Ecological information relevant for the forthcoming management plan

Small pelagics

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Background, scope and issues

Small pelagics (sardine and anchovy) are important fisheries resources in Adriatic Sea

Recent evaluations of the stocks (other presentations) highlight critical situation of the populations of these two species in Adriatic with an urgent need to act

This review is providing scientific independent basis on:

- **fluctuations in the historical series;**
- **environmental variables/factors influencing the two small pelagic species;**
- **potential relation of temperature, salinity, pollution and other factors to species dynamics;**

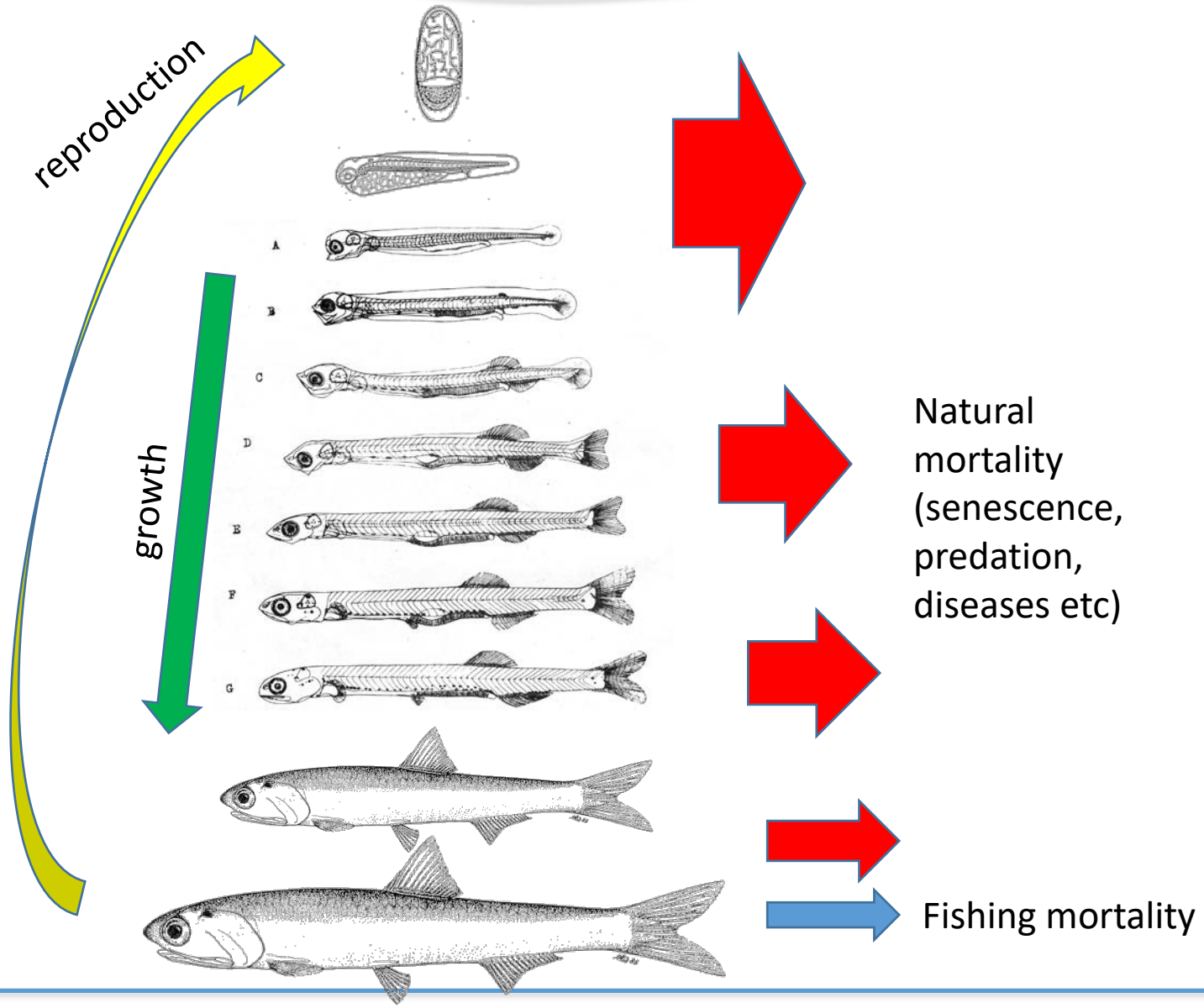
The above is presented in order to support discussion on management plans

Background, scope and issues

Growth at all life stages >> depending on prey availability; **environmental conditions**;

Survival at all life stages >> depending on fisheries pressure, on predators abundance, on **env conditions**

Recruitment >> depending on mature adults (SSB), **environmental conditions**



Spawning areas and season

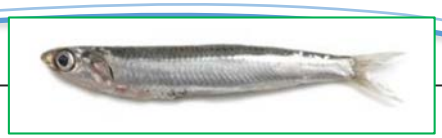
Species	Area	Spawning season	Spawning peak	Temperature range (temperatures at peak spawning) (°C)	Salinity (psu)	Reference
Sardine	Split	Oct–May	Jan–Feb	10.2–20.2 (10.2–12.4)	35.2–37.0	Gamulin 1940
	Central Adriatic	Winter				Mužinić 1954
	Northern and central Adriatic	Oct–May				Gamulin & Karlovac 1956
	Central Adriatic	Oct–Apr	Dec–Feb	(13–16)	37–38	Gamulin & Karlovac 1957
	Vlora bay, Seman-Viase bay, Sazan Island (Albania)	Nov–Feb	Dec & Feb	12–20	37.5–38.5	Rakaj 1962
	Central Adriatic	Nov–Apr		11.9–19.4	37.1–38.8	Karlovac 1969a
	Central Adriatic	Oct–May	Mar	13.1–18.0	38–38.5	Karlovac 1969b
	Central Adriatic	Sept–May				Vučetić 1971
	Central Adriatic	Oct–April	Jan			Vučetić 1975
	Kvarner, Susak and Dugi Otok	Nov–June	Nov & Apr	11.6–11.7	38.1–38.2	Teskeredžić 1978
	Northern and central Adriatic (Trieste-Gargano)			8.4–14.7 (12.1–13.9)	37.6–38.8	Regner et al. 1987
	Southern Adriatic (Gargano-Otranto)	Oct–May	Oct & Dec			Casavola et al. 1998
	Northern and central Adriatic (Trieste-Gargano)			9–15 (11–15)		Regner et al. 1988
	Albania (2003)	Sept–Apr				Kolitari 2006
	Albania (2004)	Oct–Apr				Kolitari 2006
	Albania (2005)	Oct–Apr				Kolitari 2006

spawning takes place mainly in winter, generally between October and May

Spawning, in the Adriatic Sea, has been reported to ***take place between 9 and 20°C at salinities ranging from 35.2 to 38.8 psu[****…] at depths between 30 and 150 m although more typically between 60 and 120 m*

Morello & Arneri, 2009 (Table 1)

Spawning areas and season



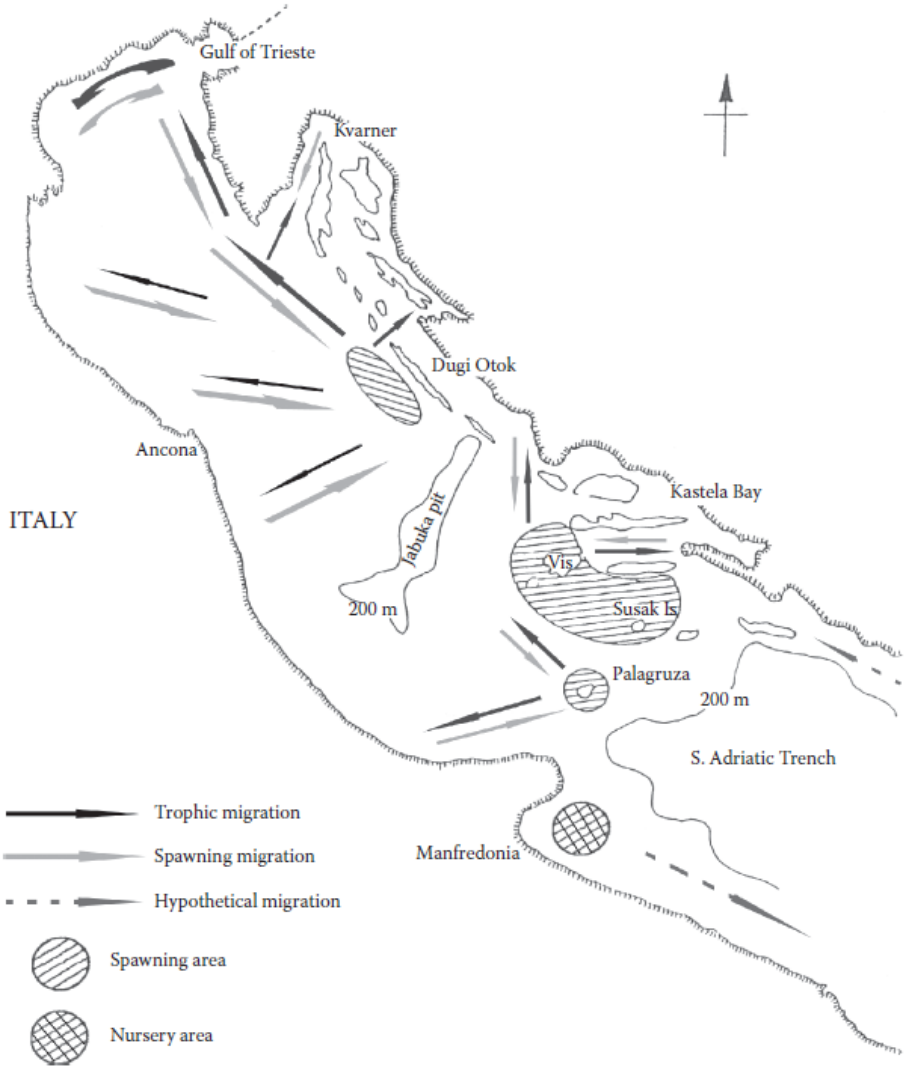
Species	Area	Spawning season	Spawning peak	Temperature range (temperatures at peak spawning) (°C)	Salinity (psu)	Reference
Anchovy	Northern Adriatic	Summer				Syrski 1876
	Northern Adriatic	Summer				Graeffe 1888
	Northern Adriatic	Apr–Oct				Steuer 1910
	Northern Adriatic	June–Sept				Stiasny 1910
	Central Adriatic (mid-Dalmatian islands)	Apr–Aug	May, July, Aug			Gamulin 1940
	Mljet Island	May–Sept		13–27		Vučetić 1957
	Northern and central Adriatic	Apr–Oct	May, Aug–Sept			Varagnolo 1964a
	Dugi Otok Island	May–Sept	June			Vučetić 1964
	Istria	May–Sept				Zavodnik 1969
	Northern Adriatic	Apr–Oct	June–July	11.6–27.5 (22)	9.1–38.5	Zavodnik 1970
	Northern Adriatic	May–Sept	July–Aug			Štirn 1969, 1970
	Central Adriatic (mid-Dalmatian Islands)	May–Sept	May–June			Vučetić 1971
	Central Adriatic (mid-Dalmatian Islands)	Mar–Nov	June–July	13.2–23.7 (18.3–22.1)	33.86–38.69	Regner 1972
	Gulf of Trieste	Apr–Oct	July			Specchi & Furlan 1974
	Central Adriatic	Late spring and summer	Aug			Sinovčić 1978
	Gulf of Trieste	Apr–Oct	May–June, Aug			Di Marcotullio & Catolla Eulambio Di Marcotullio 1983
	Northern and central Adriatic	Apr–Oct	June–Sept			Regner et al. 1985
	South-western Adriatic	Apr–Oct				Casavola et al. 1987
	Gulf of Trieste	Apr–Oct	Aug	12–28 (21–28)		Orlandi et al. 1994
	Fano	Apr–Oct	July	12–26 (25–26)		Orlandi et al., 1994
	South-western Adriatic	May–Sept	Aug			Casavola et al. 1996a
	South-western Adriatic	Apr–Oct	July–Sept			Marano et al. 1998
	Miramare (Trieste)	May–Sept	July	>17 (21–28)		Specchi et al. 1998
	Inshore coastal waters (Kastela bay)	Apr–Oct	Aug			Sinovčić 2000b
	Open waters (Vis & Bisevo Islands)	March–Oct	July			Sinovčić 2000b
	Albania (2003)	Apr–Oct				Kolitari 2006
	Albania (2004)	May–Oct				Kolitari 2006
	Albania (2005)	May–Oct				Kolitari 2006

The presence of ***anchovy eggs in the Adriatic has been reported at temperatures between 11.6 and 28°C, and at salinities ranging from 9.1 to 38.7 psu (Table 1).*** *Spawning peaks occur at the higher temperatures in the range, between 18 and 28°C (Table 1) whereas egg density is inversely proportional to salinity (Zavodnik 1970).*

In contrast to sardine, anchovy spawning takes place in the warmer months, generally between April and October

Morello & Arneri, 2009 (Table 1)

Spawning areas and season



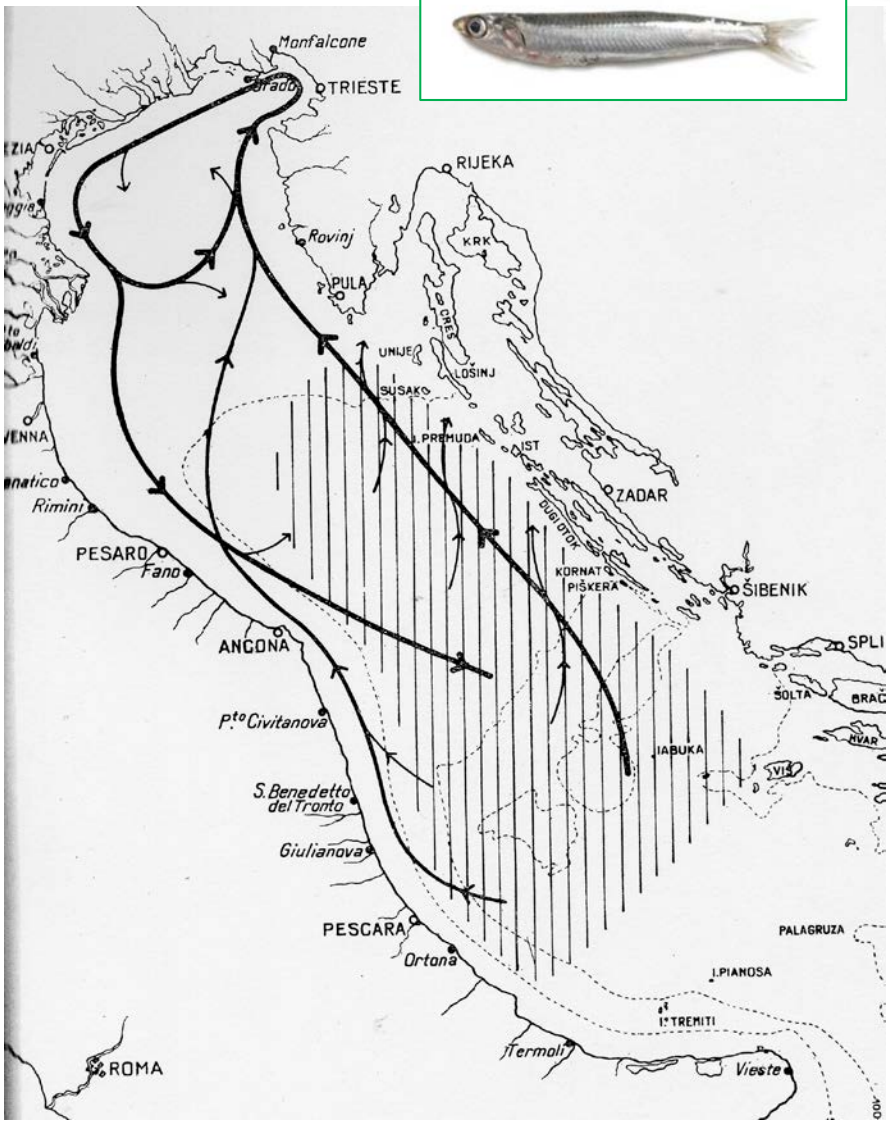
[…] two main spawning grounds in the Adriatic Sea (Piccinetti et al. 1980, 1981, Regner et al. 1981, 1987): the northern Adriatic off the Dugi Otok Island and the southern Adriatic around the exterior of the mid-Dalmatian Islands and extending offshore to Palagruža. […]

despite food being of major importance for post-larval development and survival, all sardine spawning grounds mentioned are located within the least productive […]

Sardine spawning areas, located at depths ranging from 10 to 20 m, coincided with the boundaries of these frontal zones produced by the upwelling and in both cases […]

Morello & Arneri, 2009 (Table 1)

