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Seabird responses to variability in coastal upwelling at multiple time scales

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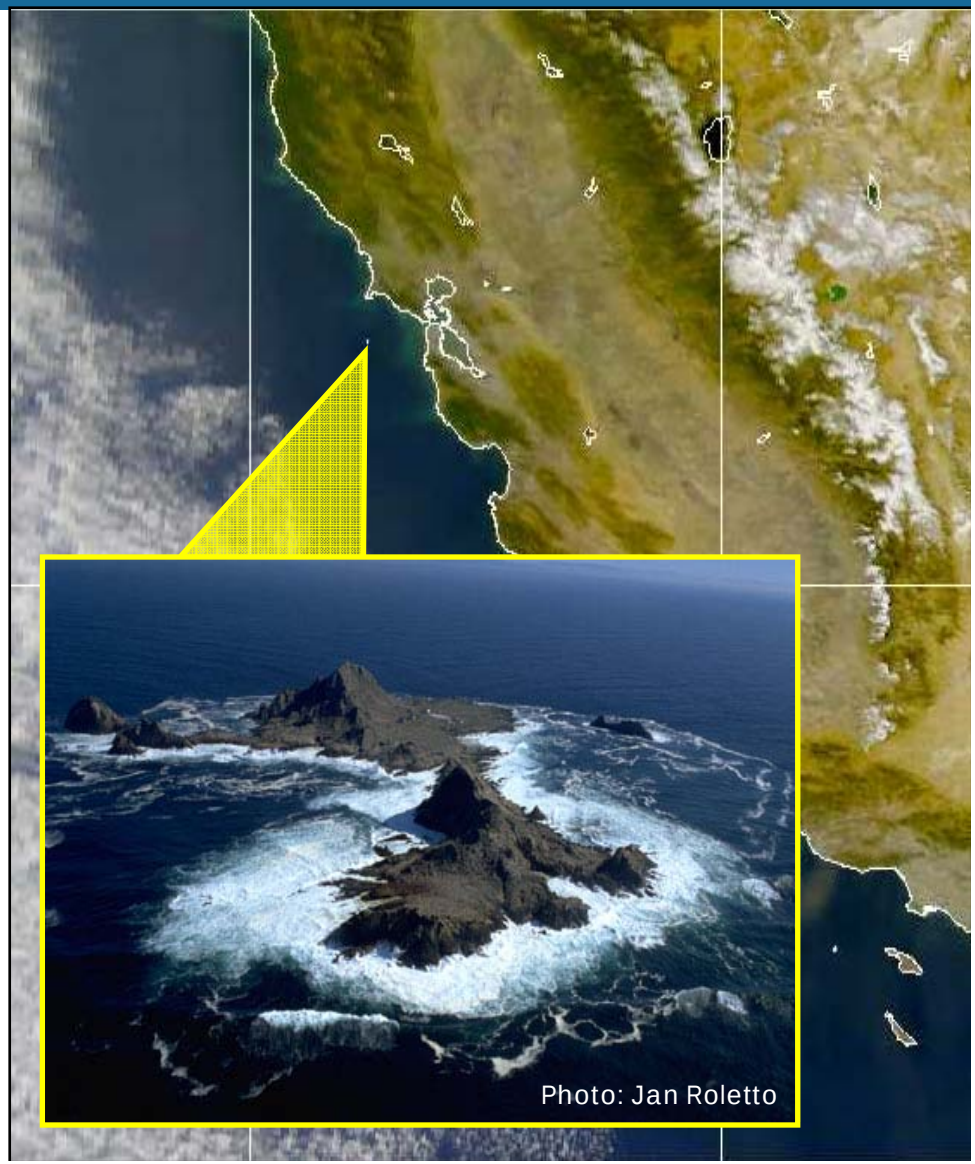
Outline

- Brief overview
- Long time scales
  - Ocean conditions
  - Seabird responses
- Short time scales
  - Upwelling forcing
  - Ecosystem responses



Upwelling in the California Current has increased

- Bakun's (1990)

  ⇧ Increase upwelling

- Snyder et al. (2003) predictions (SF – North)

  ⇧ Further increases in upwelling intensity

  ⇧ Delay in upwelling

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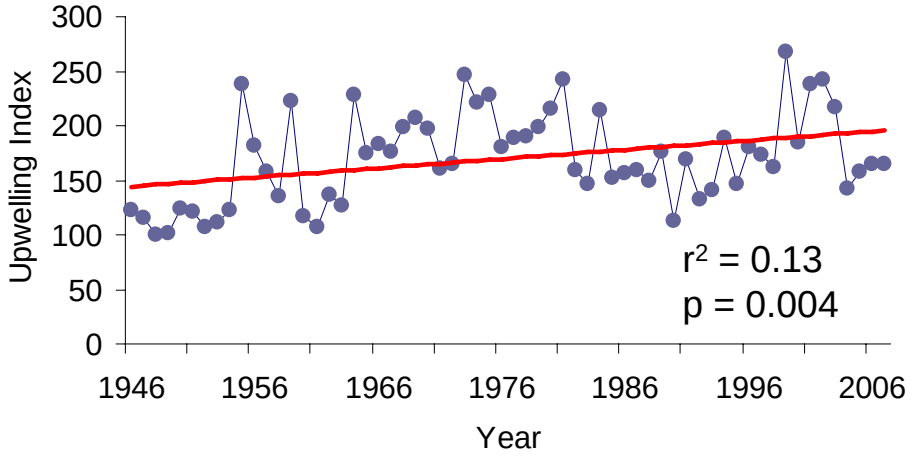
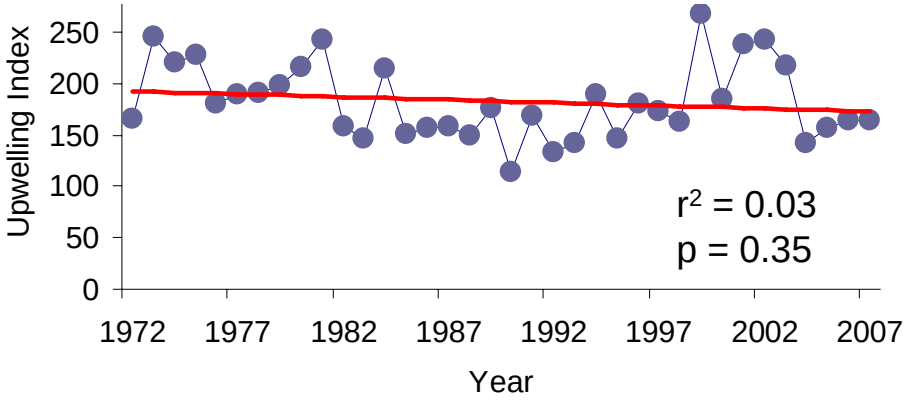
Long term changes in upwelling (Bakun revisited)

