Larval stage controls on sardine recruitment variability: the balance between predation and food availability

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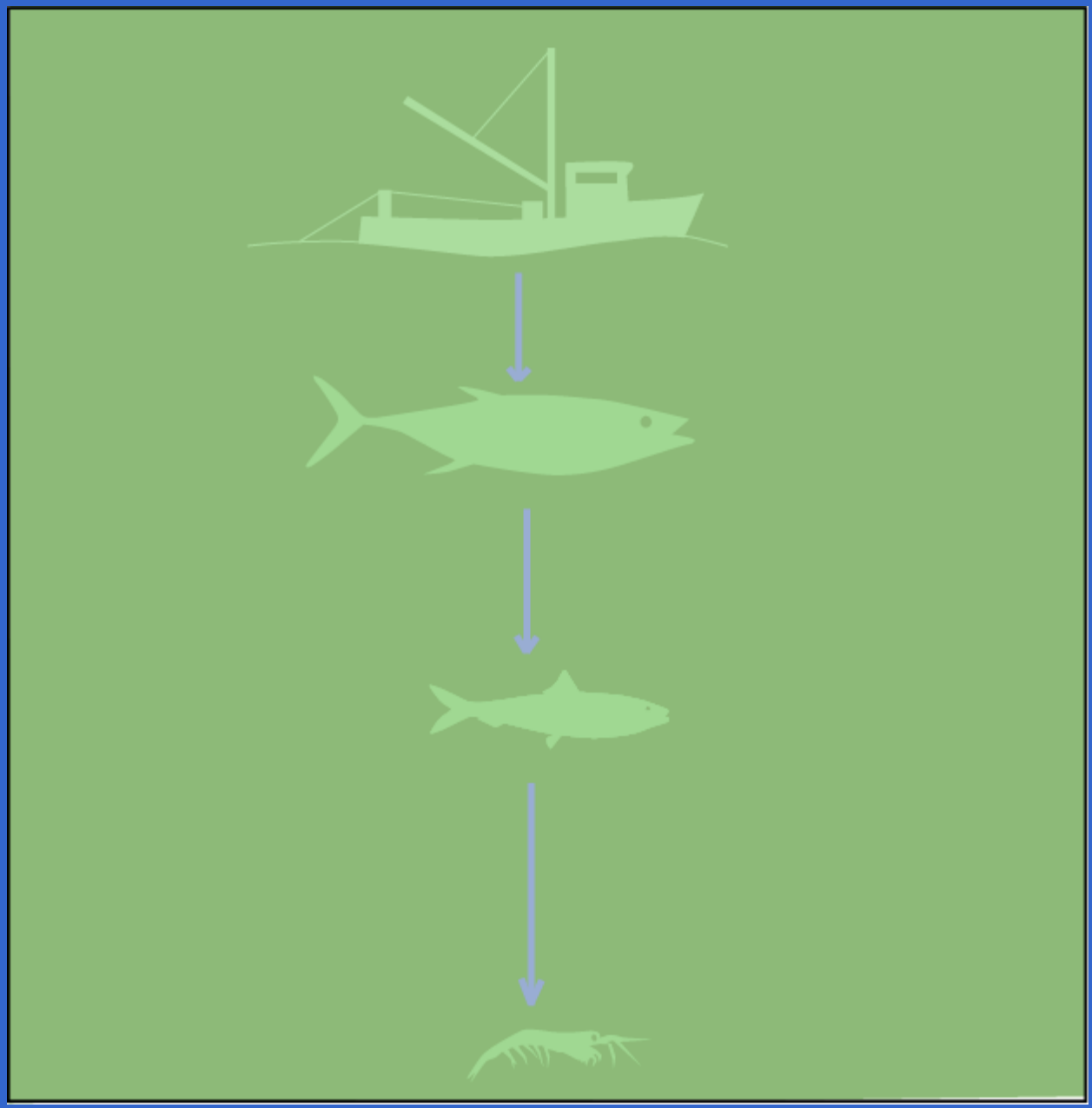
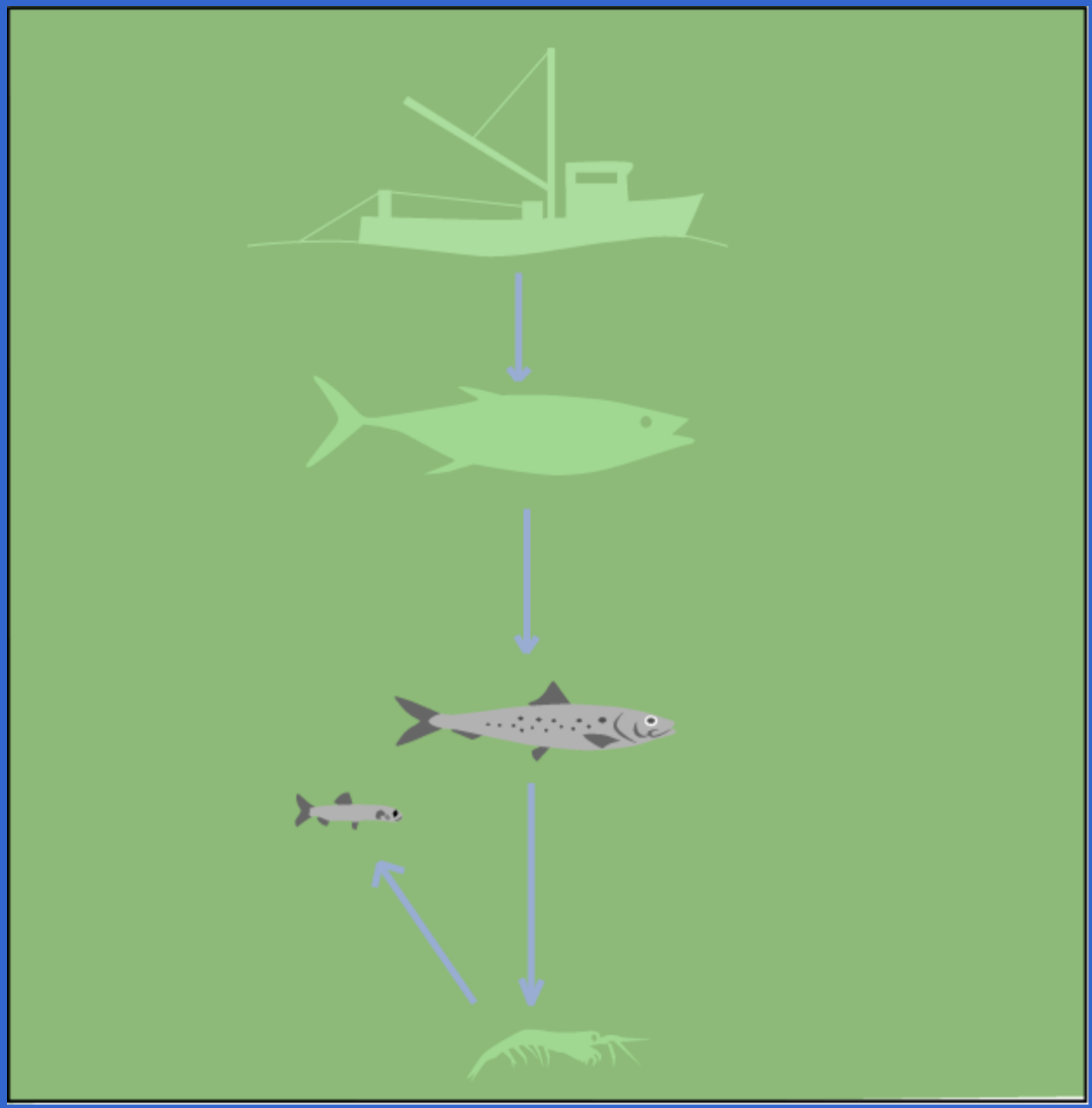
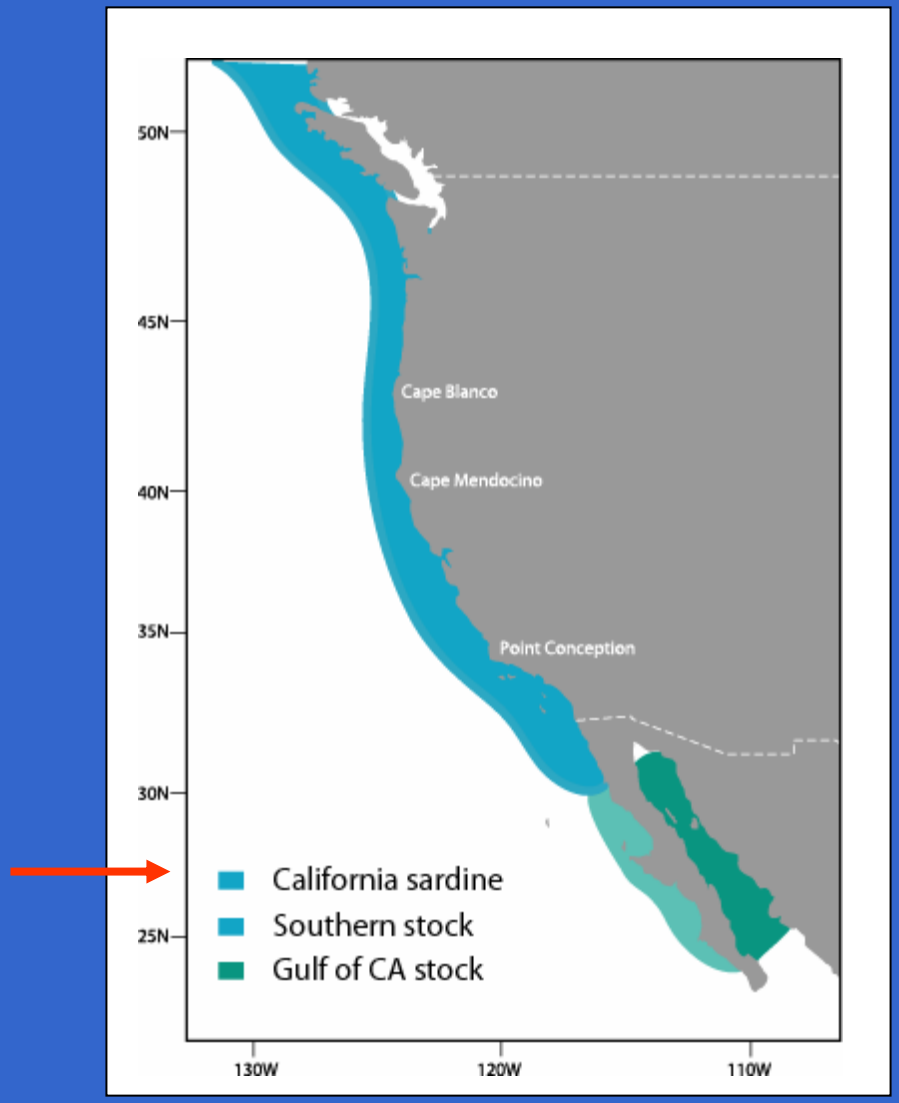
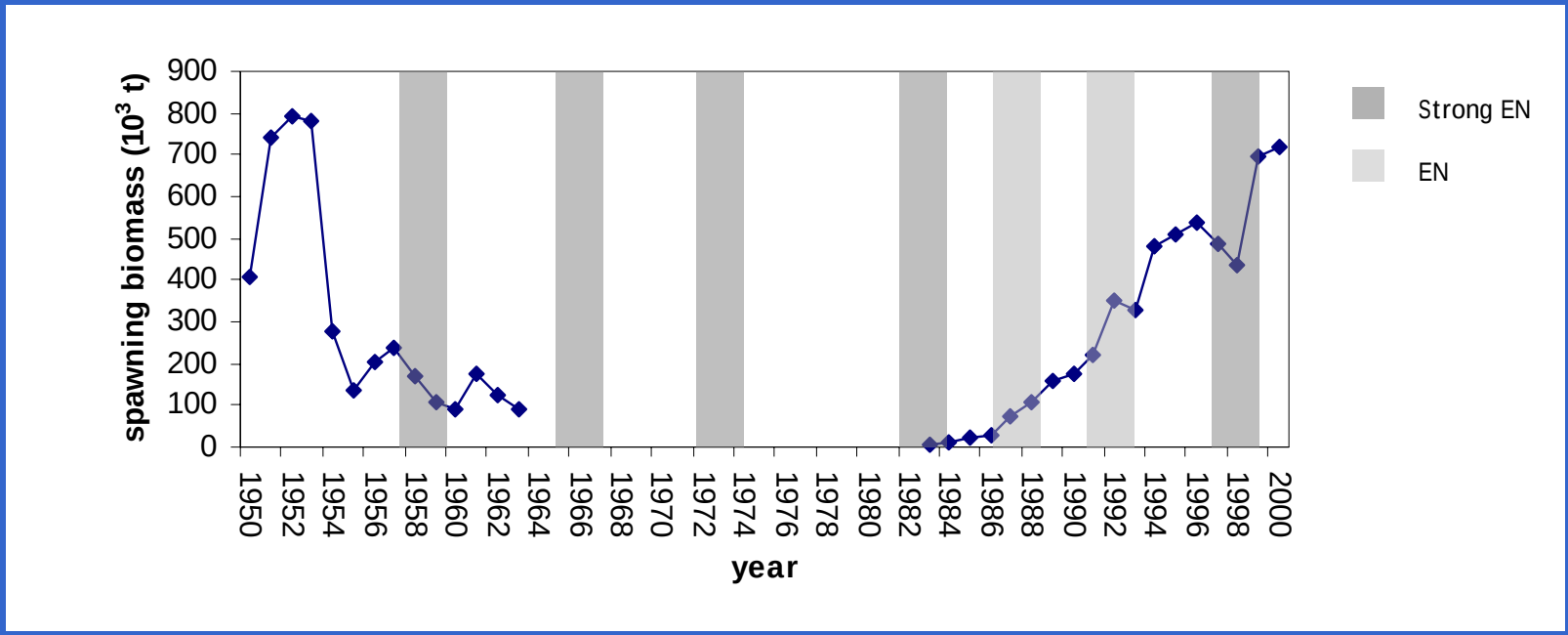





