A seabird eye-view on forage fish

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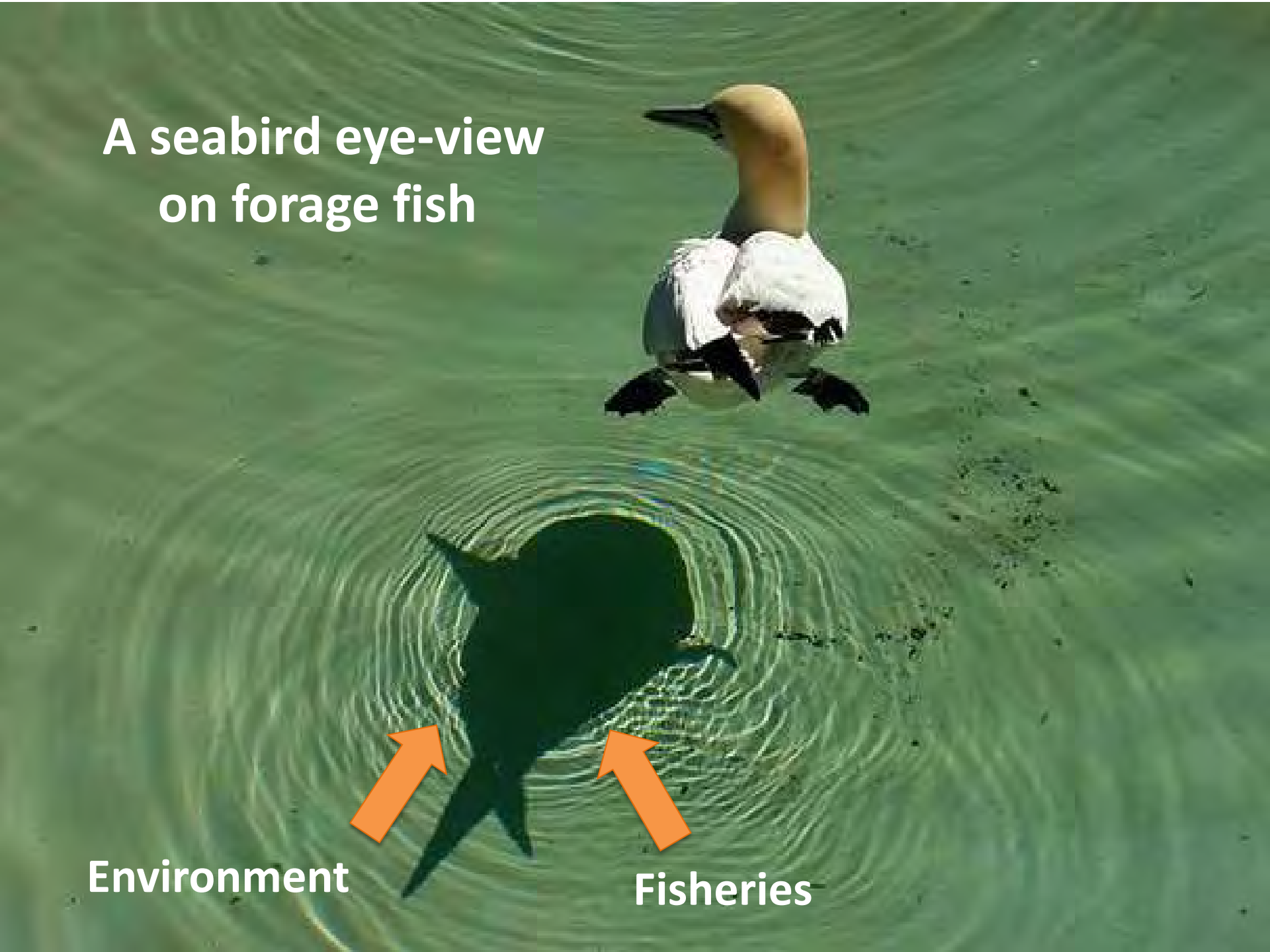
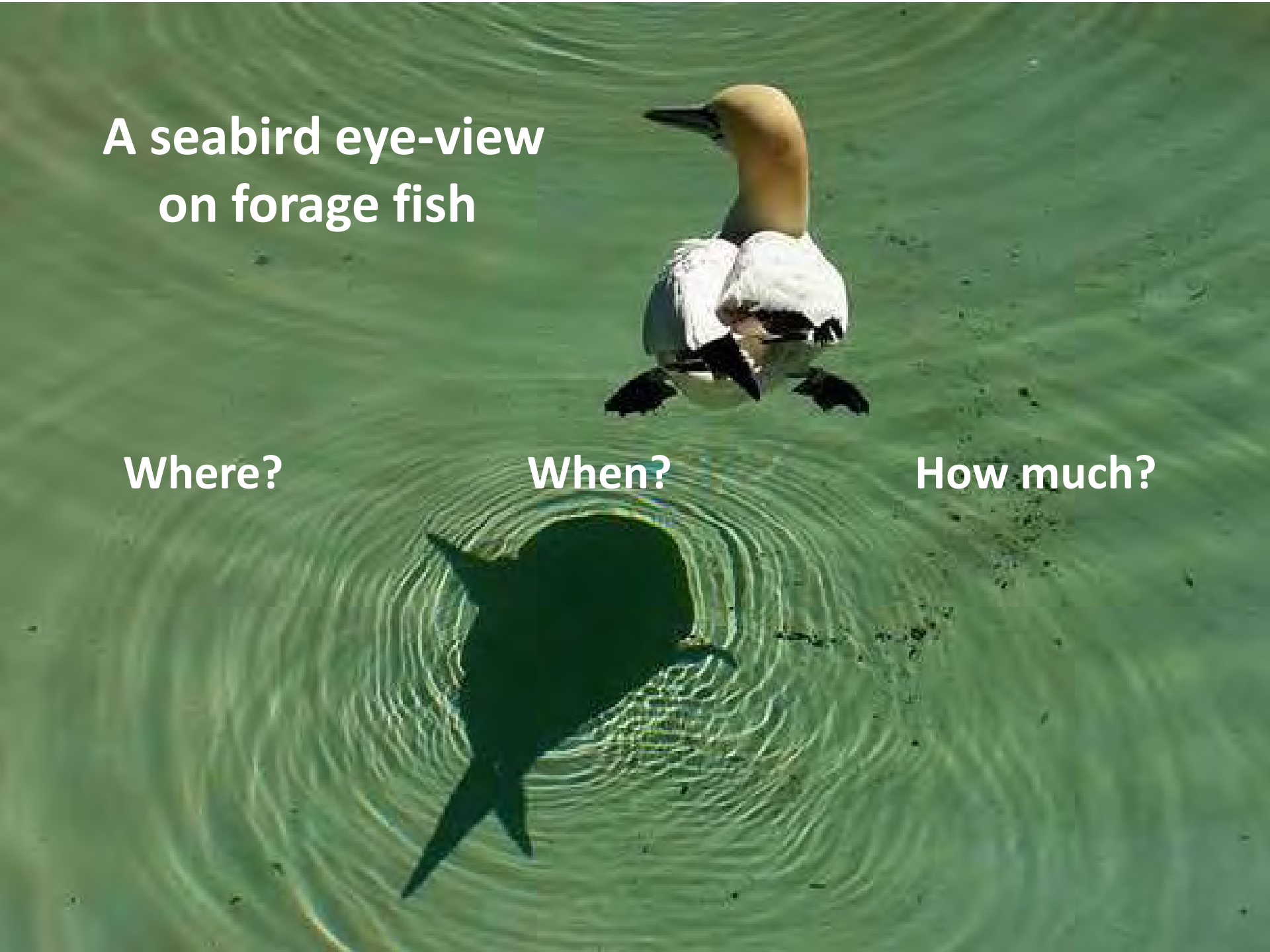
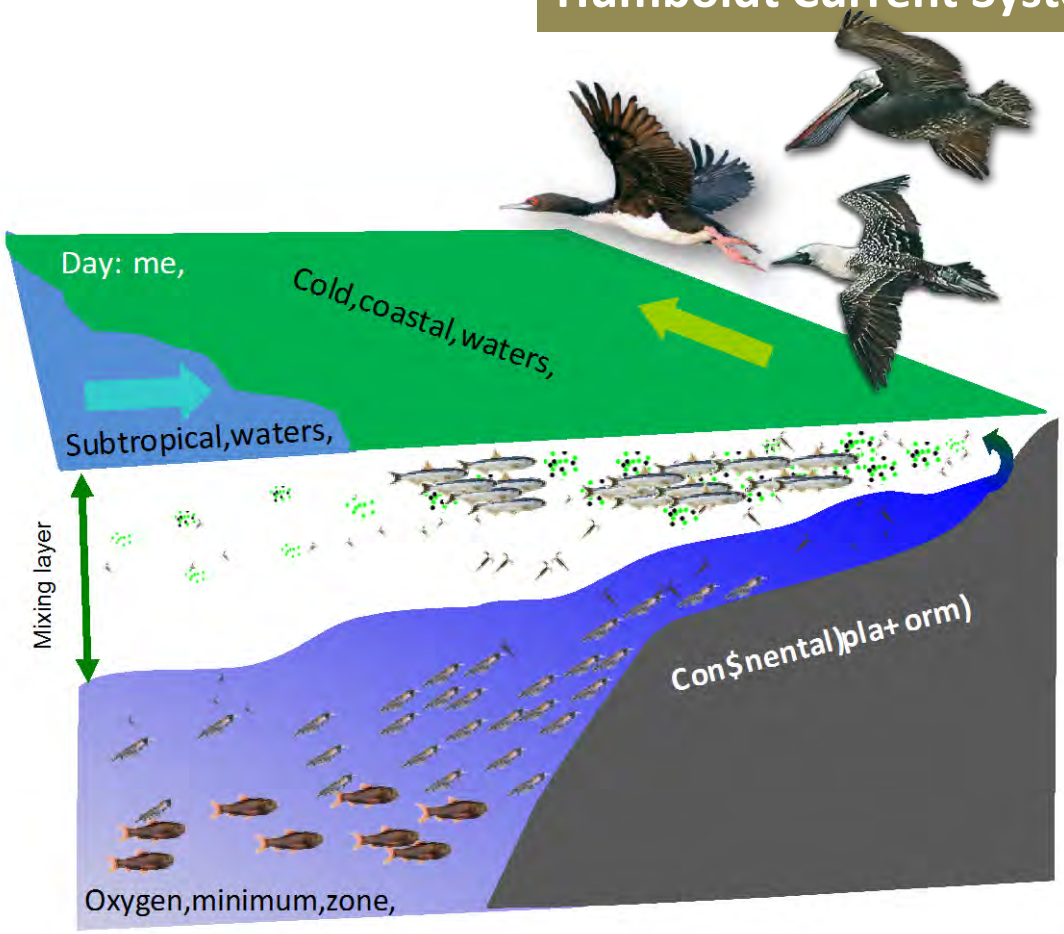
FRANCE


