

Session 4

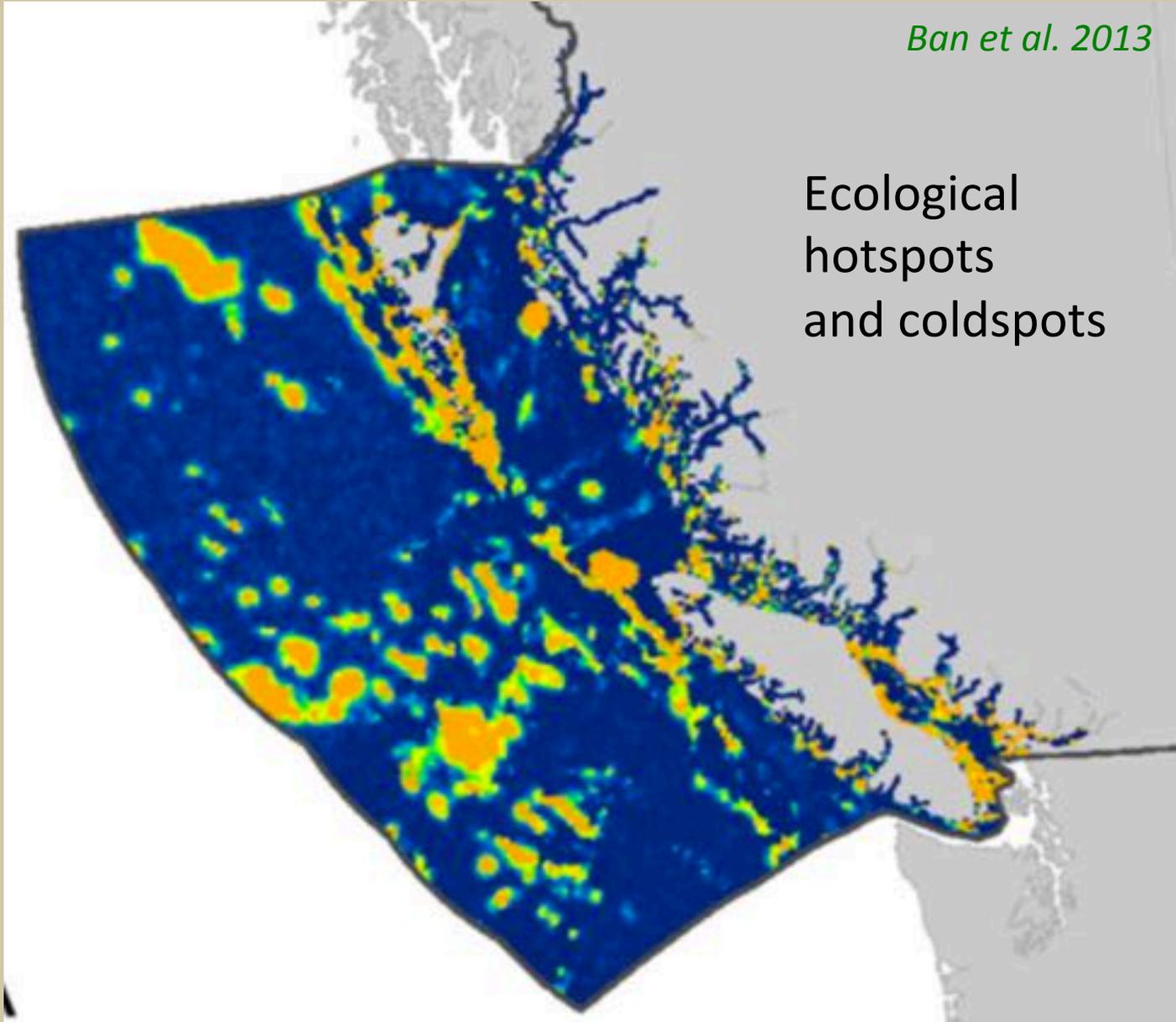
Use of ecological data in MSP tools:

Myth or reality ?

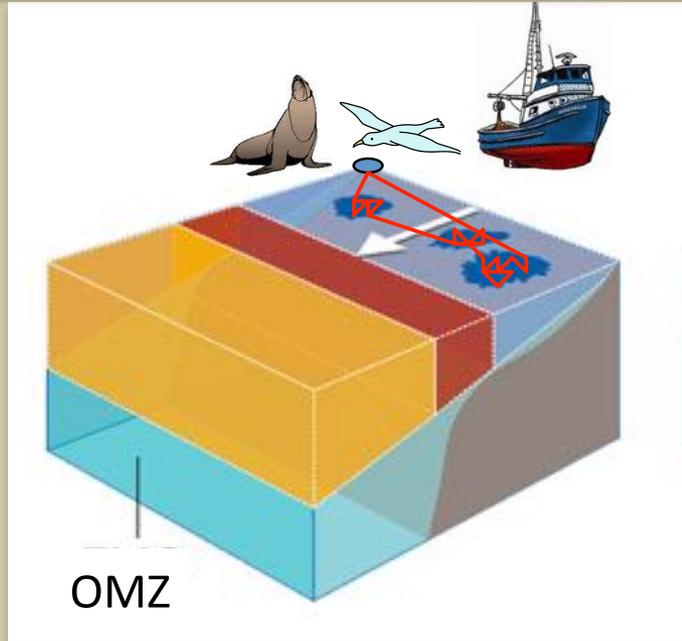
Sophie BERTRAND
Anne LEBOURGES-DHAUSSY
Matthieu LE TIXERANT



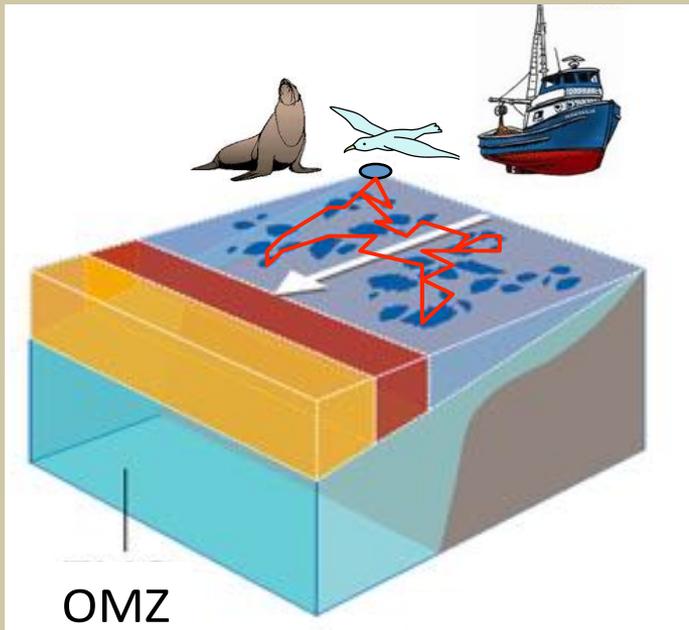
What, you, marine spatial planners, wait for



What, us, marine ecologists, deal with

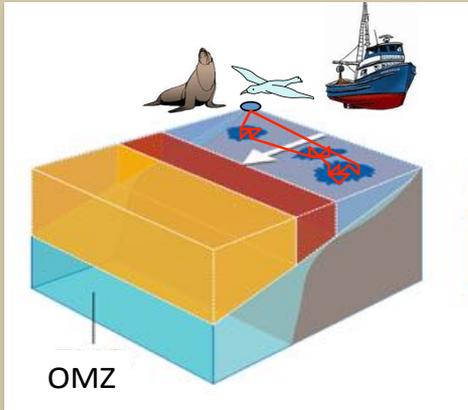


- 3D seascape
- Opaque
- Spatially and temporally dynamic
- Great variety of species / ecologies / behaviours



Marine systems /attributes particularly difficult to demarcate for purposes of management

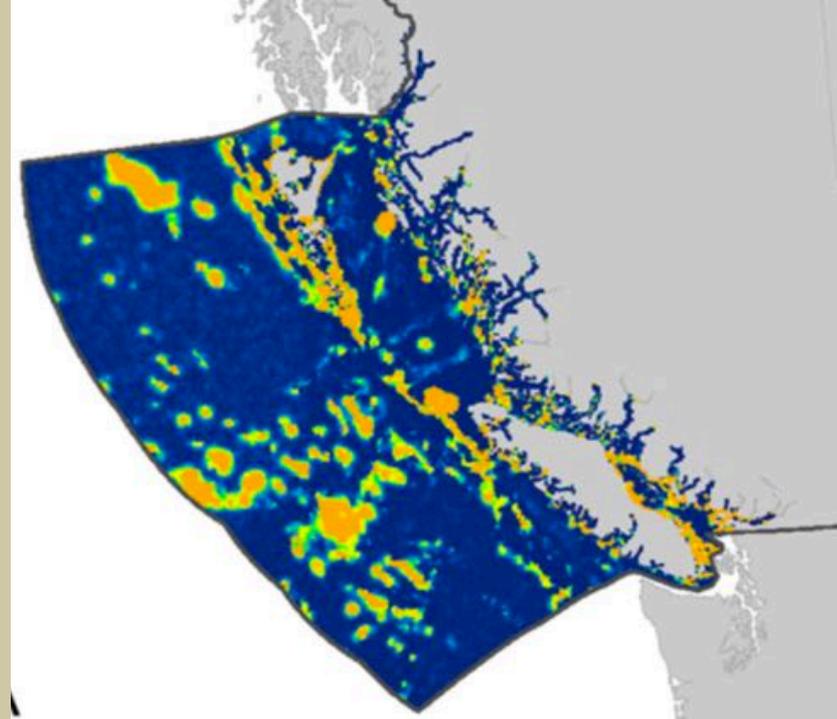
What's needed in between?



Observation instruments
Data analysis
Statistical modelling



High frequency,
multiscale, and
synoptic
characterization of
the 4-D variability
(3D space plus time)
of seascapes



Marine acoustics
Plankton/fish

Biologging
Megafauna

AIS
Vessels

How can **biologging** data
on **megafauna** be used for
marine spatial planning?

Sophie BERTRAND, IRD

- 1. What is marine megafauna?**
- 2. Threats to marine megafauna and possible answers?**
- 3. What is biologging?**
- 4. How can this data feed existing MSP approaches?**

1. What is marine megafauna?



1. What is marine megafauna?

- **Highly mobile** animals that move across large areas of sea
- **Biologically diverse** group, large vertebrates
Includes sea mammals, birds, reptiles, large fish and elasmobranchs
- **Top of their trophic food webs**, none or few predators
- **Limited resilience (low fecundity rates and high longevity)**
- **Shared conservation issues**

1. What is marine megafauna?

Marine megafauna =
key element of many marine conservation strategies

- **Charismatic** large marine vertebrates
- Used as **flagships** to mobilize society on conservation issues.
- Potential **indicator** of the ecological status
of other less visible compartments of marine ecosystems
- Useful as **umbrella** species :
Large home ranges and high trophic level
-> conservation measures focusing upon marine
megafauna often benefit lower trophic level species

2. Marine megafauna: threats

Marine defaunation

McCauley et al. 2015



Timeline (log scale) of marine and terrestrial defaunation. The marine defaunation experience is much less advanced, even though humans have been harvesting ocean wildlife for thousands of years. The recent industrialization of this harvest, however, initiated an era of intense marine wildlife declines. If left unmanaged, we predict that marine habitat alteration, along with climate change (colored bar: IPCC warming), will exacerbate marine defaunation.

