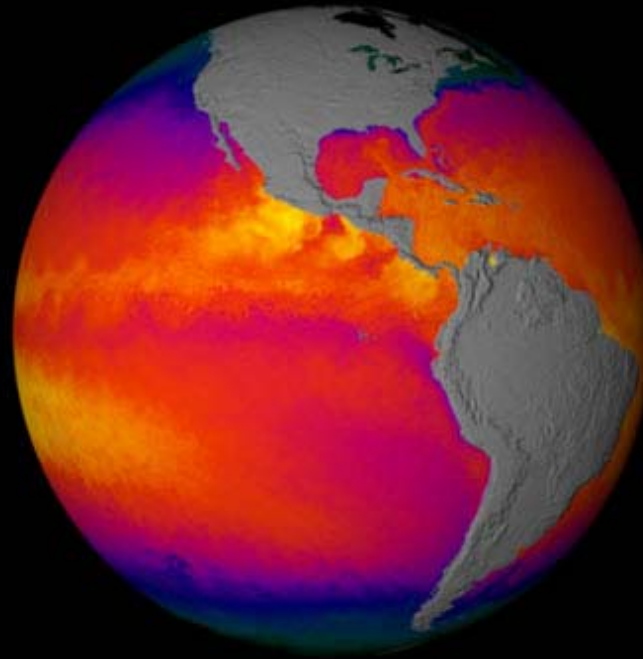


Seabirds as Indicators:
Comparative Ecosystem Dynamics in
Temperate and Tropical Upwelling Areas



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www.faralloninstitute.org



Outline

- **Seabirds as indicators of ecological change**
- **Comparative marine ecosystem dynamics**
- **Co-variation between Brandt's Cormorants and Galápagos Penguins**
- **Hind-casting the percent change of Galápagos Penguin population numbers**
- **Relationship of seabirds to the Oceanic Niño Index**
- **Conclusions and recommendations**

What Makes Seabirds Good Indicators of Ecological Change?

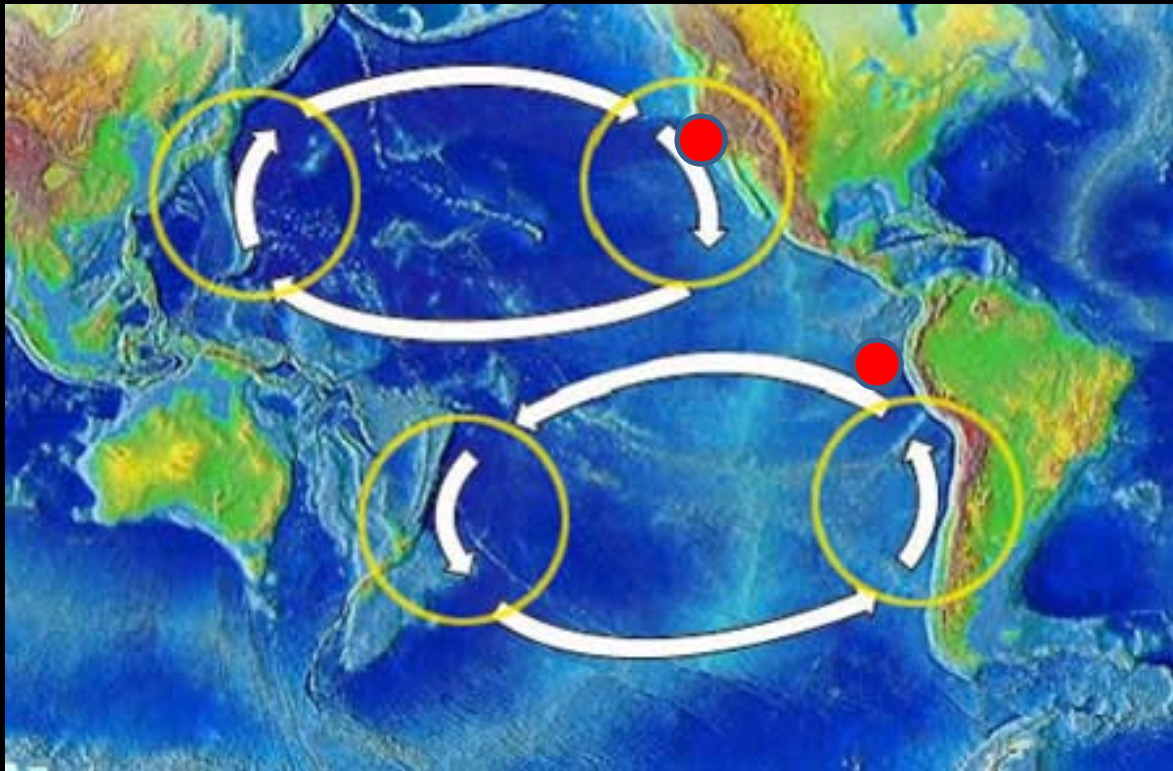
- Responsive to climate variability and change
- Zoogeographic/water mass affinities (warm vs. cold) facilitates understanding of distribution/range shifts
- Life history strategies allow for comparative analyses:
 - Migrants vs. breeding birds
 - Slow vs. faster reproductive effort
 - Various trophic levels (zooplanktivores, piscivores)
 - Divers vs. surface-foragers