Spawning areas and season



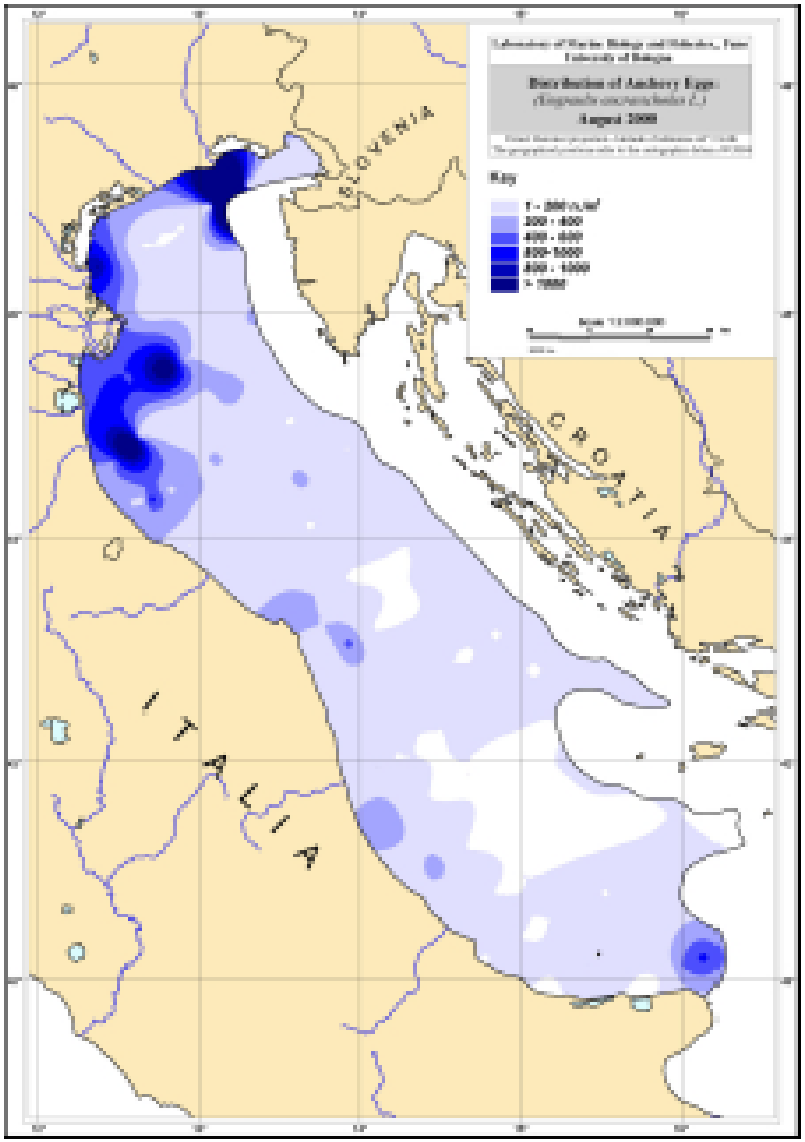
Migration routes of anchovy in the Adriatic Sea

Dashed area is main the winter resting area

Anchovy adults migrate from the deeper overwintering waters to shallower coastal areas for spawning (Sinovčić 2000b) and similar migrations have been reported for the Black Sea (Majarova & Chugunova 1954, Demir 1963).

Piccinetti, 1970; Morello & Arneri, 2009

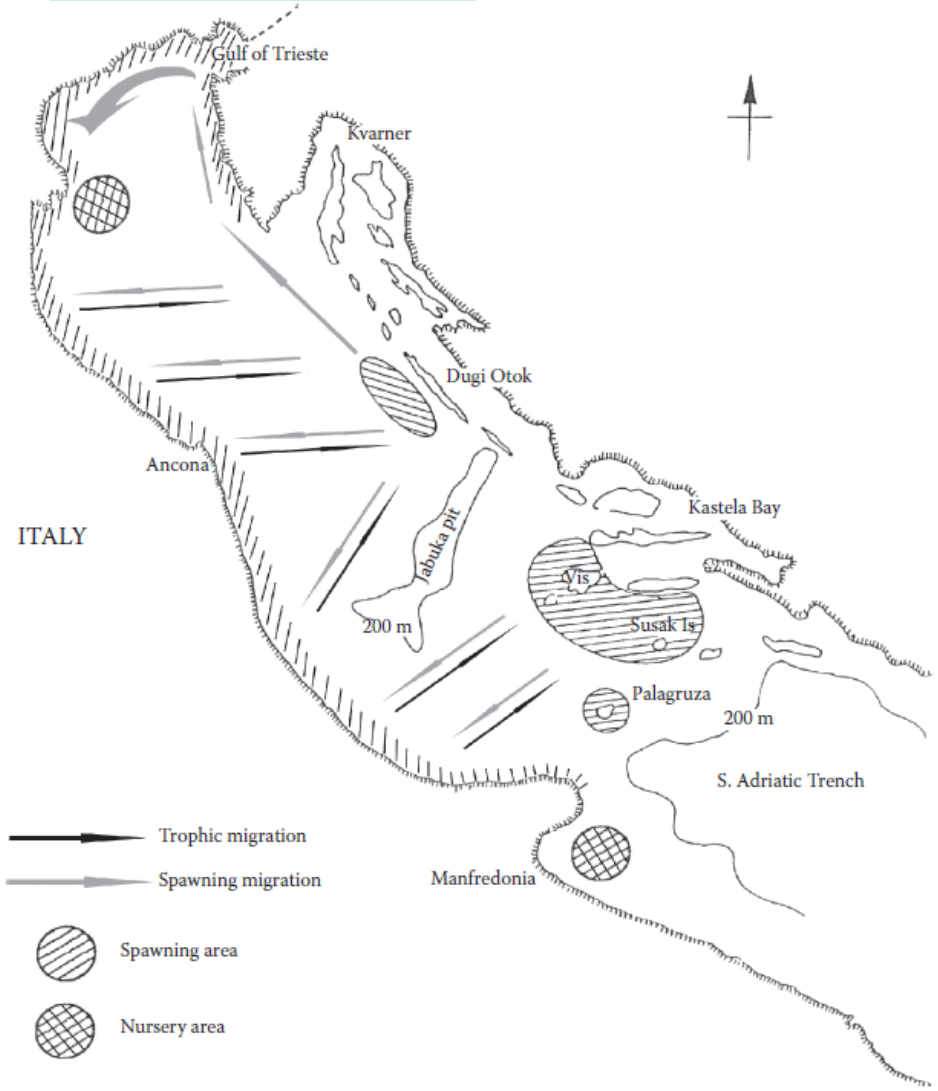
Spawning areas and season



Spawning areas for anchovy in the Adriatic Sea.

Piccinetti, 2001

Spawning areas and season

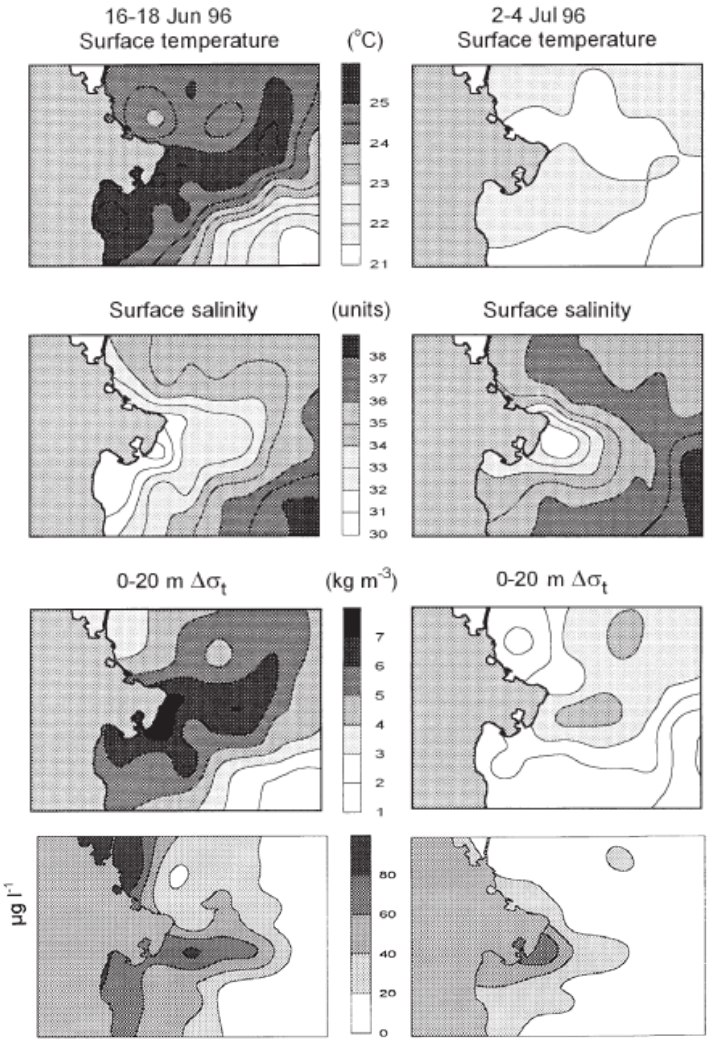


The main spawning activity takes place in the coastal waters of the western Adriatic between the Gulf of Trieste and the Gargano peninsula (Casavola et al. 1985, Regner 1996, Pinardi et al. 2005) and the largest number of eggs occurs in the Gulf of Trieste and off the river Po delta (Piccinetti et al. 1980, Coombs et al. 1997, Specchi et al. 1998, Piccinetti 2001).

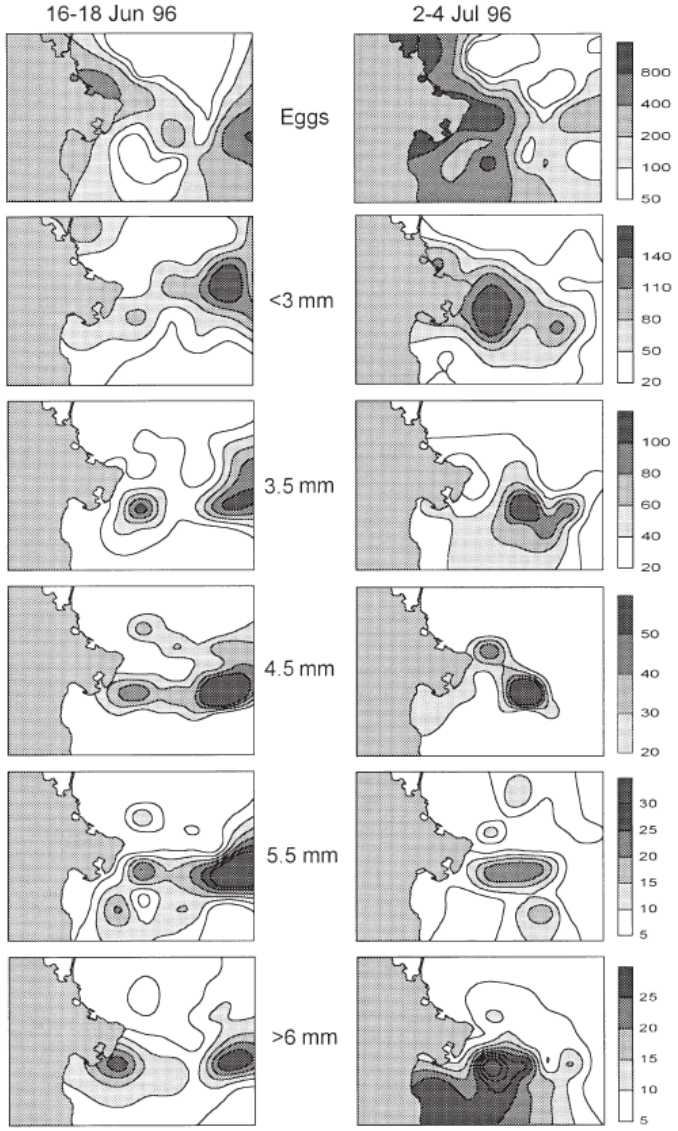
Other spawning areas have been located in open waters between Susak Island and the Jabuka pit and around Palagruža Island, as well as in the eastern Adriatic (e.g., Vis and Biševo Islands) but here the intensity of spawning is substantially lower

Morello & Arneri, 2009

Larvae distribution as a function of env var

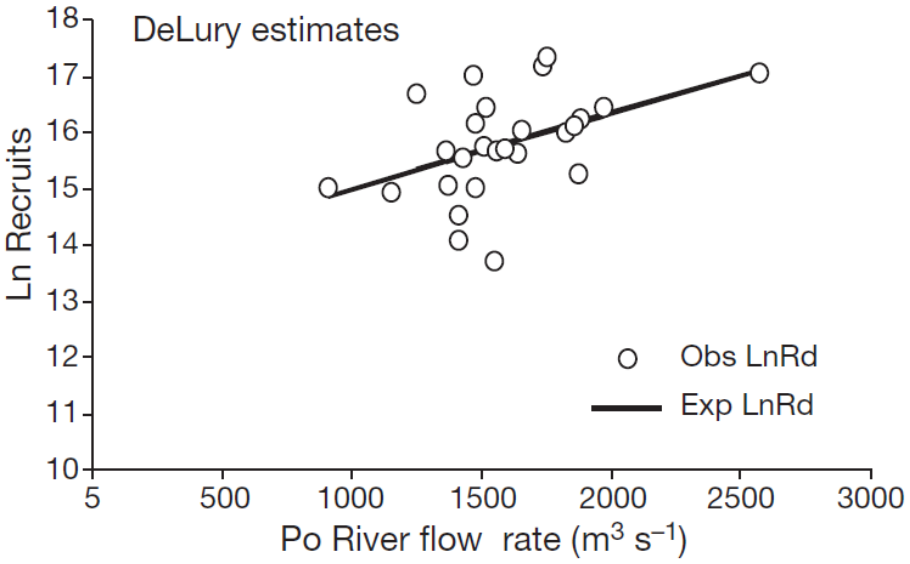


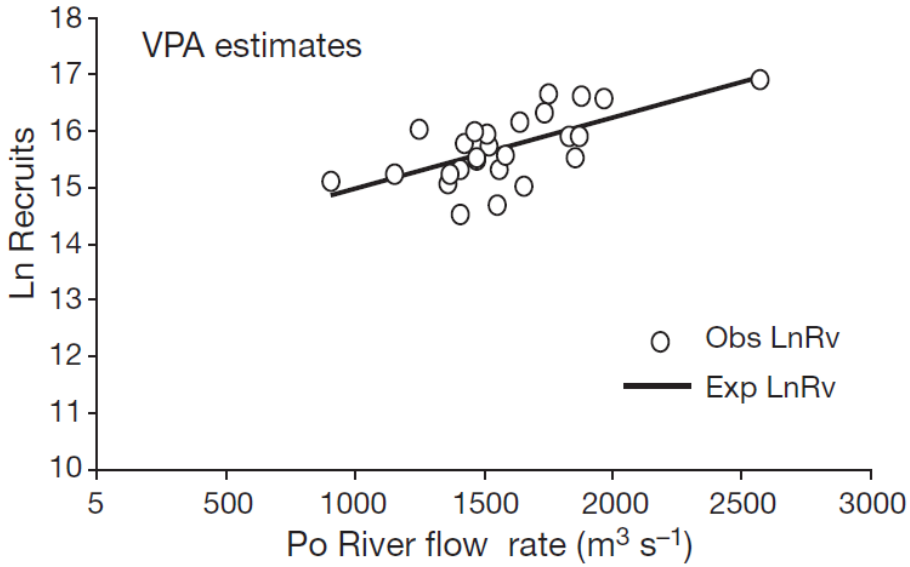
Surface temperature, surface salinity and water column stratification and potential food items in front of Po river mouth



Engraulis encrasicolus. Contoured distribution of eggs and larvae *Coombs et al., 2003*

Post-larvae anchovy



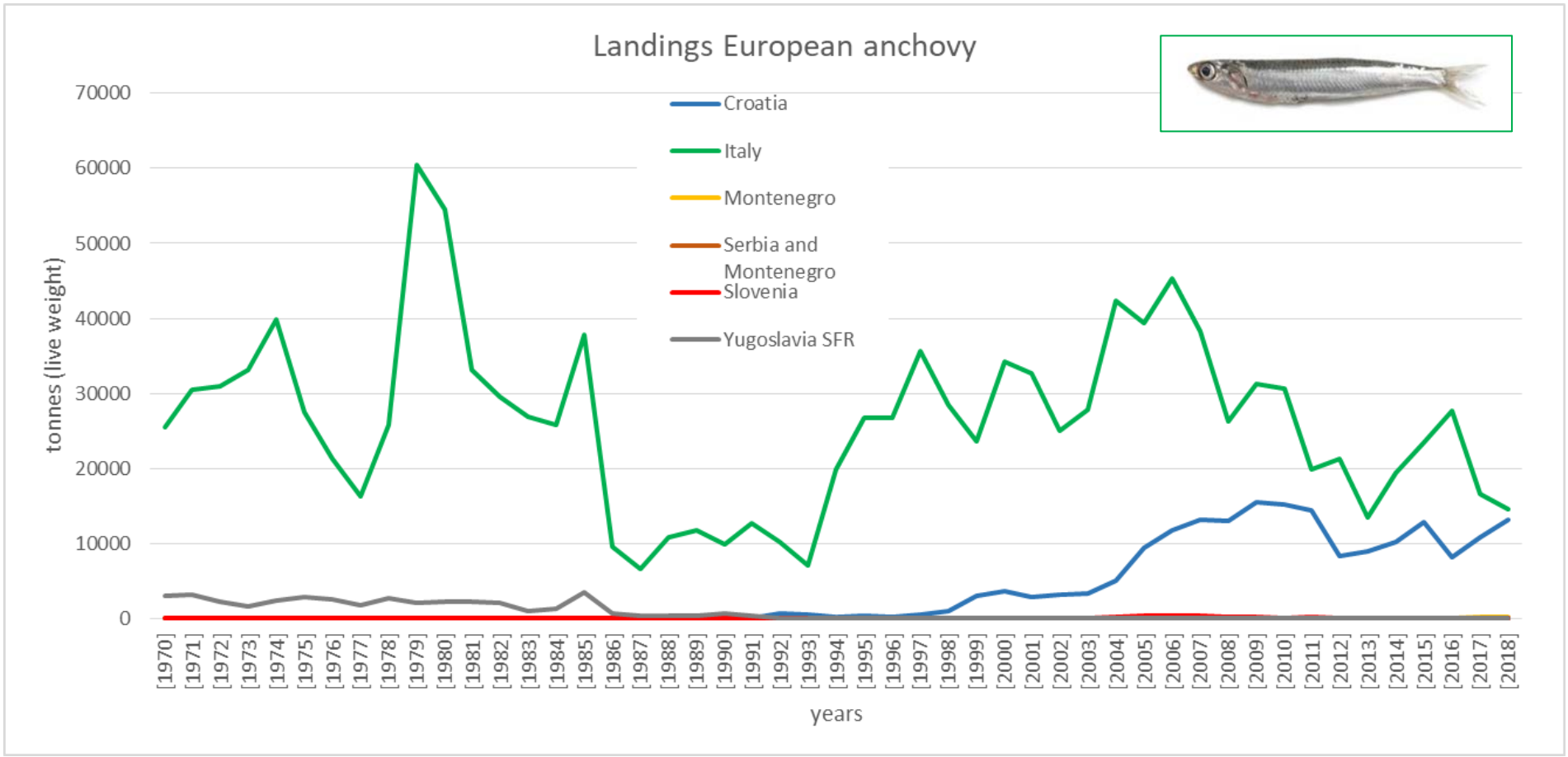


"The presence of high Po River flow rates together with moderate SSE and ESE wind stress will expand a nutrient rich WACC (western adriatic current) offshore, sustaining an increased phytoplankton and zooplankton biomass and thus increasing the extension of the area favourable to recruitment of post-larval anchovies.»