A seabird eye-view
on forage fish
Environment
Fisheries


A seabird eye-view
on forage fish
Where?
When?
How much?

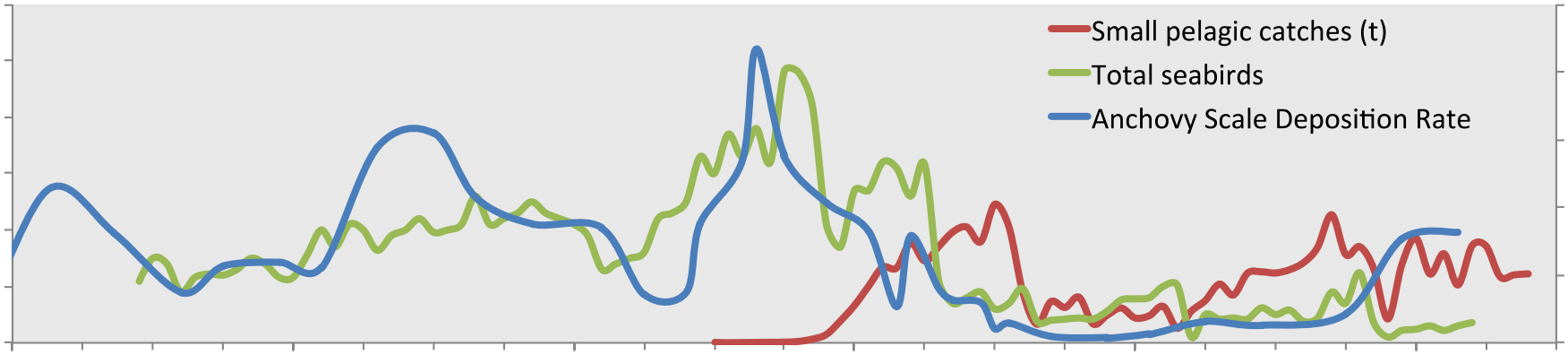
Foraging
Behaviour
Forgaing effort
Catch and diet quality
Breeding
Propensity
Success
Demography
Population size
Adult survival
Colony relocation
Where?
Distribution
Horizontal/vertical
Patchiness
Availability
When?
Interannual
Seasonnality
How much?
Abundance
Biomass
Production
Time scale

Humboldt Current System



- One of the major EBUs, Great climatic variability, Intense OMZ
- World most productive area for fish (0.1% world ocean~10% catches)
- Large industrial fishery (>1000 vessels, ~ $6.10^6 t.y^{-1}$)
- Large guano producing seabird populations (~ $4.\ 10^6$ ind.)
- Ecosystem-based fisheries management issues