- Significant increase trend in upwelling from 1946 to 2007



- Slight decrease in upwelling from 1972 to 2007



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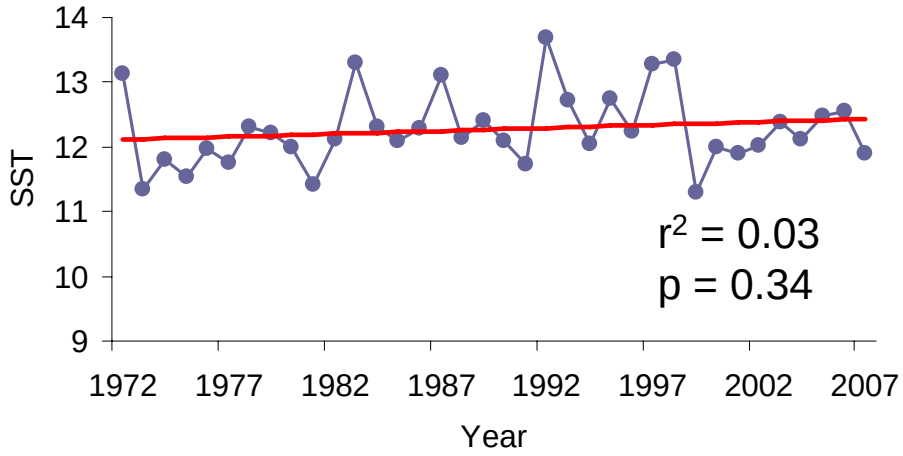
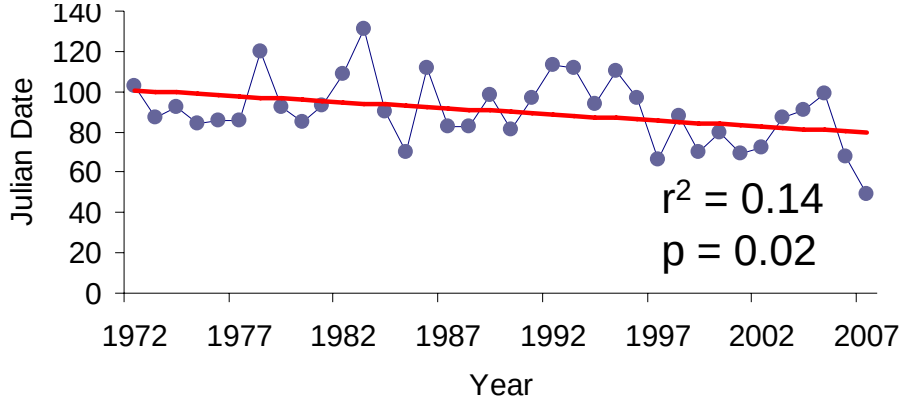
Stable temperature and earlier spring transitions

- Slight increase in sea surface temperature from 1972 to 2007



- Significant change towards earlier spring transitions from 1972 to 2007



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Long time scales

Are seabirds responding to changes in ocean conditions?

Modeled median egg-laying dates and breeding success as a function of upwelling, temperature and spring transition date.

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Cassin's auklets

Small birds (23 cm; 150-200 g)

Max dive ~ 40 m

Zooplanktivorous (80% krill)

Breeding success correlates with krill abundance
(Abraham and Sydeman 2004)

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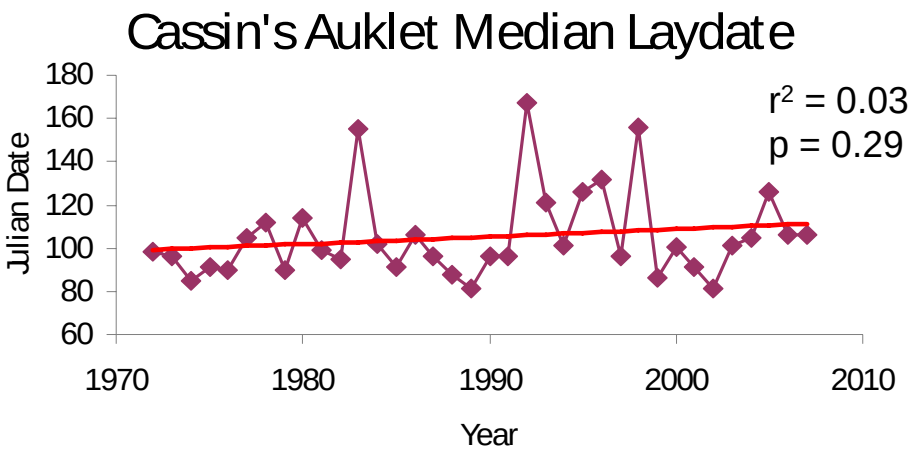
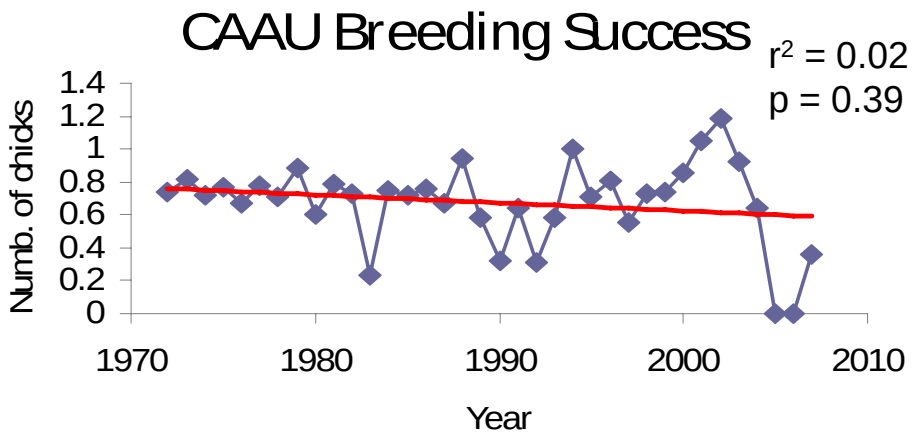
Cassin's auklets – **A Good Sentinel Species**





