect egg mortality estimates.
- This study aims to determine the gastric evacuation rate of the European sardine and Atlantic chub mackerel under the effect of different temperatures and different meal types and with the species specific gastric evacuation rates, improve estimates of egg mortality by predation of sardine in the Atlanto-Iberian waters.

METHODS

- 1500L fiberglass tanks (1000L continuous flow of seawater).

Temperatures tested:
- **Sardine:** 15°C, 17°C and 21°C
- **Atlantic chub mackerel:** 16°C and 19°C

- Diet treatments (3 different proportions of the following prey types):
  - **Fish eggs**
  - ***Artemia* nauplii**
  - **Rotifers**
  - **Microalgae**
- (Diets with the same total weight of prey but with different eggs/other prey ratios)



Diet type	Proportion of fish eggs (% µgC)
Diet 1	25%
Diet 2	70%
Diet 3	5%

- Fish were not fed for a period of 48h
- t=0h (water inlet close, food introduce)
- t=0.5h (water renewal opened)
- t=1h, 2h, 3h, 4h, 5h and 7h (at each sampling point 3 individuals sacrificed for stomach analysis)
- Water samples removed at t=0h, 1h and 2h (to check for prey concentration in the water)

Gastric Evacuation: $Y = e^{(B_0 + B_1 x)}$

- B_0 = intercept
- B_1 = slope of the equation (gastric evacuation rate)
- X = time
- Y = number of prey inside stomach contents.

RESULTS

Gastric evacuation: "number of prey ~ time + diet + temperature + time: diet + diet: temperature", GLM, negative binomial distribution, log

Sardine

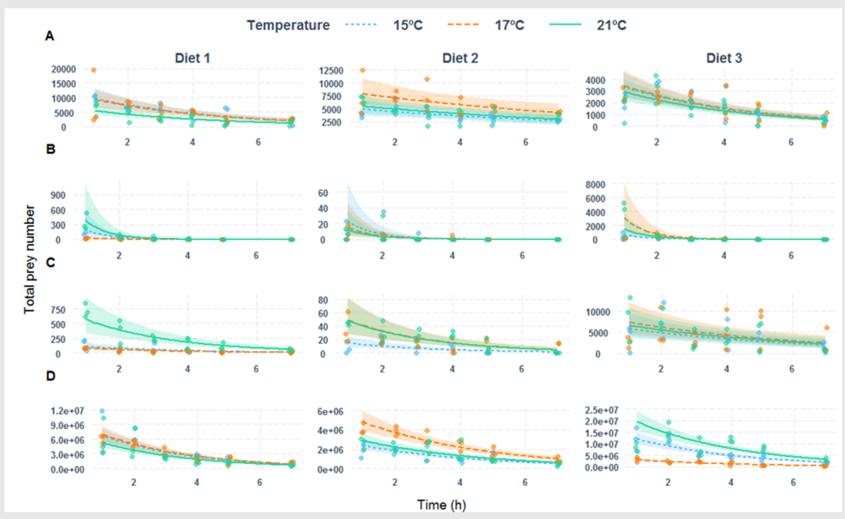


Fig 1. Total number of prey in the stomachs as a function of time (h), temperature (15° C, 17°C and 21°C), Diet (1, 2 and 3) and prey type ((A)- fish eggs, (B)- Artemia nauplii, and (C)- rotifers, (D)- microalgae). Confidence intervals 95%. Note different Y-axis scales between panels.

Diet and Temperature	Fish eggs	Artemia nauplii	Rotifers	Microalgae
D1:T15				
D1:T17	-0.255	-1.532	-0.381	-0.343
D1:T21				
D2:T15				
D2:T17	-0.105	-1.251	-0.395	-0.264
D2:T21				
D3:T15				
D3:T17	-0.274	-1.424	-0.183	-0.301
D3:T21				

Table 1. Slopes (B1) of the equation of the line resulting from GLMs (generalized linear models), divided by diets type and temperatures. The slope of equation (B1) is equal to the gastric evacuation rate.

- Fish eggs have a higher nutritional content and therefore take longer to digest, when compared with zoo- and phytoplankton.
- Gastric evacuation of fish eggs by sardines was higher for diets with lower proportion of eggs than highly concentrated.
- Microalgae and rotifers had similar gastric evacuation rates, while Artemia nauplii had digestion rates 4 times higher.
- Gastric evacuation of rotifers by sardine was higher for diets with lower proportion of rotifers than highly concentrated.