Humboldt Current System

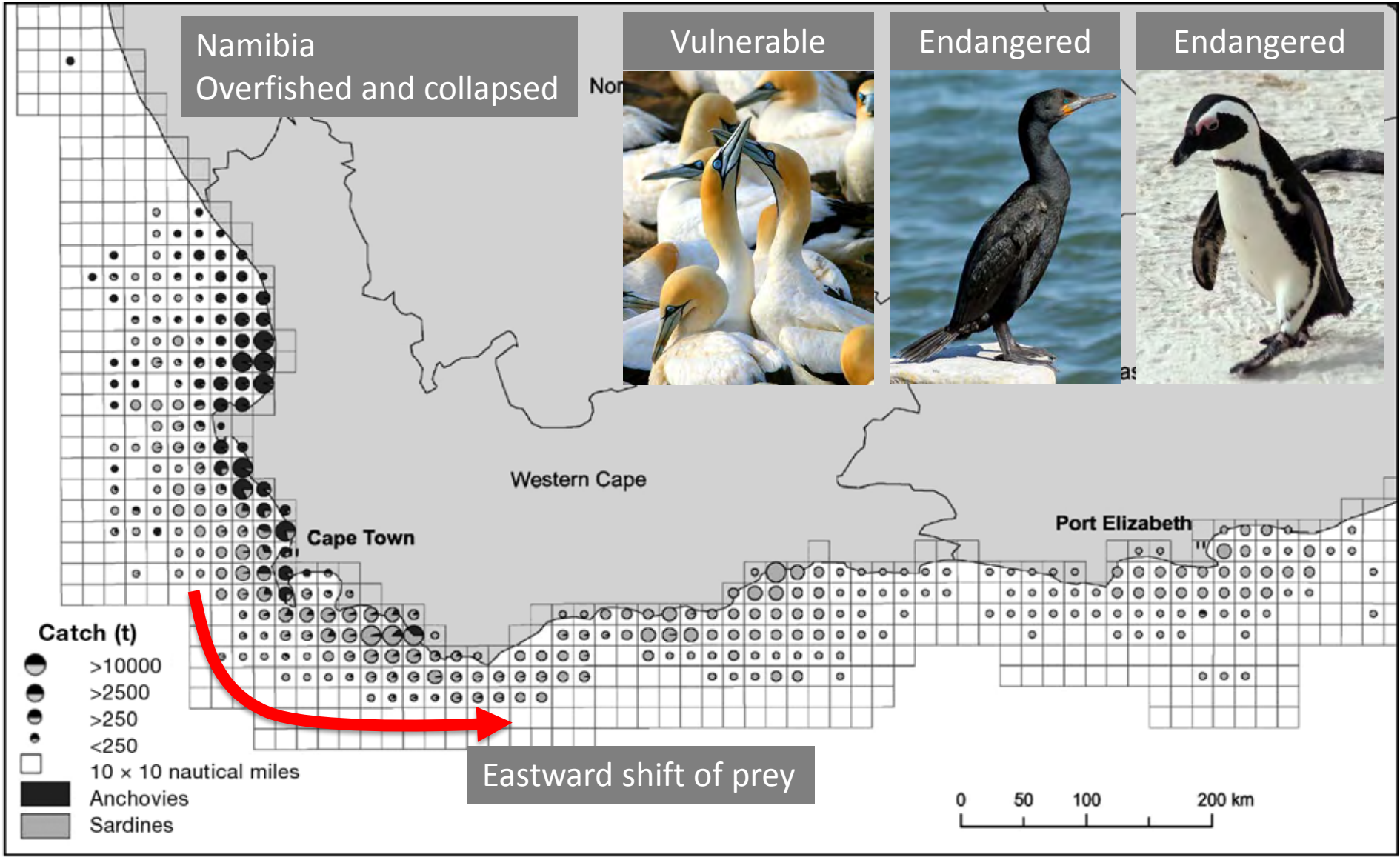


- System recently highly productive (Field, Gutiérrez, S1)

- 1946: Nesting reserves (Duffy et al. 1989)
  -> population size from ~10 to 20 millions
  Reference population size?
- 1950': Development of the forage fish industrial fishery

- 1972/73, 1982/83, 1997/98: Intense Niño events
  crash of the fishery and seabirds
- Since 97/98, anchovy recovered, but seabirds did not

Benguela Current System

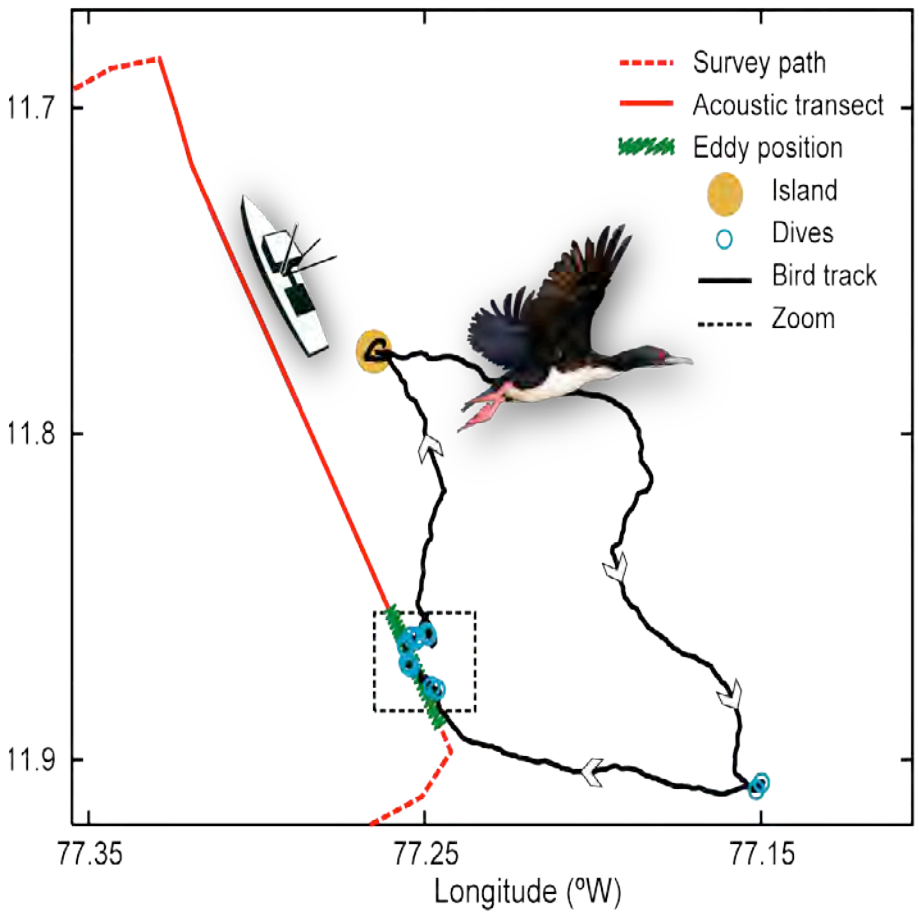


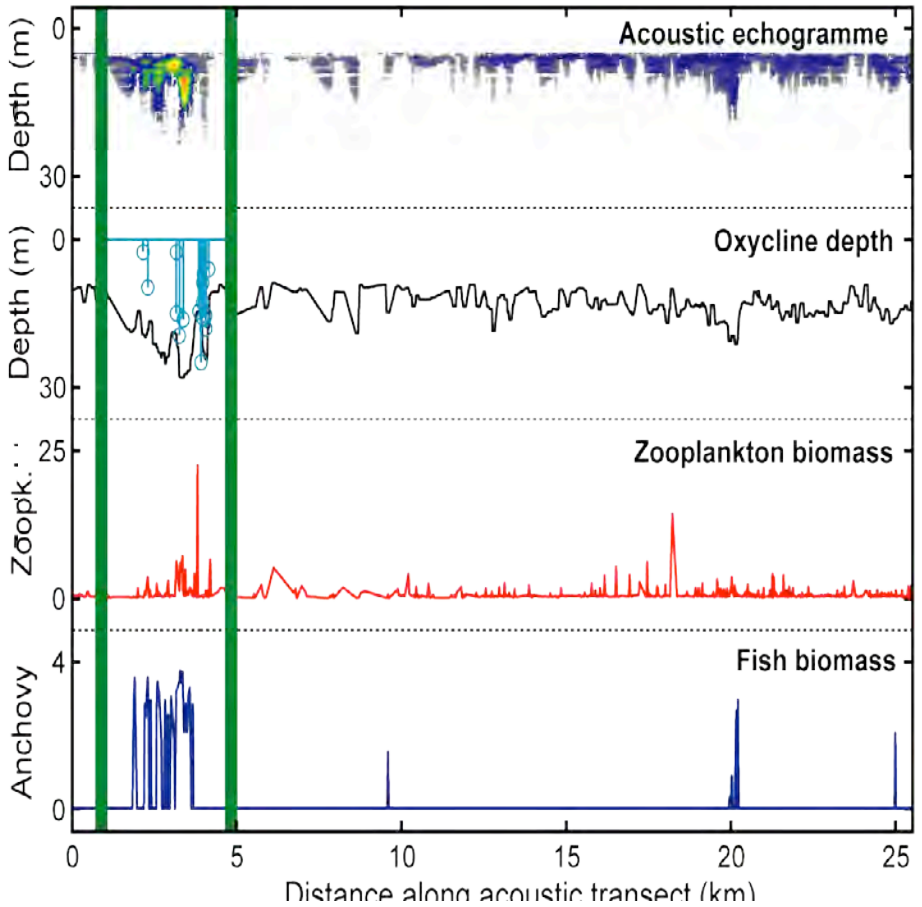
Pichegru *et al.* 2009 MEPS

Crawford *et al.* 2015 Frontiers Ecol. Evol.