50N
45N
40N
35N
30N
25N
130W
120W
110W
Cape Blanco
Cape Mendocino
Point Conception
California sardine
Southern stock
Gulf of CA stock



- Sardine success improves during warm years
- Sardine reproductive habitat shifts north during warm years

Question:

why does sardine reproductive success improve when the reproductive habitat shifts north?

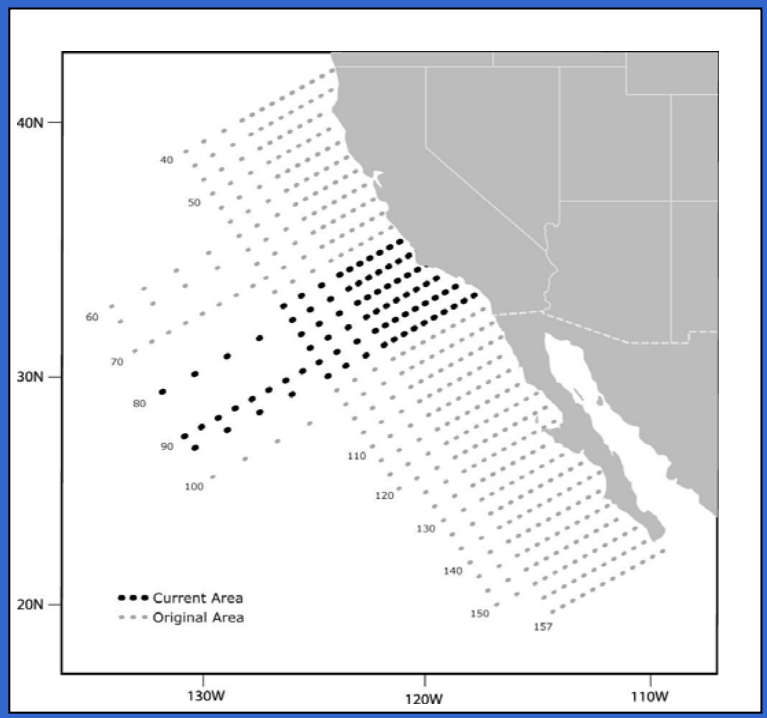
Hypotheses:

1. Larval food concentration increases
2. Larval predation pressure decreases (loophole hypothesis/predator-pit; Bakun, 2004)

METHODS

Data : **zooplankton** and **temperature** from CalCOFI program (n = 37,852); **recruitment**