2. Marine megafauna : threats

Direct mortality / accidental catch

Effects on population size

Petrels, albatrosses

Longlines, trawl, nets

Melvin & Parrish, 1999
Bull, 2007; Anderson et al. 2011

Effects on evolutive aspects

Behavioural selection

Great albatros

Possession island, Crozet

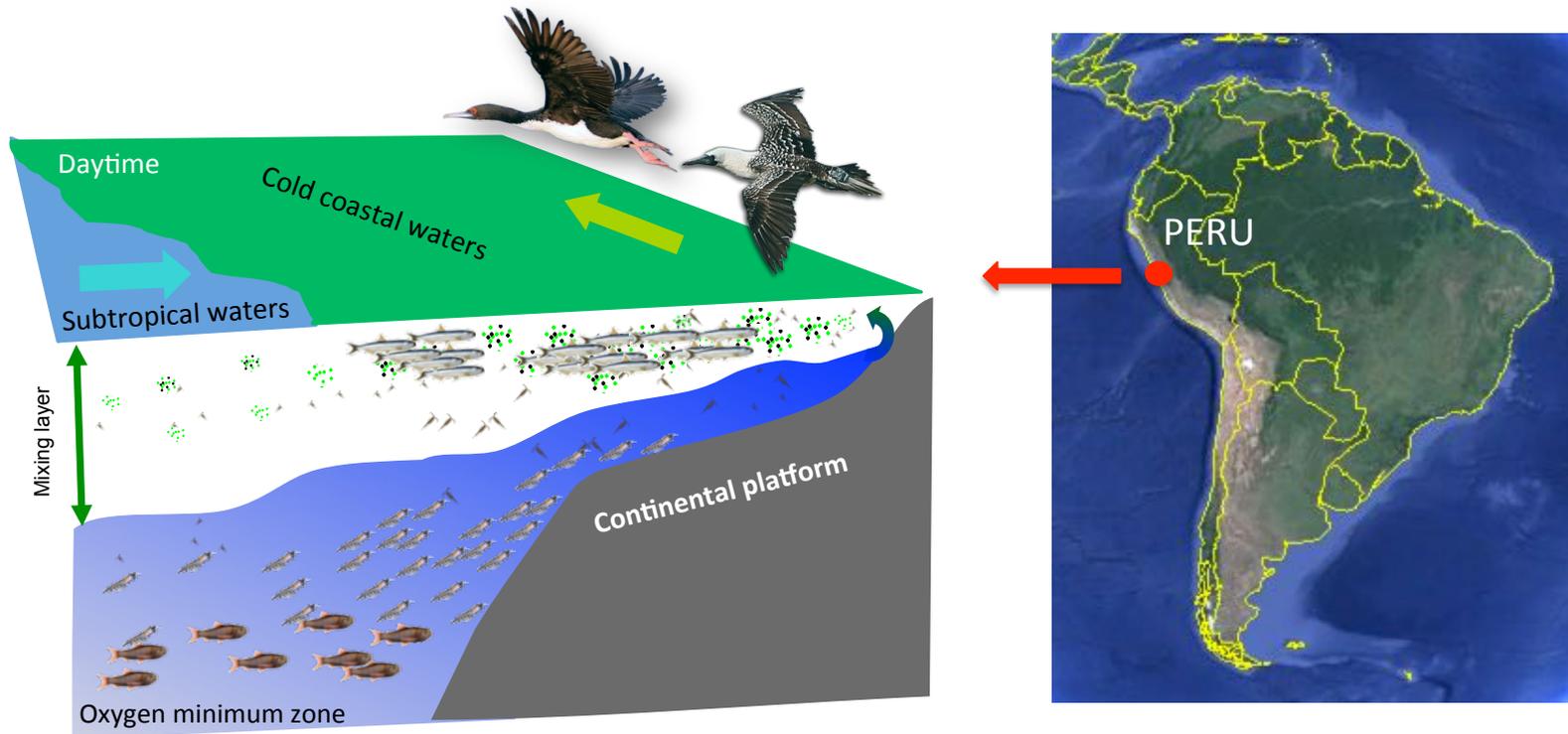
Longlines

Barbraud et al., 2013



2. Marine megafauna: threats

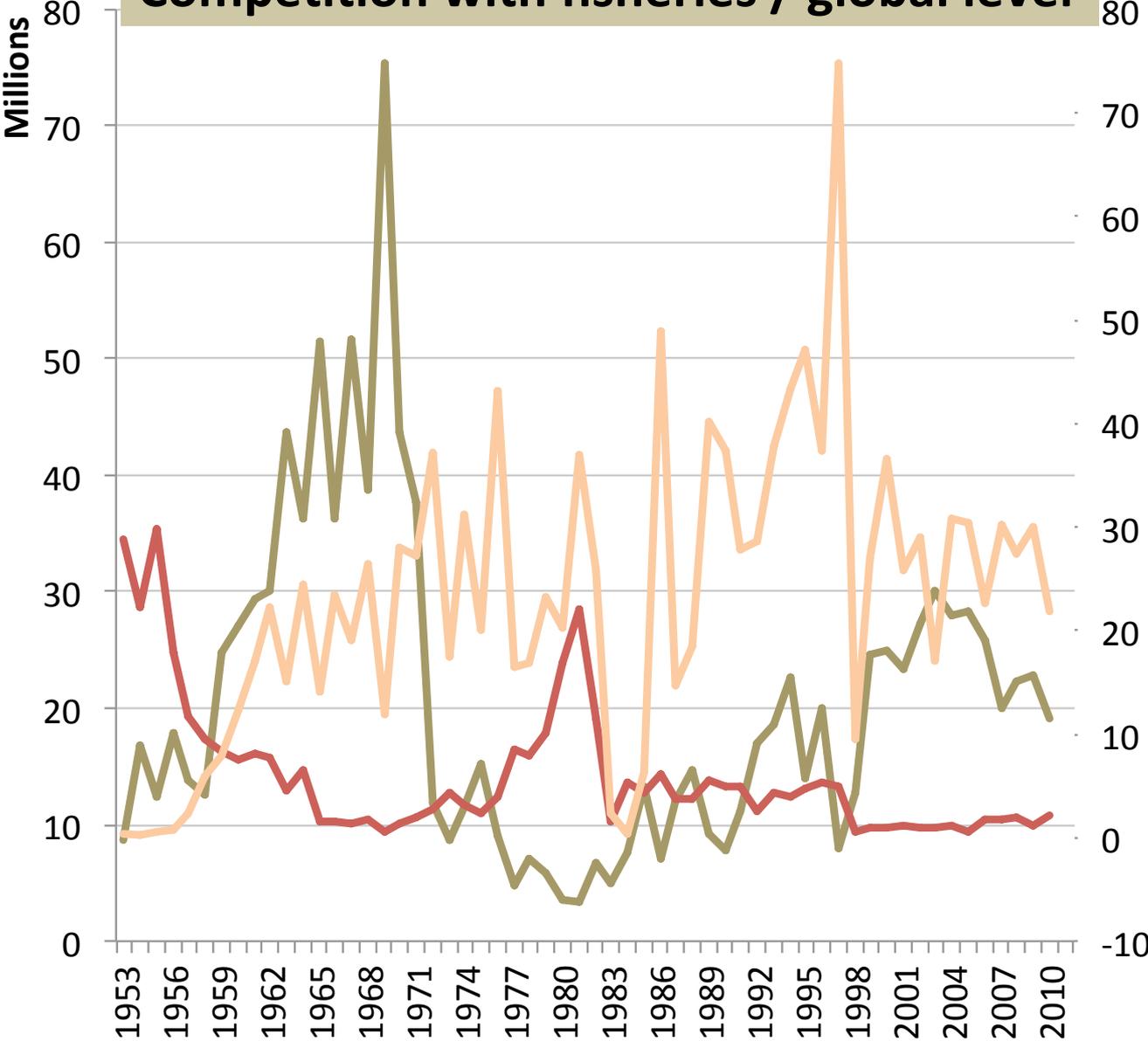
Competition with fisheries



- 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, $\sim 6 \cdot 10^6 \text{t} \cdot \text{y}^{-1}$)
- Large guano producing seabird populations ($\sim 4 \cdot 10^6$ ind.)
- Ecosystem-based fisheries management issues