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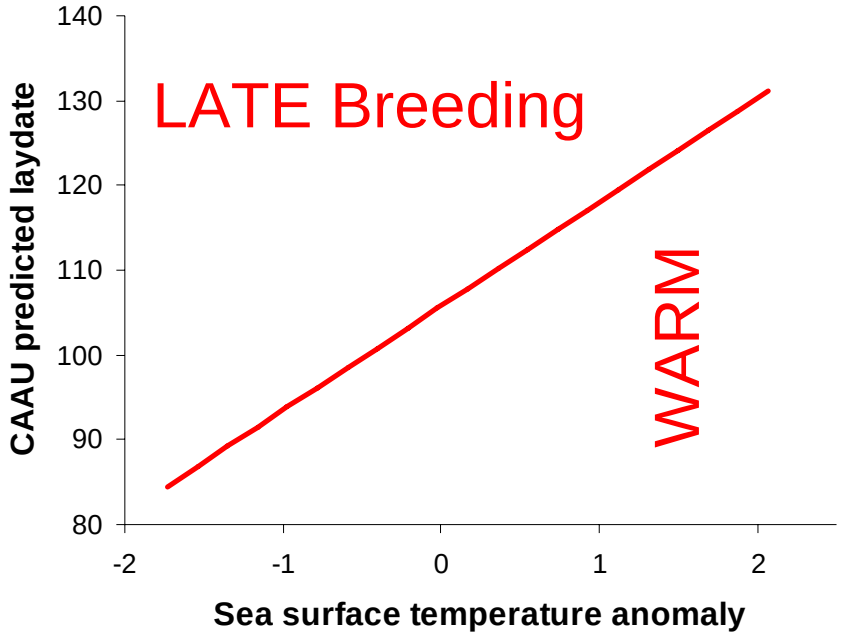
Temperature important to auklet timing

Variable	Variable Importance	Sign
UI	0.47	+
UI^2	0.13	+
SST	**0.99**	+
SST^2	0.32	+
DATE	0.62	-
$DATE^2$	0.34	+
SST x UI	0.38	-



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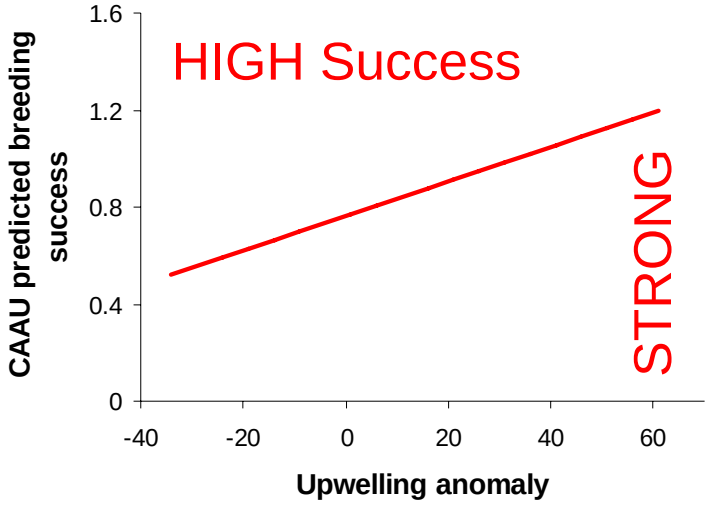
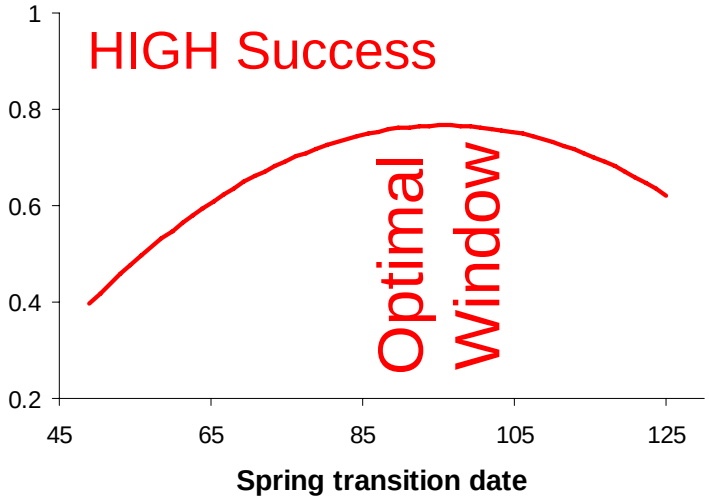
Upwelling and date important to breeding success

Variable	Variable Importance	Sign
UI	**0.99**	+
UI^2	0.31	+
SST	0.70	+
SST^2	0.43	-
DATE	**0.87**	+
$DATE^2$	**0.78**	-
UI x SST	0.47	+





Roth et al. (in prep)

Summary – LONG TIME SCALES

1. Earlier spring transitions and slight weakening of upwelling and warming ocean from 1972 – 2007.

2. Egg-laying date related to sea surface temperature.

3. Breeding success related to spring transition date and upwelling.

At short time scales

What are the mechanisms that lead to changes in egg-laying date and breeding success?

Conducted cruises to examine how ocean processes influence the ecology of Cassin's auklets.