Time period: 1951-1998

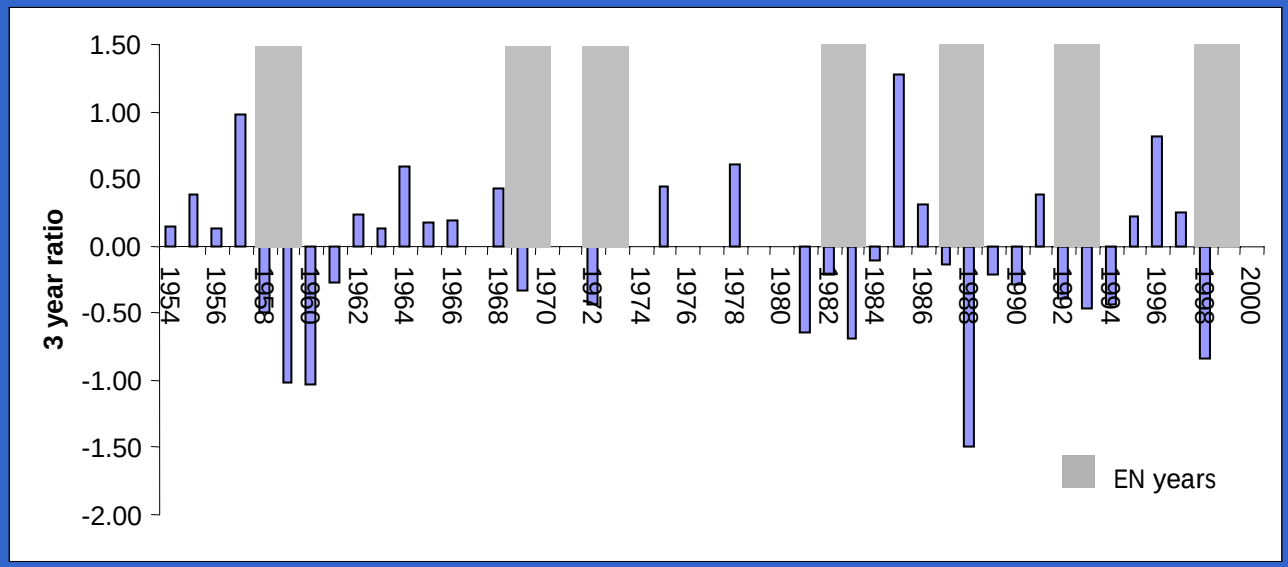


Analysis:
Sardine reproductive habitat
February-August, 13.5-16.5 ^{o}C
(Tibby, 1937; Ahlstrom, 1954; Lluch-Belda et al., 1991; Parrish, 1989; Bentley et al., 1996)

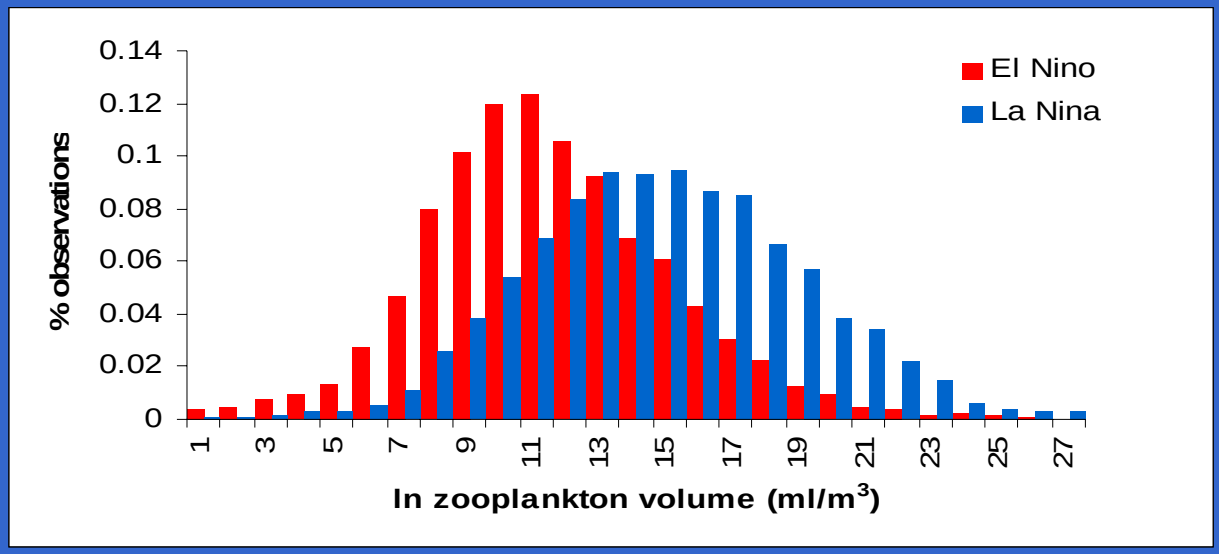
1951-1963; 1980-1998 (reliable recruitment estimates do not exist for period 1963-1980)

RESULTS

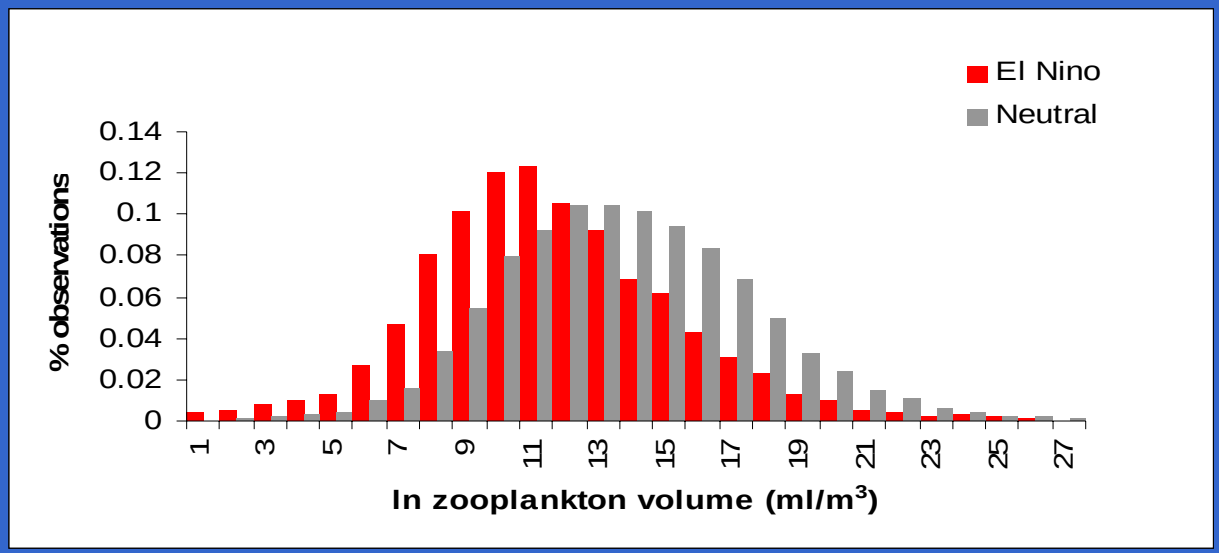
Zooplankton abundance low during El Niño years