2. Marine megafauna: threats

Competition with fisheries / global level



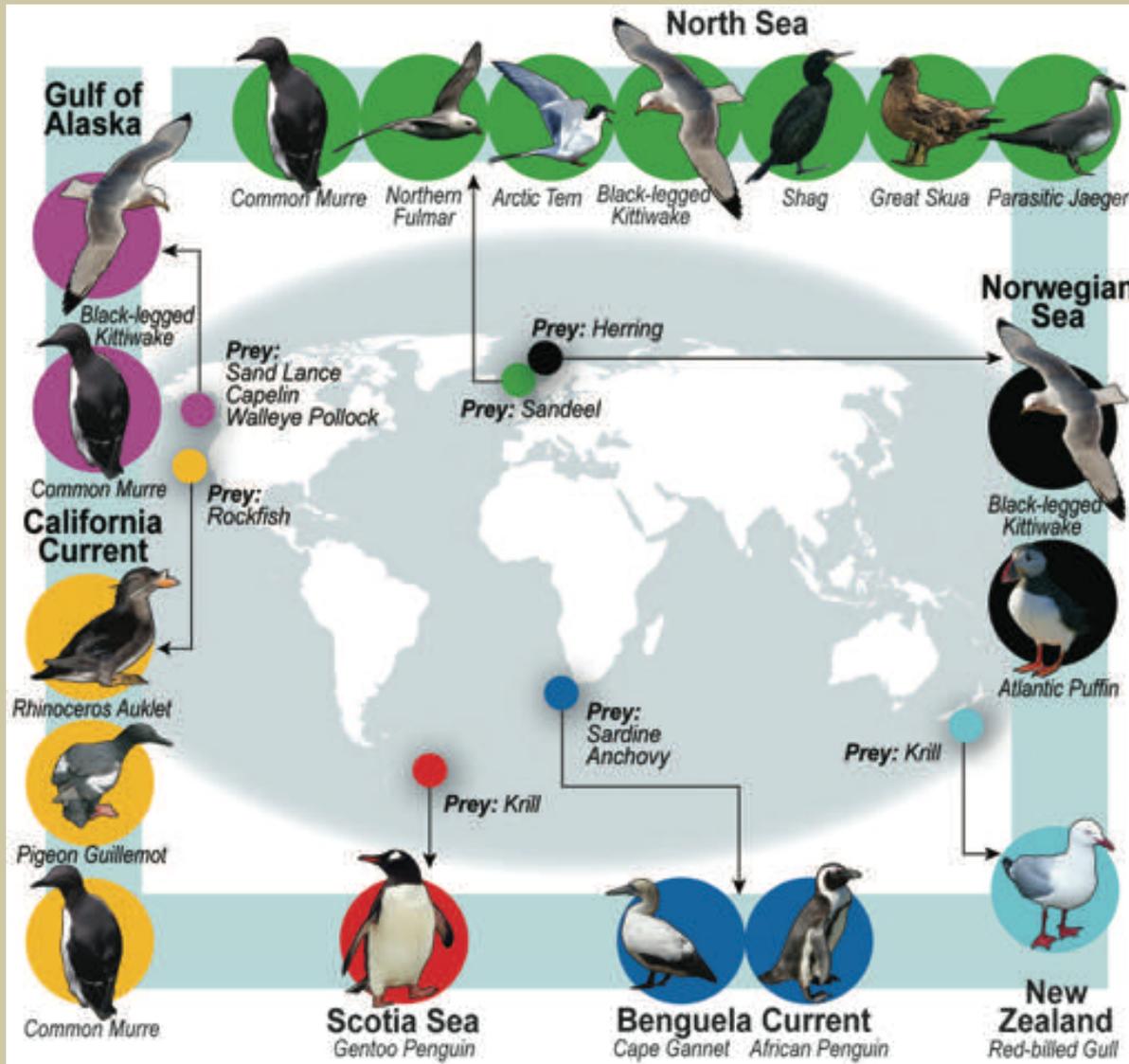
Humboldt Current System

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

- Anchovy production
- Fishery removals
- Seabird removals

2. Marine megafauna: threats

Competition with fisheries / global level



14 species
7 ecosystems

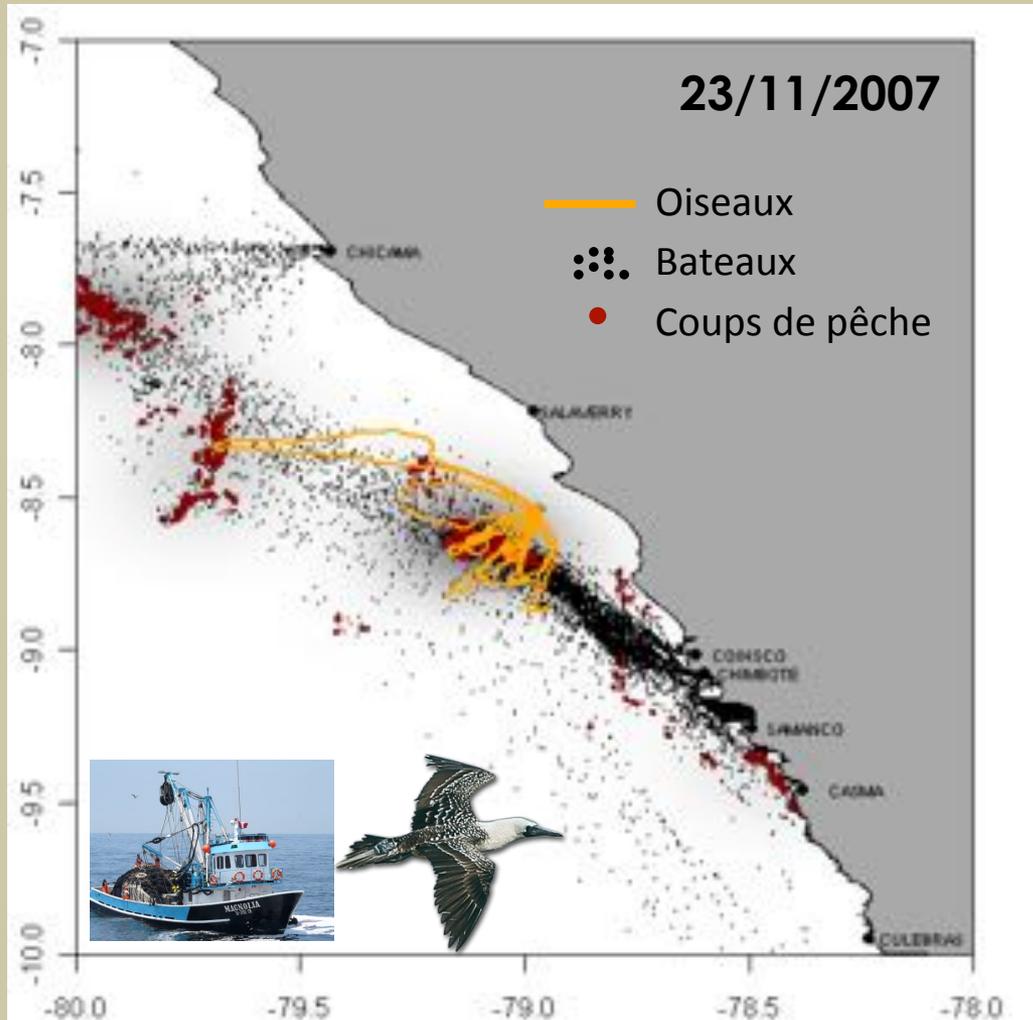
Breeding success and fish
prey abundance

Threshold effect
« 1/3 for the birds »

2. Marine megafauna: threats

Competition with fisheries / local level

Bertrand et al. 2012



Peru

Peruvian boobies

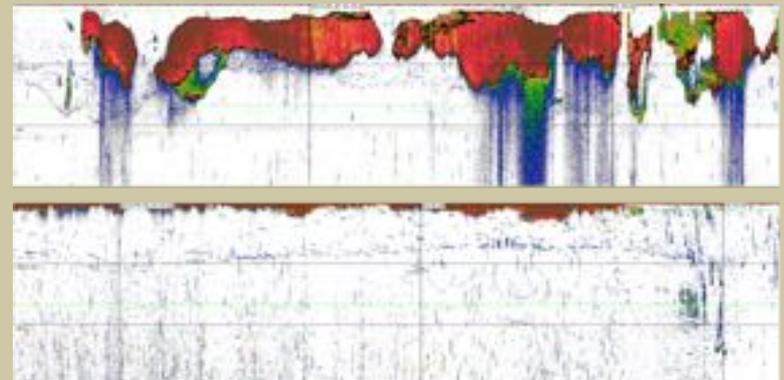
Anchovy purse seiners

Local depletions

Competition for prey

Seabird needs: $\sim 200 \text{ t.d}^{-1}$

Fishery removals: $\sim 50\,000 \text{ t.d}^{-1}$



2. Marine megafauna: threats

Fishery discards as junk food

Cape gannets
South Africa
From fat blue fish
to white fish
discards

Grémillet et al. 2008



© M. Hardenberg



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2. Marine megafauna: threats

Entanglement risk – Anthropogenic activities at sea

- Fisheries gear (active and ghost)
- Aquaculture
- Offshore petrochemical industry
- Marine telecommunication cables
- Vessel moorings
- Wind turbines?

Benjamin et al. 2014

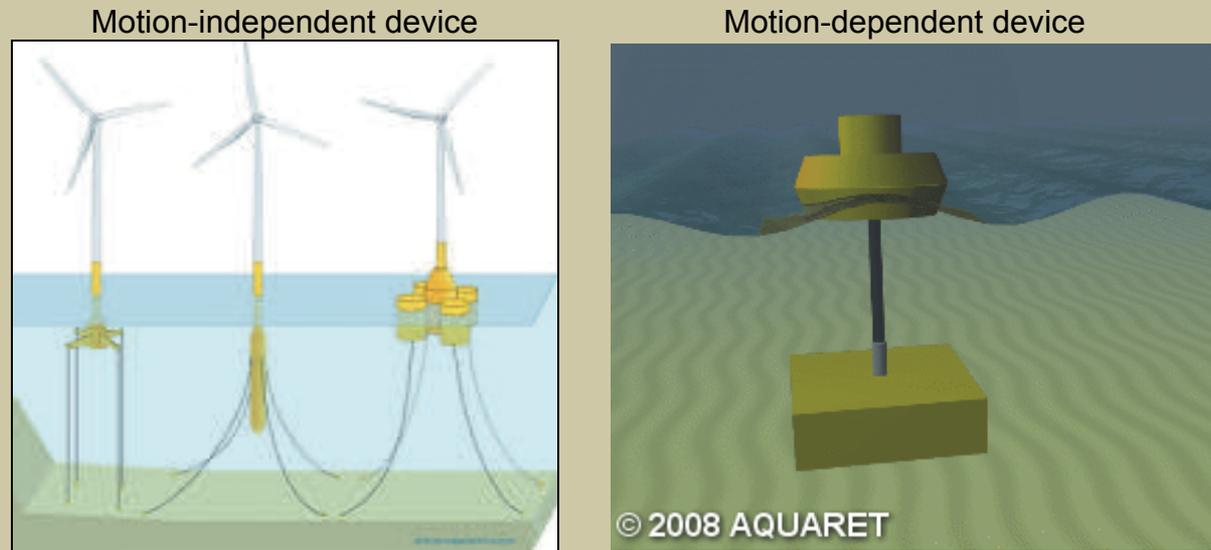
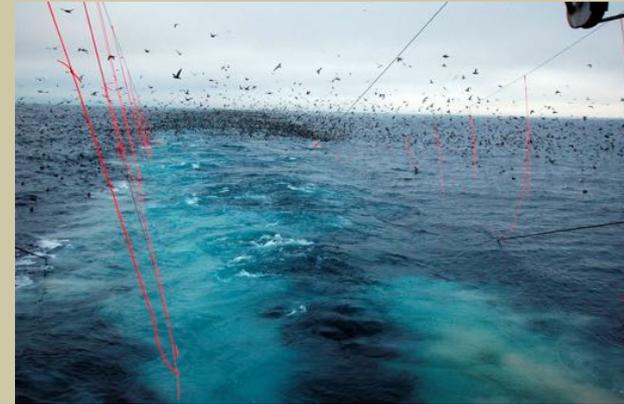


Figure 3.1 Example of motion-independent (floating wind turbines) and motion-dependent devices (wave energy point absorber; source: Aquaret). The motion-dependent device is designed to be far more mobile, with potential entanglement consequences.

2. Marine megafauna: threats

What can be done?

- Technical solutions for accidental catches
- Ban on discards (see EU)
- Ecosystemic quotas for securing 1/3
- **Marine protected areas** for managing local depletions and direct interactions:
Hot debate
Conservation first (sea enclosure) or
compromise with human activities (MSP)?
Pelagic MPA?



3. What is biologging?



3. What is biologging?

Tremblay and Bertrand 2016
Hays et al. 2016

- “Recording of the living world”
- Use of **miniaturised** animal-**attached** tags for logging or transmission of data about the movements, behaviour, physiology, or environment of an animal
- Remote transmission (biotelemetry) or data stored on tags that must be recovered for download
- **Different from « marking »**: attaching a mark (such as a band for a bird) to an animal to identify it, as a tool for population biology studies (survival rates, population monitoring, etc.
-> CMR techniques

3. What is biologging?

Arsenal of sensors

GPS
Dive sensors
Tri-accelerometers
Cameras
Gastric temperature
EEG
Cardiac recorder, etc.

Variety of data

Location (residency, migration)
Behaviour (foraging, resting, etc.)
Caloric expenditure (cost of activities)
Collective behaviour and social strategies
External environment

From biologging to MSP

Interpreting and modelling multi-dimension data sets

Biologging technologies + state of the art movement ecology statistics

-> dynamic ecological niches of megafauna species

-> delineate **spatial hotspots and coldspots**

-> improved statement of conservation issues within a marine spatial planning framework.

3. What is biologging?

Which instrument
On which animal?

Geolocation
techniques

Harsh
environments

Weight and
drag issues



3. What is biologging?

Movement logging

VHF



3. What is biologging?

Movement logging



VHF



3. What is biologging?

Movement logging



GPS



3. What is biologging?

Movement logging

GLS

Bertrand et al. current work in Noronha



3. What is biologging?

Green et al. 2009

GLS

Pop up archival tags



Movement logging

Figure 1. (a) Implantable archival tag. (b) Pop-up satellite archival tag (PAT) used in the study of wide-ranging pelagic vertebrates. (c) Surgical implantation of archival tag in a bluefin tuna. (d) Bluefin tuna swimming in situ with PAT tag attached.