Santojanni et al.2006

Yield of small pelagics in the Adriatic Sea

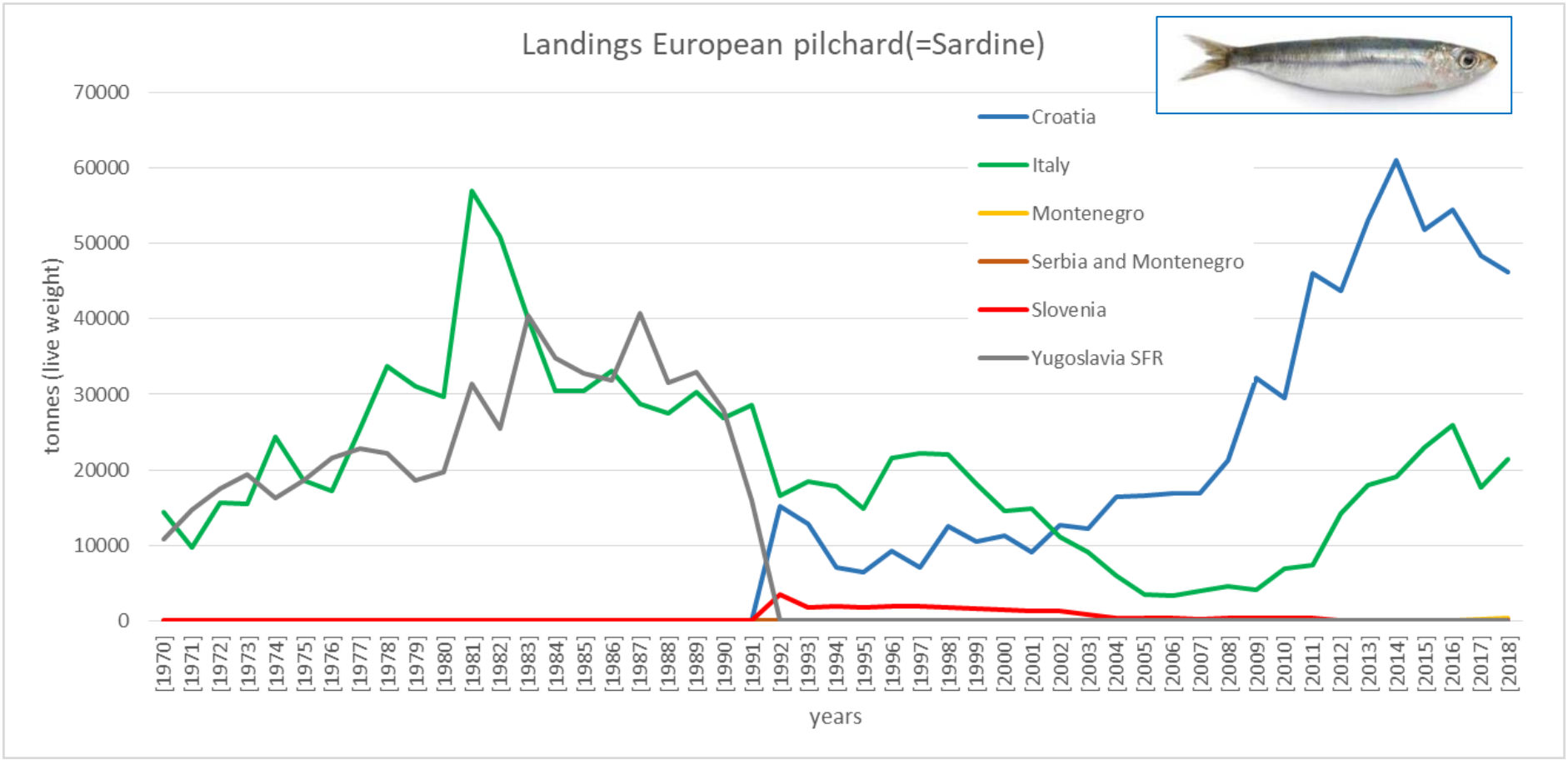
European anchovy or, more commonly, **anchovy** (*Engraulis encrasicolus*, Linnaeus, 1758)



Data from: FishstatJ+ (GFCM regional database; updated 2020)

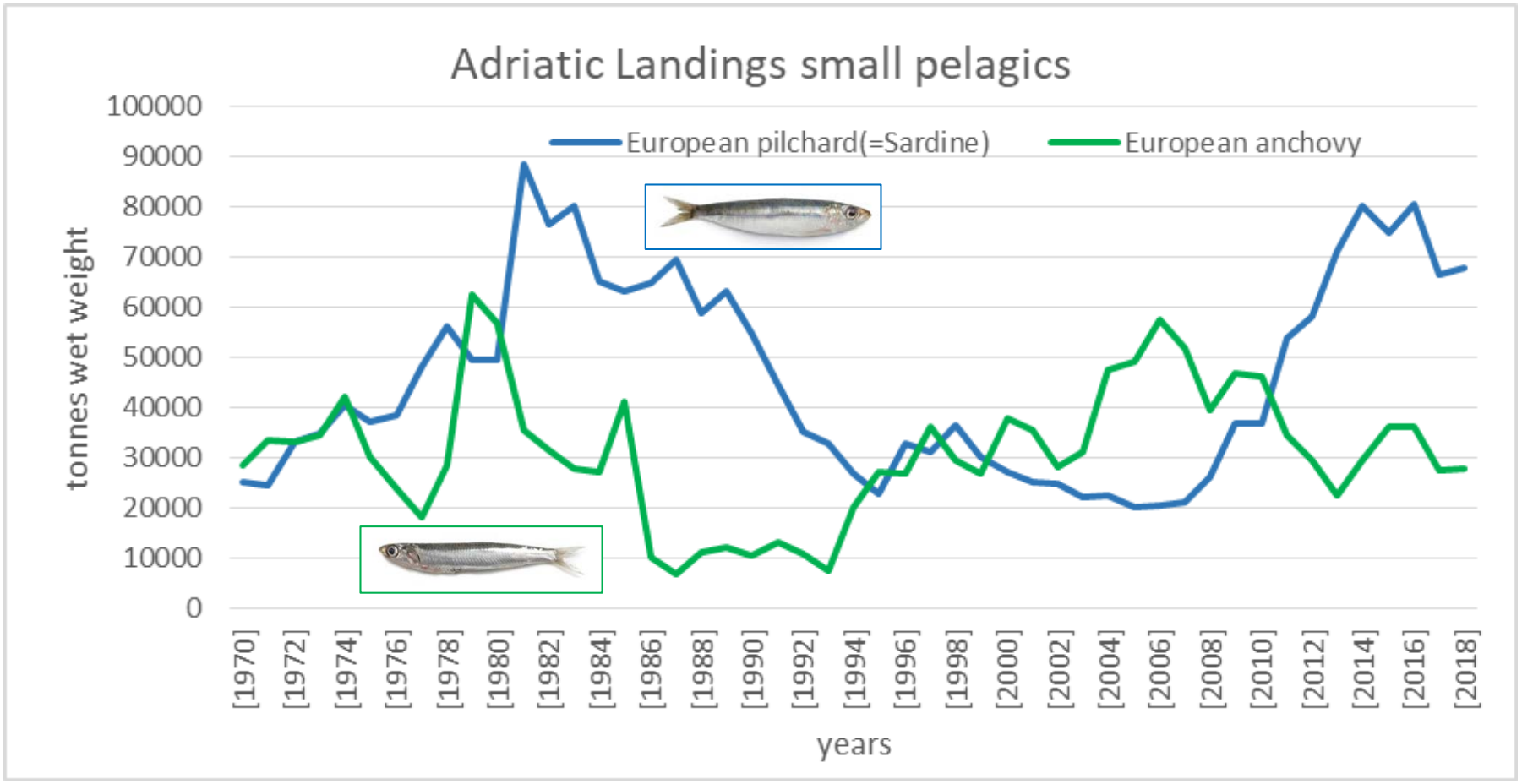
Yield of small pelagics in the Adriatic Sea

European pilchard or, more commonly, **sardine** (*Sardina pilchardus*, Walbaum, 1792)



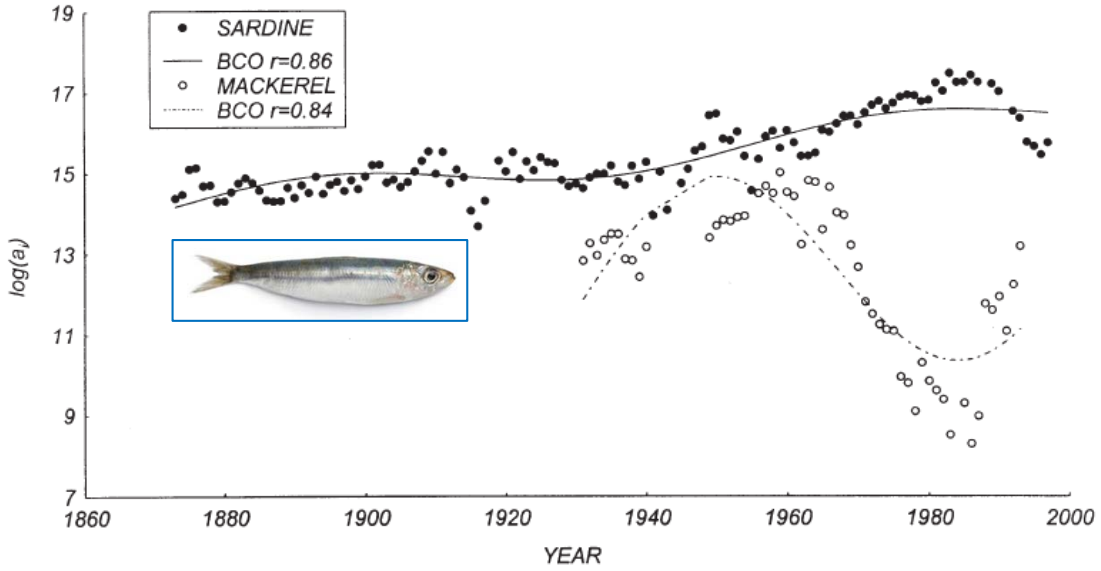
Data from: FishstatJ+ (GFCM regional database; updated 2020)

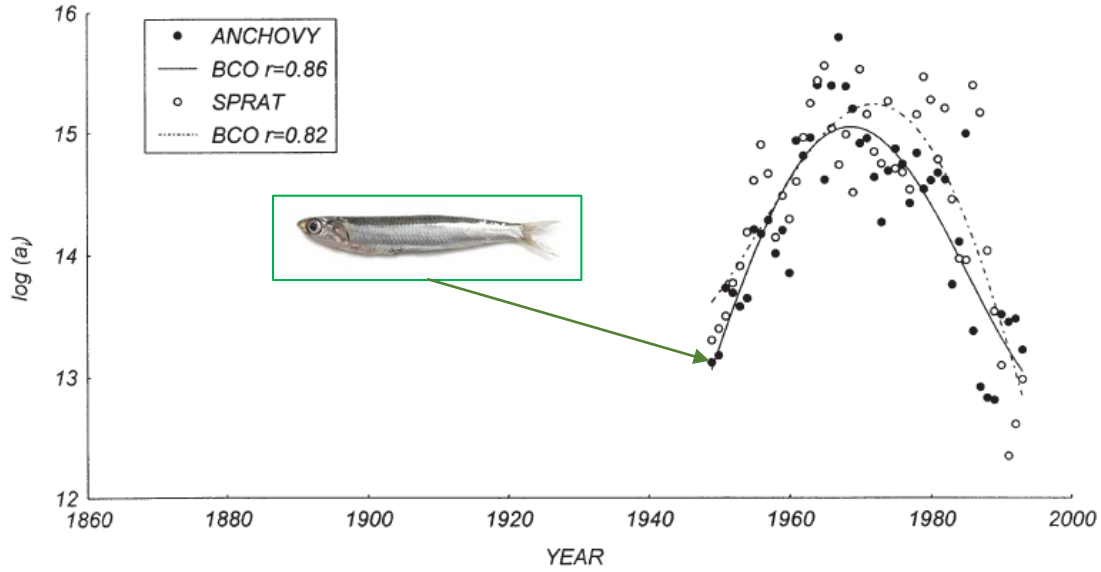
TOTAL Yield of small pelagics in the Adriatic Sea



Data from: FishstatJ+ (GFCM regional database; updated 2020)

Long term changes of anchovy & sardine





sardine, mackerel, anchovy and sprat catch data: log-transformed annual values of fish landing data (a_i)

"since these species prefer somewhat different hydrographic conditions, it is possible that suitable conditions for one of them means that conditions are not favourable for the other. Different responses to salinity are confirmed from the opposite sign of the correlation coefficients between the fish data (sardine and mackerel) and salinity."