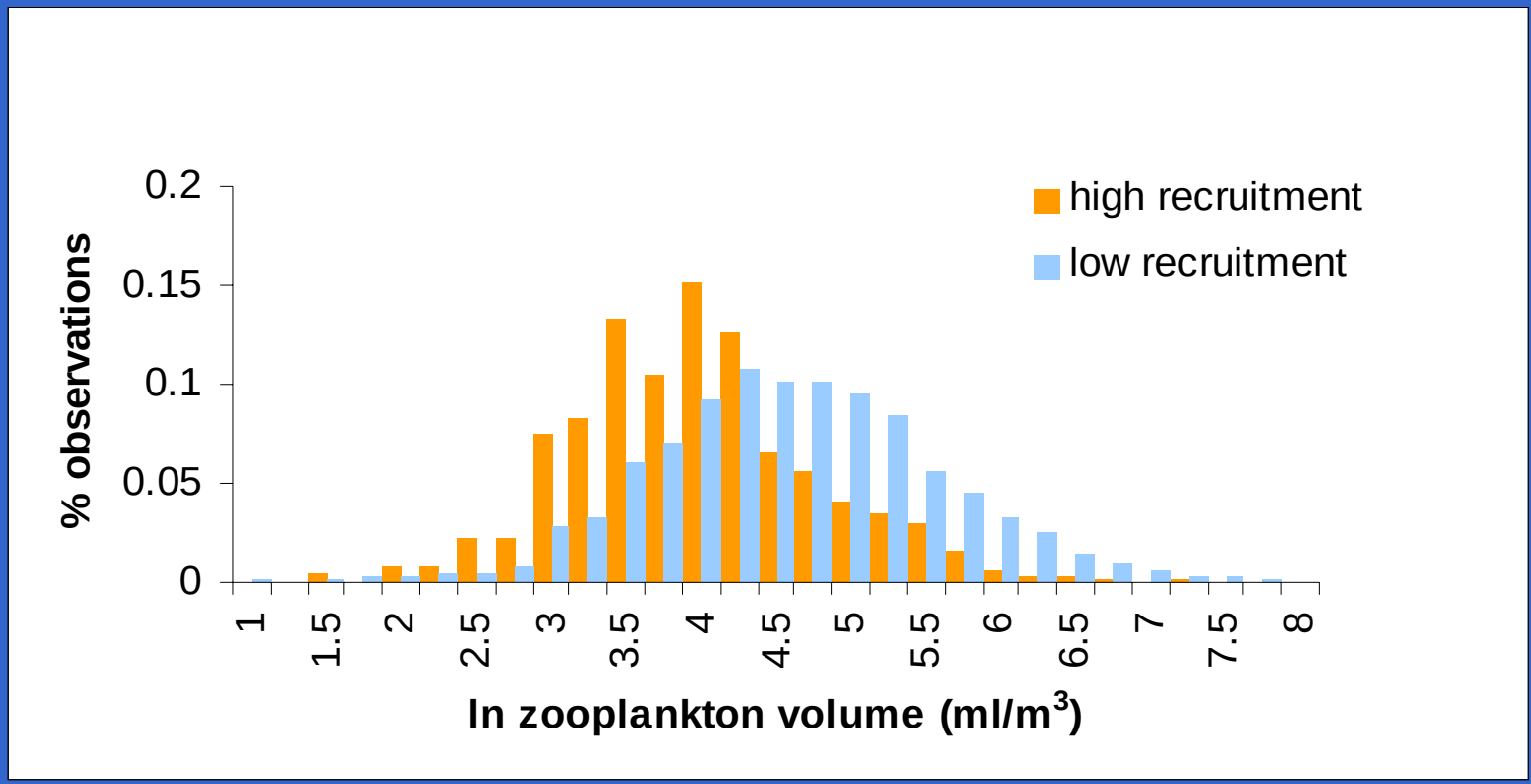
3 year ratio = $zoopl._t / zoopl._{(t-3)}$ (as per Smith, 2004)