3. What is biologging?

Movement logging

Types of movement

seasonal migration

foraging

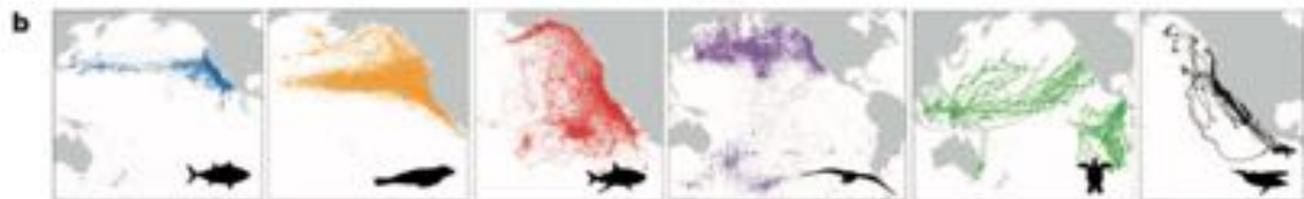
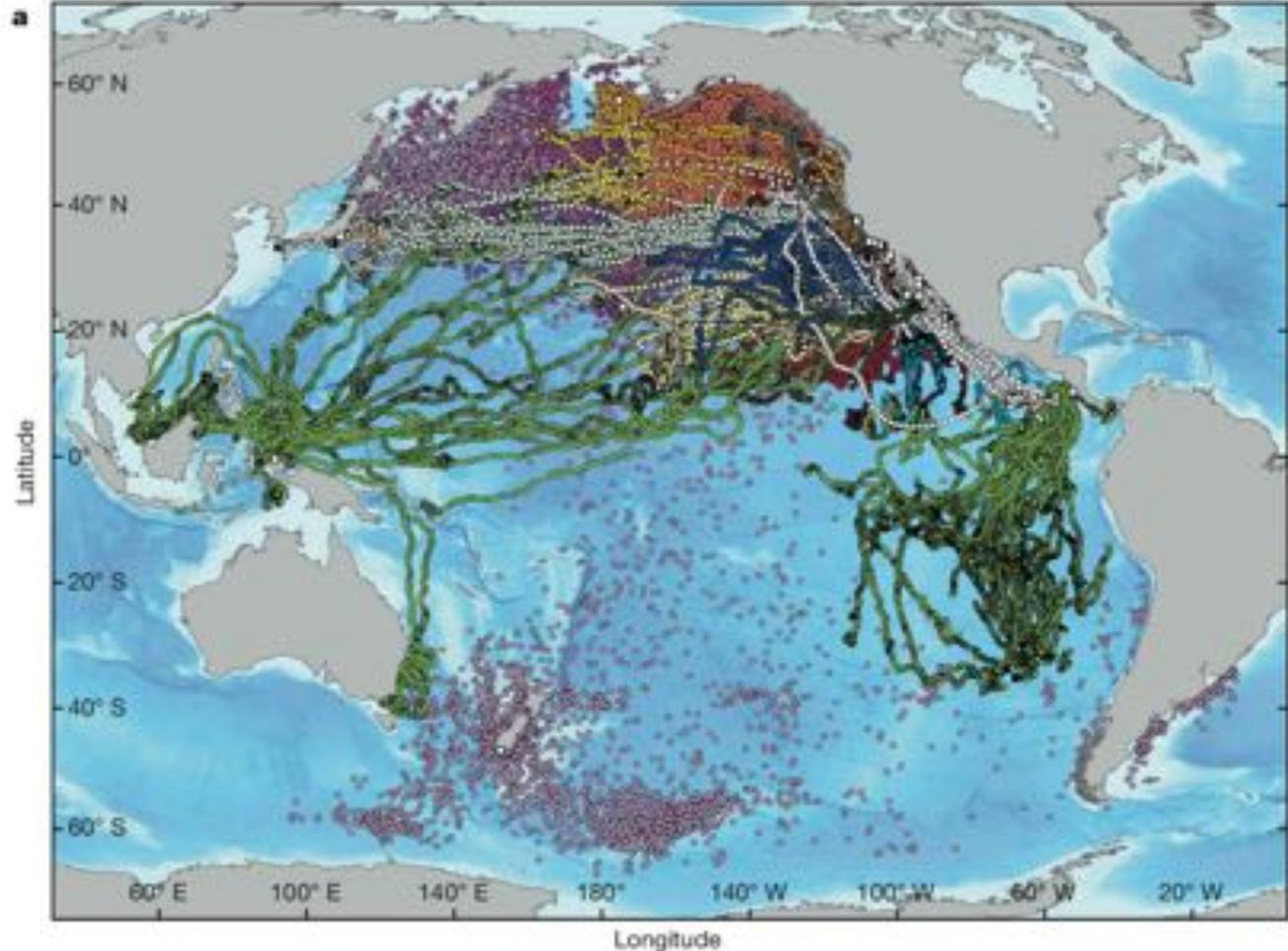
wandering

dispersal

nomadism

nyctemeral migration

ontogenic migration

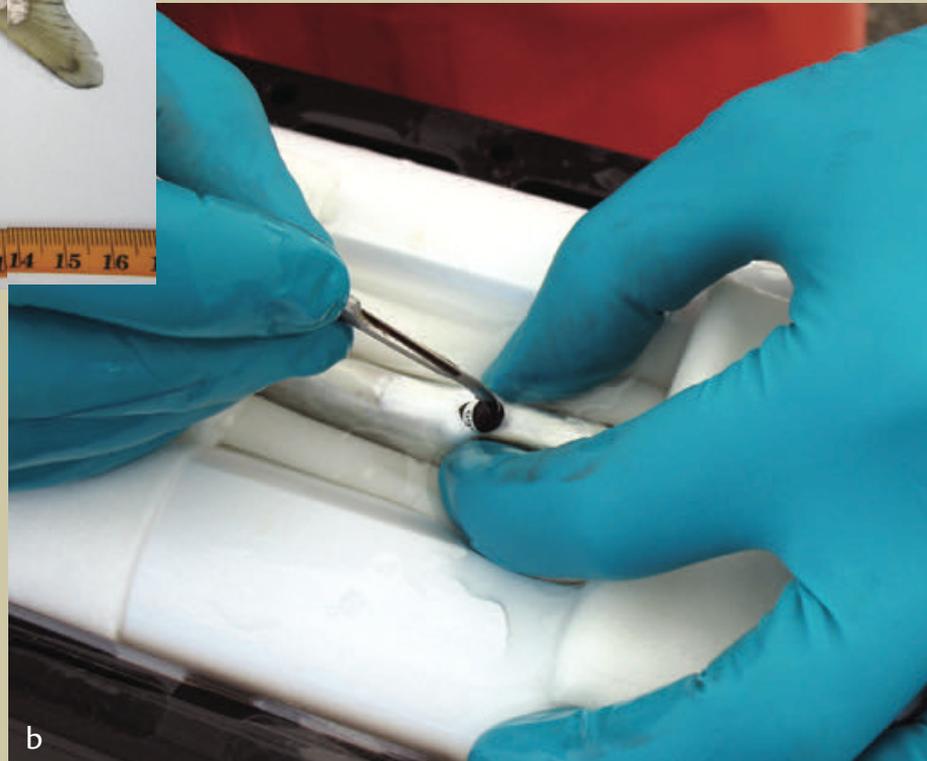


Implantable acoustic tags

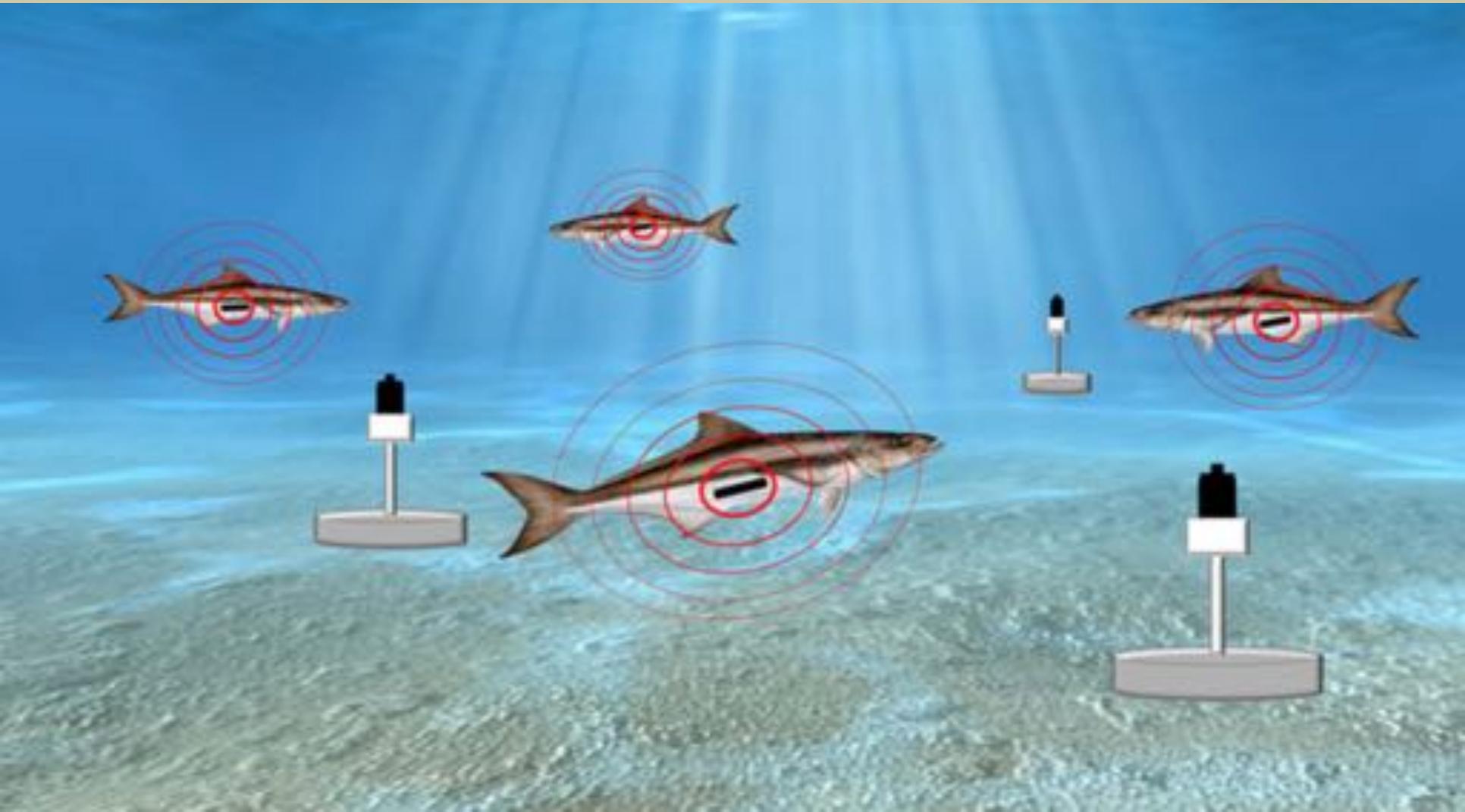
Green et al. 2009



Figure 4. (a) Relative sizes of acoustic tags and a juvenile salmon. (b) Surgical implantation of acoustic tag.



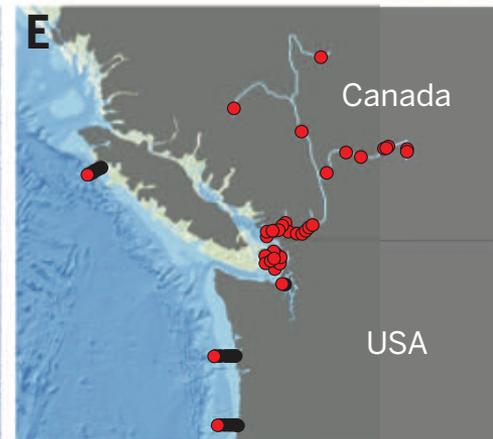
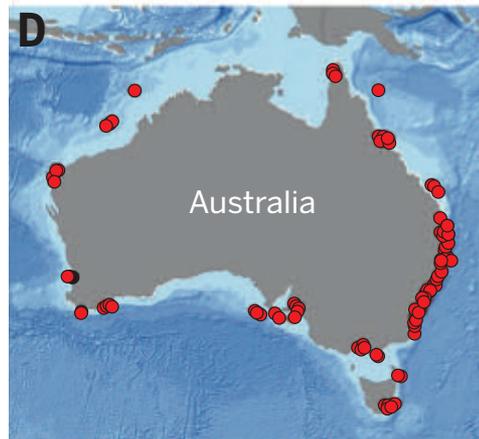
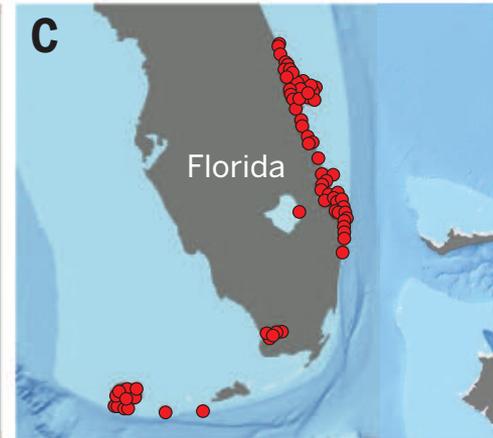
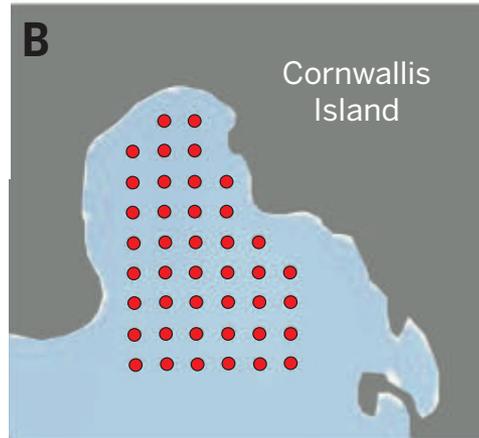
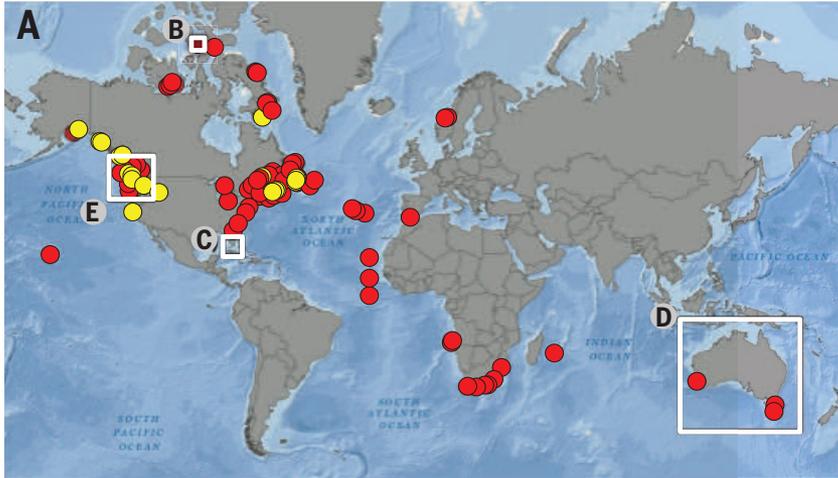
Acoustic network