MARINE ECOSYSTEM CONTEXT

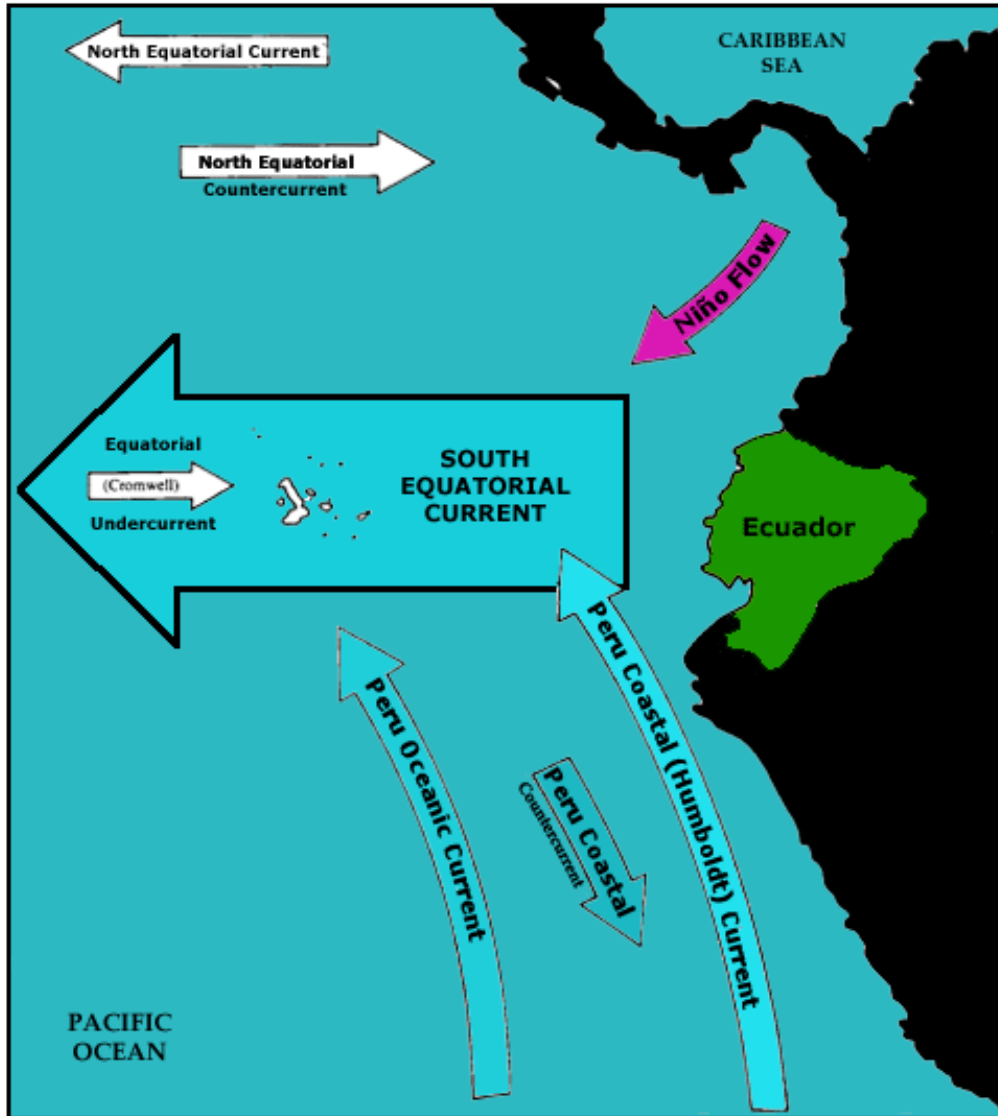
Similarities between the California Current and Peru (Humboldt) Current:

1. Eastern Boundary currents
2. Coastal Upwelling Systems



Transport cold water
from higher latitudes
+
Coastal upwelling
=
PRODUCTIVITY

The Galapagos Marine Ecosystem



Confluence of Currents:

Peru (Humboldt) Current

South Equatorial Current

Panama Current

Equatorial Undercurrent

Galápagos Penguin Distribution

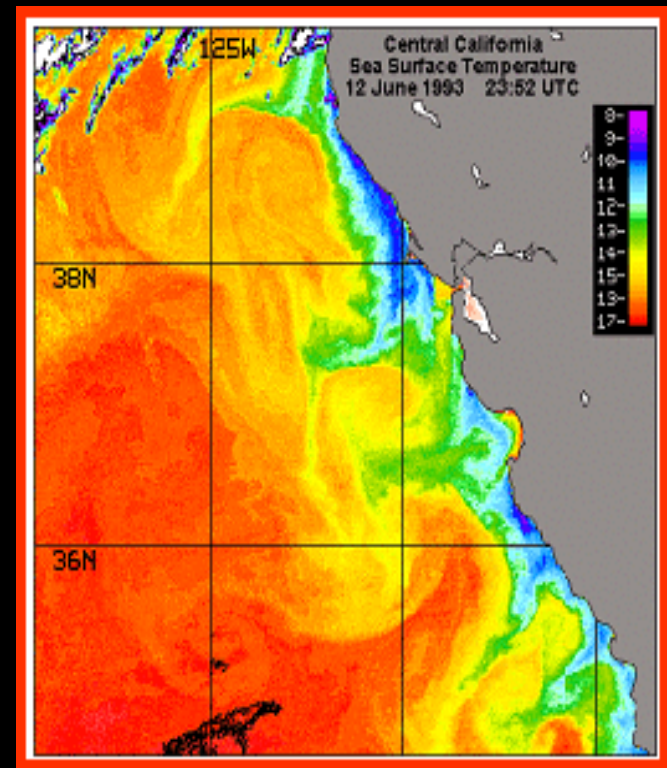
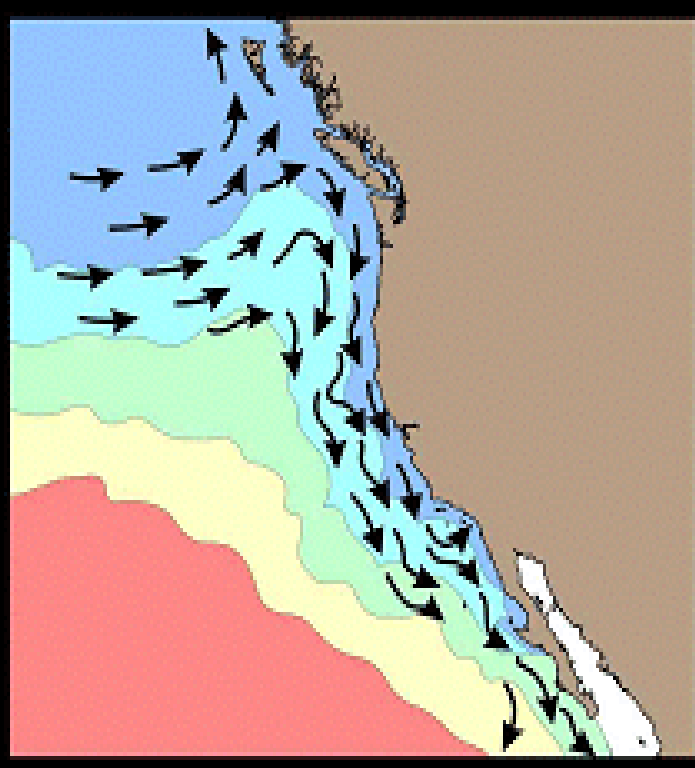
Cromwell Current: upwells around Fernandina and w. Isabela Island



Galápagos Penguins are found mostly in these regions of upwelling

The California Current Large Marine Ecosystem

- Part of the North Pacific Gyre
- From British Columbia to Baja California
- Predominant feature: California Current
- Strong coastal upwelling, dependent on winds



GALAPAGOS PENGUIN

Spheniscus mendiculus



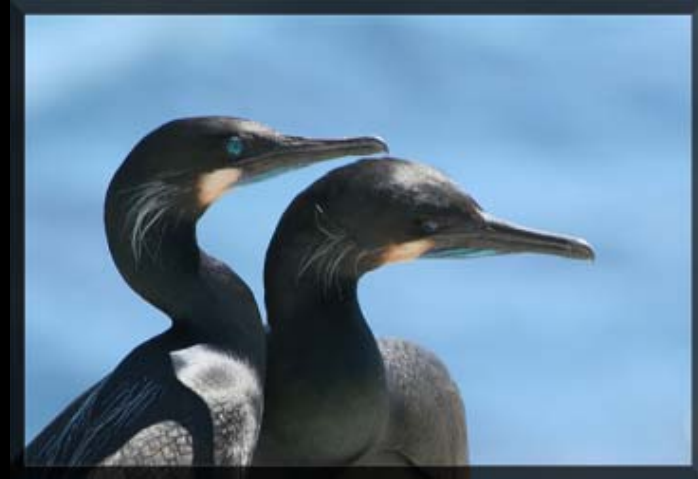
**Distribution – upwelling
Zones (breeding and foraging)**