means: p <0.0005 *variances: p* = 0.025

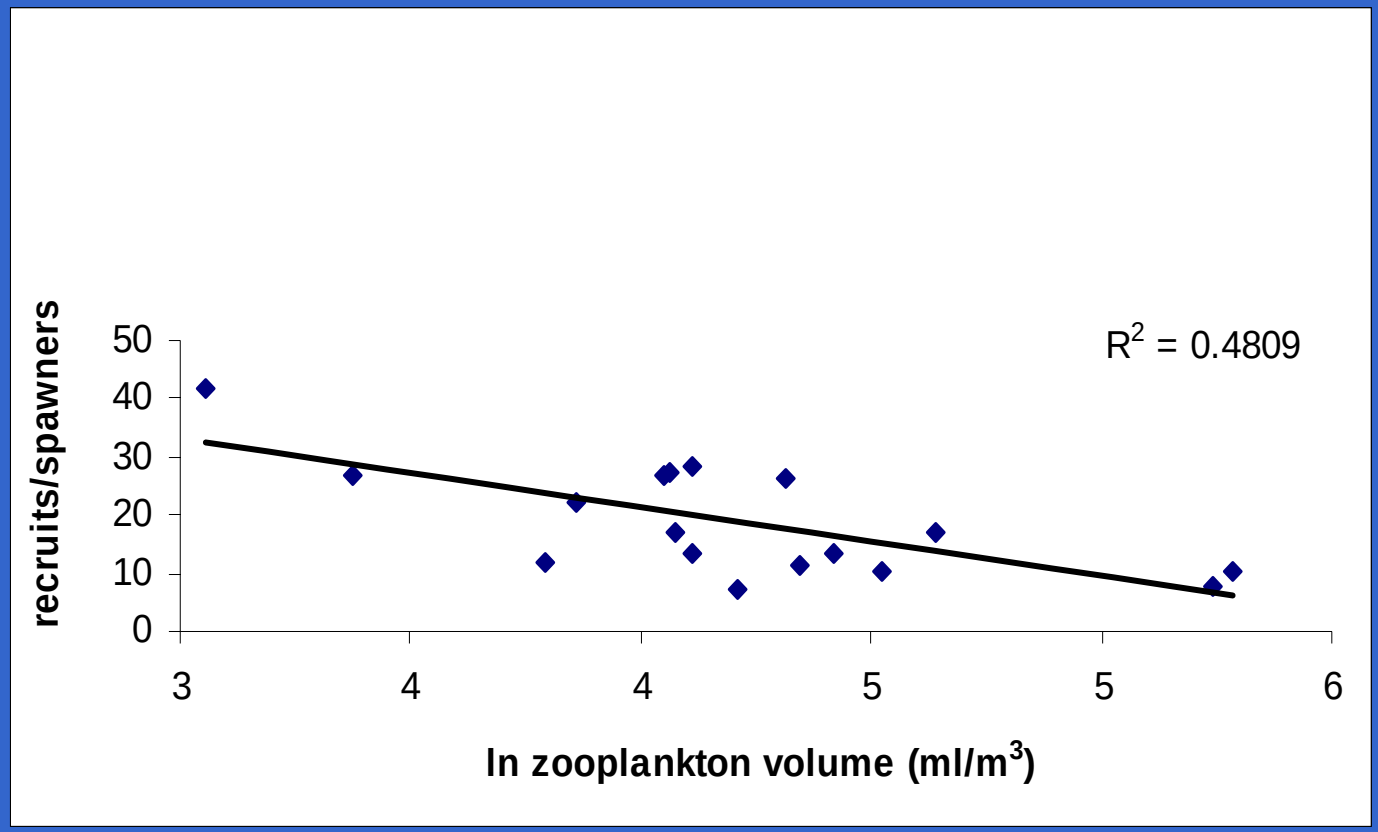


means: p <0.0005 *variances: p* = 0.55



means: p <0.0005 *variances: p* = 0.0001

Negative relationship between recruitment and zooplankton abundance; higher recruitment at lower zoop. abund.



r/s > 5

SUMMARY

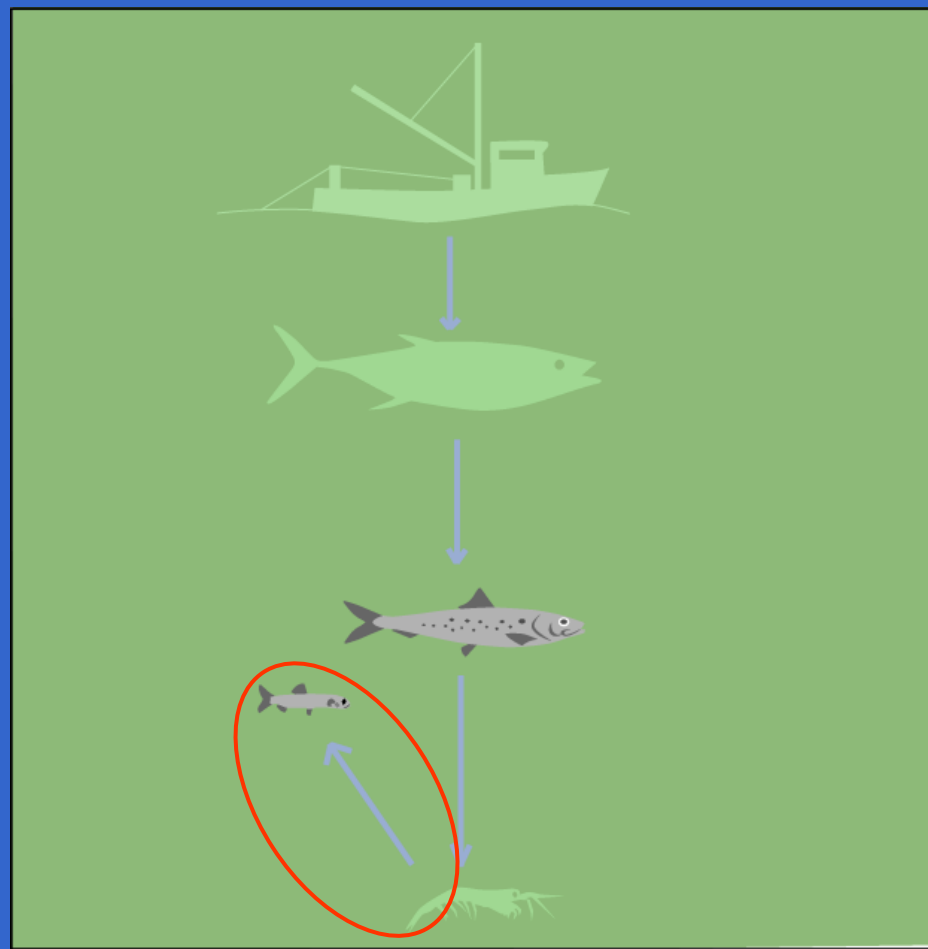
Zooplankton abundance in sardine reproductive habitat:

- decreases during El Niño years
- decreases during high recruitment years
- is more patchy during low recruitment years
- is negatively correlated to sardine recruitment