3. What is biologging?

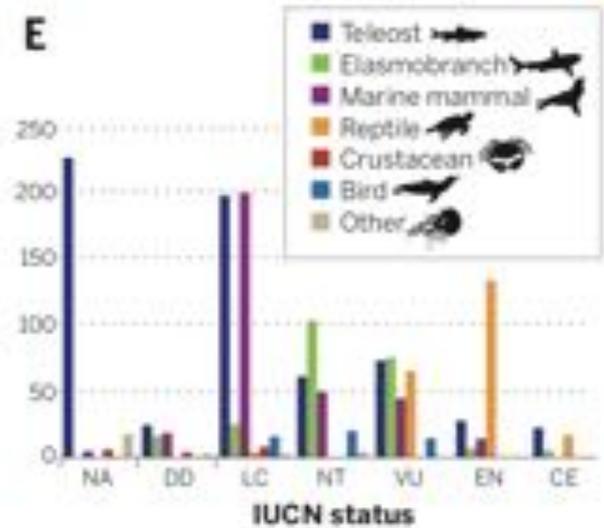
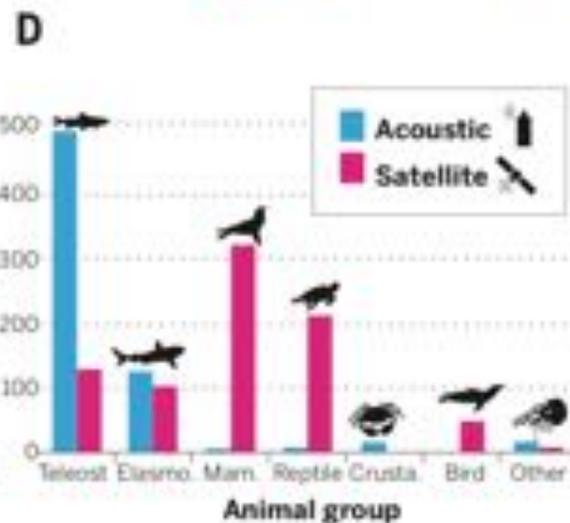
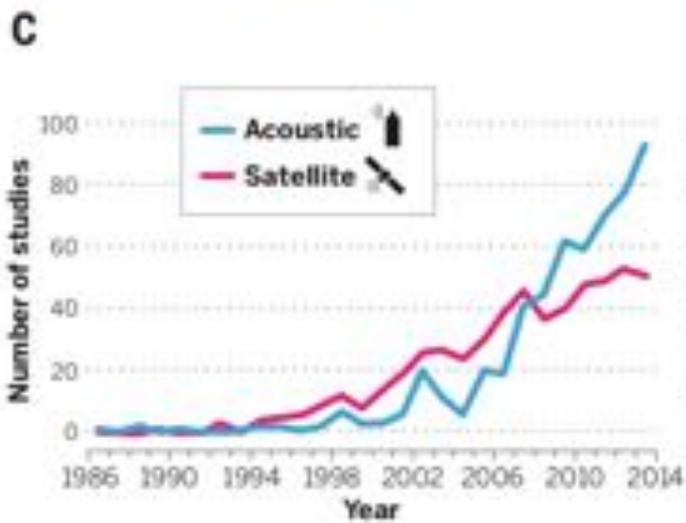
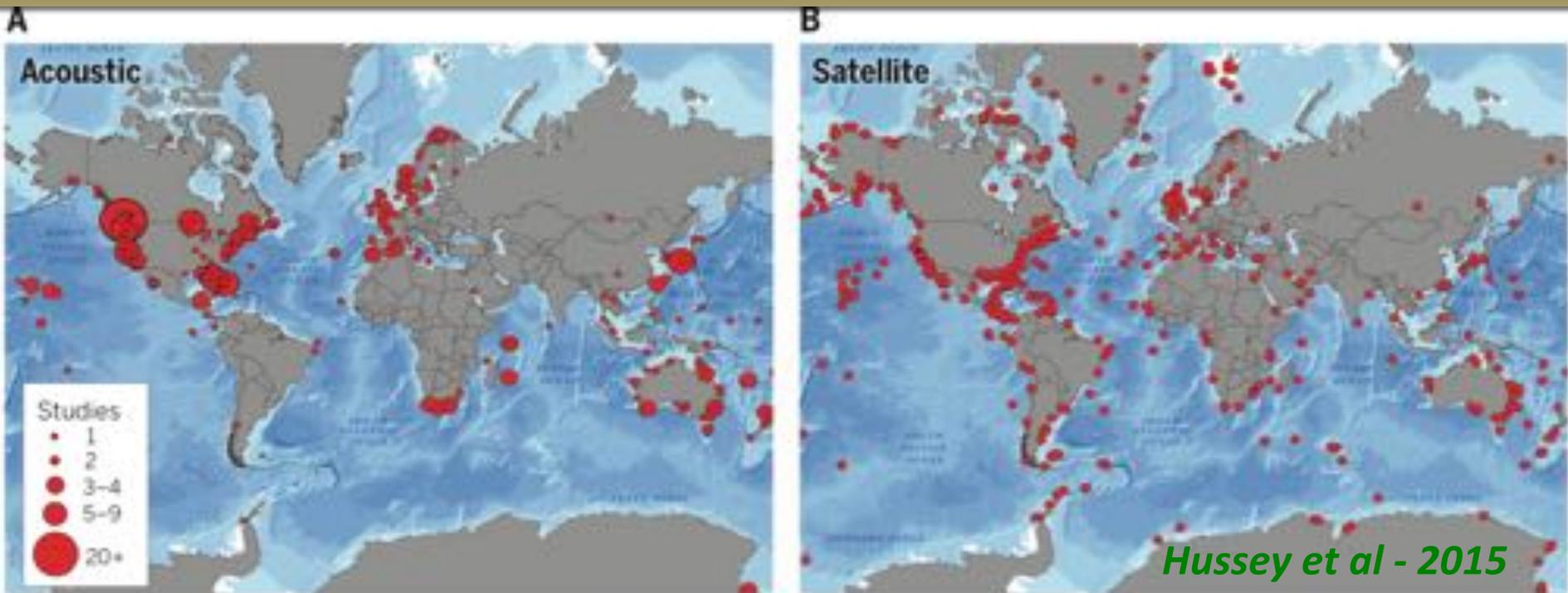
Movement logging



Hussey et al - 2015

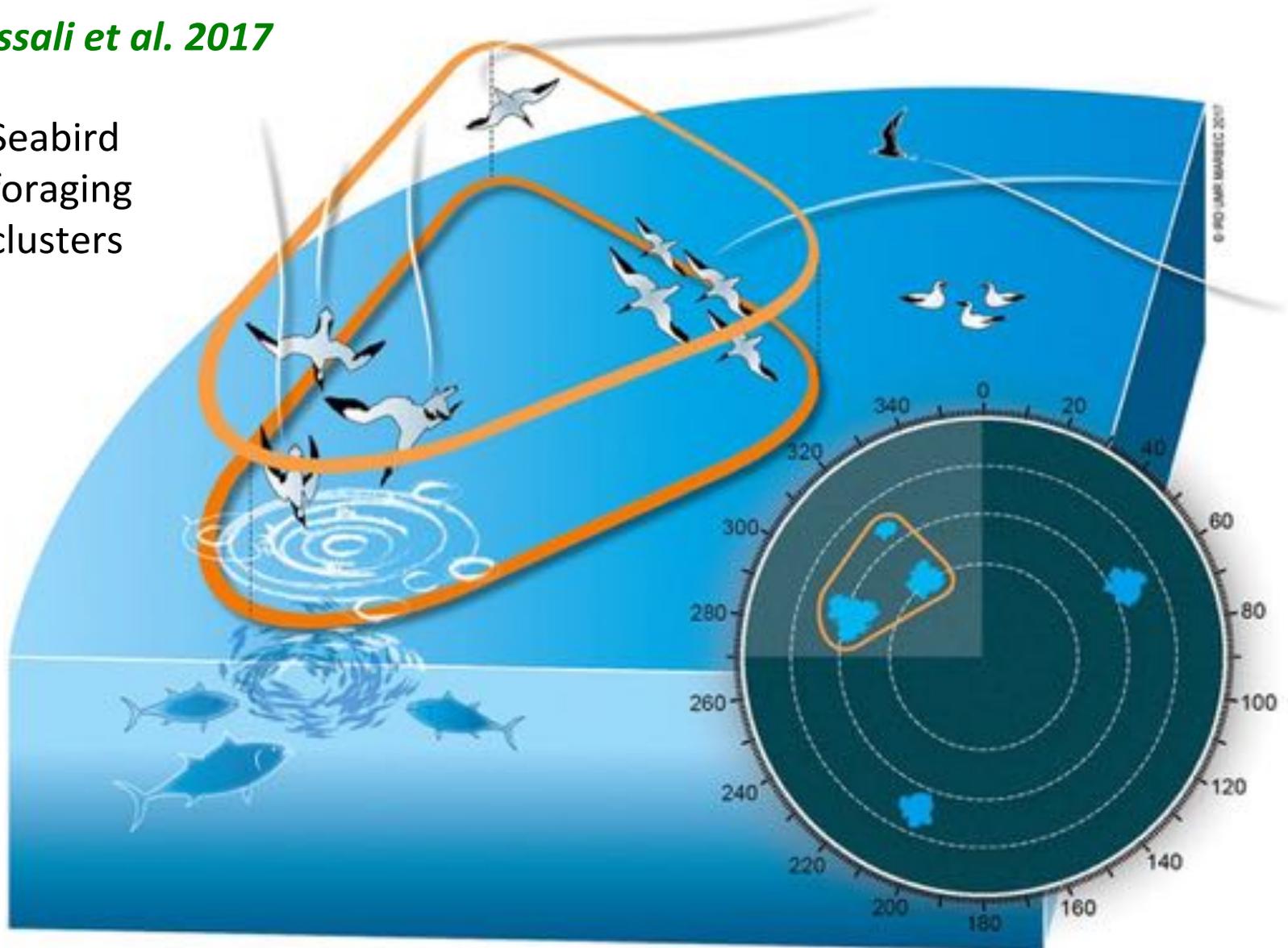
3. What is biologging?