Grbec et al., 2003

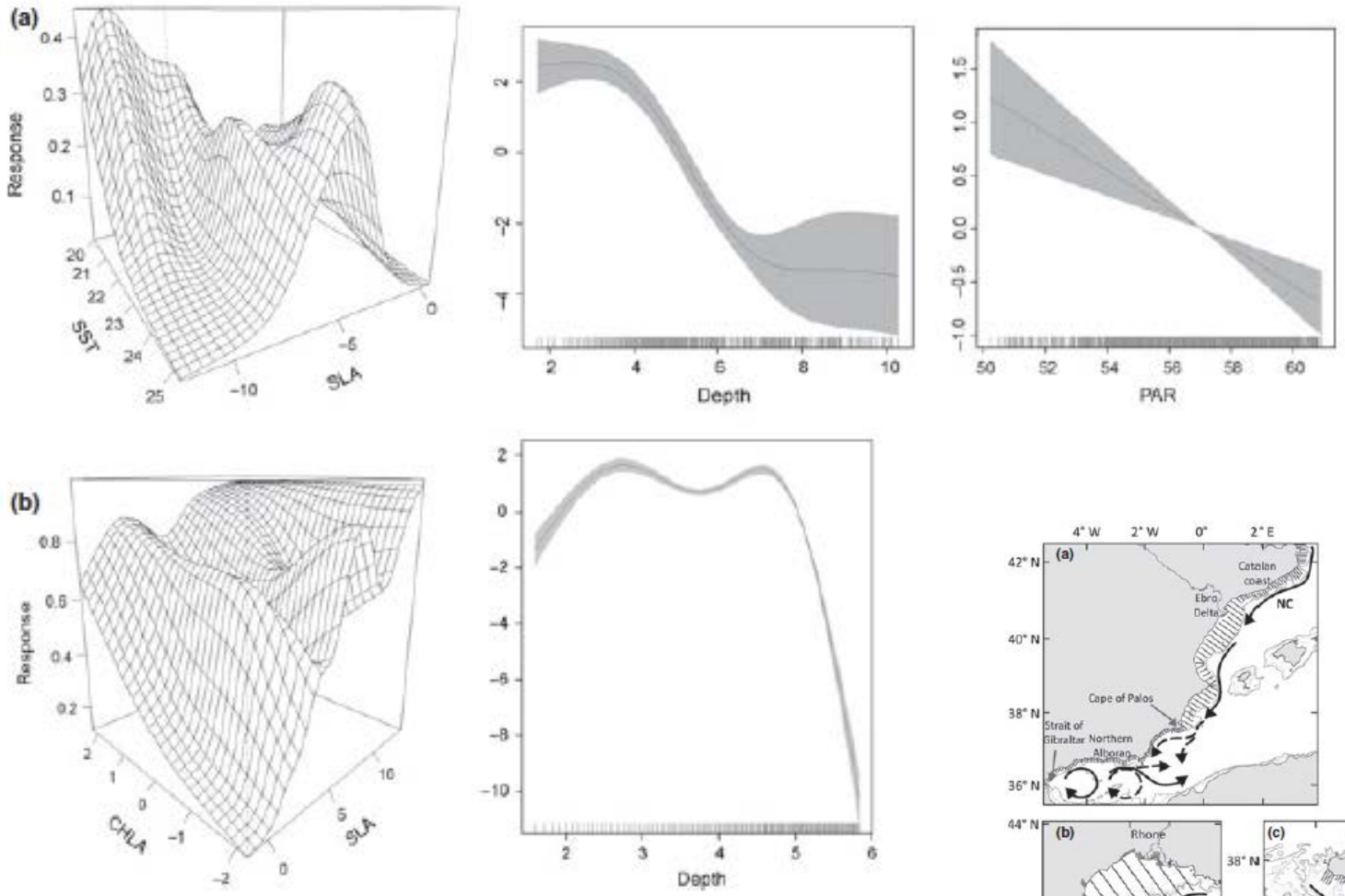
Long term changes of anchovy & sardine

	NAO index	Pressure differences	Salinity
Sardine	0.05	0.56*	0.43*
Mackerel	−0.08	−0.19	−0.53*
Anchovy	−0.45*	0.04	0.12
Sprat	−0.52*	0.03	0.34*

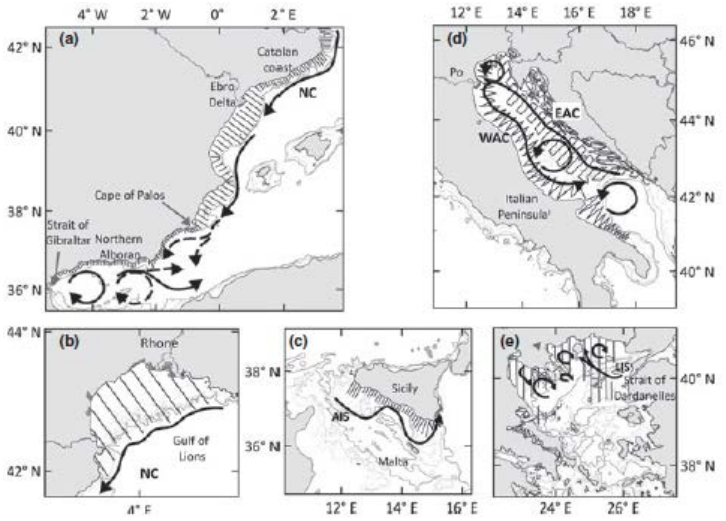
“The positive pressure difference implies higher pressure over the mid Atlantic and lower pressure over the southeast Mediterranean. Such a pressure distribution is favourable for LIW formation in the eastern Mediterranean, intensified inflow of more saline LIW into the Adriatic and dense water formation in the northern Adriatic. […] Years with positive pressure differences, which are years of higher salinity, are also more productive years, considering the phytoplankton productivity.»