Diver, Piscivorous

**Affected by warm-water
events**

BRANDT'S CORMORANT

Phalacrocorax penicillatus

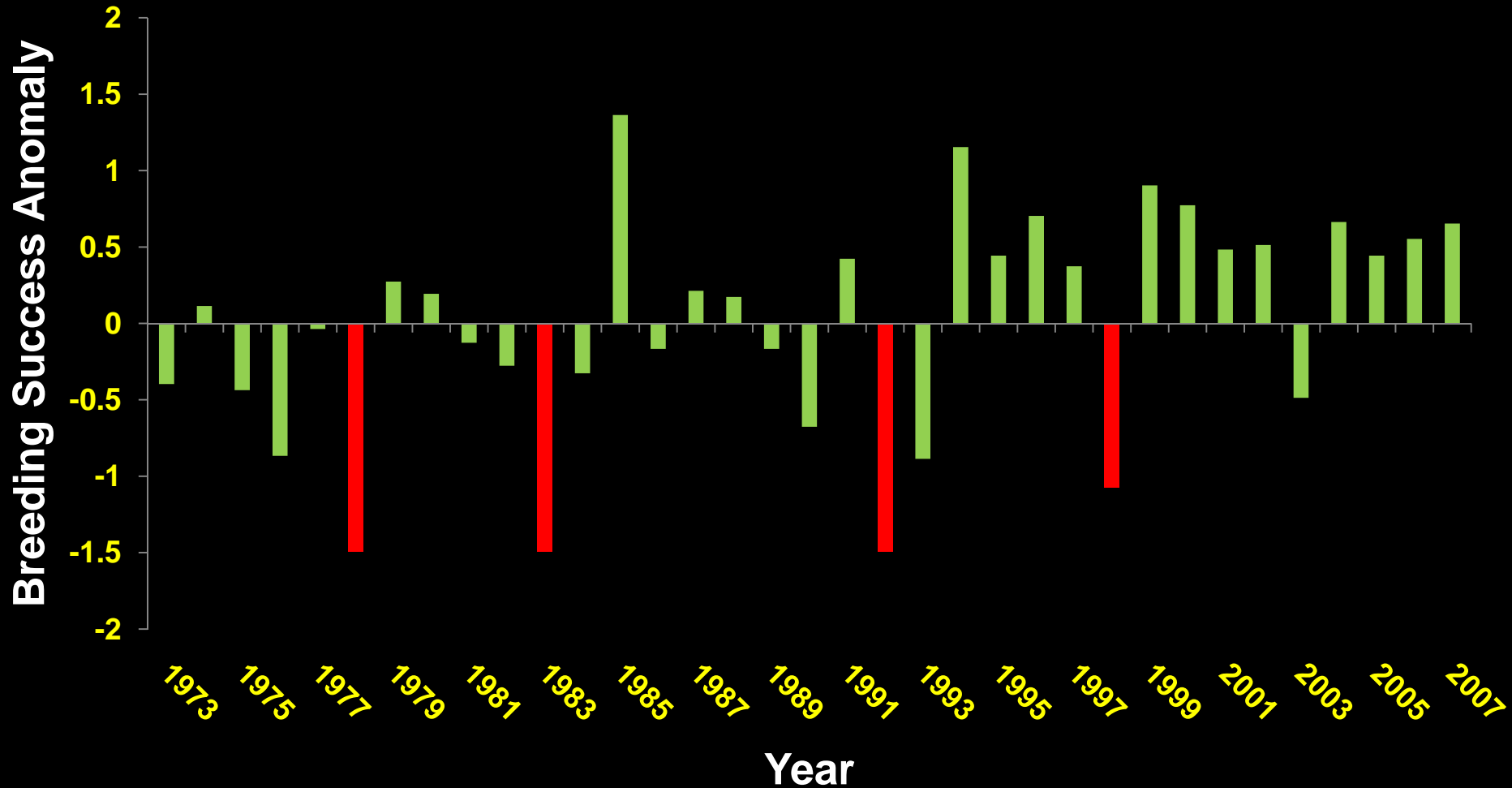


**Endemic to the
California Current**

Diver, Piscivorous

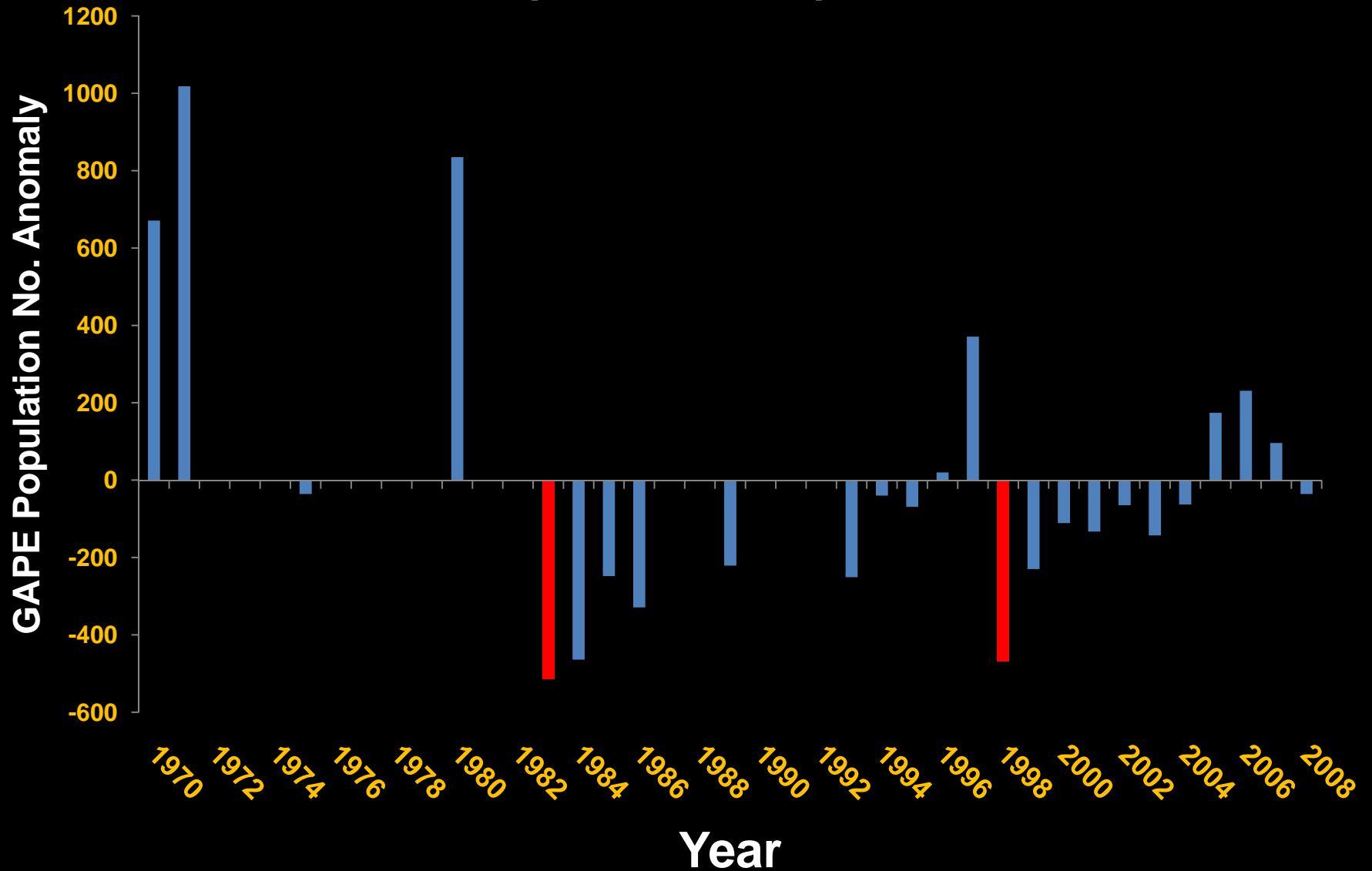
**Affected by warm-water
events**

BRANDT'S CORMORANT (1973-2007)



(Sydeman et al. 2009, $\rho=0.4692$, $p=0.0034$, $N=37$)

GALAPAGOS PENGUIN (1970-2008)



DATA

1. Galápagos Penguins:

Population number – annual census:

(1970-71, 1975, 1980, 1983-1986, 1993-2007)

* Calculated % population change

Sources: CDF Annual Census Reports; Vargas, et al. 2005

2. Brandt's Cormorant:

Annual breeding success (chicks/pair/yr) on S.E.
Farallon Island (1973-2007)

Source: PRBO Conservation Science and U.S. Fish & Wildlife Service

3. Oceanic Niño Index (ONI):

SST anomalies

NOAA Climate Prediction Center

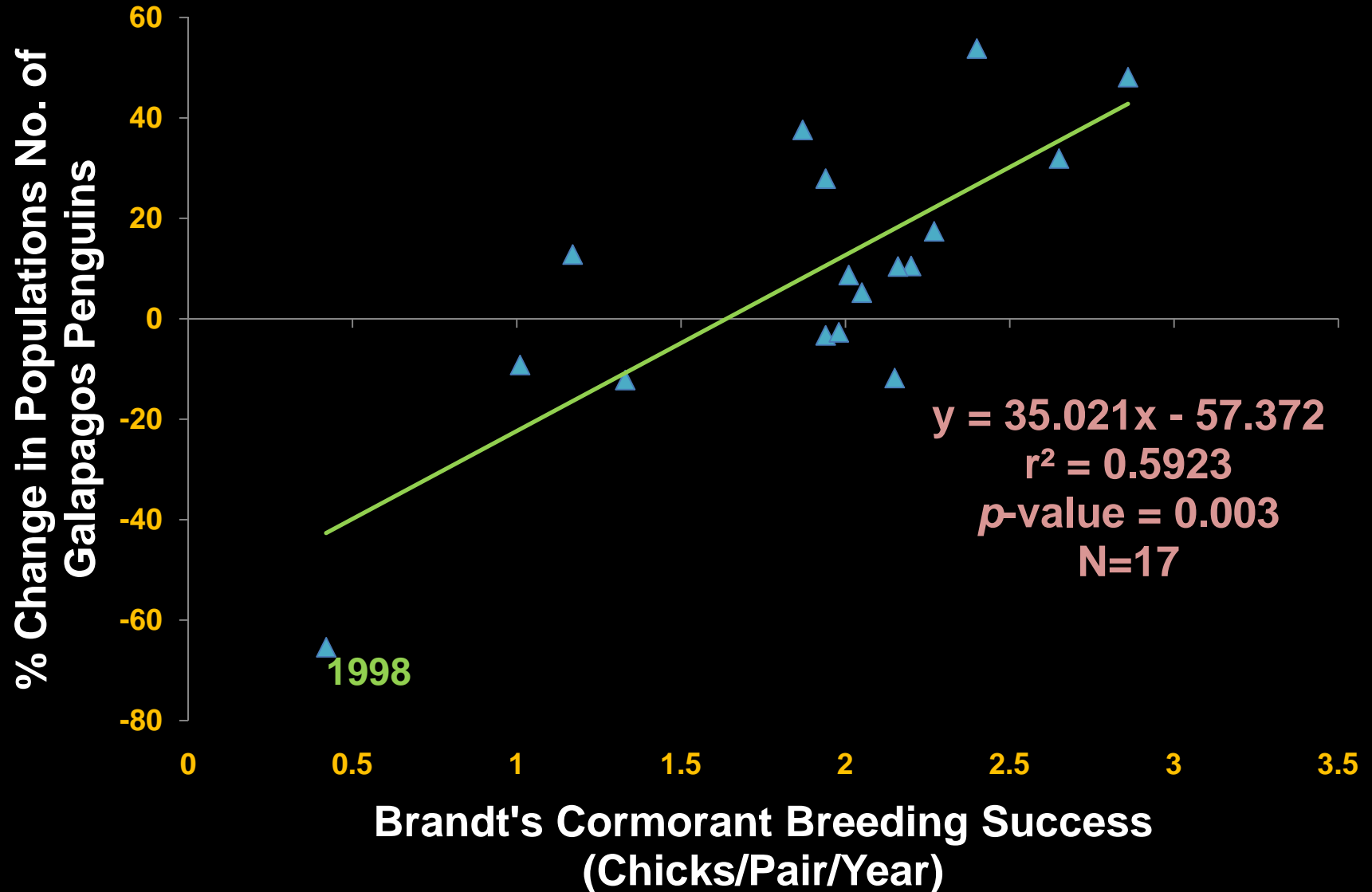
Source:

http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

PERCENT CHANGE OF GALAPAGOS PENGUIN POPULATION NUMBERS

- 1. Demographic parameter**
- 2. Function of mortality and recruitment**
- 3. Reflects environmental conditions from one year to the next.**
- 4. $N = 17$ – could only use contiguous years when census was conducted**

CO-VARIANCE OF DEMOGRAPHIC PARAMETERS IN TWO UPWELLING SYSTEMS



Why Calculate Percent Population Change?

JUSTIFICATION:

NEEDED A COMPLETE DEMOGRAPHIC PARAMETER
FOR GALAPAGOS PENGUINS TO RELATE TO
ENVIRONMENTAL INDEX

$$y = 35.021x - 57.372$$

USING BREEDING SUCCESS TO HINDCAST GALAPAGOS PENGUIN POPULATION CHANGE

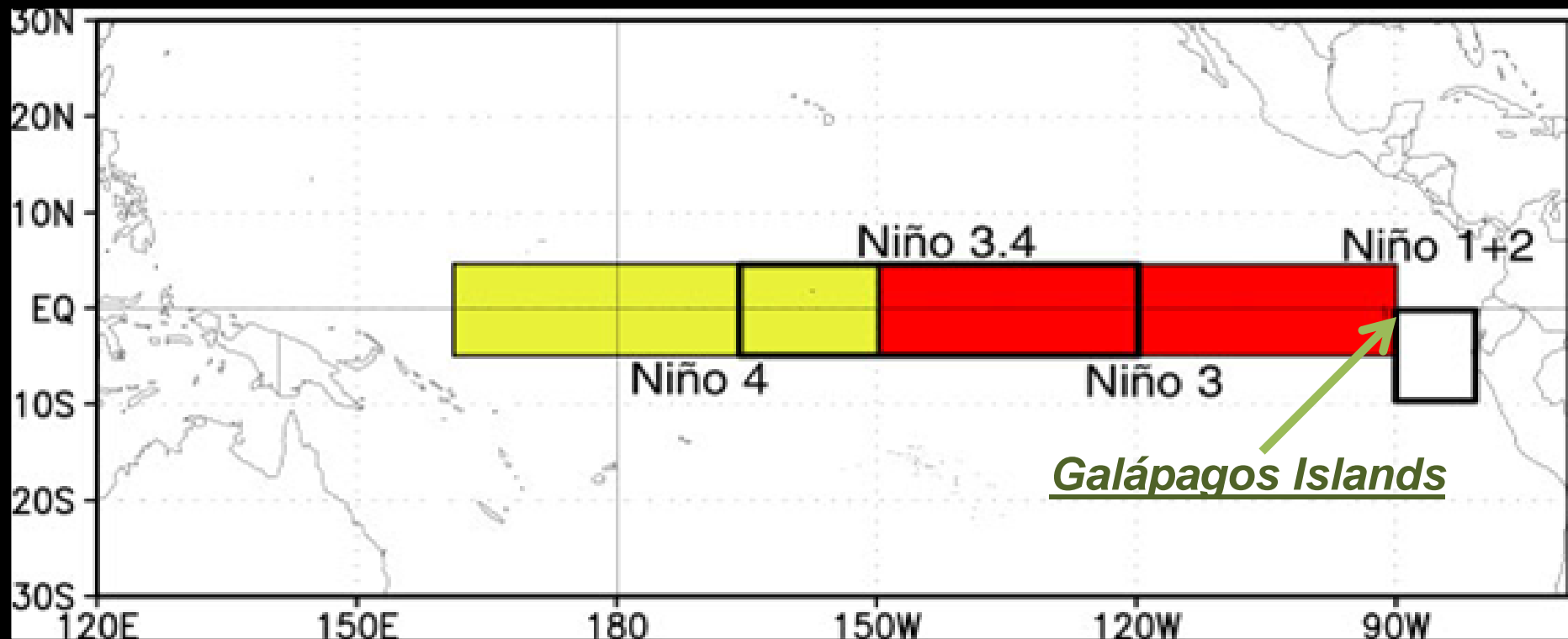
$$y = 35.021x - 57.372$$

YEAR	GAPE POP. NUMBER	BRAC BREEDING SUCCESS	% CHANGE GAPE POP. NO.
1973		<u>1.1</u>	<u>-18.85</u>
1974		1.61	0.99
1975	877	1.06	-20.25
1976		0.63	-35.31
1977		1.46	-6.24
1978		0	-57.37
1979		1.77	4.62
1980	1748	1.69	1.81
1981		1.37	-9.39