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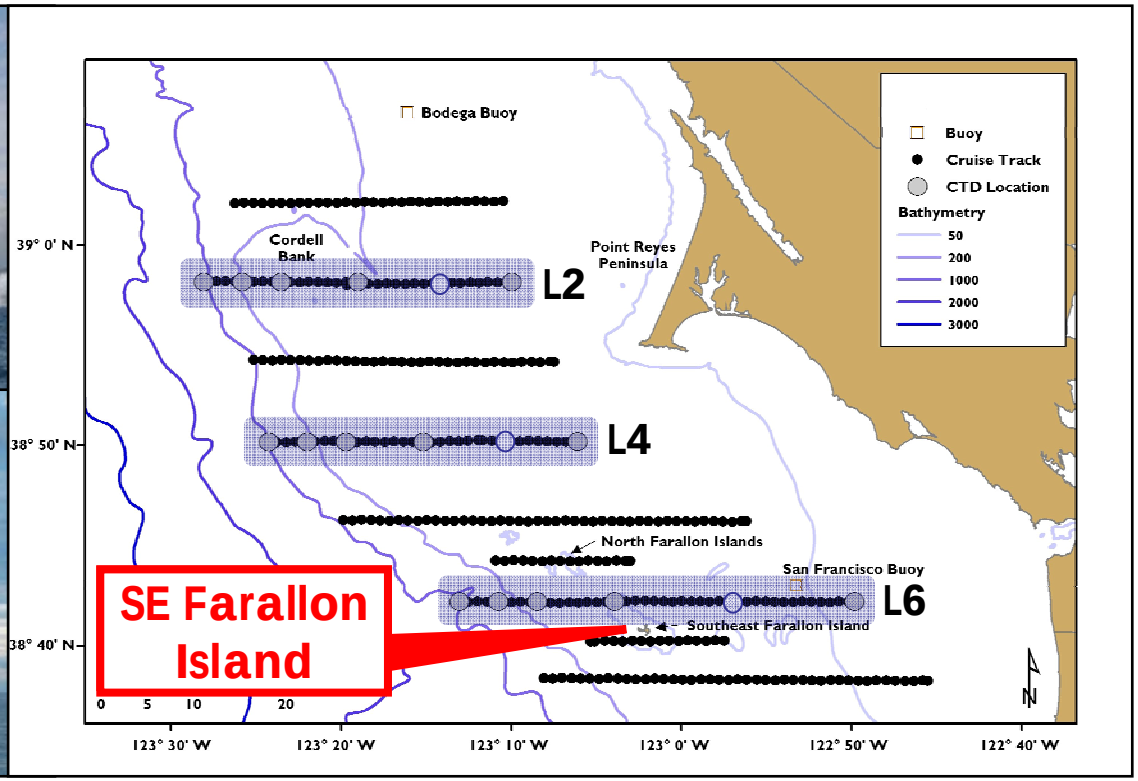
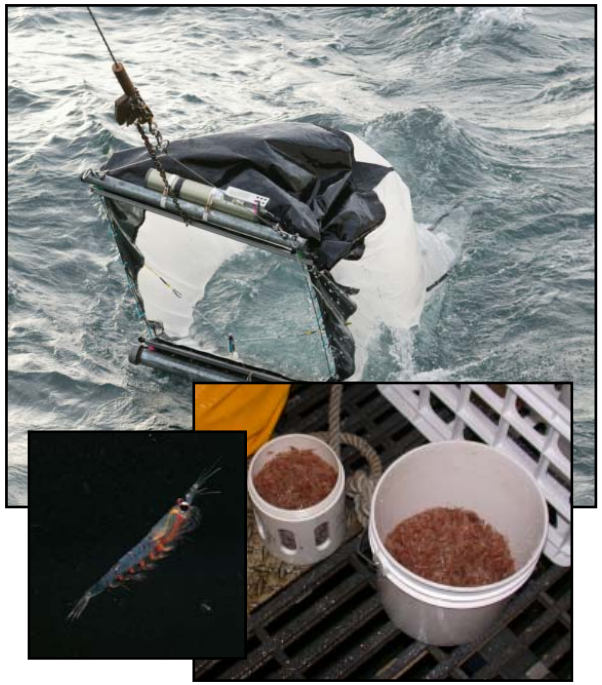
Research cruises around Farallon Islands



Surveys include predators, prey and ocean

- Birds/mammals (standardized strip and line transects)
- Zooplankton/fish (hydroacoustics and nets)
- Oceanography (CTD casts and continuous CT and fluorometry)



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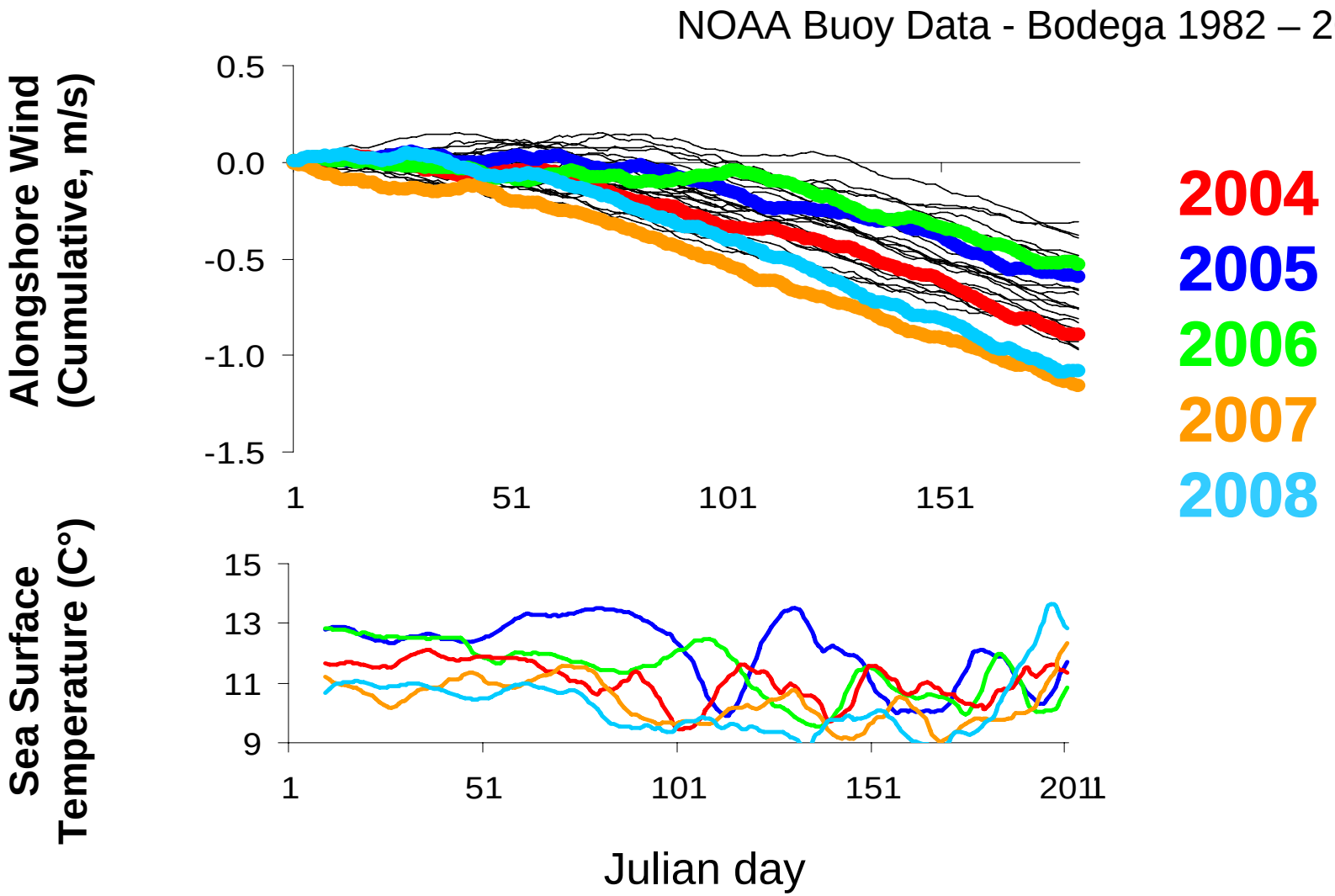
Great variability in ocean conditions