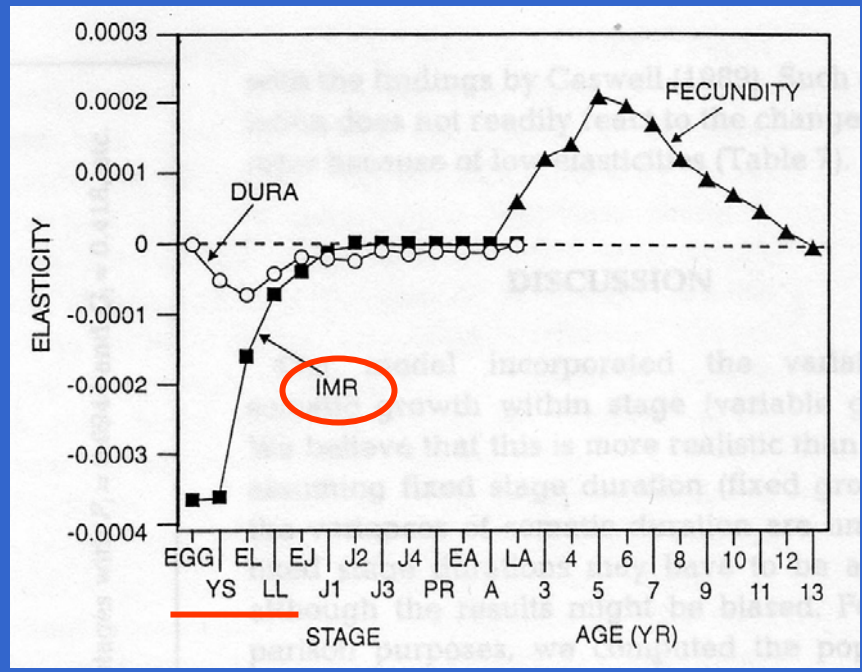
CONCLUSIONS:

- Food availability alone does not seem to affect recruitment success of California sardine

- Possible impact of predation? "shallowing of predator pit", release in predation pressure allows sardine population to thrive



Processes affecting early life history stages are important determinants of recruitment and population growth



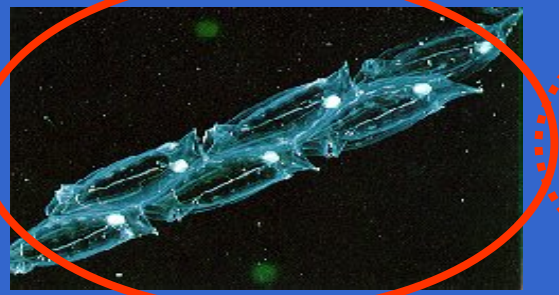
Lo et al., 2004

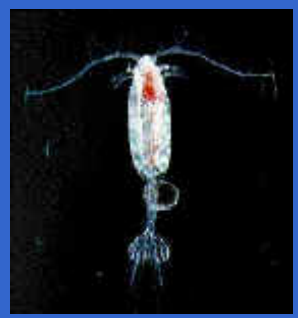
Stage based model; vital rates considered:

- Stage duration (DURA)
- Inst. Mortality rate (IMR)
- Fecundity

Range of species in CalCOFI zooplantkon samples




Photos from http://www.pac.dfo-mpo.gc.ca/sci/osap/projects/plankton/zoolab_e.htm

FUTURE STUDIES

- Geostatistics on sardine egg/larvae and zooplankton
- Update stage specific model
- Build bioenergetics model to quantify potential impact of zooplankton predation on sardine
- Zooplankton predation experiments on sardine
- Species composition of CalCOFI samples (shift in species composition/preferred prey ?)

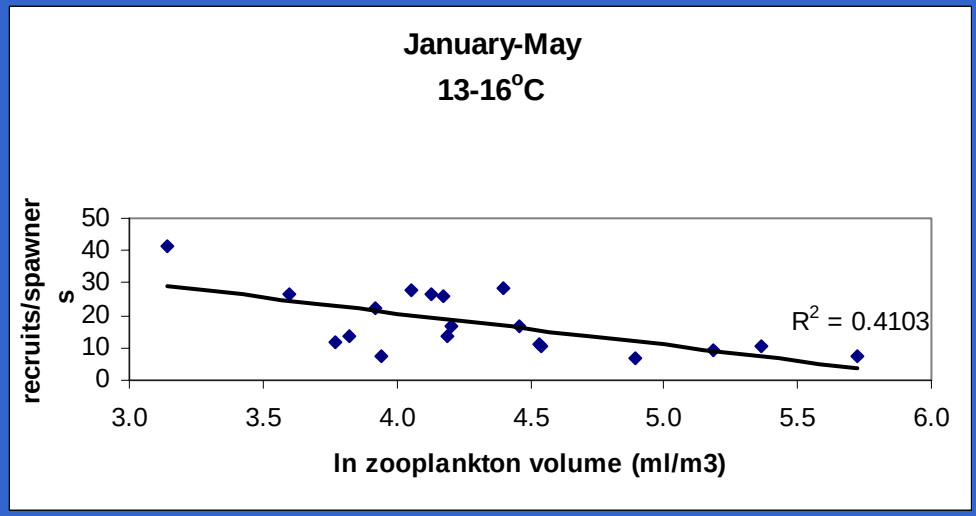
SPECIAL THANKS TO:

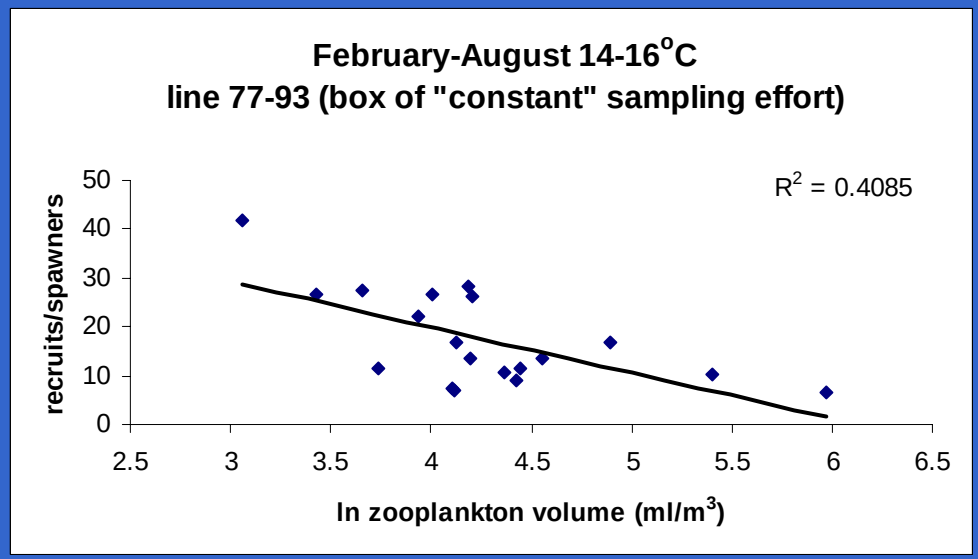
Scientist and vessel crew participating in CalCOFI program
John Field (NMFS), Anne Hollowed (NMFS), Elizabeth Logerwell (NMFS), Paul Smith (NMFS)