Movement logging



Assali et al. 2017

Seabird
foraging
clusters

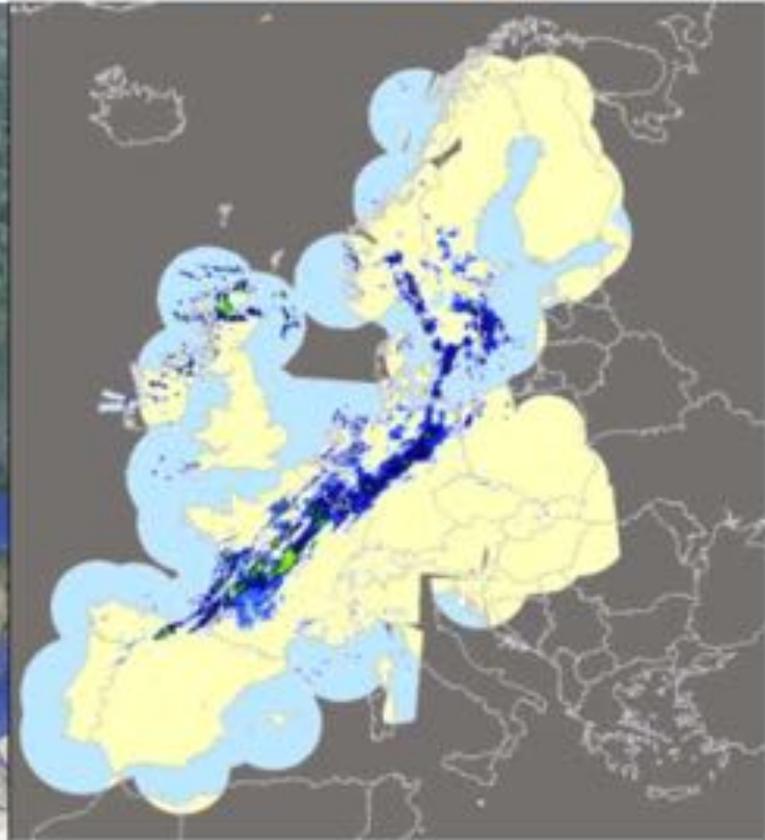


How can we monitor bird movement at the continental scale?

ENRAM weather radars



ENRAM coverage



Behavioural measurements

- Pressure sensors (TDR) linked to a time base
 - > diving behaviors of marine birds and mammals
- Altimeters for birds
- Accelerometers and magnetometers
 - > 3D representation of movement
 - > feed intake
 - > energy expenditure
 - > feeding activities (mandibular opening)
- Internal temperature
 - > feed intake (stomach logger)
- Conductivity sensors: dry/wet states
 - > birds flying or resting on water
- Hydrophones
 - > animals reaction to their sound environment



3. What is biologging?

Behaviour logging

Behavioural measurements

Weimerskirch et al. 2003

Weimerskirch et al. 2004

Altimeters + GPS

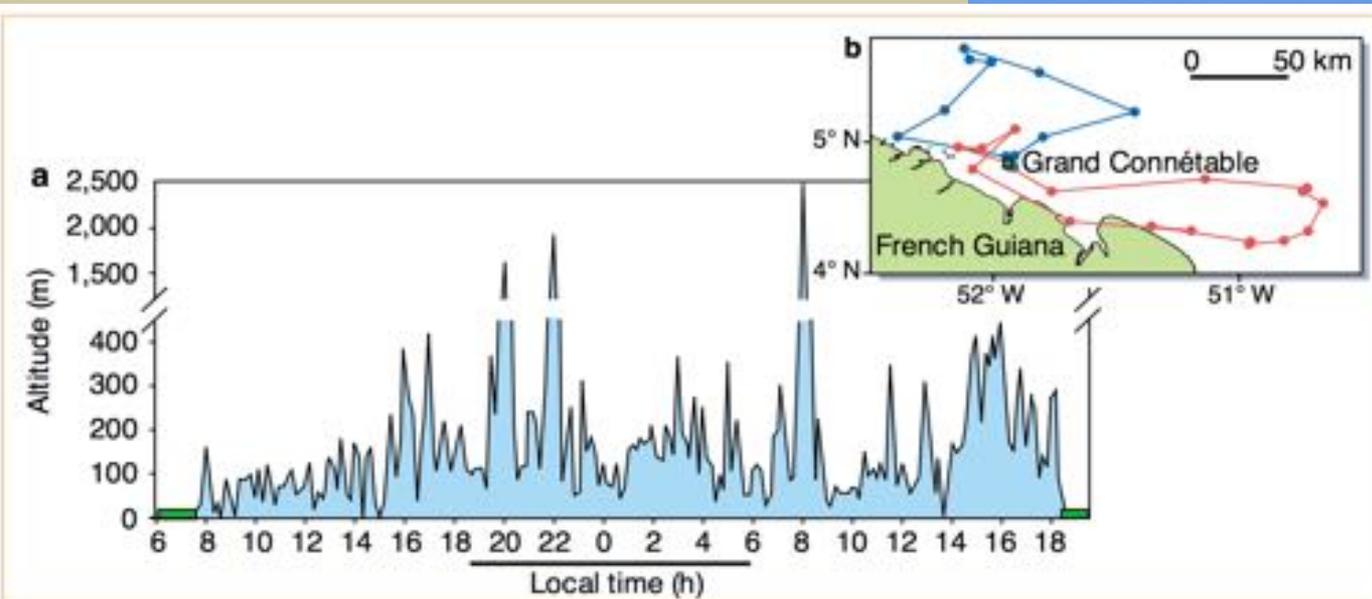
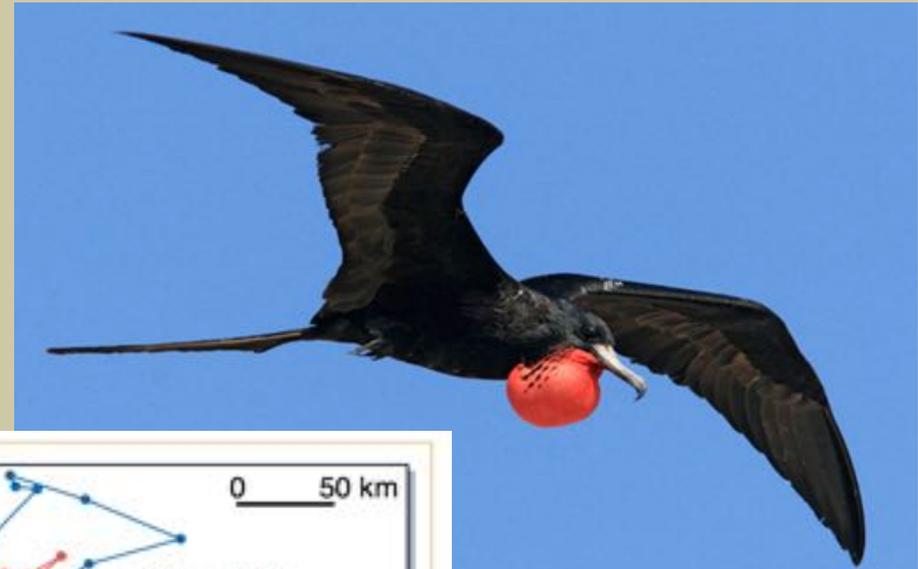
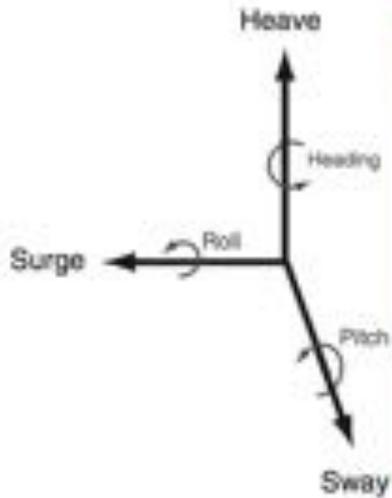


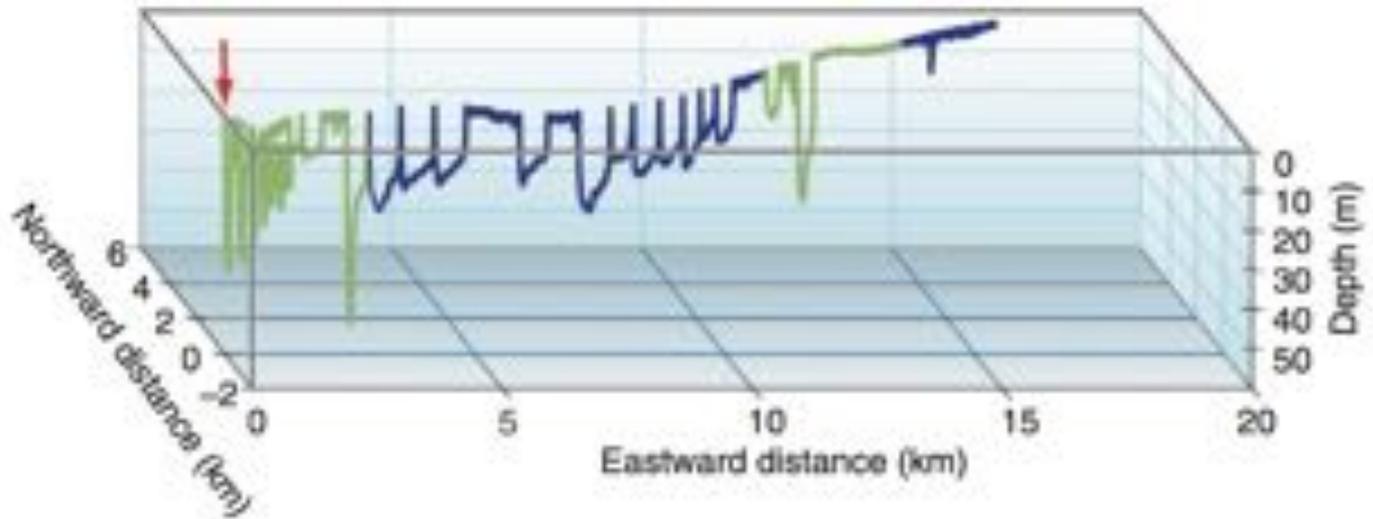
Figure 2 Foraging movements of flying frigatebirds, as revealed by altimetry (for vertical movements) and satellite telemetry (for horizontal movements). **a**, Vertical flight pattern of a sample female during a foraging trip, recorded over two days (24 and 25 April 2002). Black bar shows hours of darkness; green bars represent periods when the bird is in its nest in the colony. **b**, Horizontal movements of two frigatebirds (blue, brooding male; red, incubating female) foraging from the breeding colony (green box) and tracked by satellite telemetry.