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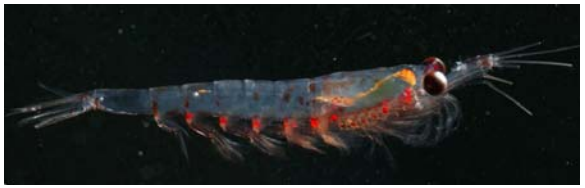
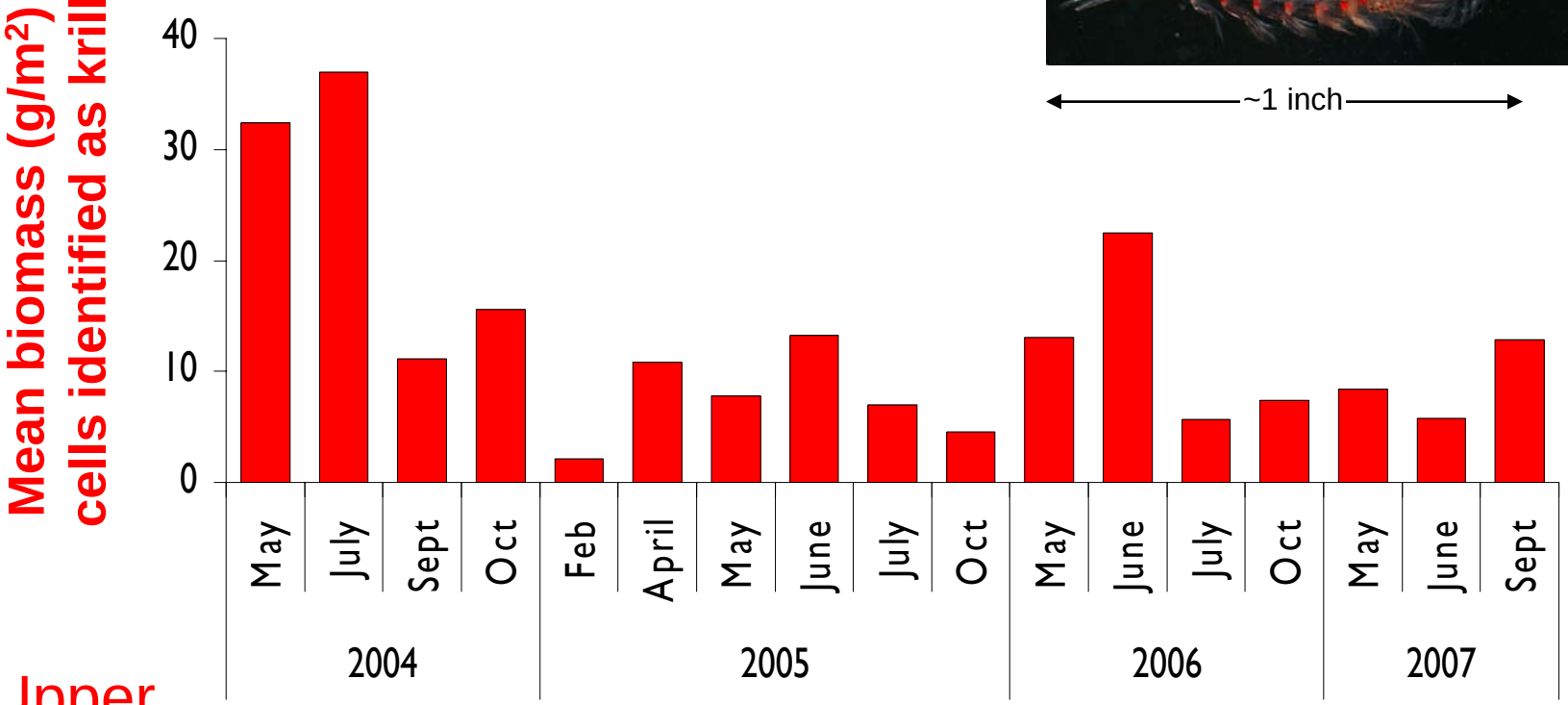
Less acoustic krill available in upper 200-m