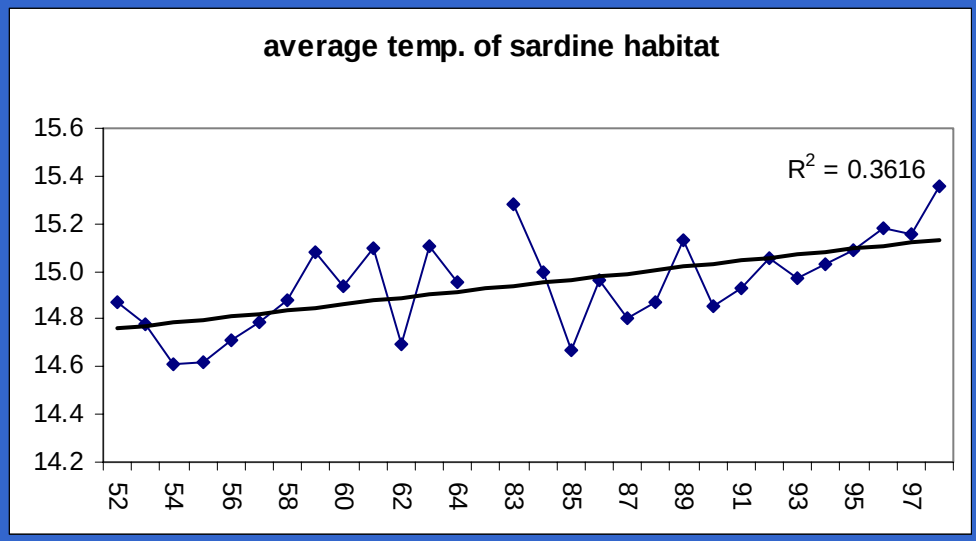
Results

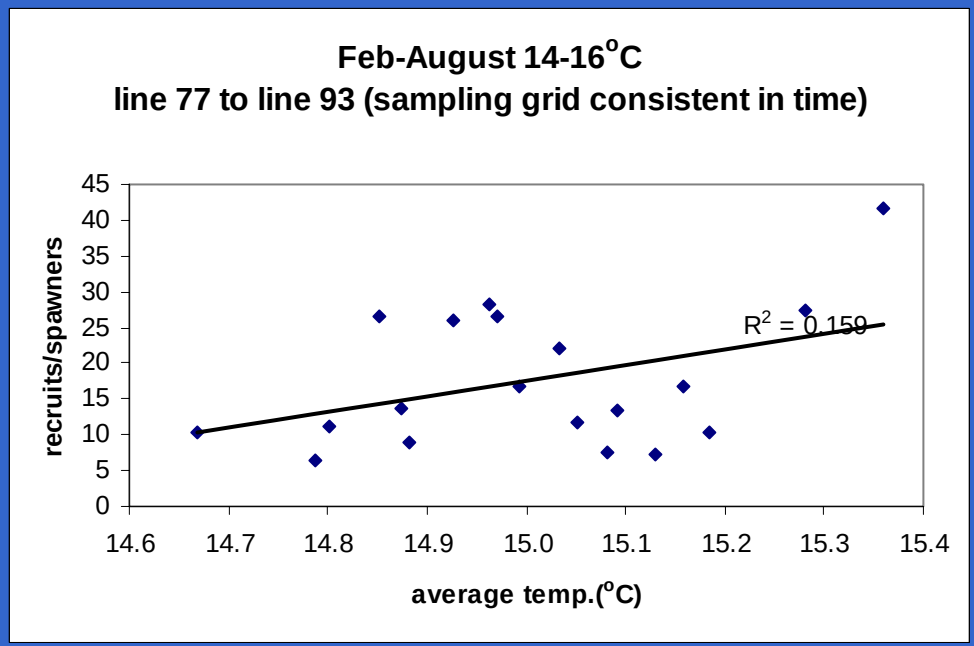
Group tested	Mean *var. 1**	Mean *var. 2**	Variance *var. 1**	Variance *var. 2**	d.o.f	p-value (two tail) for differences in means	p-value differences in variances
high recr. (*var 1*) and low recr. (*var2*)	3.85	4.46	0.728	0.93	1125	**3.26×10^{-43}**	**0.0001**
EN years (*var.1*) and LN years (*var. 2*)	3.85	4.71	0.86	1.02	1129	**1.75×10^{-45}**	**0.025**
EN years (*var.1*) and neutral years (*var. 2*)	3.85	4.42	0.86	0.85	1637	**3.95×10^{-30}**	0.55

*Ln(zooplankton abundance) (ml/m^3)


January-May
13-16°C
recruits/spawners
50
40
30
20
10
0
3.0
3.5
4.0
4.5
5.0
5.5
6.0
R2 = 0.4103
ln zooplankton volume (ml/m3)


February-August 14-16°C
line 77-93 (box of "constant" sampling effort)
recruits/spawners
50
40
30
20
10
0
2.5
3
3.5
4
4.5
5
5.5
6
6.5
R2 = 0.4085
ln zooplankton volume (ml/m3)


average temp. of sardine habitat
15.6
15.4
15.2
15.0
14.8
14.6
14.4
14.2
R^2 = 0.3616
52
54
56
58
60
62
64
83
85
87
89
91
93
95
97


Feb-August 14-16°C
line 77 to line 93 (sampling grid consistent in time)
recruits/spawners
45
40
35
30
25
20
15
10
5
0
R^2 = 0.159
14.6
14.7
14.8
14.9
15.0
15.1
15.2
15.3
15.4
average temp.(°C)