A seabird eye-view on forage fish

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Where?  When?  How much?
Foraging
Behaviour
Foraging 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
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
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


Since 97/98, anchovy recovered, but seabirds did not

System recently highly productive (Field, Gutiérrez, S1)
Namibia: Overfished and collapsed

Vulnerable

Endangered

Endangered

Eastward shift of prey

Pichegru et al. 2009 MEPS

Crawford et al. 2015 Frontiers Ecol. Evol.
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.
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: $\sim 200 \, \text{t.d}^{-1}$
Fishery removals: $\sim 50 \, 000 \, \text{t.d}^{-1}$

Bertrand et al. (2012) JAE
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

Bertrand et al. unpublished
Prey abundance

Prey depth

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

Seabird foraging probability

Boyd et al. 2014/2015a/2015b/2016a/2016b
Boyd et al. (2016) Behav. Ecol.

Abundance and distribution of prey

Depth = primary factor of seabird foraging success

Prey accessibility +++

Social information

Important when prey spatially concentrated and for mitigating poor foraging conditions

Seabird population size -> efficient foraging

Boyd et al. (2016) JAE
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
Interannual variability: Unprofitable foraging and starving seabirds

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 $\sim$ env. Parameters seasonality by period

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### Species-specific breeding adjustment
A shift of 'abundance-driven' versus 'accessibility-driven' breeding seasonality?

Passuni et al. submitted
Foraging  Breeding  Demography
How much?
Prey abundance (biomass) -> breeding success

Cury et al. 2011
Robinson et al. 2015
Punt et al. 2016

1 / 3
1 / 4  Bmax <10%

7 ecosystems 14 species
Penguin SA
Brown Pelican California
Anchovy production
Fishery removals
Seabird removals
Prey abundance (new production) -> seabird consumption vs. Fishery removals

Humboldt Current System

![Graph showing time series of millions and percentages for Anchovy production, Fishery removals, and Seabird removals from 1953 to 2010.](image-url)
Humboldt Current System

Cormorants Crashed in 60-65
Much before Fishery Removals > 30%

20.10^6
~30%

~0.4%
40 \times 10^3 T

~22%
6.10^6 T

3.10^6
~2%
So what?
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.
- **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 community 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