Upper 200 m

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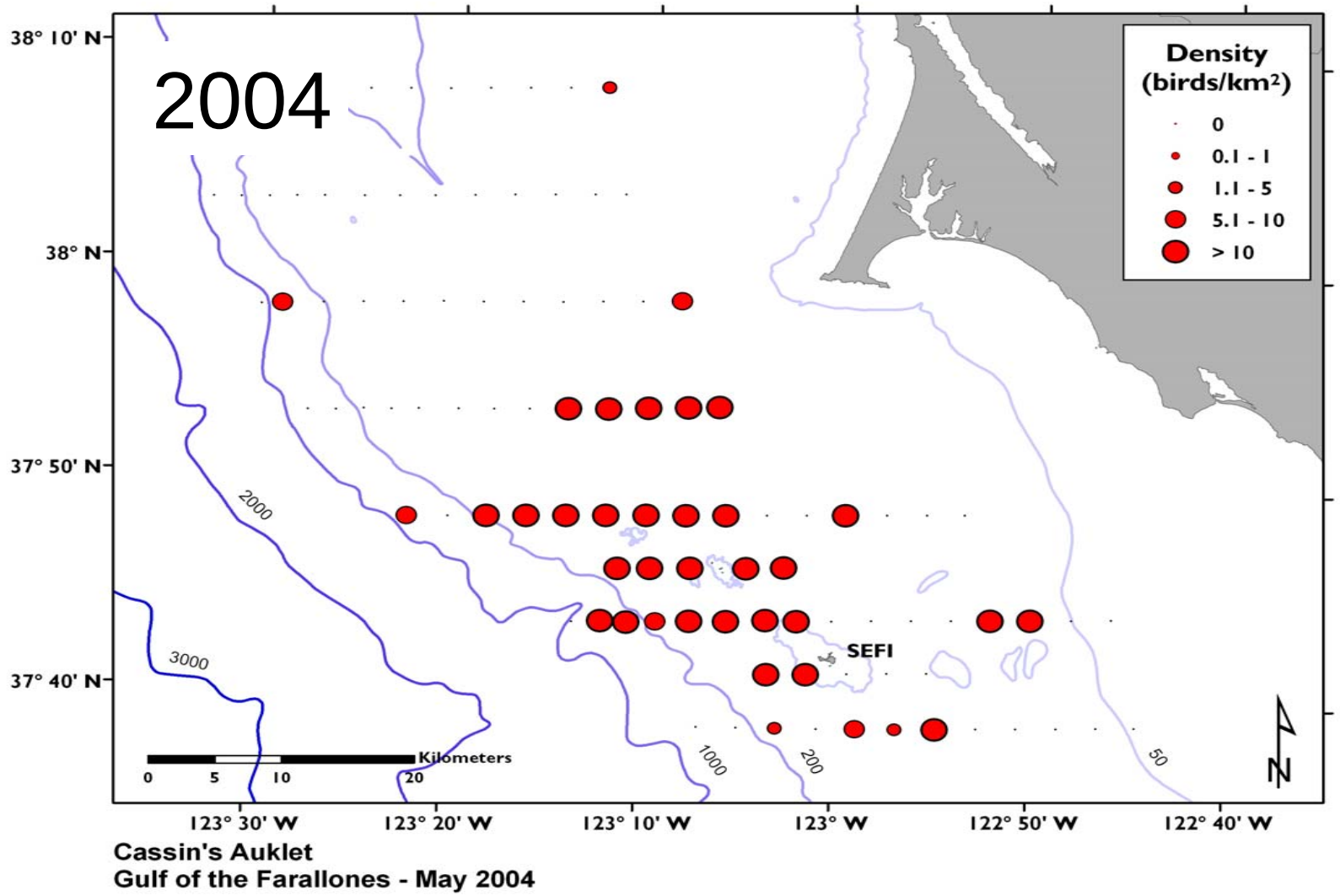
Large and densely aggregated flocks of auklets



Cassin's Auklet
Gulf of the Farallones - May 2004

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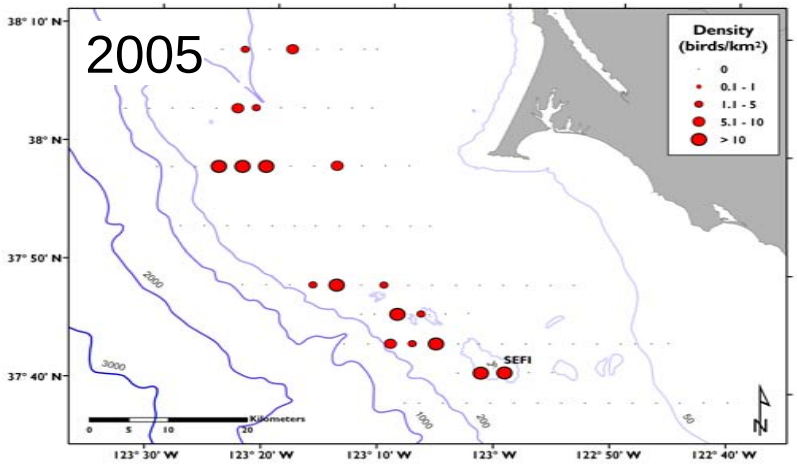
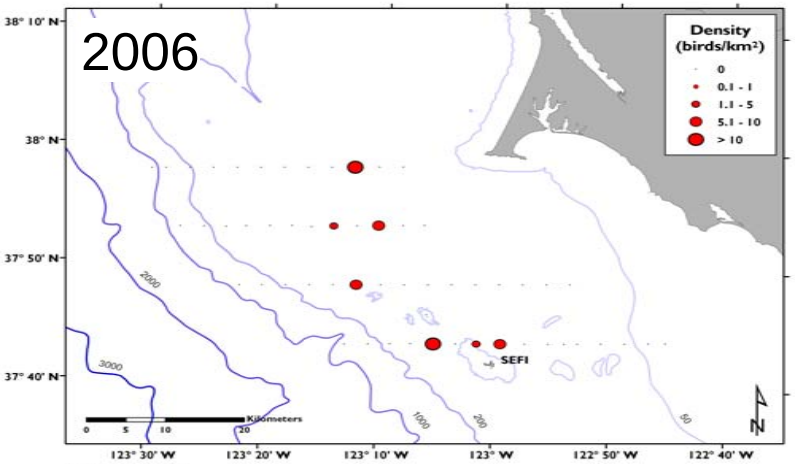
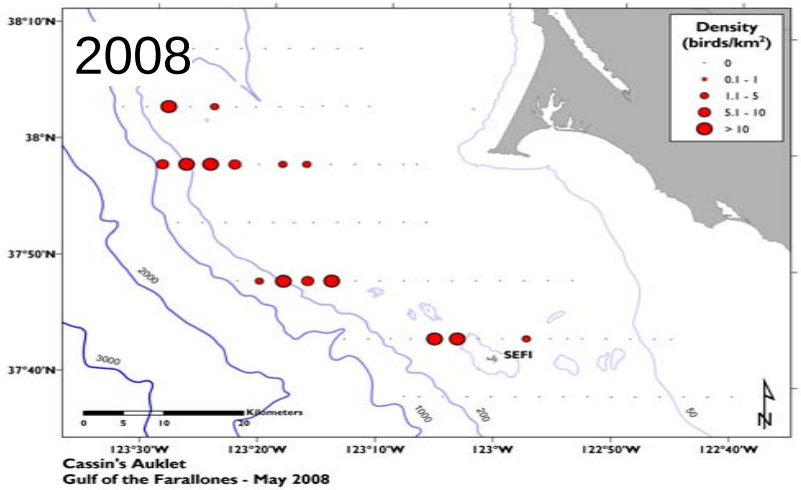
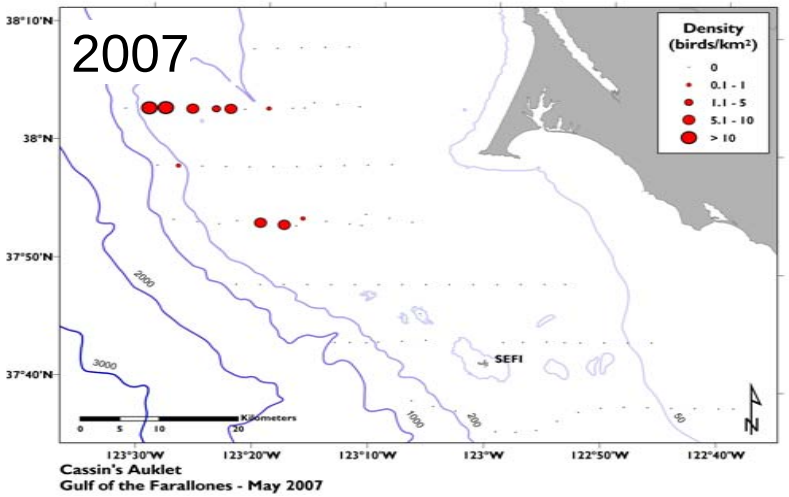
Small and loosely dispersed flocks of auklets