Foraging
Breeding
Demography
Where?

Humboldt Current System





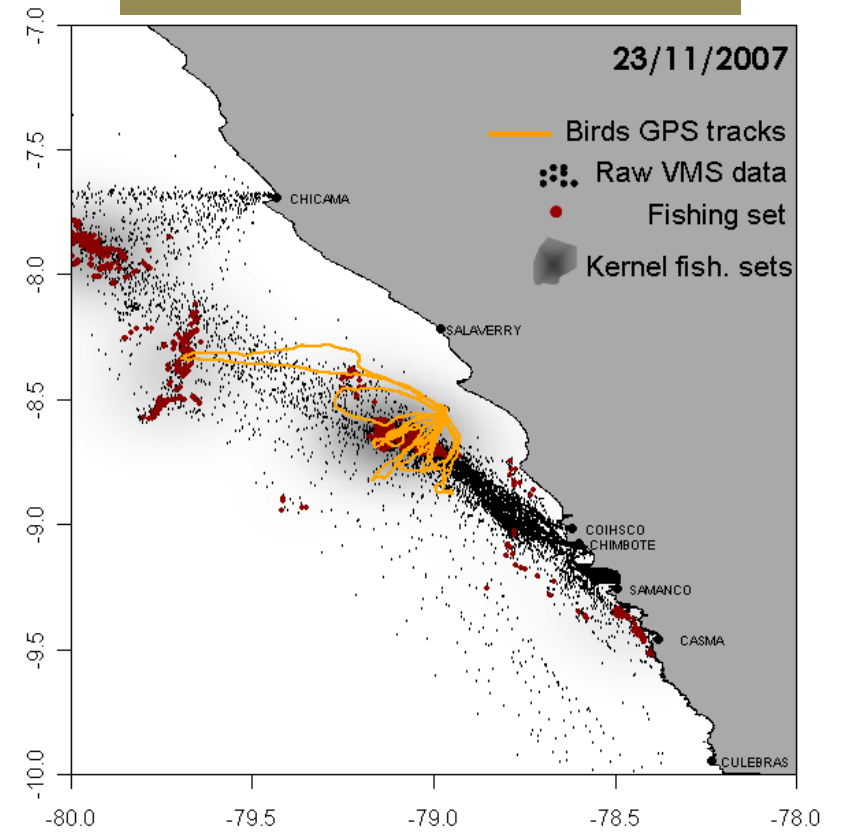
Seabirds fine scale foraging

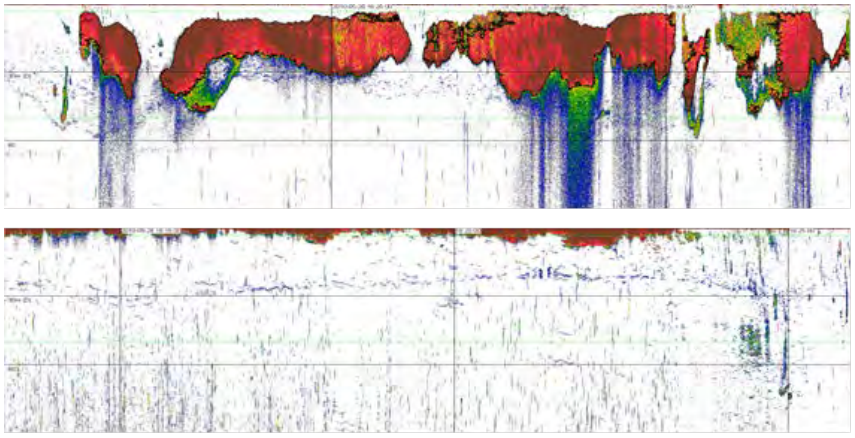
Relies on **small scale (1-4km) , transient pelagic 'oasis of life'**

CC impacts -> Grados et al. S1 07/03

Bertrand et al. , 2014, Nat. Comm.

Humboldt Current System





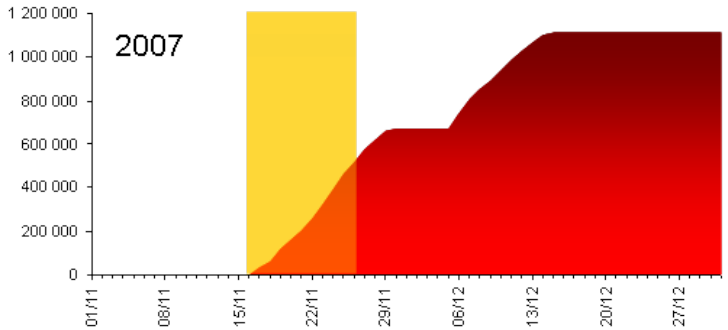
Bertrand et al. (2012) JAE

Tracking at the opening of fishing season

Seabird foraging effort increase day after day, seabirds forage farther from vessels

Mixed effect models:
Main effect from the local depletion generated by the fishery removals

Seabird needs: ~ 200 $t.d^{-1}$
Fishery removals: ~ 50 000 $t.d^{-1}$



Competition seabirds / fishery
Localized depletions

Humboldt Current System

Δ foraging effort of breeding seabirds
Relative contribution of climate, prey and fishing

Random Forests
2008-2013 time series
10 response variables = f(43 covariates)
Ordering effects and quantifying contributions

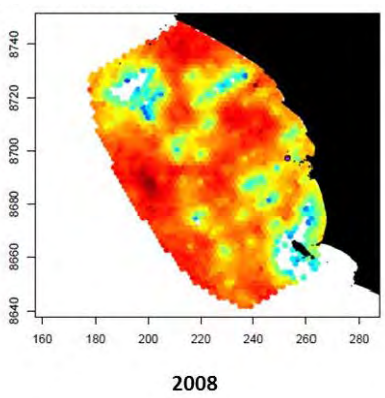
'Fishing' Facilitation/competition	**'Oceanography'** Hor. and vert. habitat
'Seabirds' Density dependence	**'Seabirds'** Density dependence
'Oceanography' Hor. and vert. habitat	**'Fishing'** Facilitation/competition
~~**'Prey'** Abundance~~	~~**'Prey'** Abundance~~