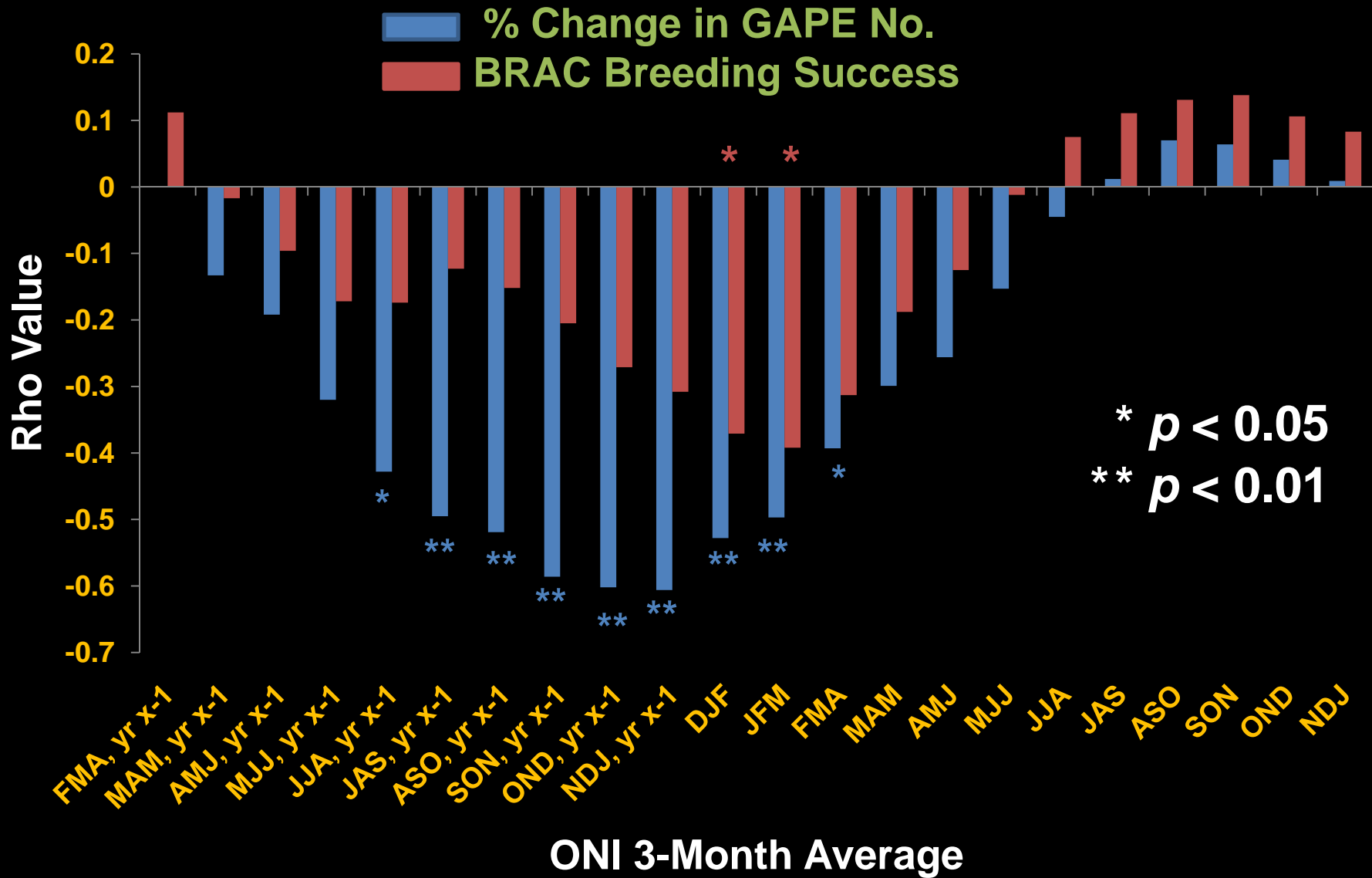
$$y = (35.021 \times 1.1) - 57.373 = \underline{-18.85}$$

OCEANIC NIÑO INDEX (ONI)