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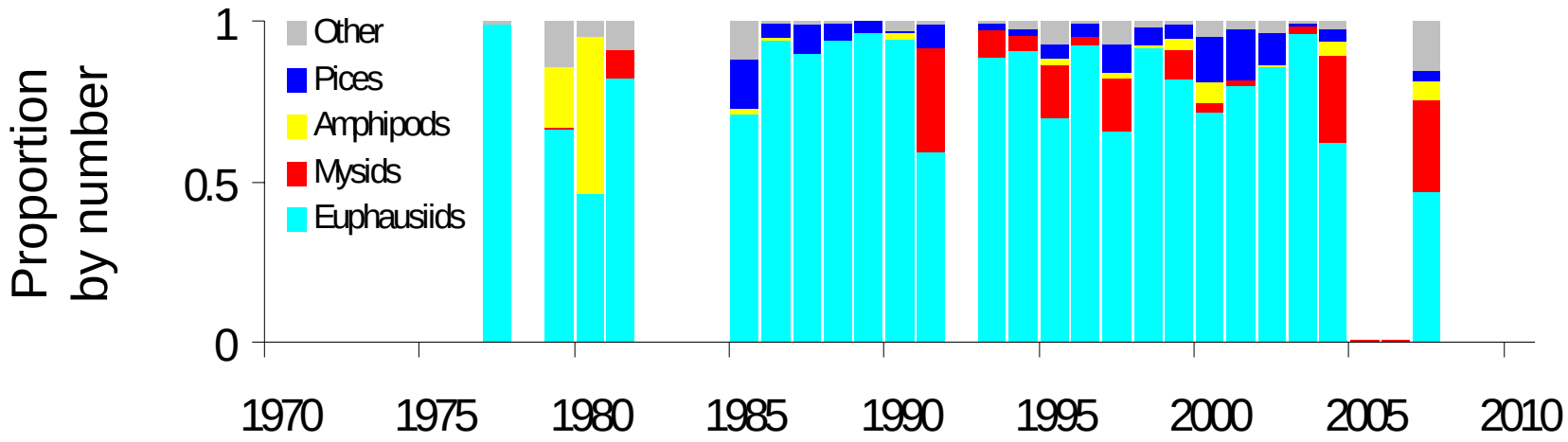
Cassin's auklets feed on krill – *most of the time*



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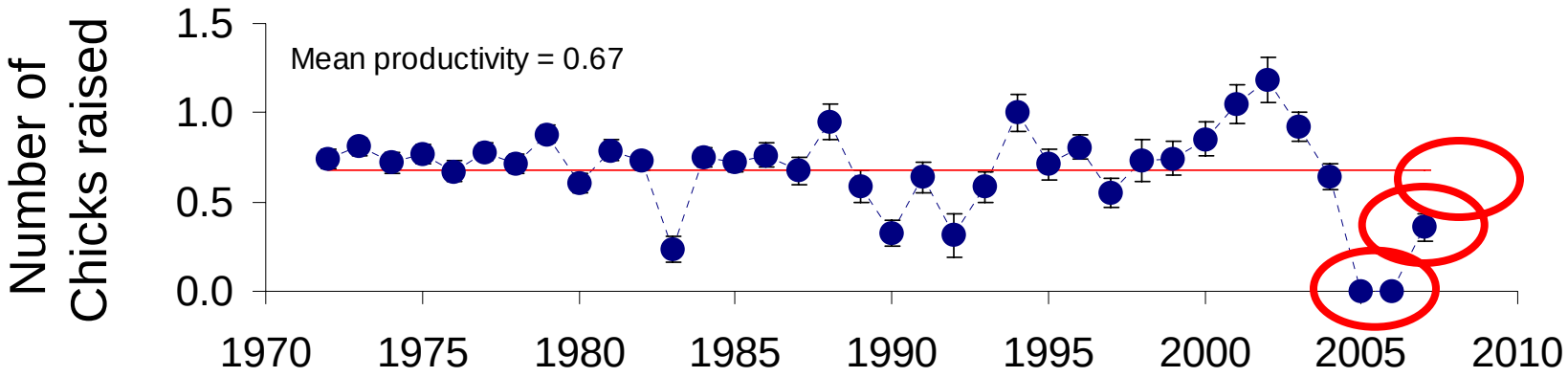
Cassin's auklets on the rebound