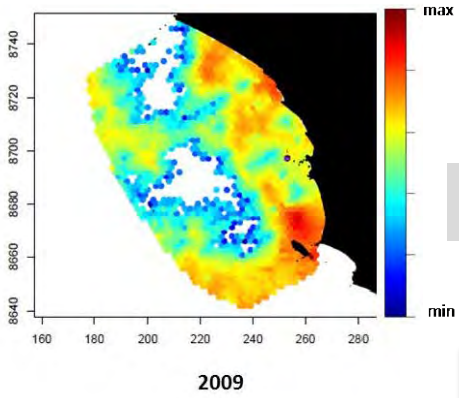
Bertrand et al. unpublished

Humboldt Current System

IBM approach

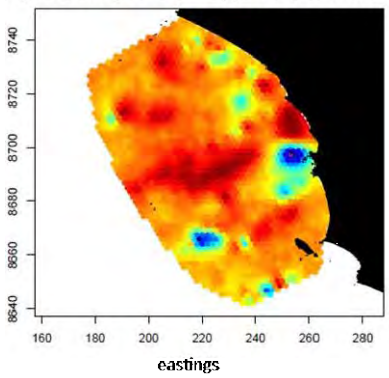
Prey abundance

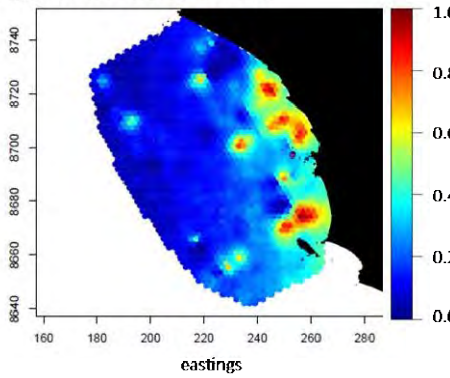




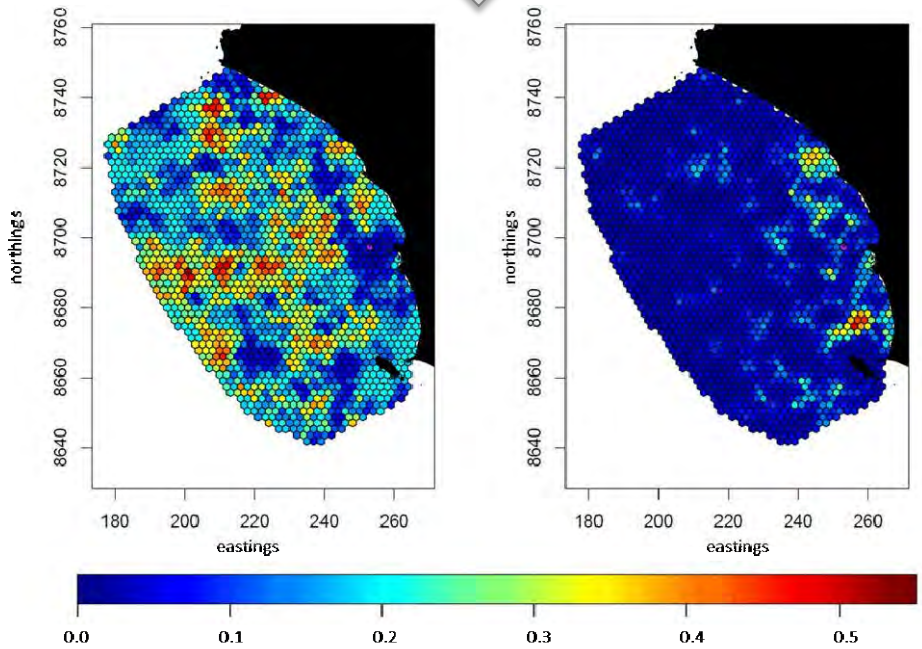
+

Prey depth





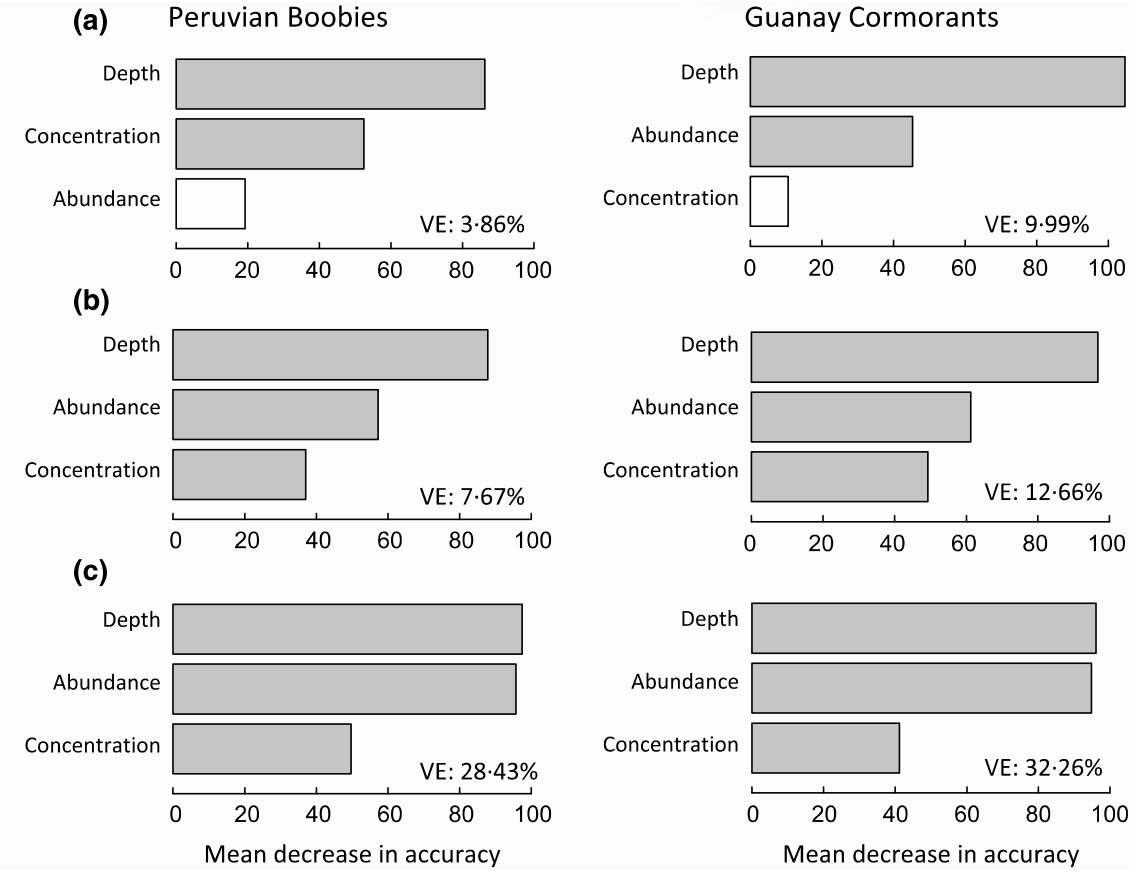
Seabird foraging probability



A virtual lab for studying the effects of ecosystem and fishery management changes

Boyd et al. 2014/2015a/2015b/2016a/2016b

Humboldt Current System



Foraging effort variability
Foraging success

Abundance and distribution of prey

Depth = primary factor of seabird foraging success

Prey accessibility +++

Boyd et al. (2016) JAE

Social information

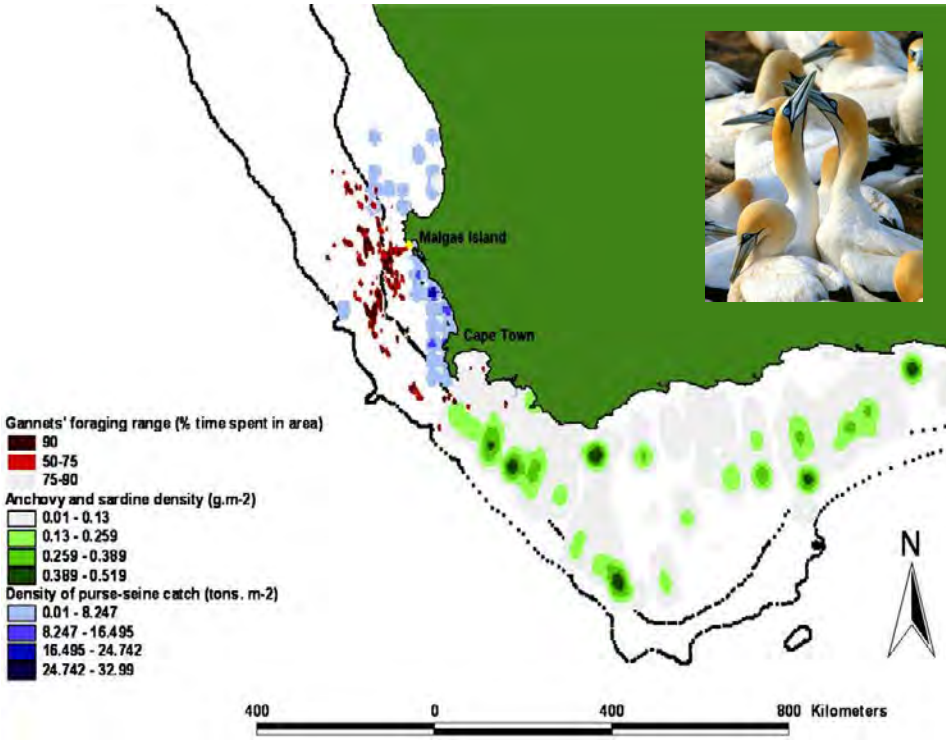
Important when prey spatially concentrated and for mitigating poor foraging conditions

Seabird population size -> efficient foraging

Boyd et al. (2016) Behav. Ecol.