3. What is biologging?

Behaviour logging

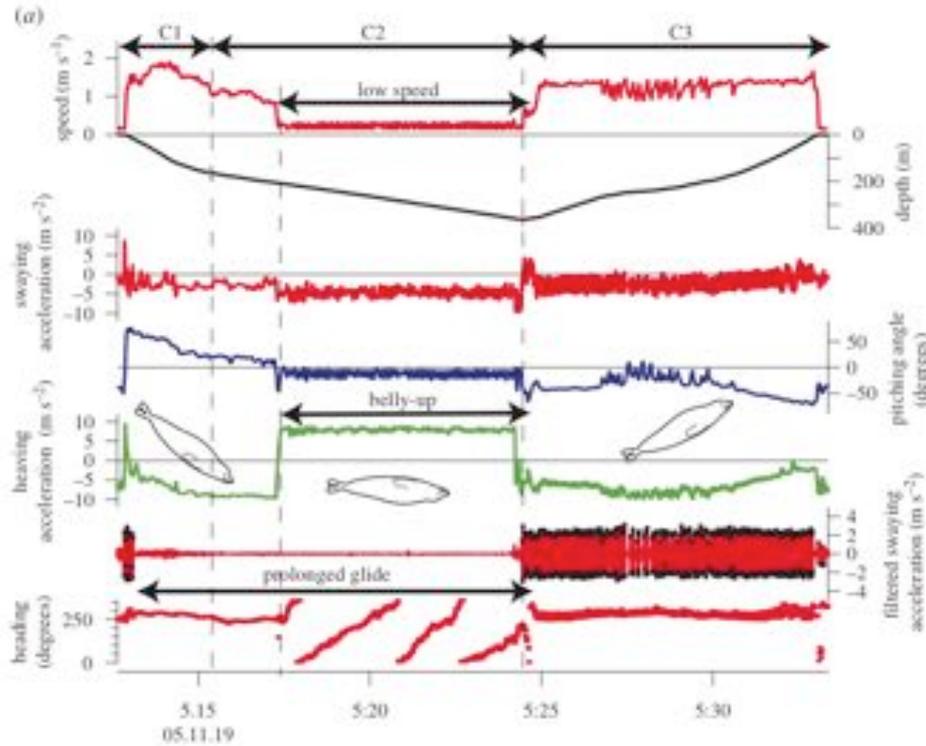


Accelerometers / TDR



Narazaki et al - 2009

3. What is biologging?



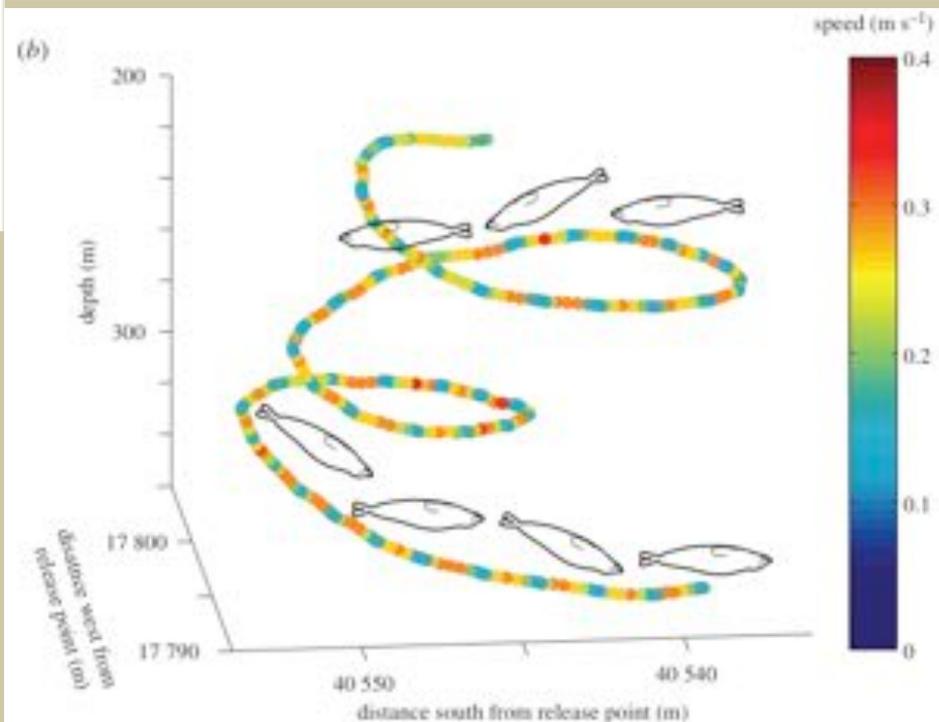
3D resting behaviour of northern elephant seals: drifting like a falling leaf

Behaviour logging

Accelerometers

TDR

Mitani et al - 2009



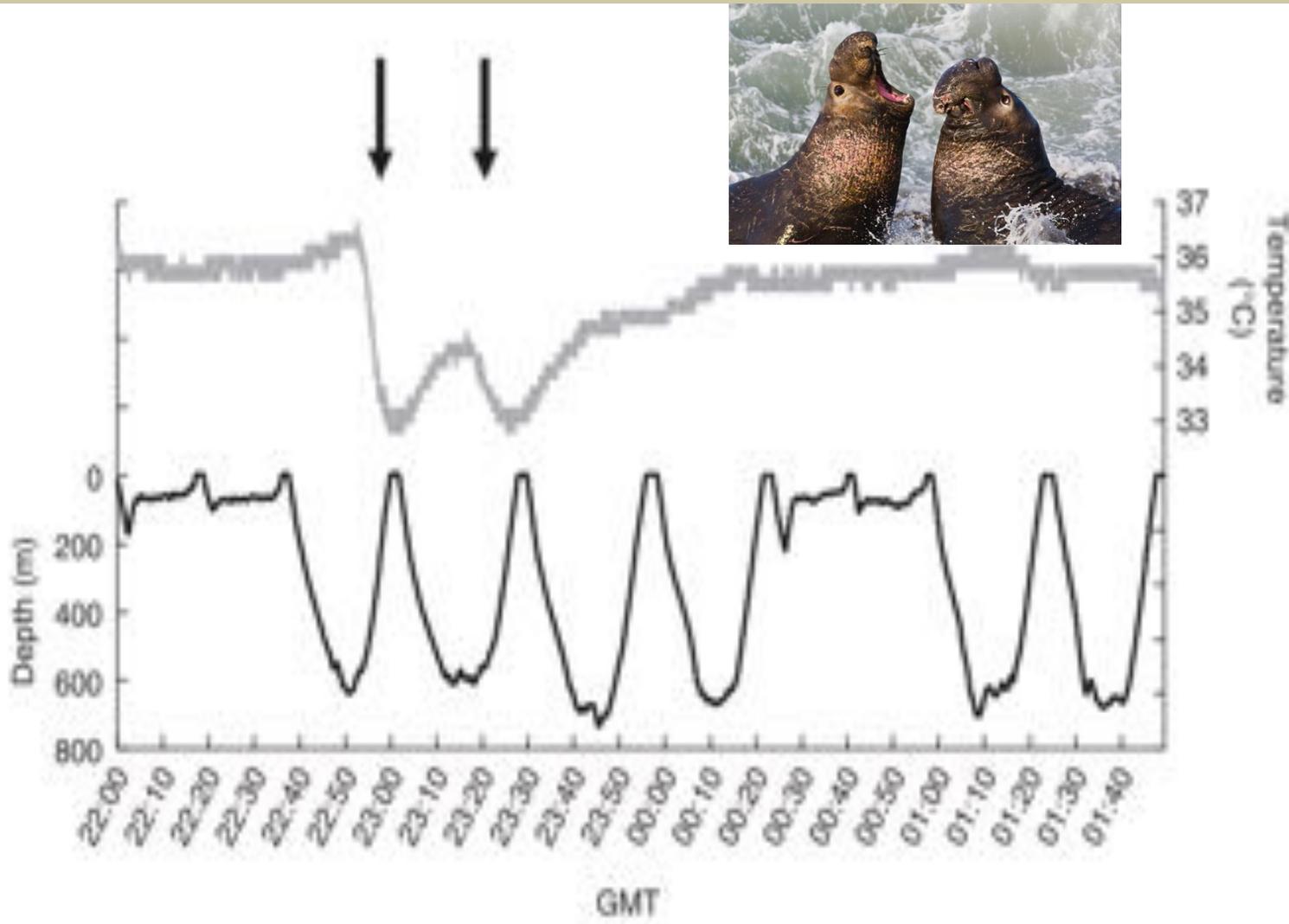
3. What is biologging?