Grbec et al., 2003

Distribution of anchovy: adults

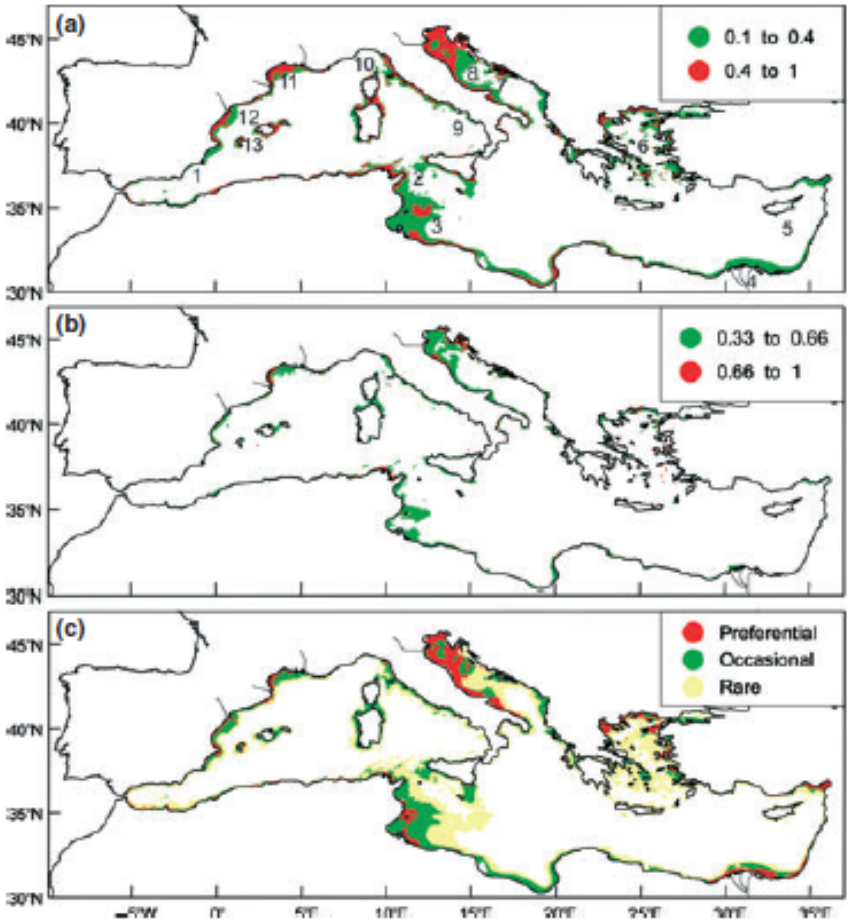


Sea level anomaly, depth and photosynthetic active radiation

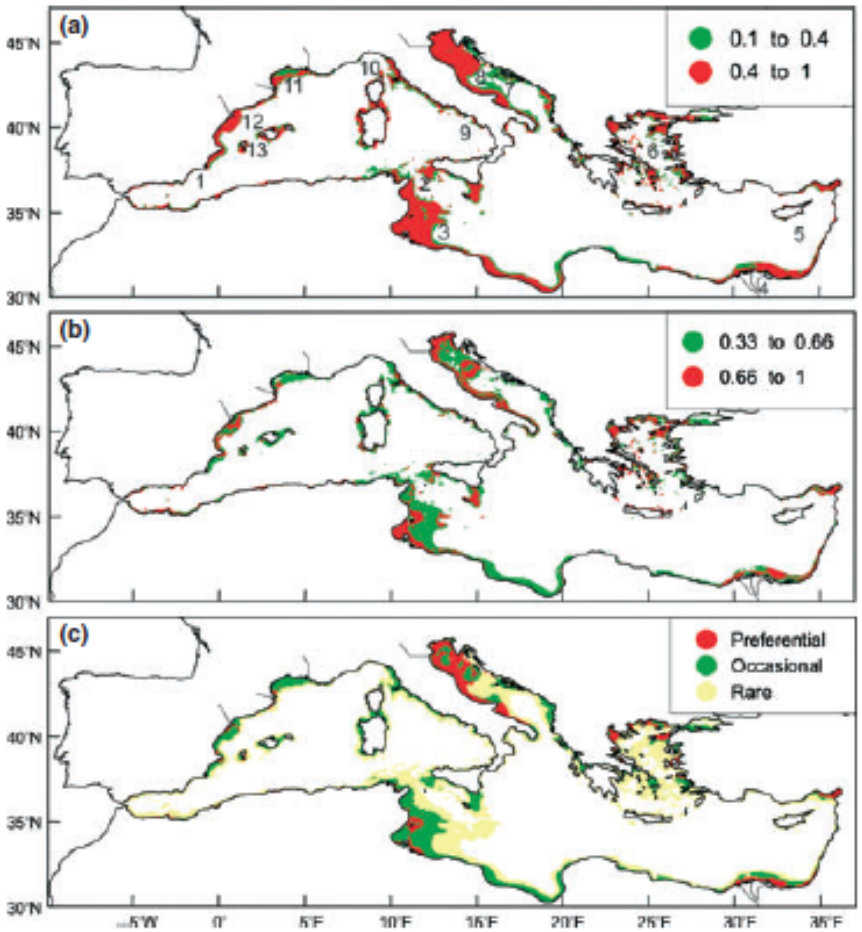


Giannoulaki et al., 2013

Distribution of anchovy



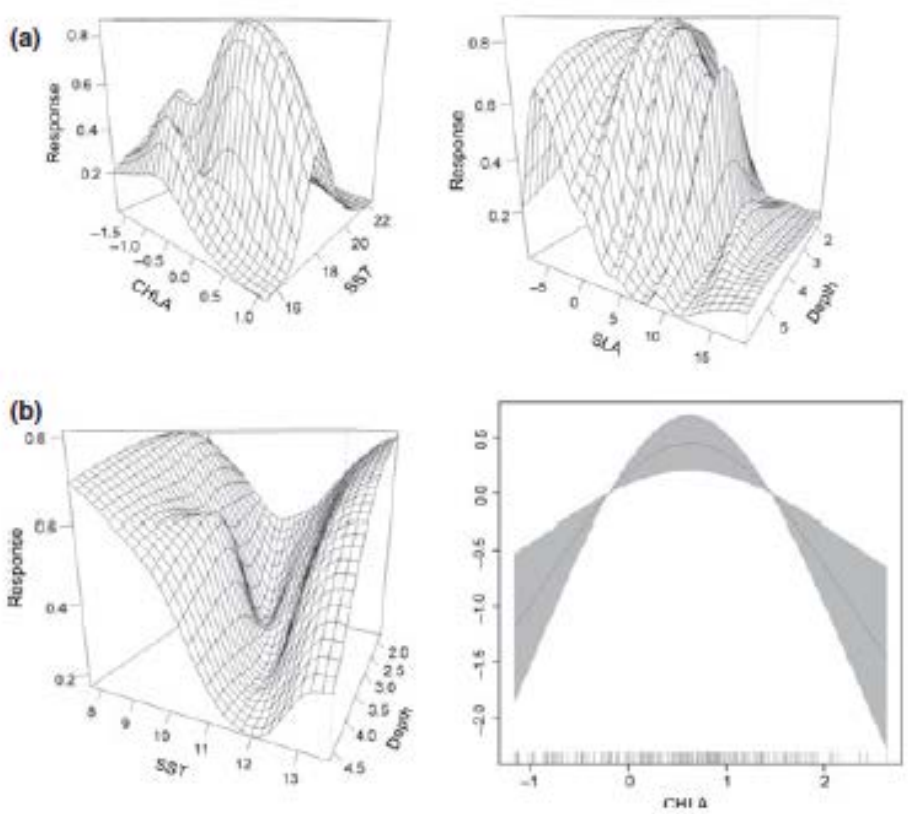
Adults, early summer



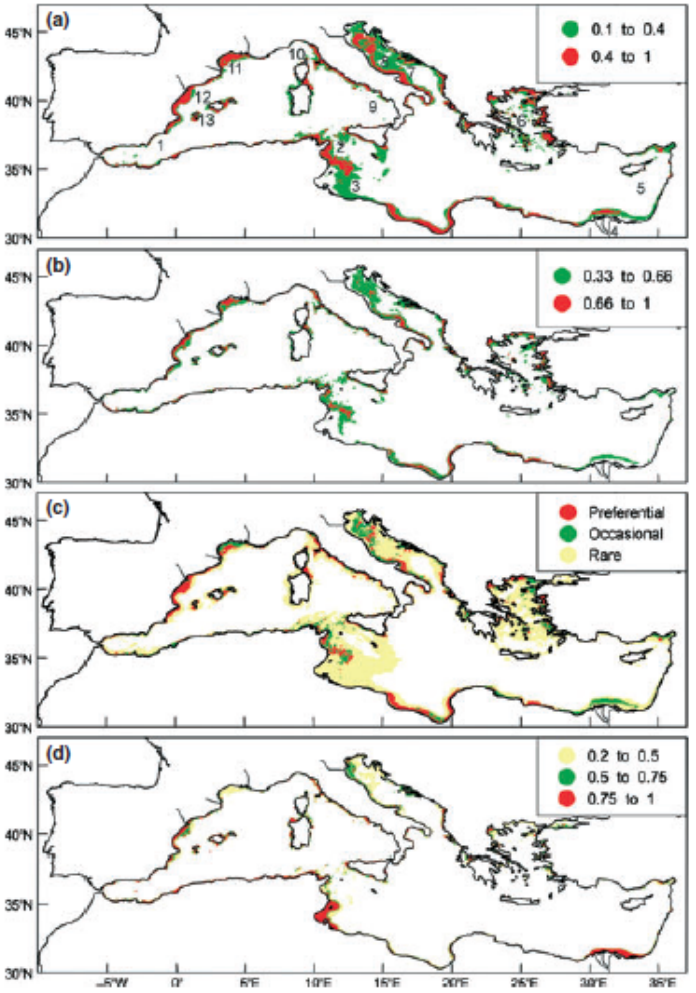
Adults, early autumn

Giannoulaki et al., 2013

Distribution of anchovy: juveniles

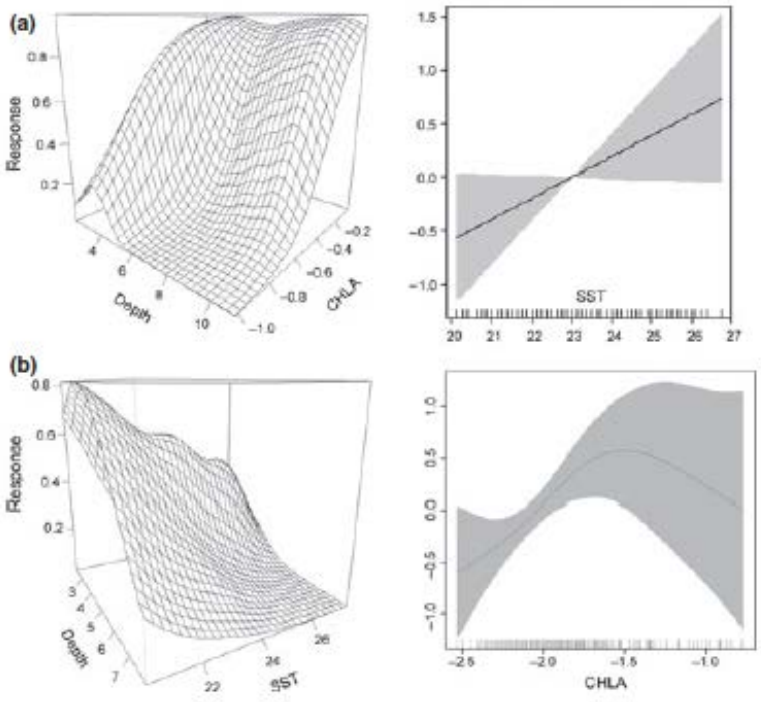


Sea level anomaly, depth, Sea surface temperature and Chlorophyll-a

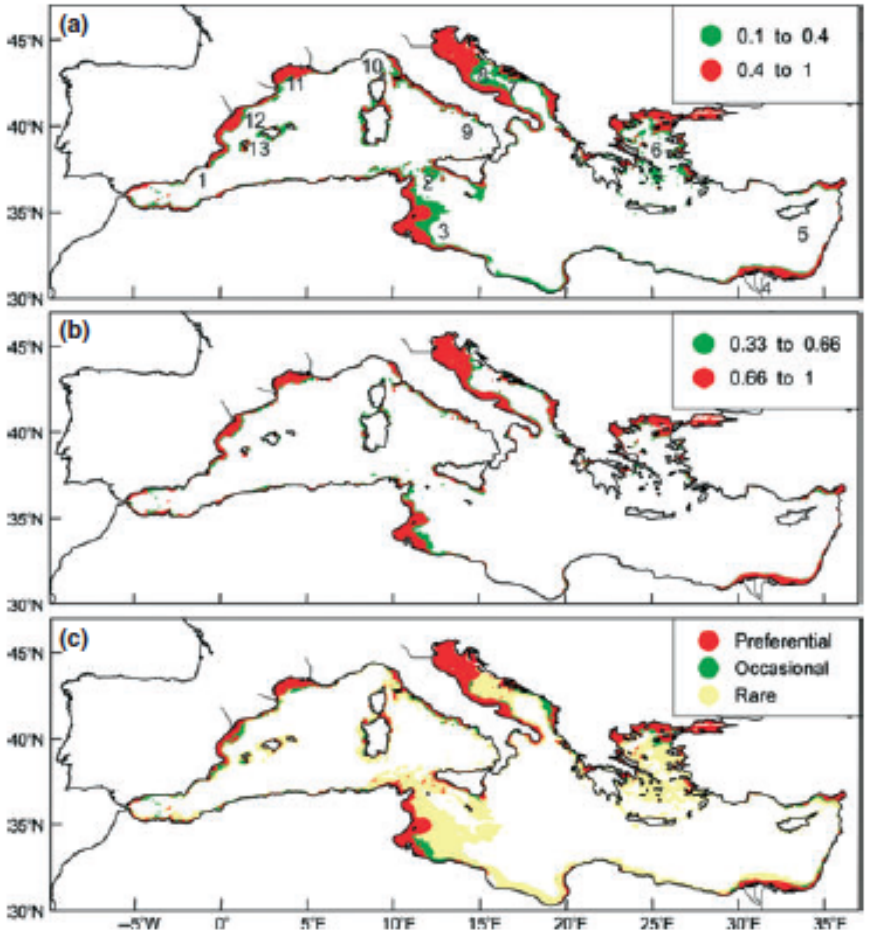


Giannoulaki et al., 2013

Distribution of anchovy: eggs



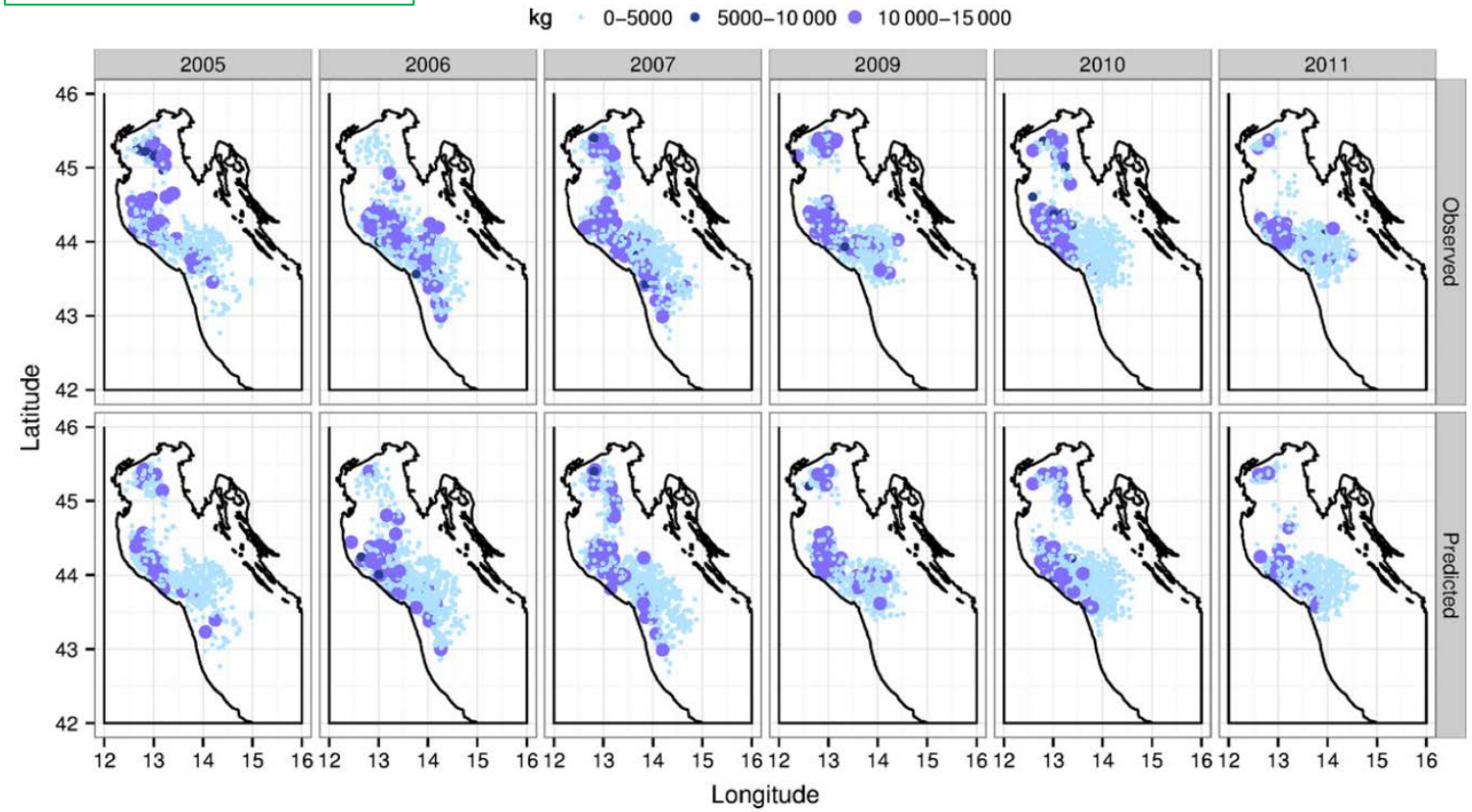
depth, Sea surface temperature and Chlorophyll-a



Eggs, june

Giannoulaki et al., 2013

Environmental variables influencing distribution



Data (FOOS catches)

Best GAMM model prediction

The results indicate that the **mean depth, surface temperature and salinity gradients** are the most important predictors in the anchovy model. This means that anchovy catches increase according to these three parameters, more specifically at temperatures **below 11 °C and between 14 and 22 °C**, **depths between 20 and 50 m and with a positive increase in the salinity gradient**. Surface temperatures higher than 22 °C seem to reduce the catches of anchovy and high salinity gradients

Carpi et al., 2015

Growth anchovy

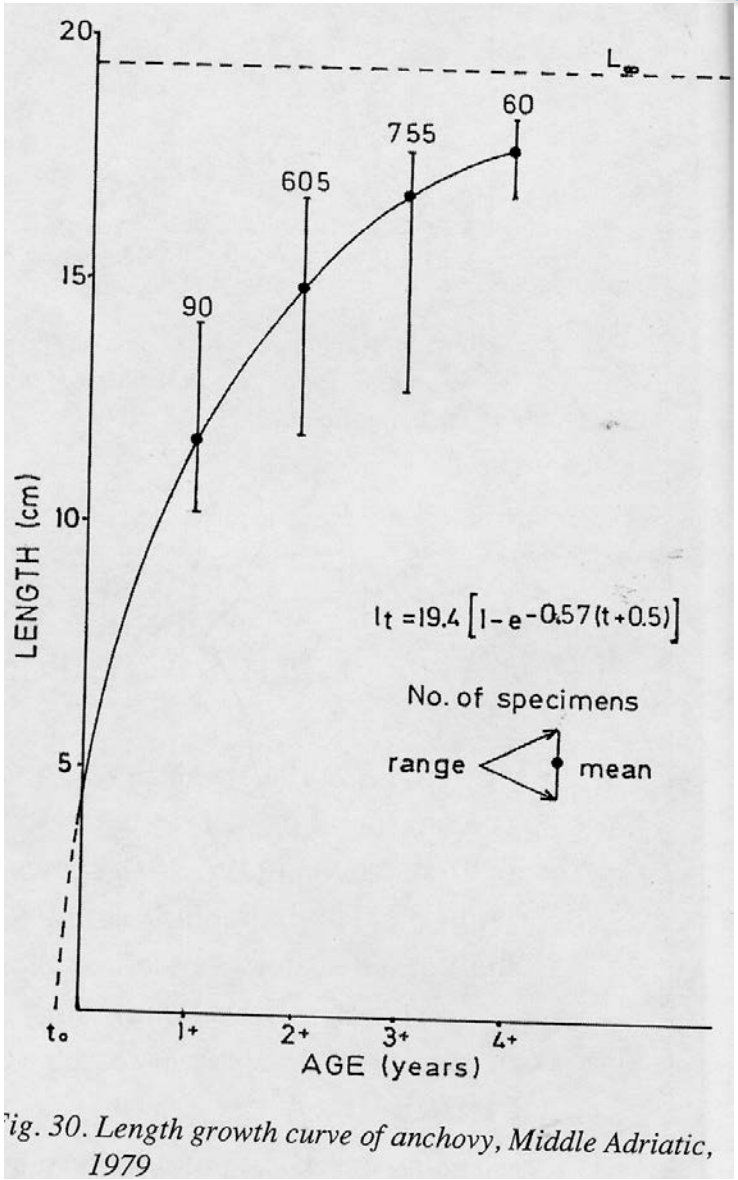


Fig. 30. Length growth curve of anchovy, Middle Adriatic, 1979

Sinovčić, 2000

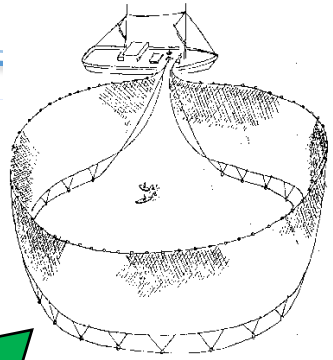
Role of small pelagics in the marine ecosystem

Nutrients

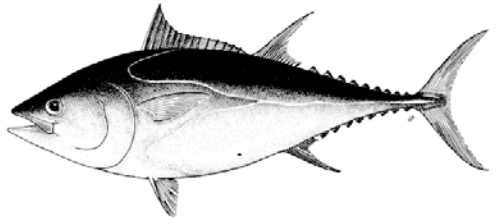
Phytoplankton

Zooplankton

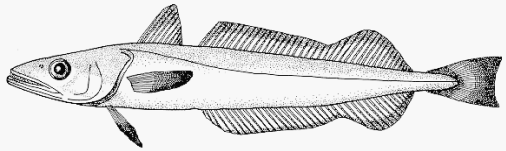
Gelatinous plankton



Fisheries

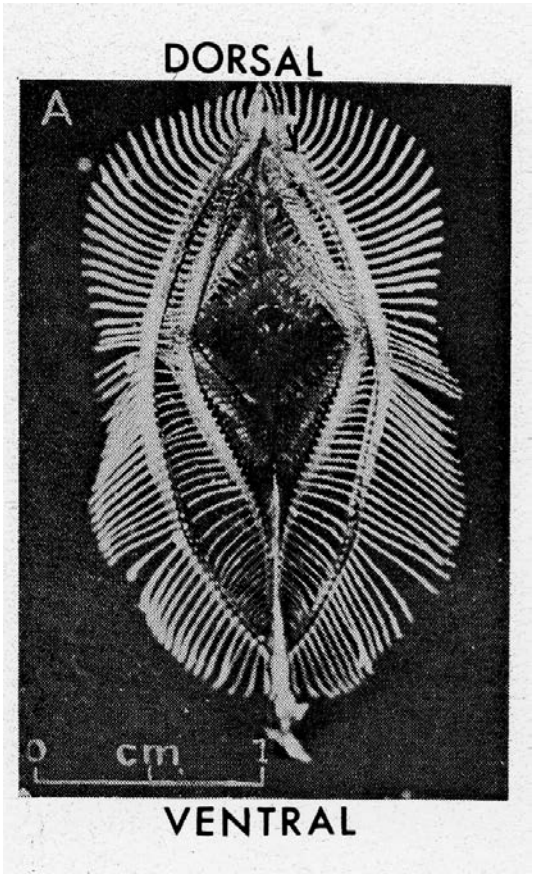


Pelagic predators



Demersal predators

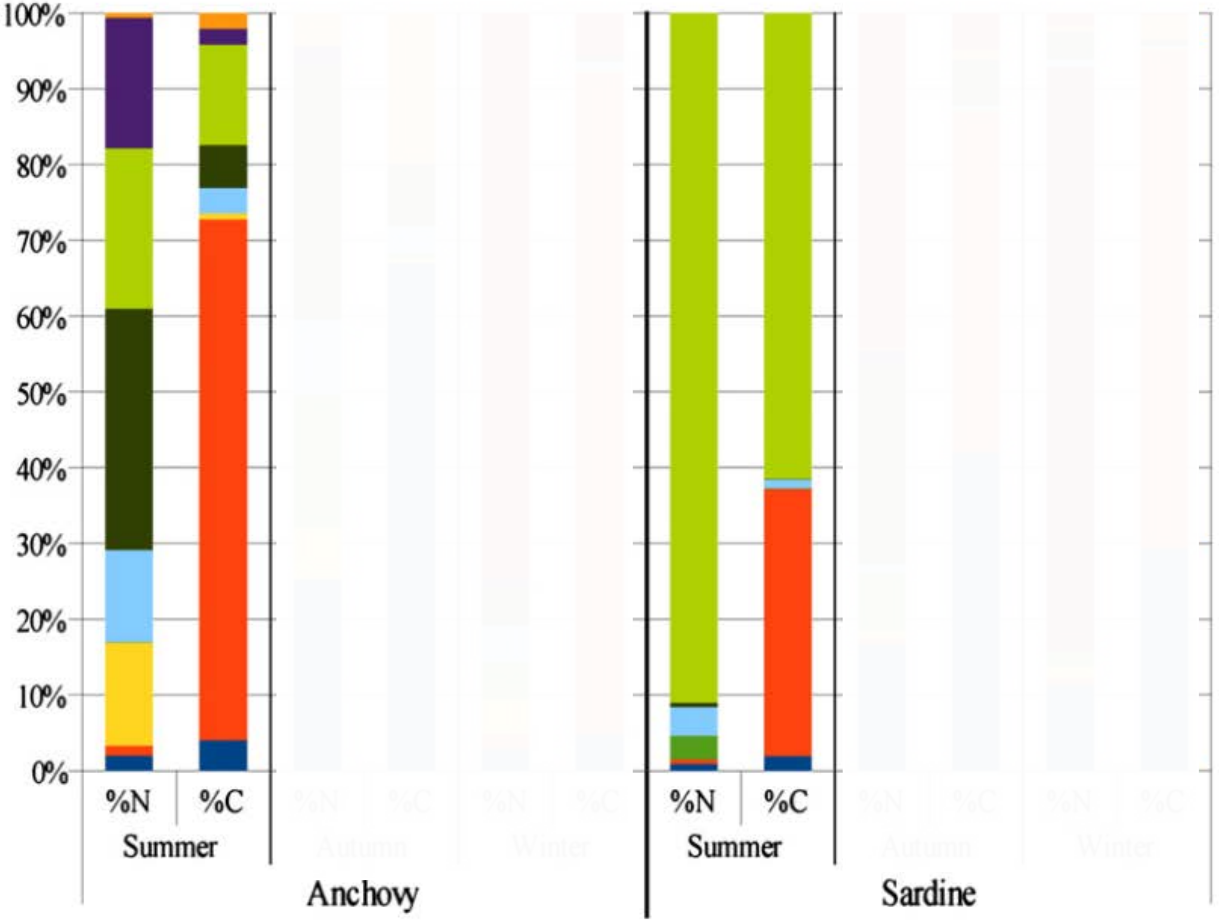
Feeding preferences: anchovy

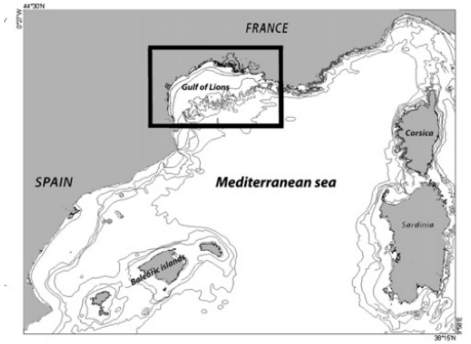


Branchial archs (*Engraulis capensis*, in King & Macleod, 1974).

Feeding preferences sardine

Prey in the stomachs of juvenile anchovy and sardine, in percentages of number (%N) and of carbon content (%C).