Benguela Current System

Competition for Shifting Resources : Seabirds versus Purse-Seine Fisheries



Seabird populations decreasing
Reduced availability of pelagic fish.

GPS-tracking of the birds,
Echo-sounding of pelagic fish
Vessel log books

2007: purse-seine fishing grounds and gannet foraging areas overlapped by only 13% but purse seiners caught 41% of seabird food needs

-> considering and experimenting with **at-sea 'no-take' areas for the purse-seine fishery**

Okes et al., 2009 Biol. Cons.

Benguela Current System

Interannual variability:
Unprofitable foraging and starving seabirds

Grémillet D., et al 2016 Mar. Biol.

Benguela Current System

African penguins
Postnatal dispersal
GPS tracking

Juveniles go to low SST, high Chlo areas that were once reliable cues for prey-rich waters

-> Marine ecological trap

Sherley et al., 2017, Current Biology

Foraging
Breeding
Demography
When?

Humboldt Current System

Monthly presence-absence of breeders
1952-1968
1977-1990
2003-2014

Dynamic occupancy models
Covariables: oceanographic conditions, anchovy production, fishery removals

Humboldt Current System

Bayesian dynamic occupancy models
Breeding onset seasonality ~ env. Parameters seasonality by period

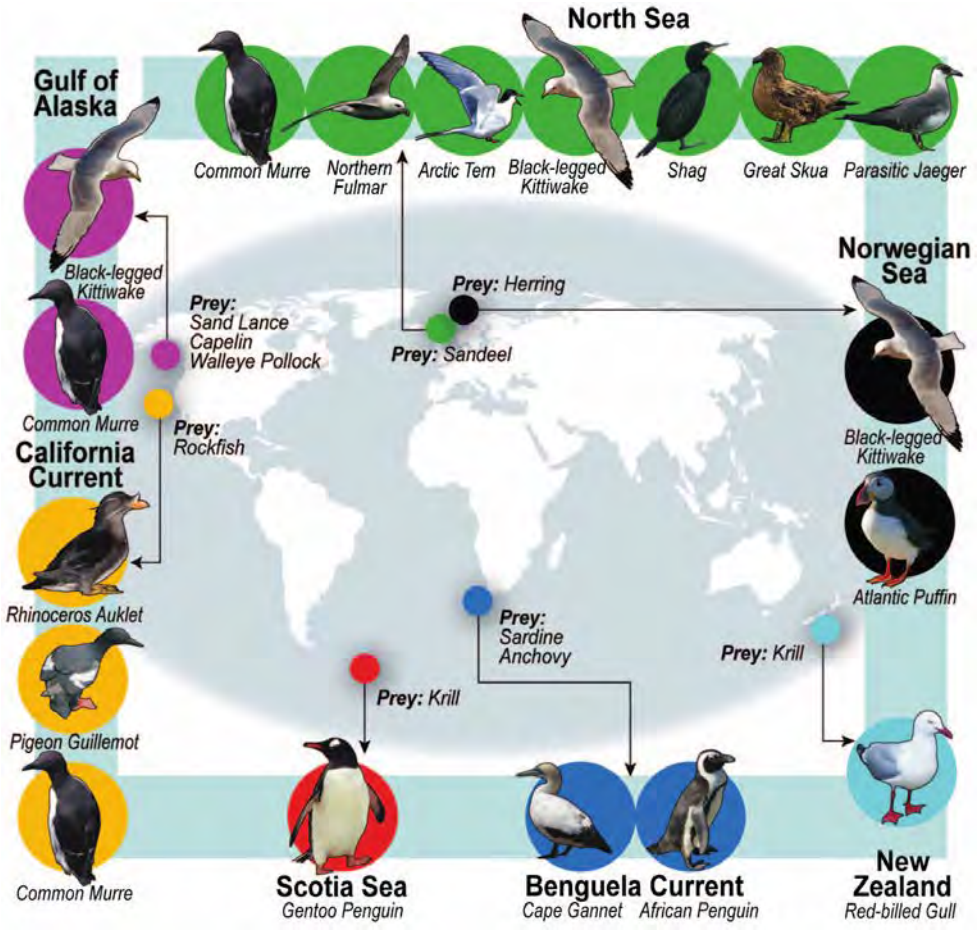
Periods Species	1952-1968	1977-1990	2003-2014
	SST Anch. Prod.	SST Chlo	SST Oxy. depth
	SST Anch. Prod	SST Oxy. depth	SST Oxy. depth
	SST Anch. Prod	SST	SST Oxy. depth

Species-specific breeding adjustment
A shift of 'abondance-driven' versus 'accessibility - driven' breeding seasonnality?

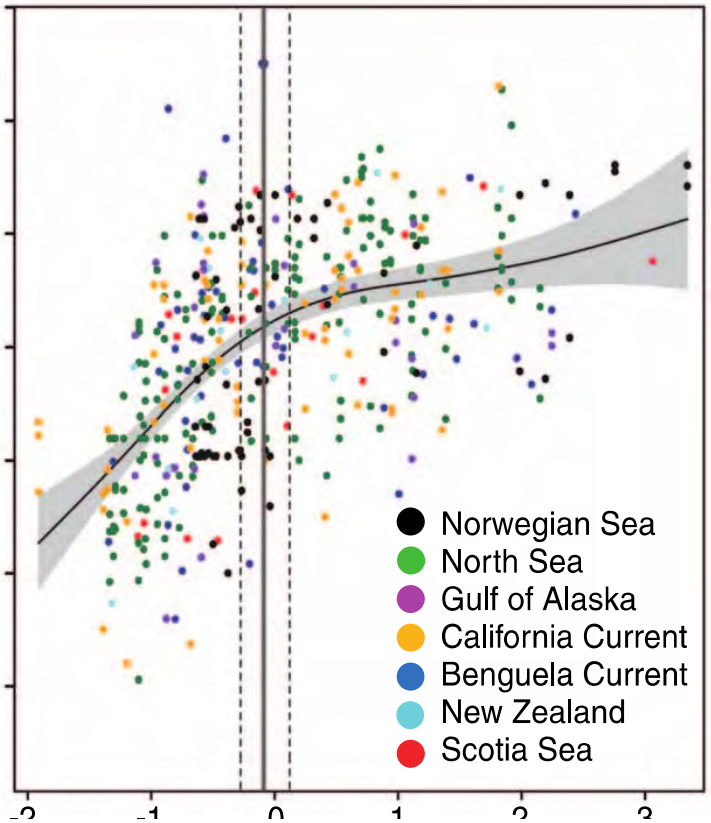
Passuni et al. submitted

Foraging
Breeding
Demography
How much?

Prey abundance (biomass) -> breeding success



species considered in our analysis.