Atlantic chub mackerel

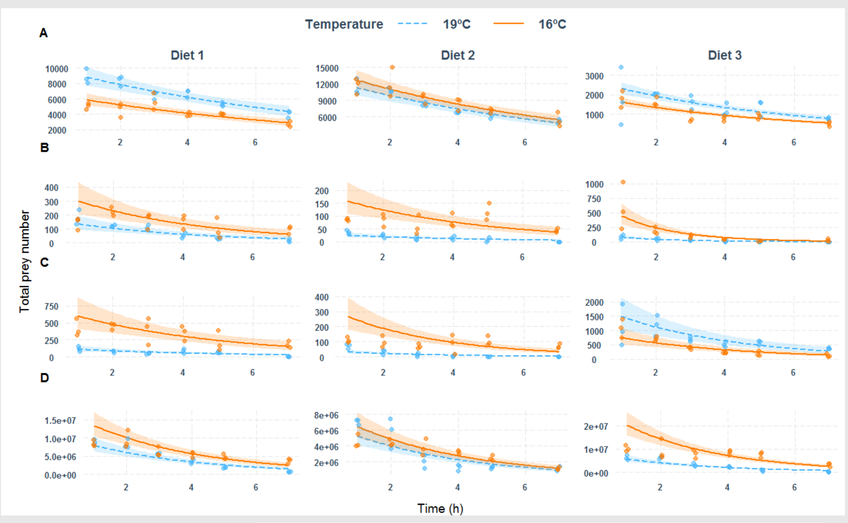


Fig 2. Total number of prey in the stomachs as a function of time (h), temperature (16°C and 19°C), Diet (1, 2 and 3) and prey type ((A)- fish eggs, (B)- Artemia nauplii, and (C)- rotifers, (D)- microalgae). Confidence intervals 95%. Note different Y-axis scales between panels.

- Gastric evacuation of fish eggs was lower than all the other prey, for all diets and temperatures.
- Microalgae and rotifers had similar gastric evacuation rates.
- Gastric evacuation of rotifers by Atlantic chub mackerel was higher for diets with lower proportion of rotifers than highly concentrated.
- Gastric evacuation of Artemia nauplii was 3 times higher on diet 3 (highly concentrated on Artemia nauplii) when compared with diets 1 and 2.

Diet and Temperature	Fish eggs	Artemia nauplii	Rotifers	Microalgae
D1:T16 D1:T19	-0.118	-0.267	-0.229	-0.286
D2:T16 D2:T19	-0.141	-0.240	-0.345	-0.283
D3:T16 D3:T19	-0.184	-0.613	-0.279	-0.347

Table 2. Slopes (B1) of the equation of the line resulting from GLMs (generalized linear models), divided by diets type and temperatures. The slope of equation (B1) is equal to the gastric

CONCLUSIONS

- On average, sardines had higher gastric evacuation rates (GER) than Atlantic chub mackerel.
- The proportion of eggs in the diet had a significant effect on the gastric evacuation rates, being generally higher for diets with lower proportion of eggs.
- Temperature had no significant effect on gastric rates of sardine and Atlantic chub mackerel for the range of temperatures generally experienced by this small pelagic fish off the Atlanto Iberian coast.
- Previous calculations of egg mortality using literature based gastric evacuation rates were likely overestimated.
- This study provides important information on gastric evacuation rates that allow improving estimates of egg mortality by predation, to improve understanding of SPF population dynamics, and specifically to inform models for an ecosystem approach to fisheries management.

% of fish eggs consumed in a day by sardine

Season (2018)	Region	Egg Species	With gastric evacuation rates from the literature	With species-specific gastric evacuation rates obtained in the present work
Spring	Northwest coast	anchovy	70.80%	21.30%
Spring	Algarve and Cadiz region	anchovy	12.90%	3.90%
Fall	Northwest coast	sardine	0.70%	0.20%
Fall	Southwest coast	sardine	5.90%	1.90%

Table 3. Application of the new species-specific gastric evacuation rates obtained in the present work to previous fish eggs predation estimates by sardine in Atlanto Iberian waters; previous estimates made by Fonseca *et al. (*2022).

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