Costalago et al., 2014

Feeding preferences sardine

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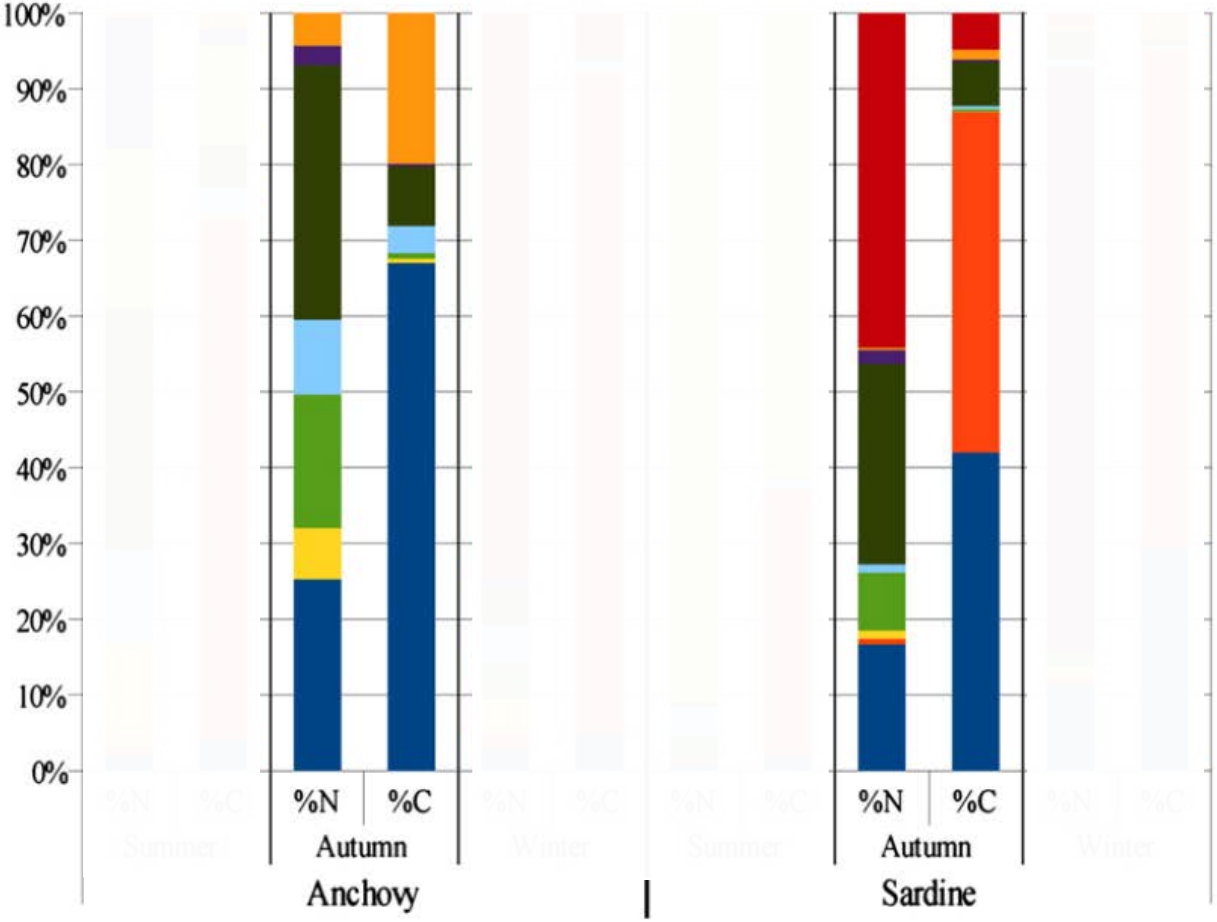

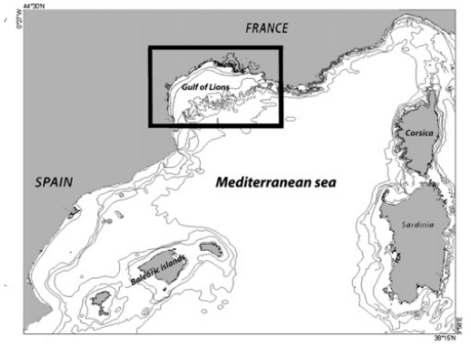

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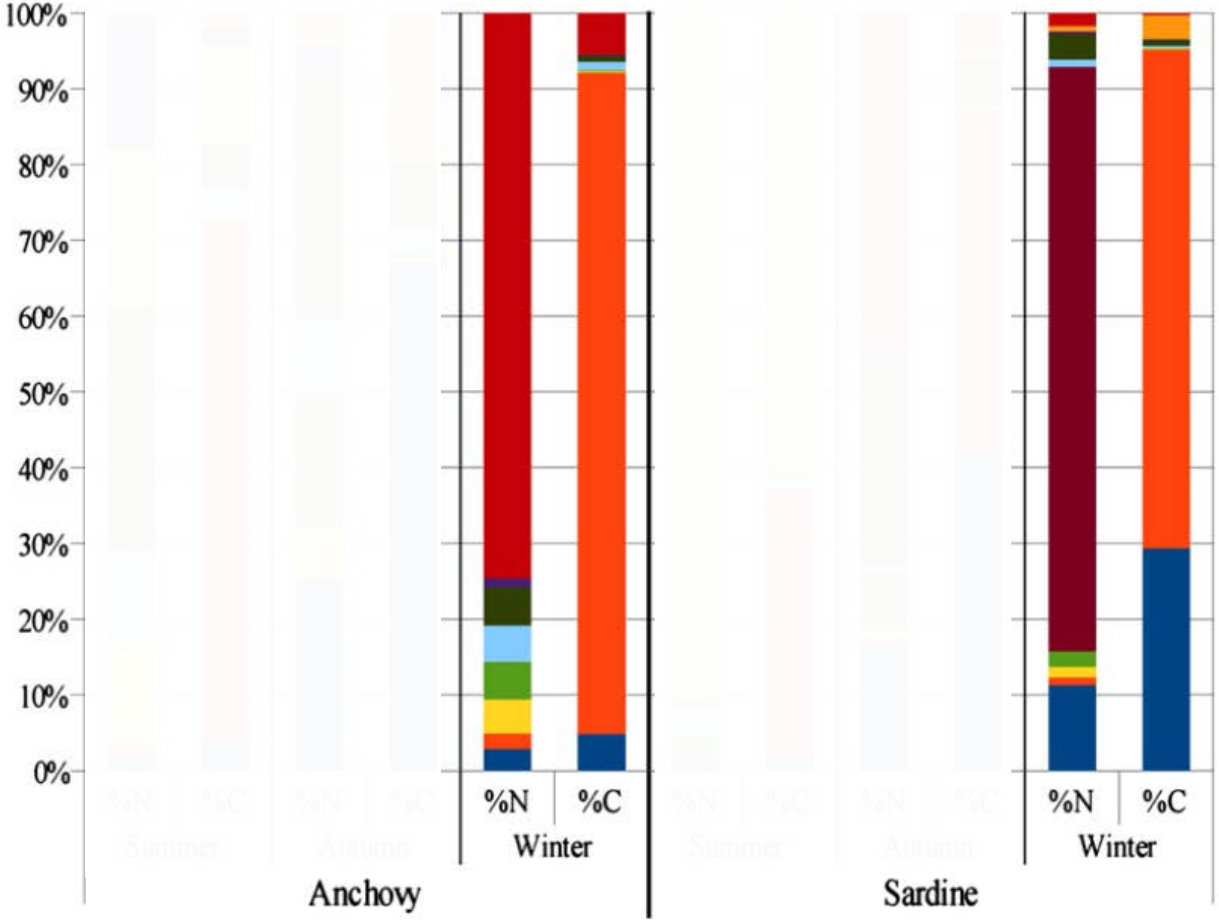
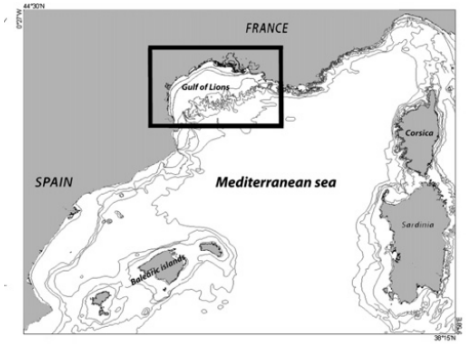
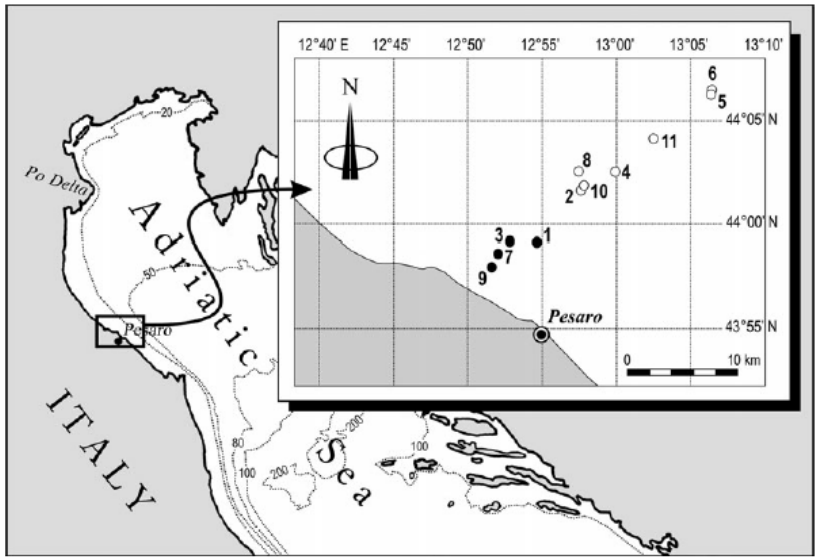
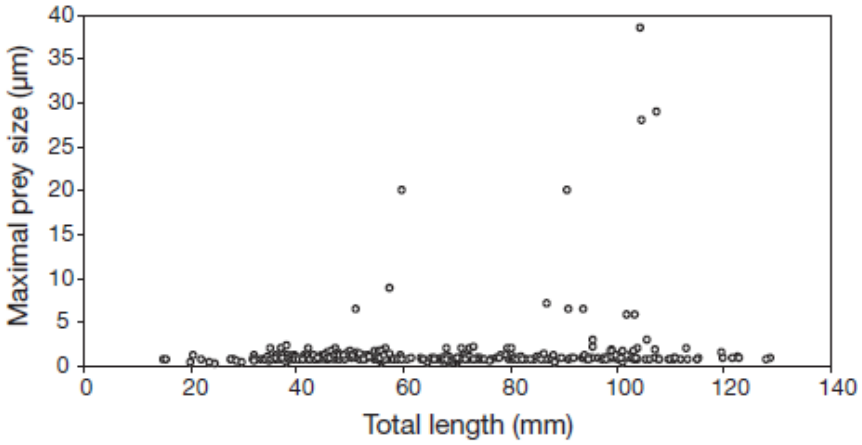


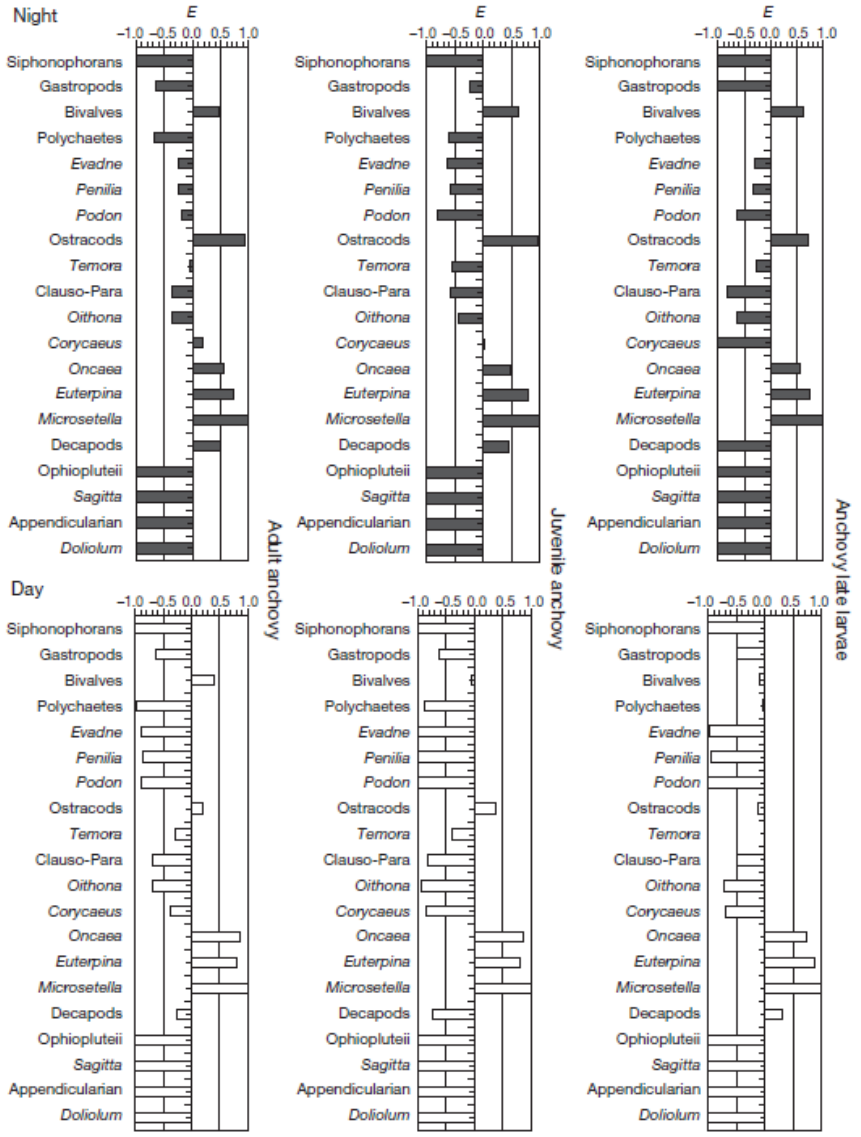


Costalago et al., 2014

Feeding preferences anchovy

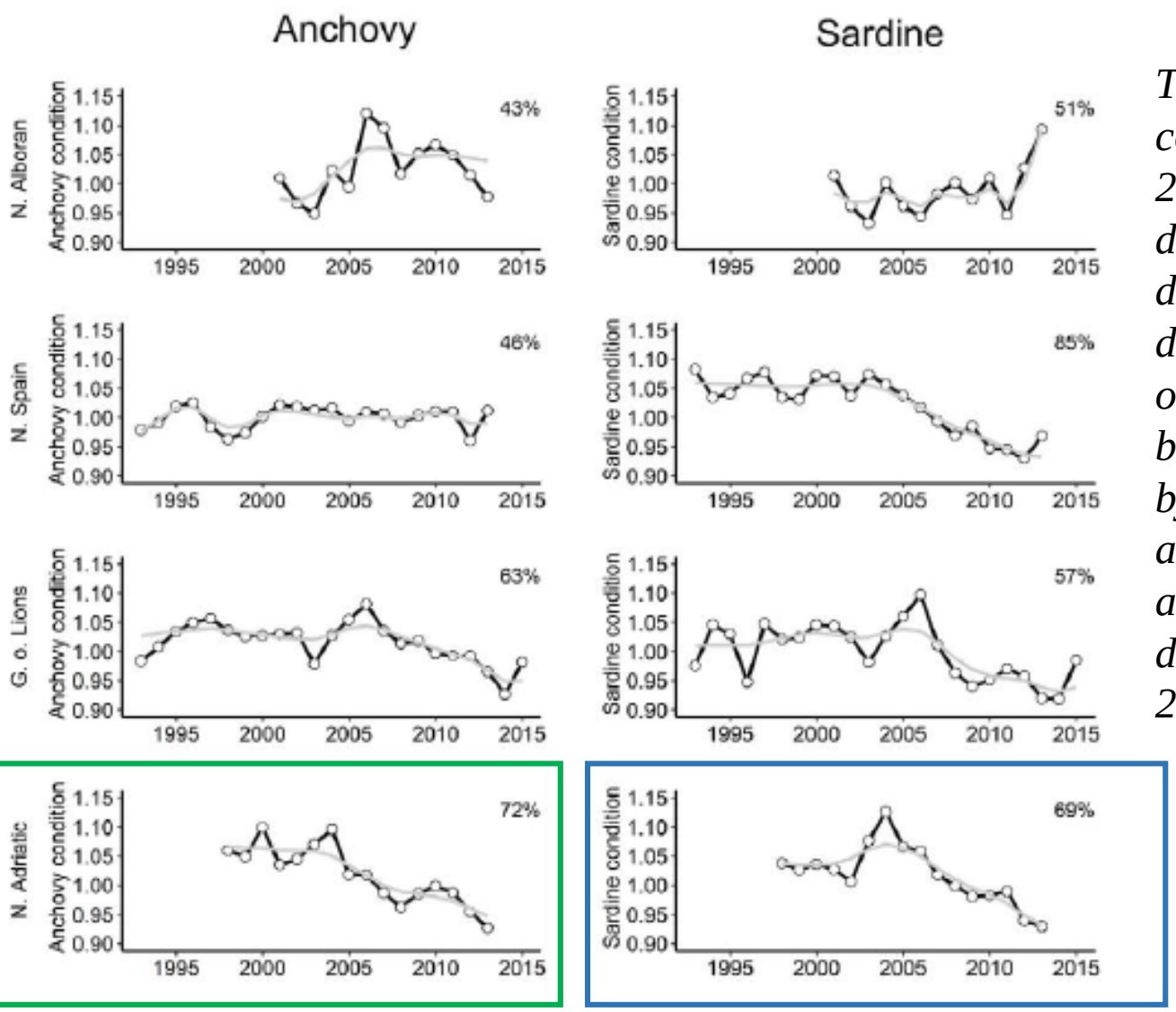






Borme et al., 2009

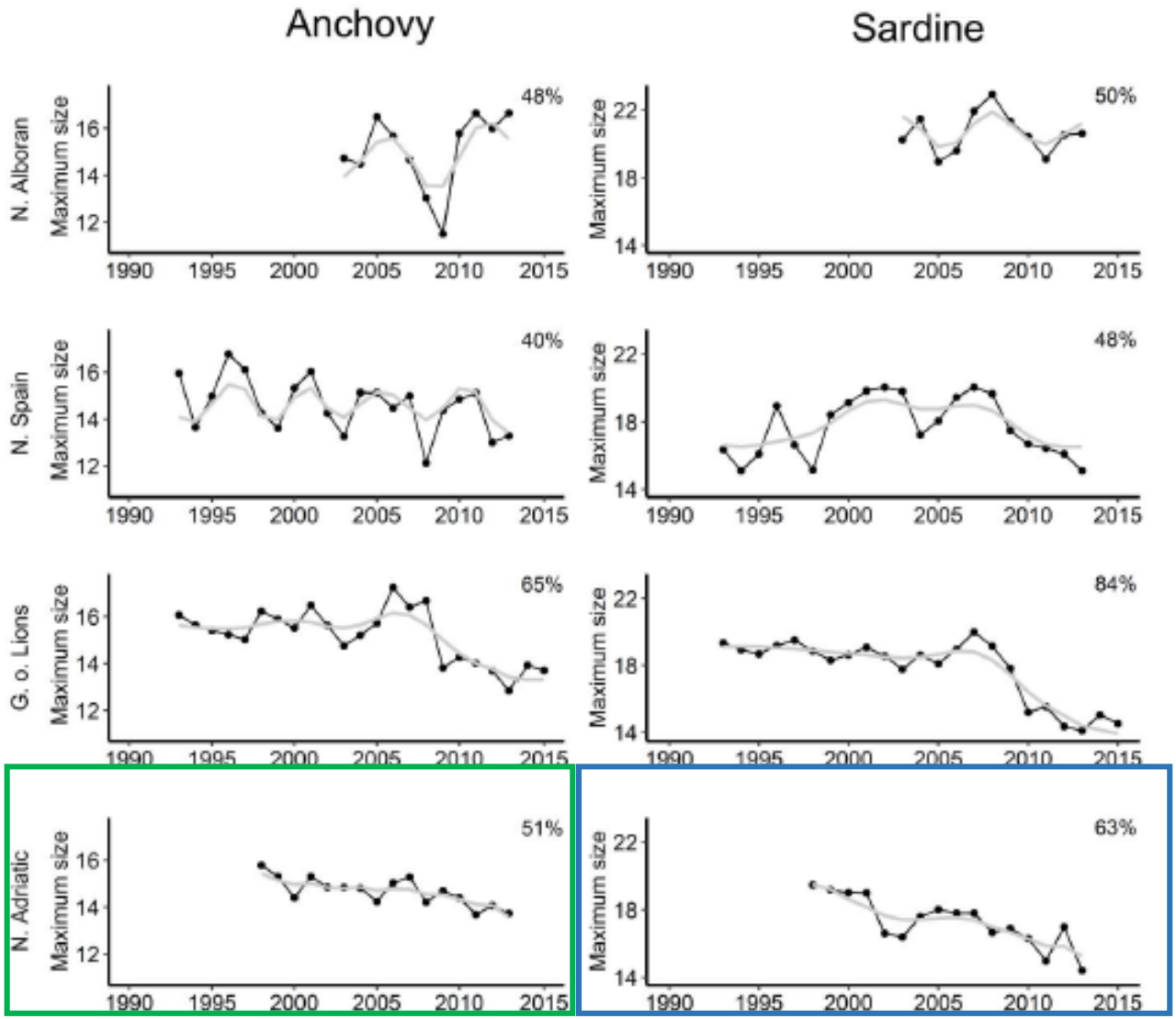
Body condition



Time series of monthly body condition from 1975 to 2012 derived from fisheries data in the Adriatic Sea displayed long term decreases. A first drop occurred in the mid-80s for both species. It is followed by a slight decrease (1995) and increase (2005) for anchovy and a final decrease between 2008 and 2012 only for sardine,