Cury et al. 2011 1 / 3

Robinson et al. 2015 1 / 4 Bmax

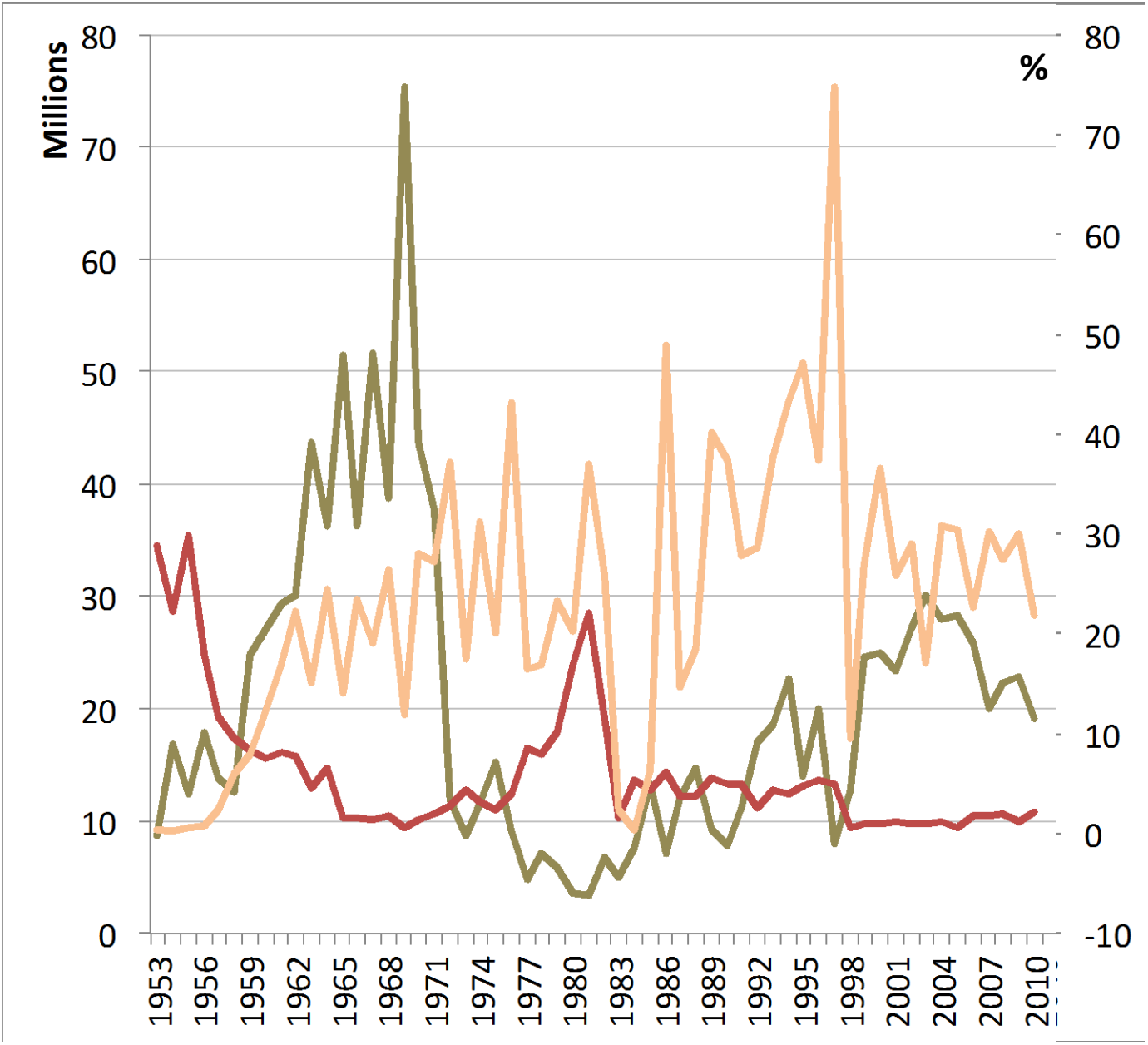
Punt et al. 2016 <10%

7 ecosystems 14 species

Penguin SA

Brown Pelican California

Humboldt Current System



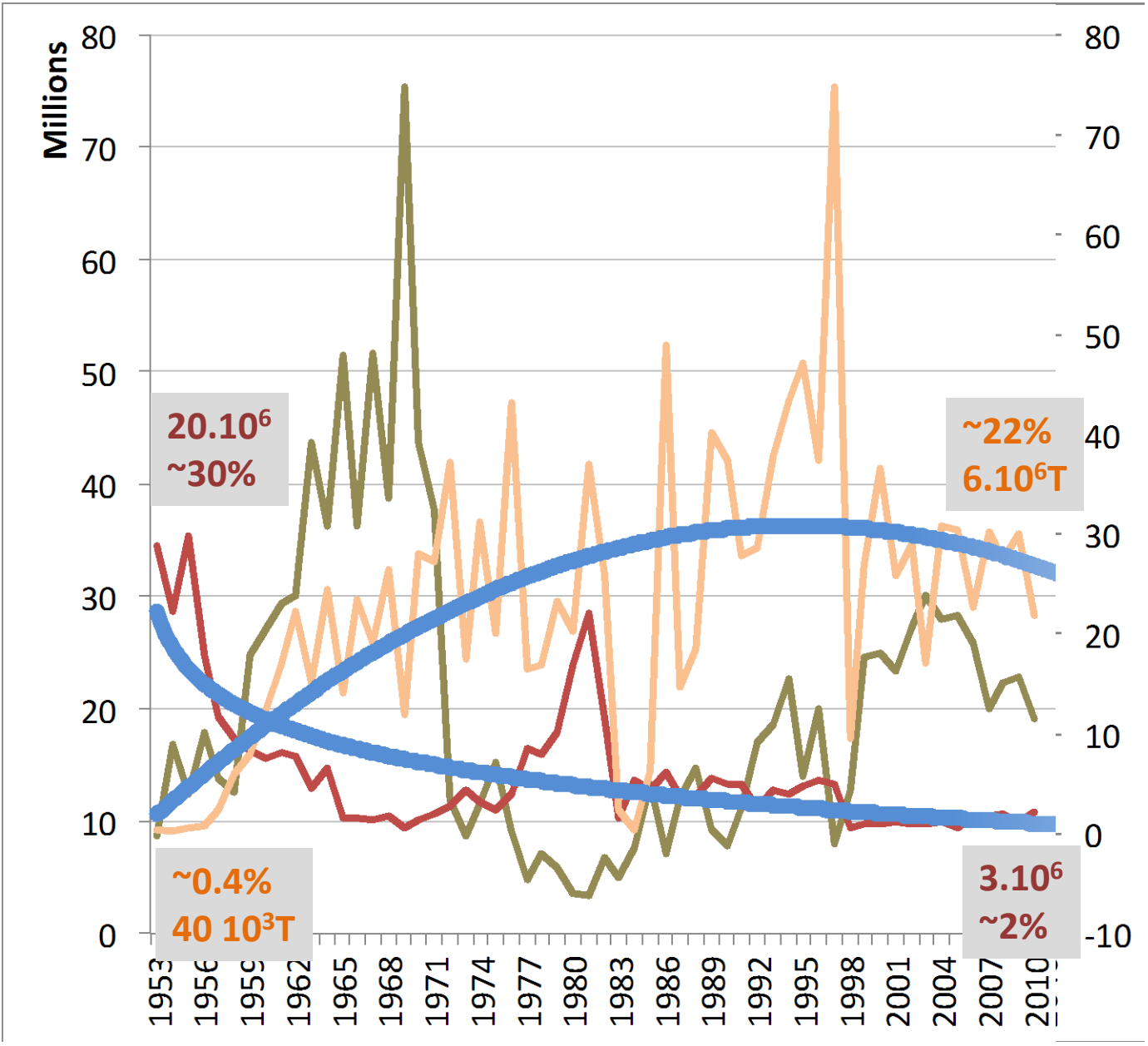
Prey abundance (new production) -> seabird consumption vs. Fishery removals