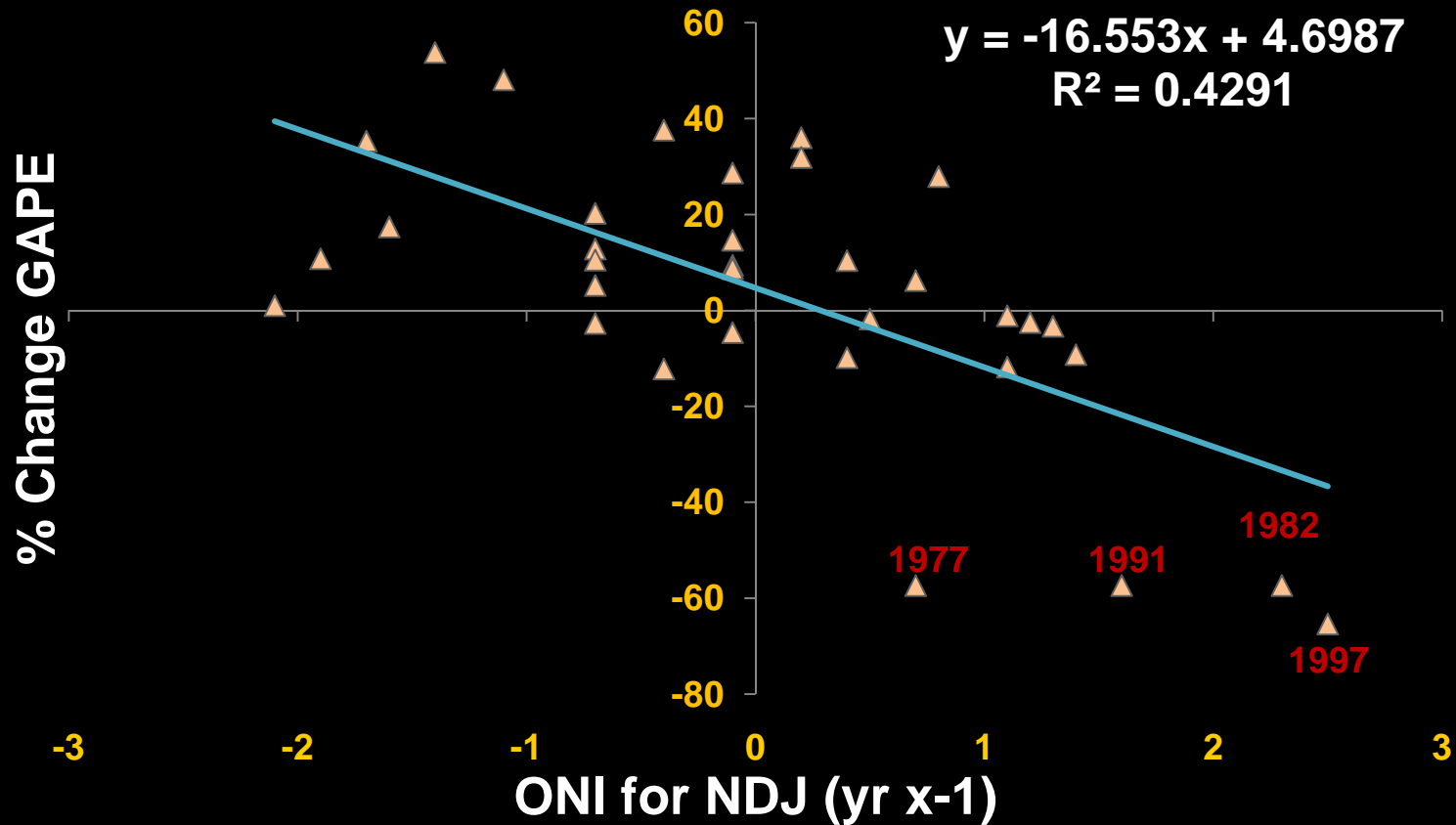
- Three-month running-mean SST anomalies in the Niño 3.4 region.
- Principal measure for monitoring, assessing, and predicting ENSO.



IS THE OCEANIC NINO INDEX REFLECTED IN SEABIRD DEMOGRAPHY?



HOW WELL CAN WE PREDICT CHANGE IN GALAPAGOS PENGUIN NUMBERS?



If ONI = 1.39 (Ave. 82-83), % change =
-18.31 (746 based on ave. census no.)

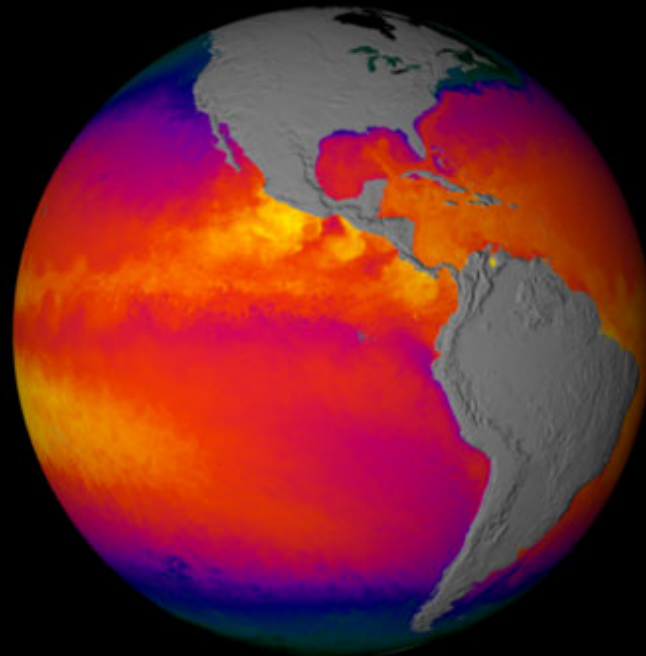
If ONI = 1.74 (Ave. 97-98), % change =
-24.10 (693 based on ave. census no.)

CONCLUSIONS & RECOMMENDATIONS

- **Galapagos Penguin and Brandt's Cormorants co-vary and illustrate similar response to environmental variability (ONI); as such..**
- **are sensitive and reliable indicators of change in these upwelling ecosystems**
- **The California Current and the Galapagos upwelling systems are connected via large-scale atmospheric-oceanographic interactions**

More...

- **Expand research on Galapagos Penguins to include breeding biology and diet to better understand Galapagos system. Long-term data are essential for understanding climate/ecosystem interactions**
- **Ecosystem-based management in should integrate environmental relationships in a mechanistic sense**



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