Brosset et al., 2016

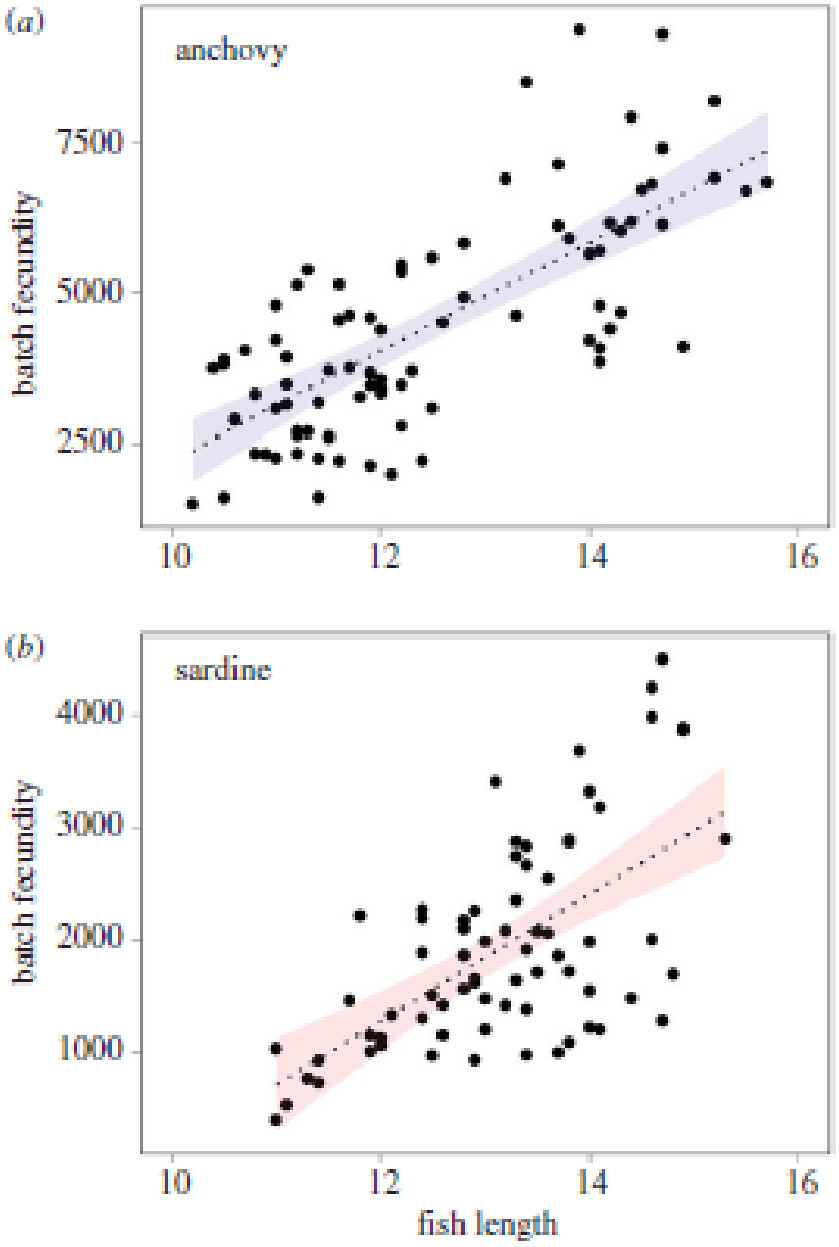
Maximum size



Small pelagic fish body condition is known to be primarily affected by food availability, especially the zooplanktonic compartment which constitutes the bulk of small pelagic fish preys

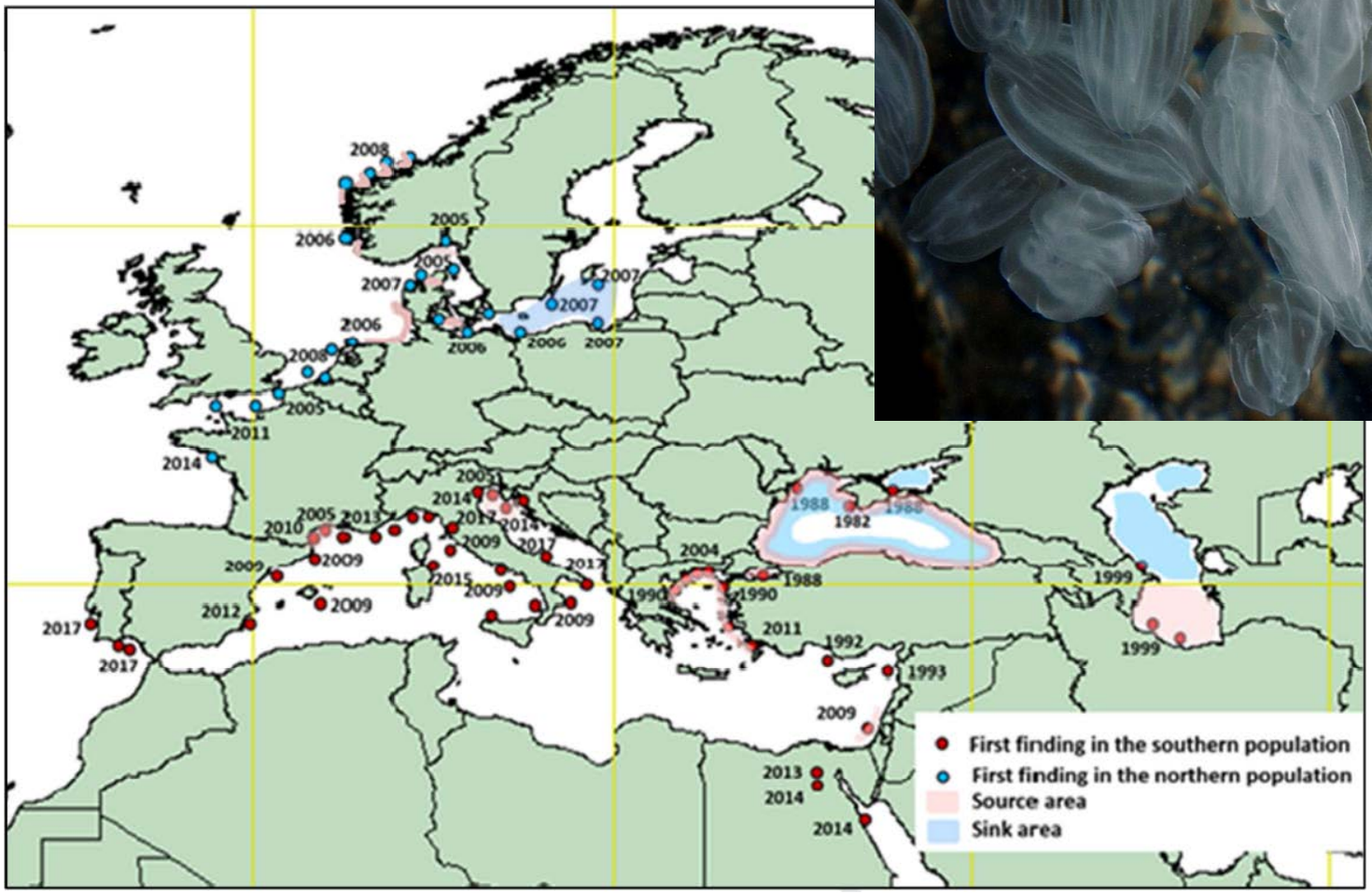
Brosset et al., 2016

Fecundity vs size



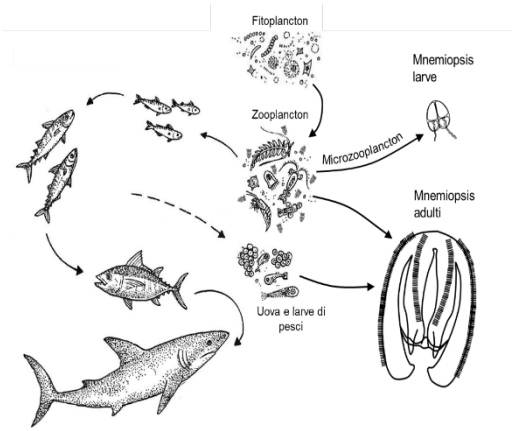
Brosset et al., 2016

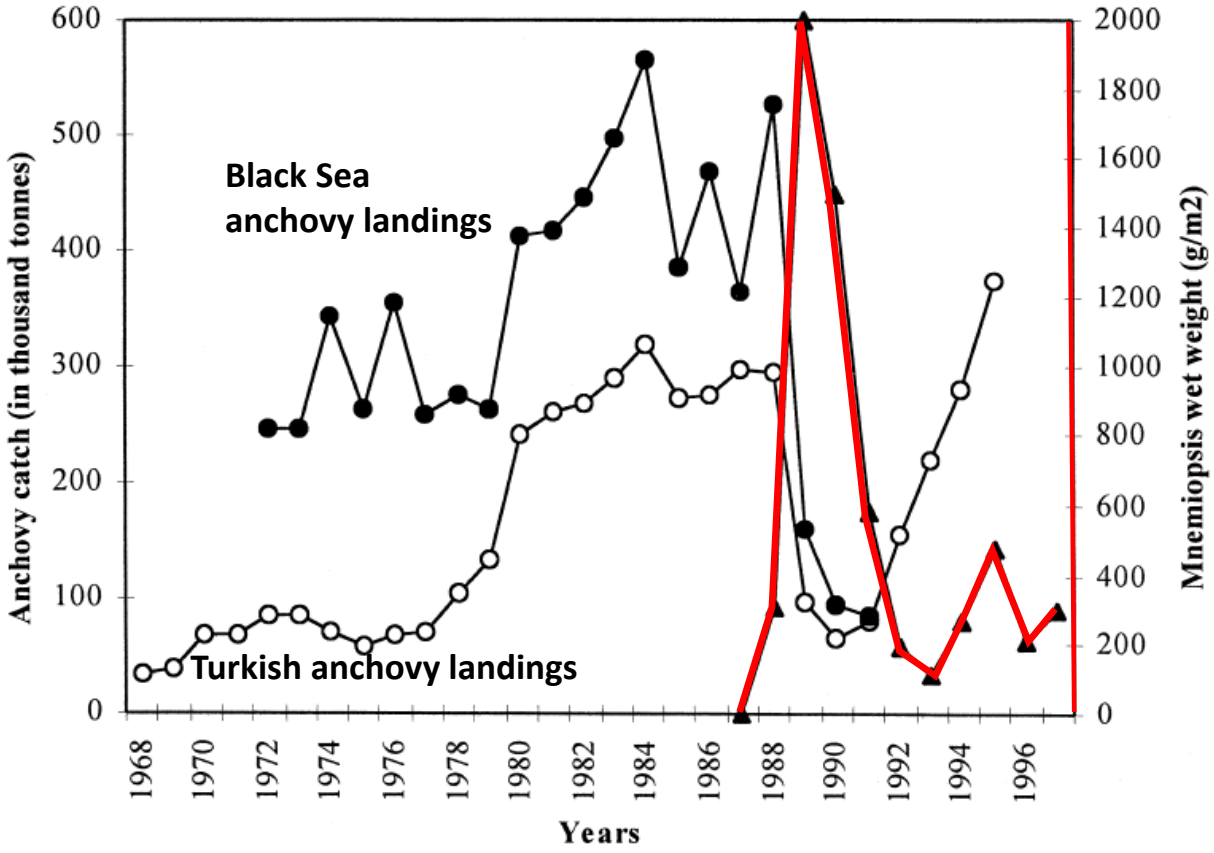
Effects of the invasive species *Mnemiopsis leydi*



Shiganova et al., 2019

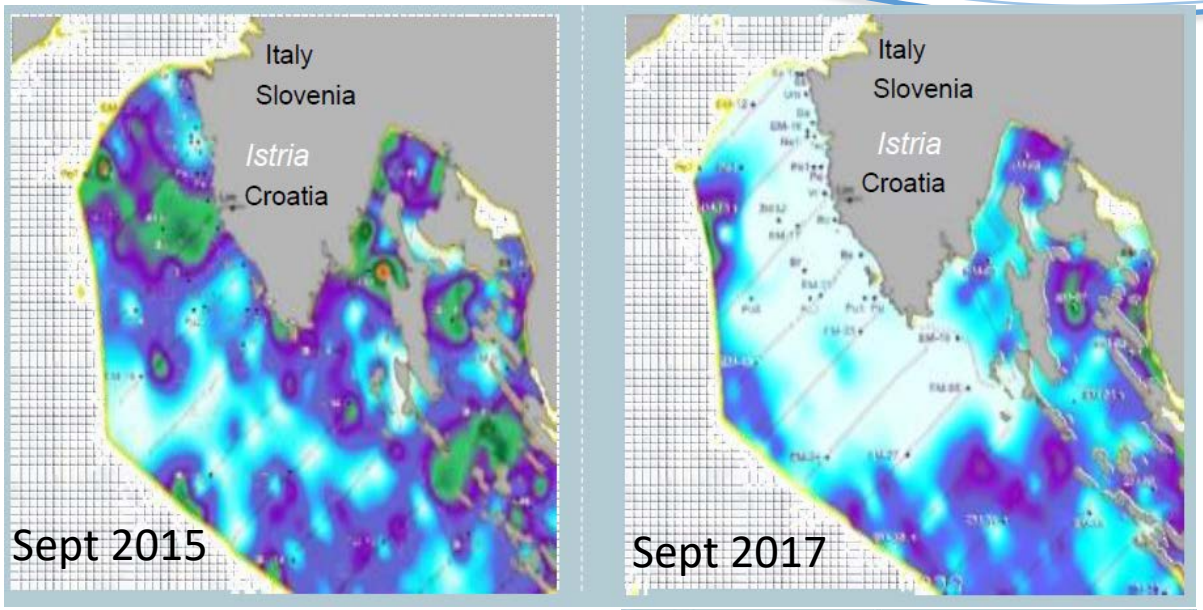
Effects of the invasive species *Mnemiopsis leydi*





Kideys et al., 2000

Mnemiopsis competition?