Anchovy production

Fishery removals

Seabird removals

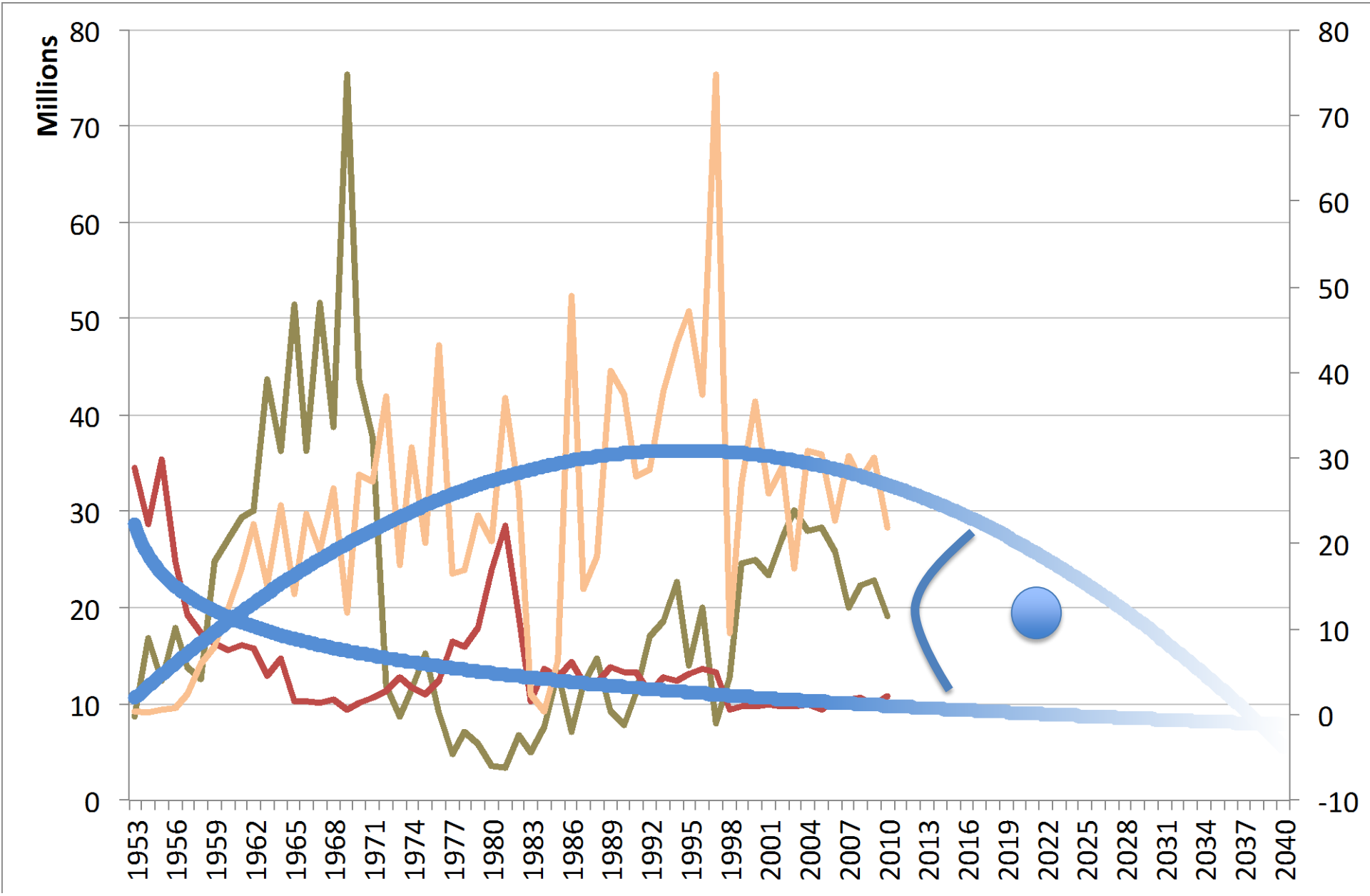
Humboldt Current System



Cormorants
Crashed in 60-65

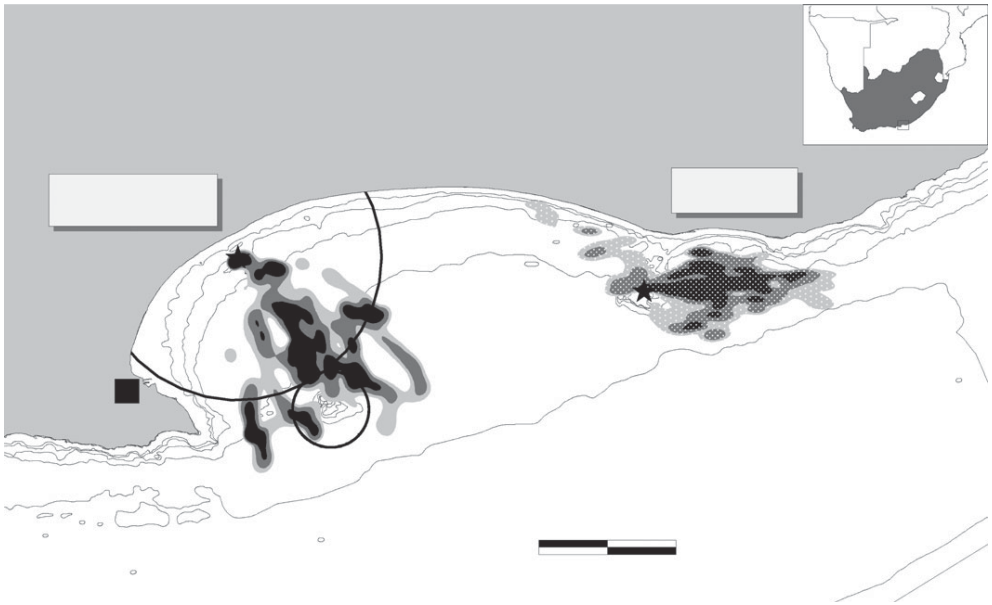
Much before
Fishery Removals > 30%

Humboldt Current System



So what?

Benguela Current System



Purse seine fishing exclusion 10nm around main penguin colonies since 2008

Marine no-take zone rapidly benefits endangered penguin

Pichegru et al 2010
Biol. Let.

Management Implications

- **Diversify modelling/simulation tools: IBM, MICE (Punt et al. 2016)**

- **Management objectives** for the ecosystem
  -> target for seabird population size ,
  especially those requiring large numbers for efficient foraging
  -> Think at seabird communitiy level

- **Ecosystem-based fishing quota definition** (CCAMLR): adaptive quota with biomass escapement rule (e.g krill Antarctica, anchoveta Peru)…
  -> 1/3 for the birds not always enough

- **Temporal pattern of fishery removals** do count:
  -> Overcapacity and race for fish-> localized depletions (IQs?)

- FF abundance not enough, **prey availability** >>>
  ->adaptive regional quotas, fishing closures in areas surrounding seabird colonies (critical periods for abundance and/or accessibility)

Laura E. Koehn (S5) 09/03
Evaluating alternative forage fish harvest control rules from a seabird perspective

William J. Sydeman (S3) 10/03
Small pelagics sheries competition with seabirds: Review and application

Julie A. Thayer (S3) 10/03
Predator forage needs: Comparison and synthesis of bioenergetic and numerical response models

Laura Wise (S3) 10/03
Portuguese purse seine fishery spatio-temporal overlap with top predators

Many thanks