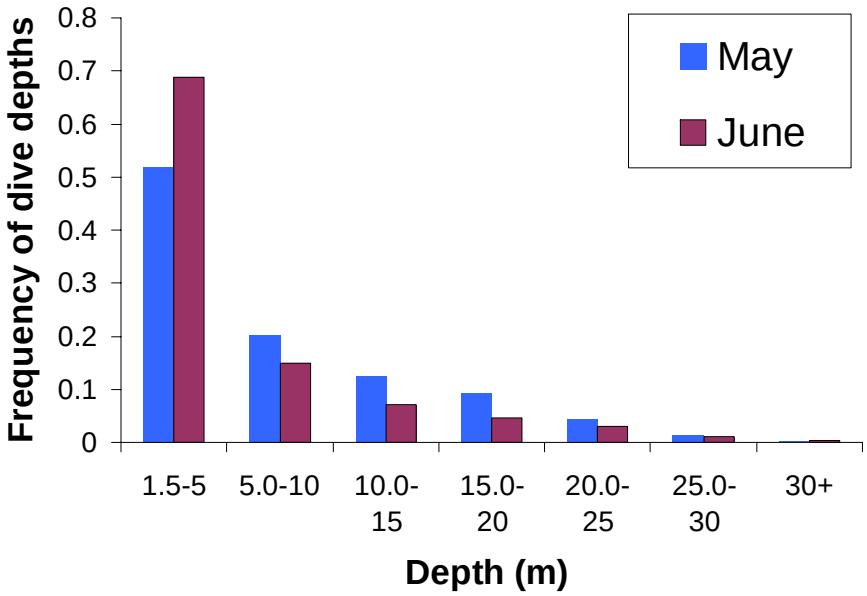
Summary – SHORT TIME SCALES

1. Variability in ocean conditions can lead to rapid changes in zooplankton communities and decrease in krill.

2. Dense layers of krill and aggregated flocks of auklets in 2004. Thin layers of krill and scattered flocks of birds in other years (2005-2008).

Even finer scales… Time-Depth-Recorders on auklets

70-85% of dives are less than 10 m



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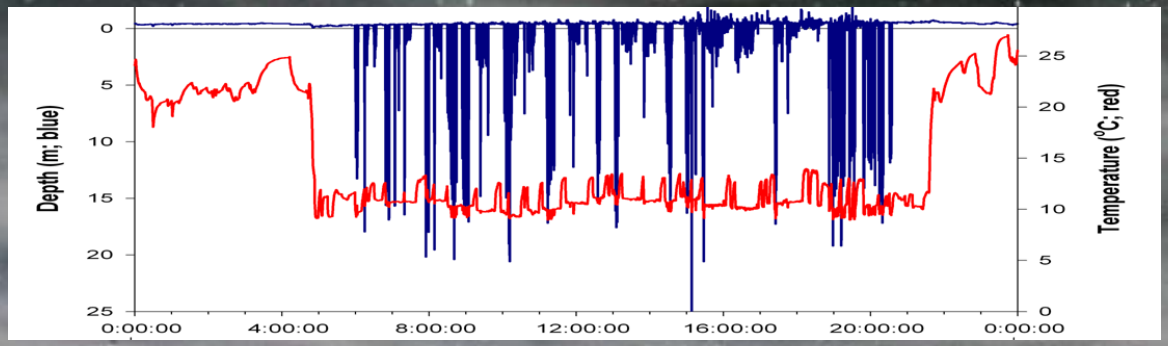
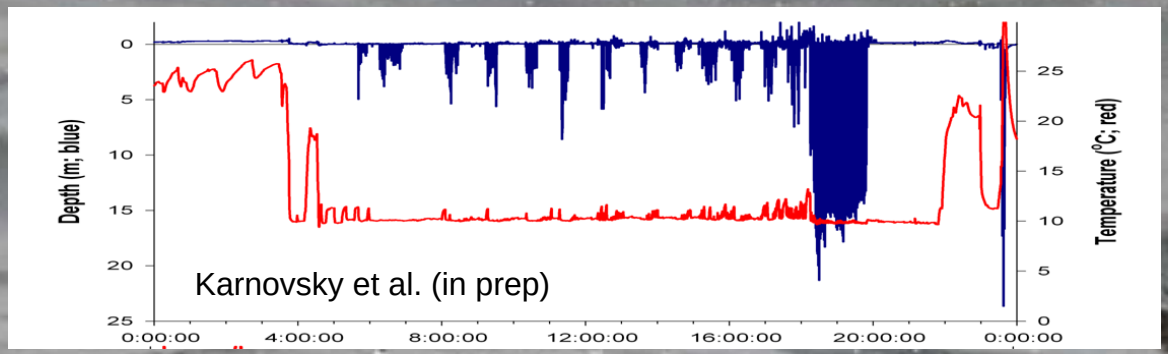
Further warming of the ocean will affect auklets





Karnovsky et al. (in prep)

Photo: Glen Tepke

Conclusion

1. Earlier spring transition, slight weakening of upwelling and slight warming of the ocean.

2. Ocean conditions affect timing of breeding and productivity of auklets on the Farallon Islands.

3. Ocean conditions lead to decreased prey availability and low auklet breeding success.

4. Deepening of upper mixed layer may further reduce krill availability with negative consequences for the auklets.

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Acknowledgements

PRBO staff, interns, volunteers.

Gerry McChesney, United States Fish and Wildlife Service

Lisa Etherington, Cordell Bank National Marine Sanctuary
Jan Roletto, Gulf of the Farallones National Marine Sanctuary

Moira Galbraith, Institute of Ocean Sciences, Canada
Rachel Fontana and John Largier, Bodega Marine Laboratory
Zachary Brown, Charlotte Chang, Andre Cavalcanti, Pomona College

Nancy Kachel and Carol Ladd, Pacific Marine Environmental Lab.
Pacific Fisheries Environmental Lab.

Resources Legacy Fund Foundation
National Fish and Wildlife Foundation
Moore Family Foundation
California Sea Grant