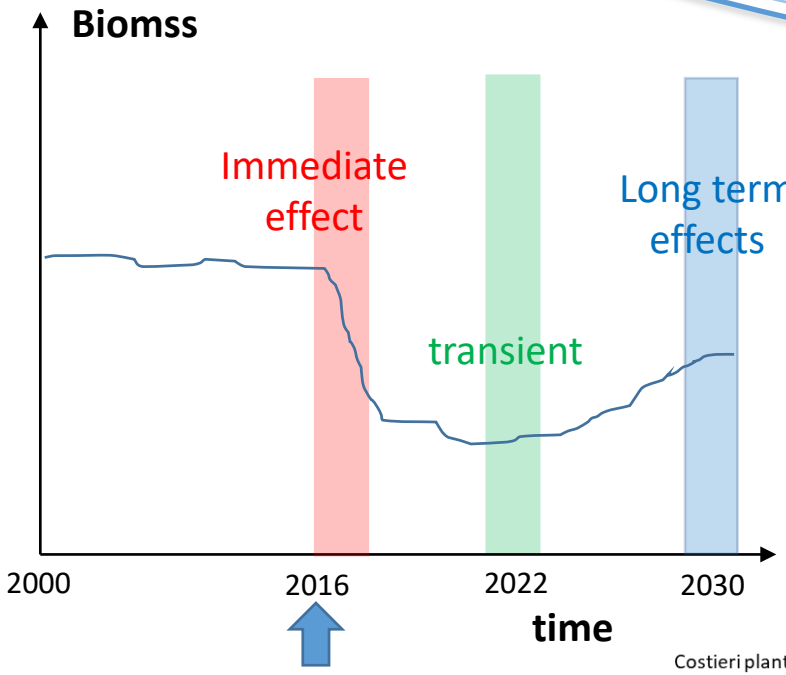


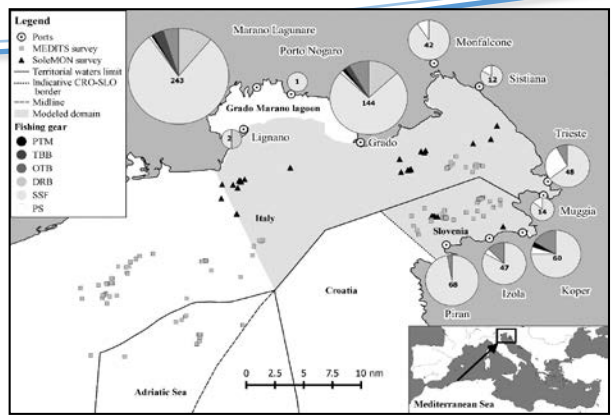
Anchovy (echosurvey)

Mnemiopsis leydi, september 2017

Paliaga et al., 2019

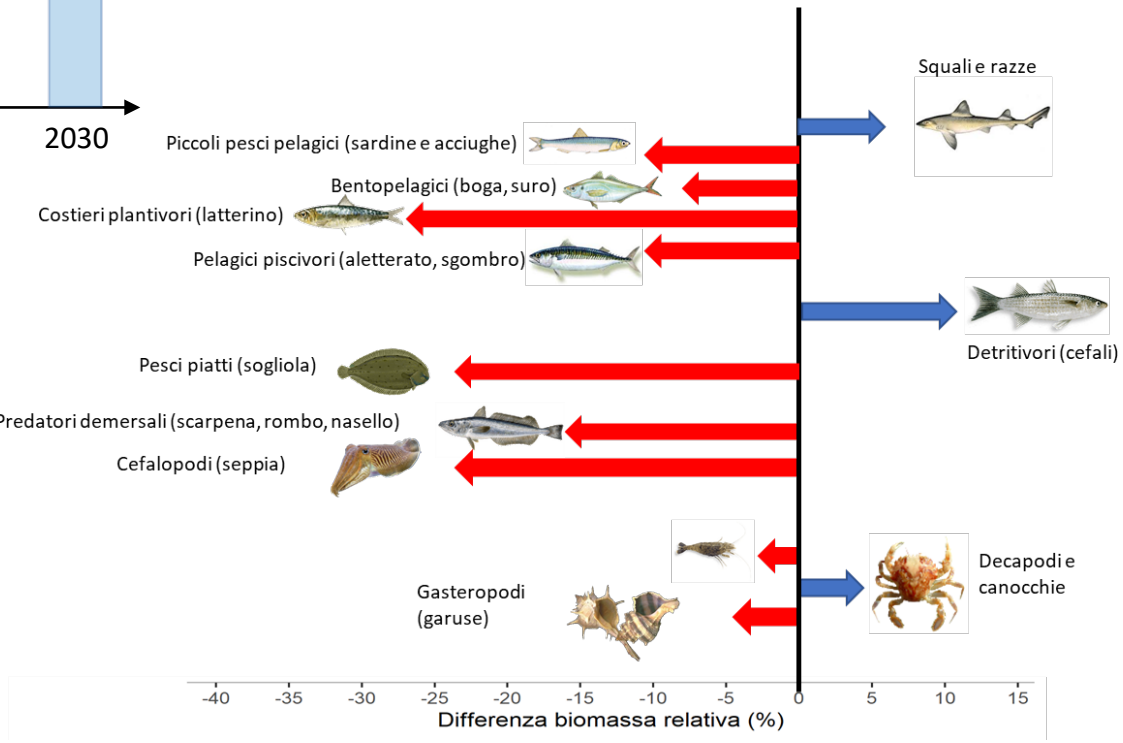
Modelling Mnemiopsis invasion





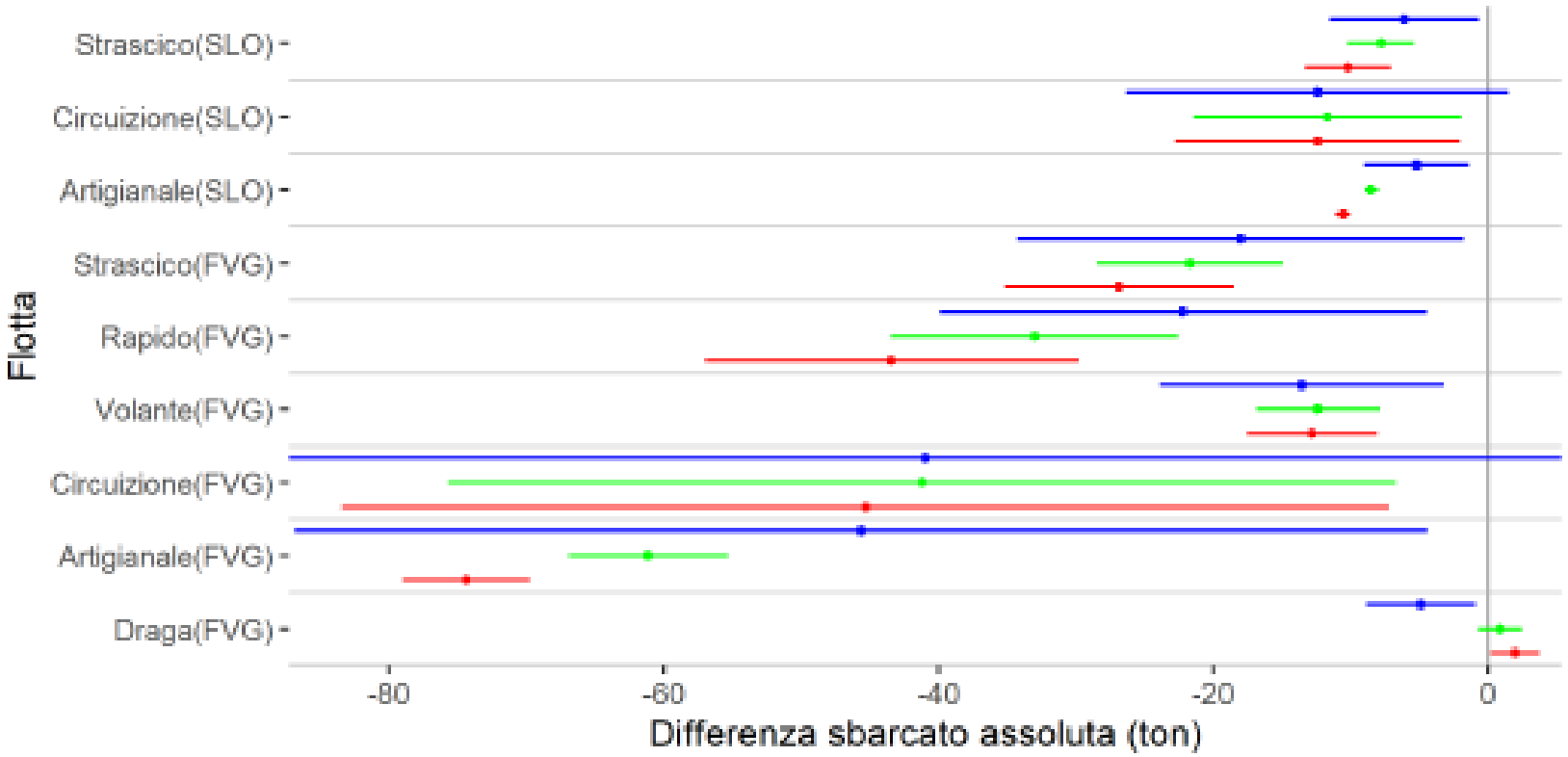
NOCE DI MARE

Valutazione preliminare degli impatti di *Mnemiopsis leidyi* (Ctenoforo) sull'ecosistema marino e lagunare del Friuli Venezia Giulia con particolare riferimento al comparto ittico.



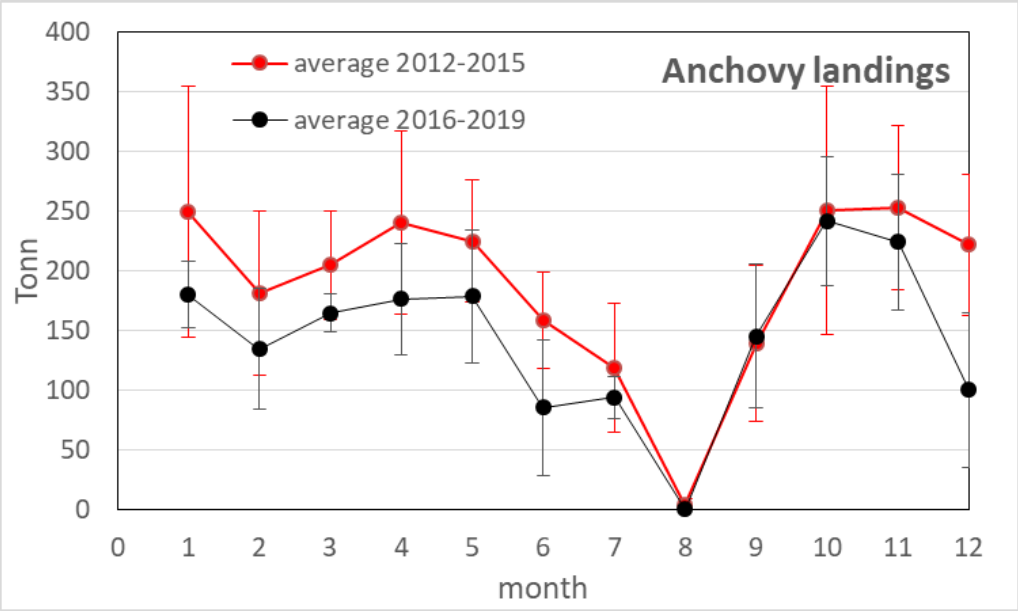
Tirelli et al., 2019

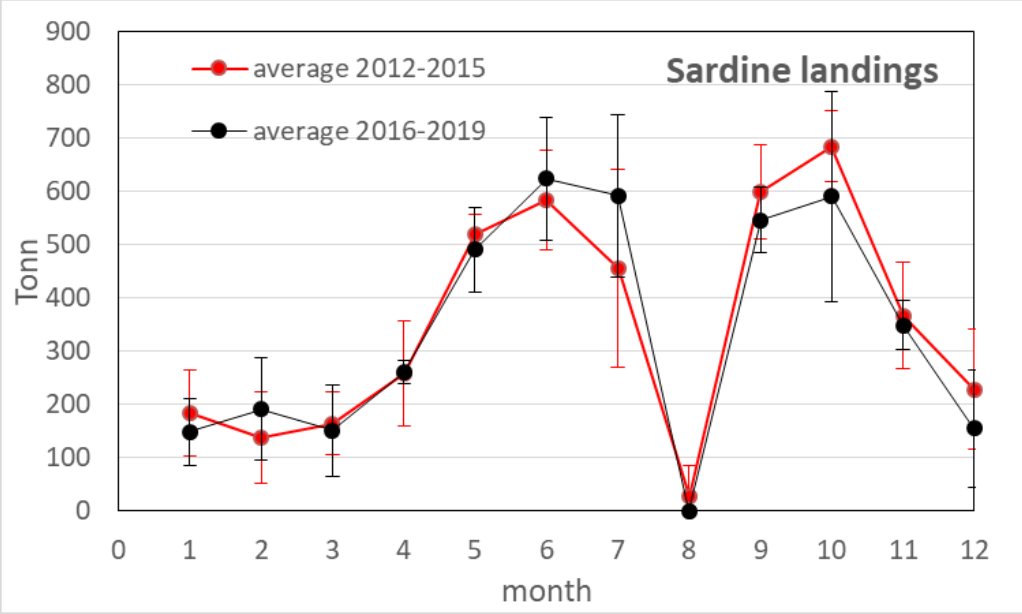
Mnemiopsis competition?



Tirelli et al., 2019

Effect on landings? the case of Chioggia

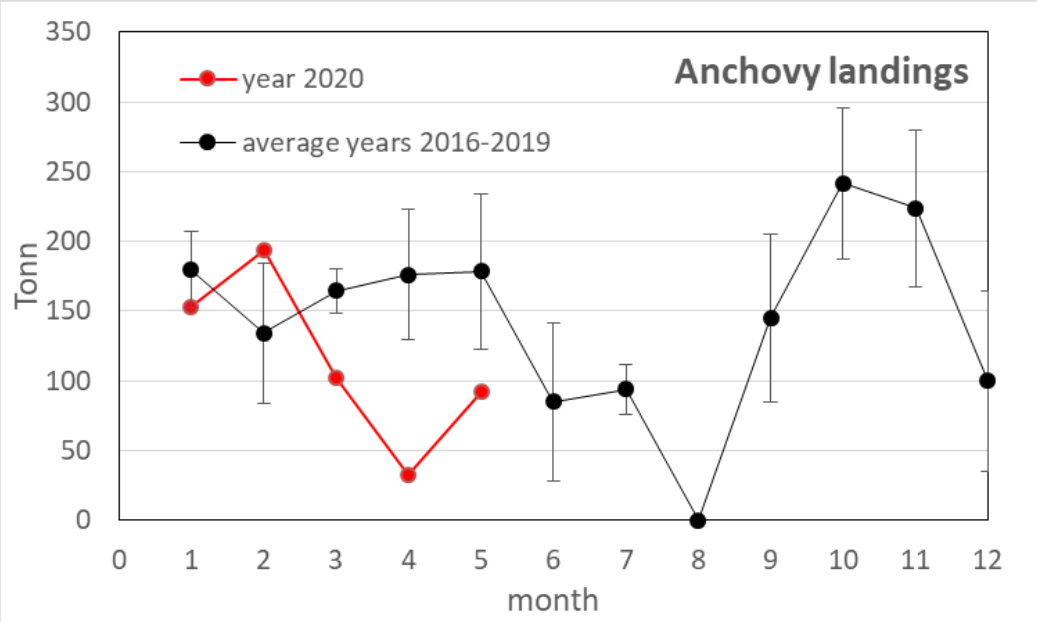


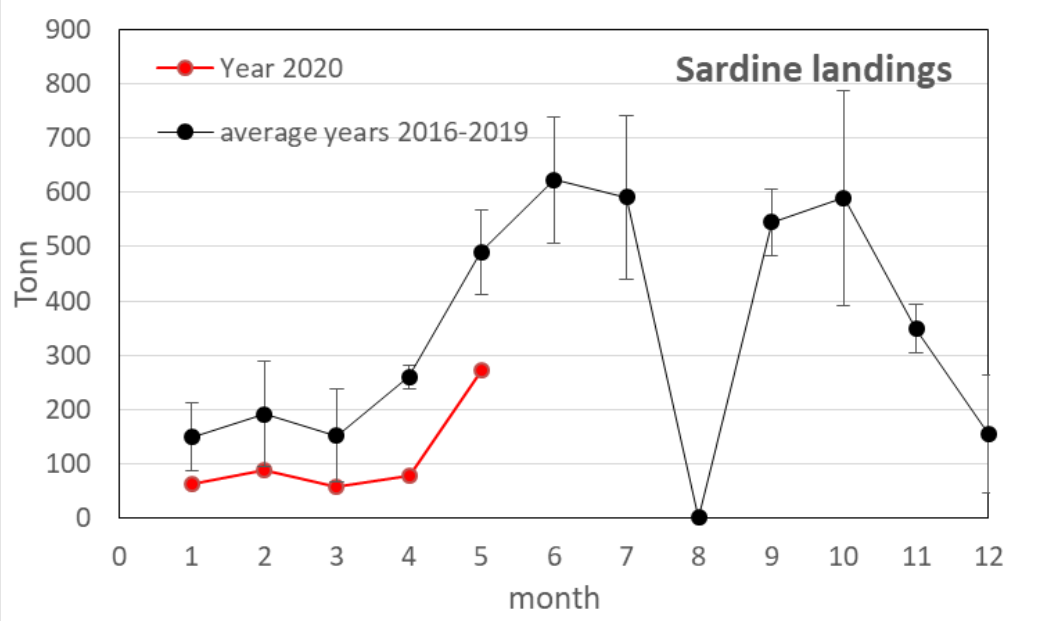


Clodia Database:
https://chioggia.biologia.unipd.it/banche-dati/

Year 2020 data:
Carlotta Mazzoldi (University of Padua)

Covid Effect on landings for small pelagics?





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Year 2020 data:
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Thank you!

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