Behaviour logging

Kuhn et al - 2009

Gastric temperature loggers + TDR

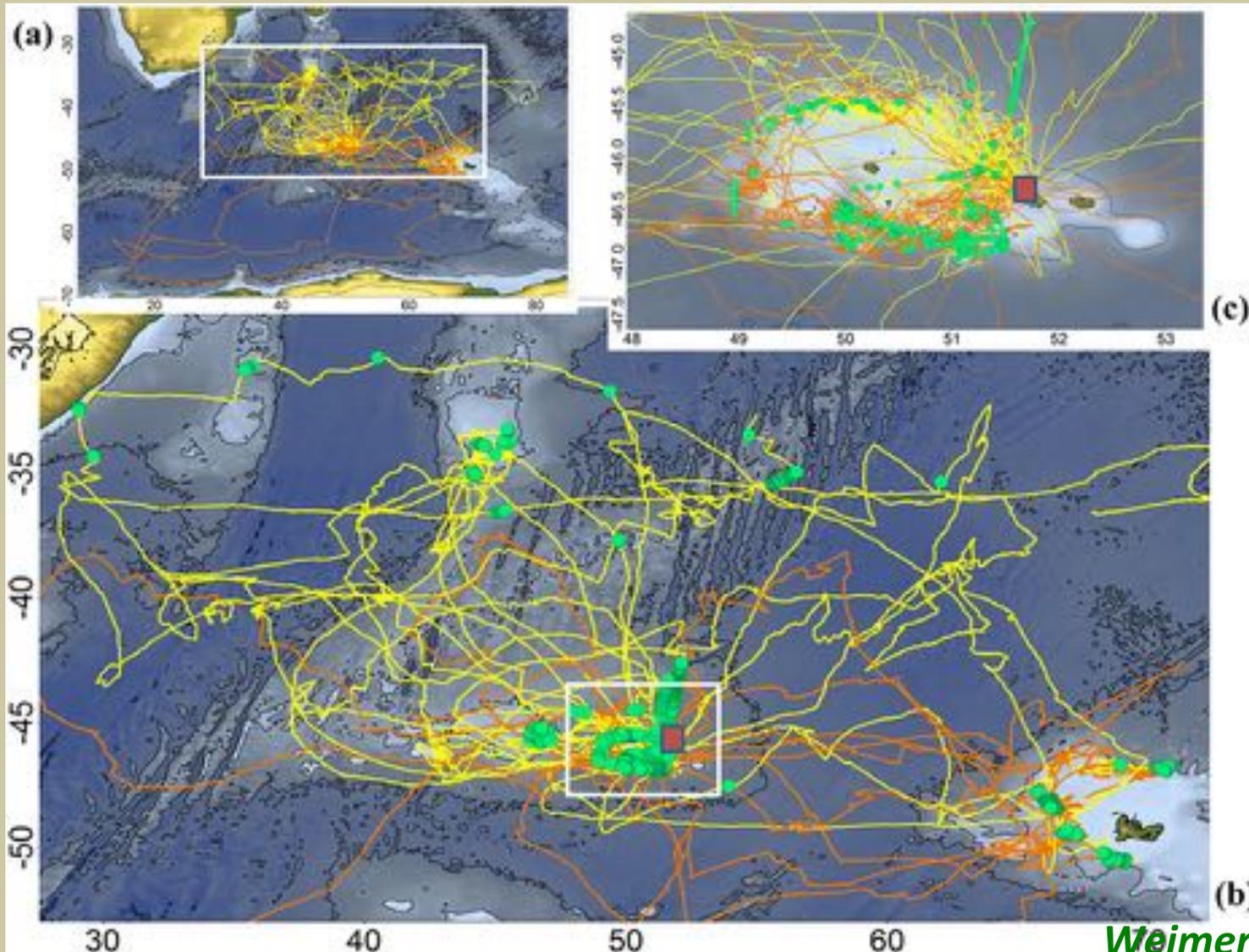
Northern elephant seal



3. What is biologging?

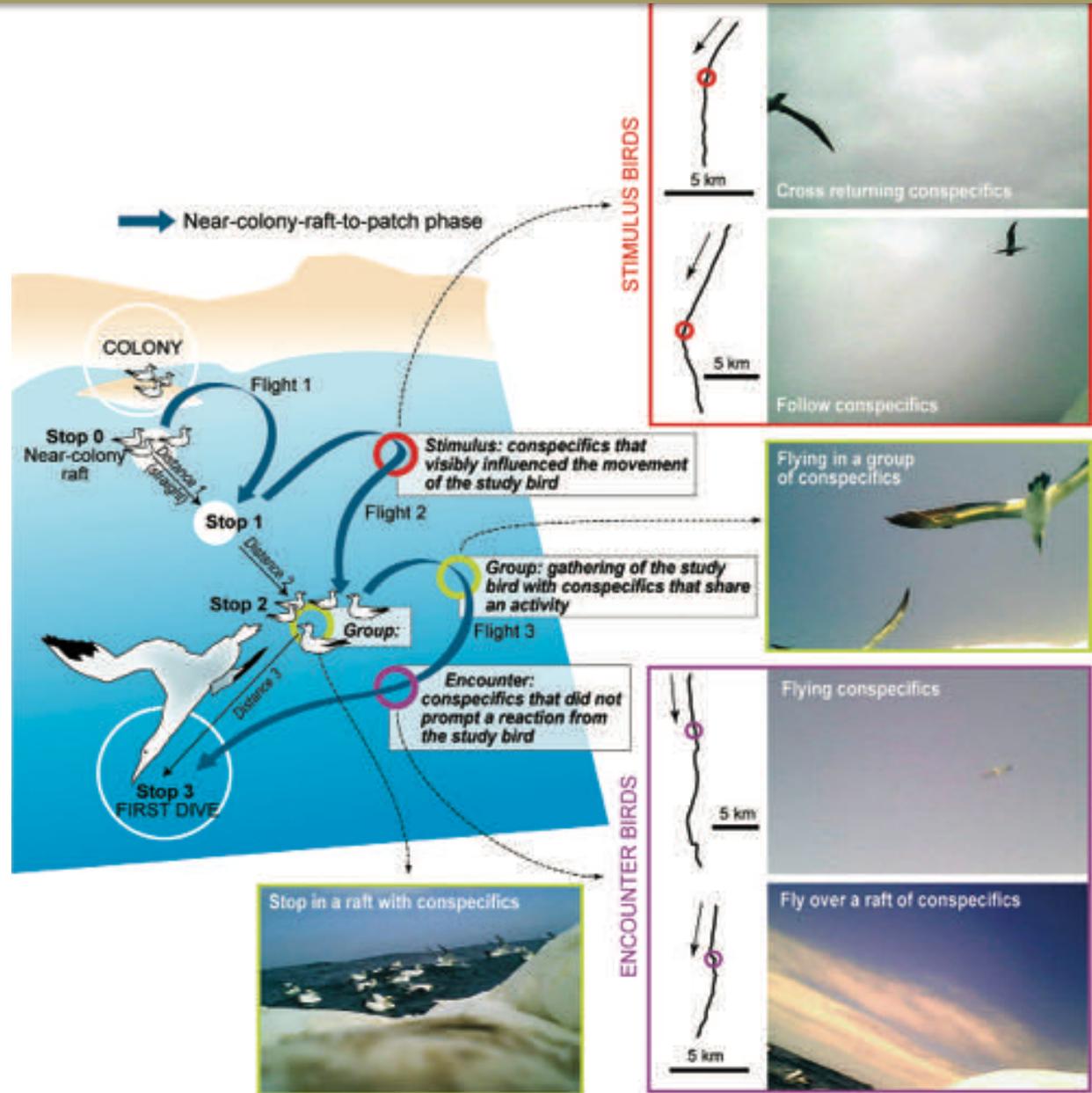
Environment logging

Use of radar detectors to track attendance of albatrosses at fishing vessels



Video

Thiebault et al - 2014



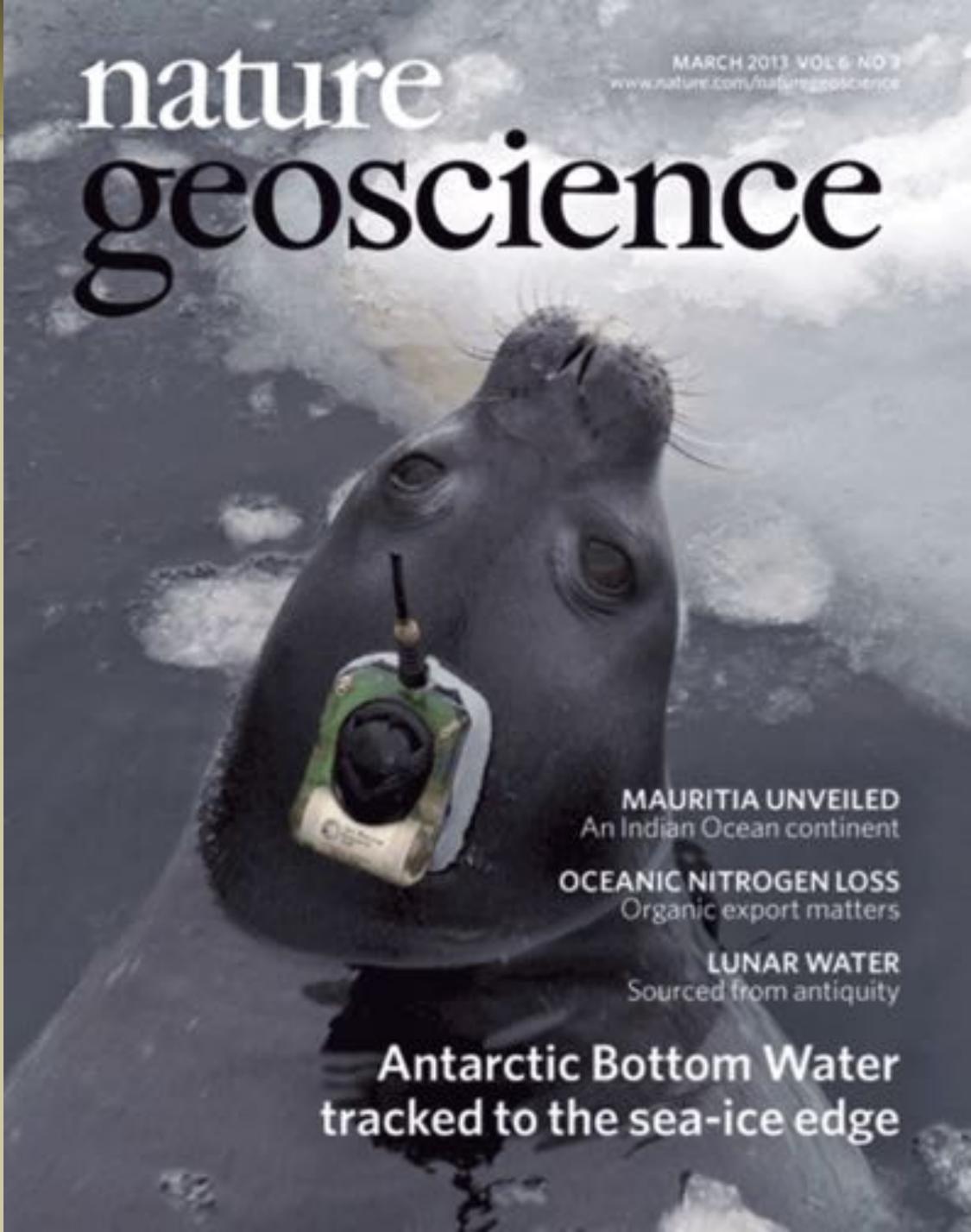
2.4 Environment logging

Animals as oceanographic platforms

Temperature, Salinity,
chlorophyll sensors

Acoustic recorders,
built-in sonars or micro-cameras

A better understanding of the
interactions between animals and
the environment itself



nature
geoscience

MARCH 2013 VOL 6 NO 3
www.nature.com/naturegeoscience

MAURITIA UNVEILED
An Indian Ocean continent

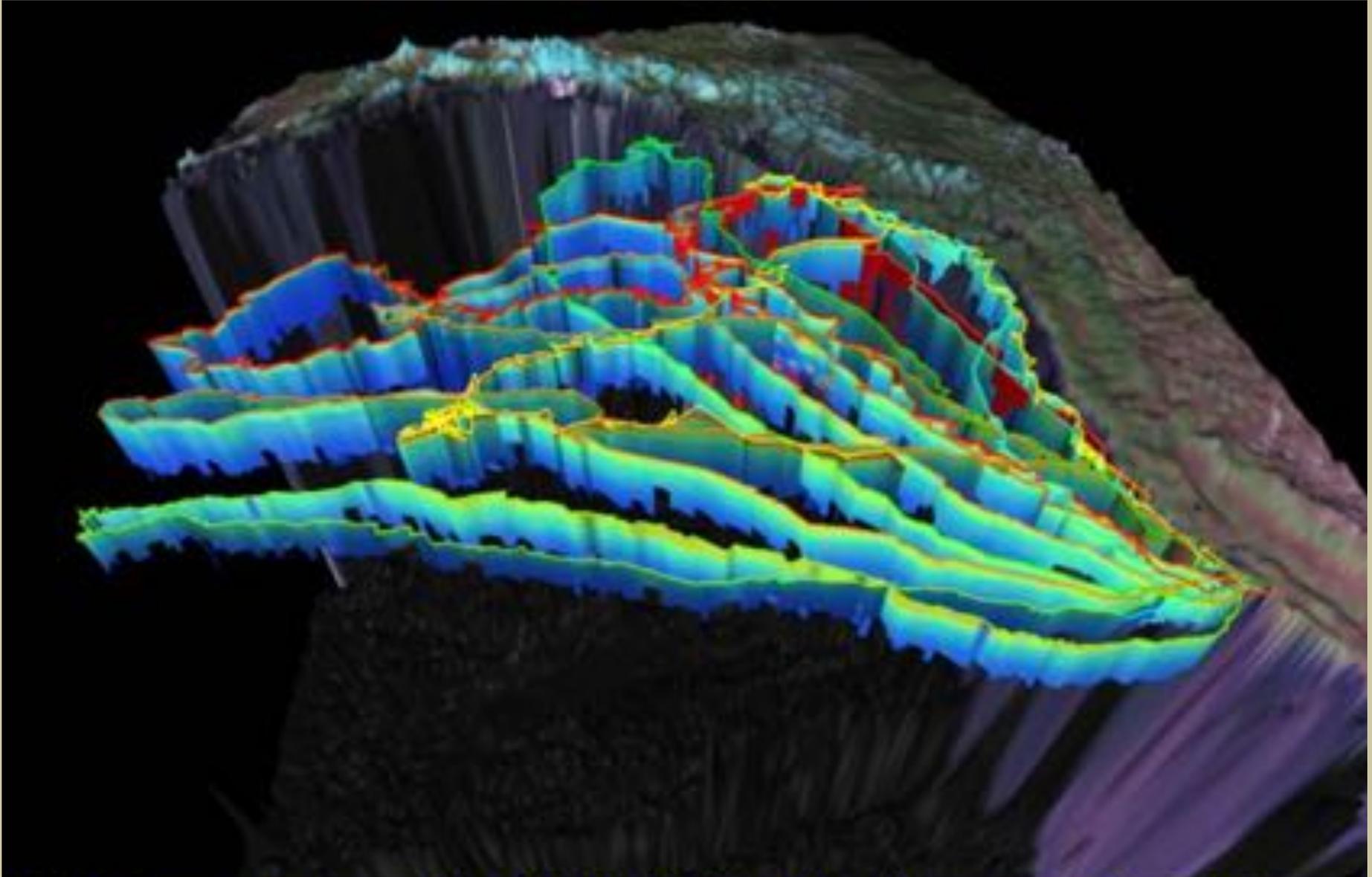
OCEANIC NITROGEN LOSS
Organic export matters

LUNAR WATER
Sourced from antiquity

**Antarctic Bottom Water
tracked to the sea-ice edge**

3. What is biologging?

Environment logging



3. What is biologging?

Where we are?

Hussey et al - 2015

Horizontal

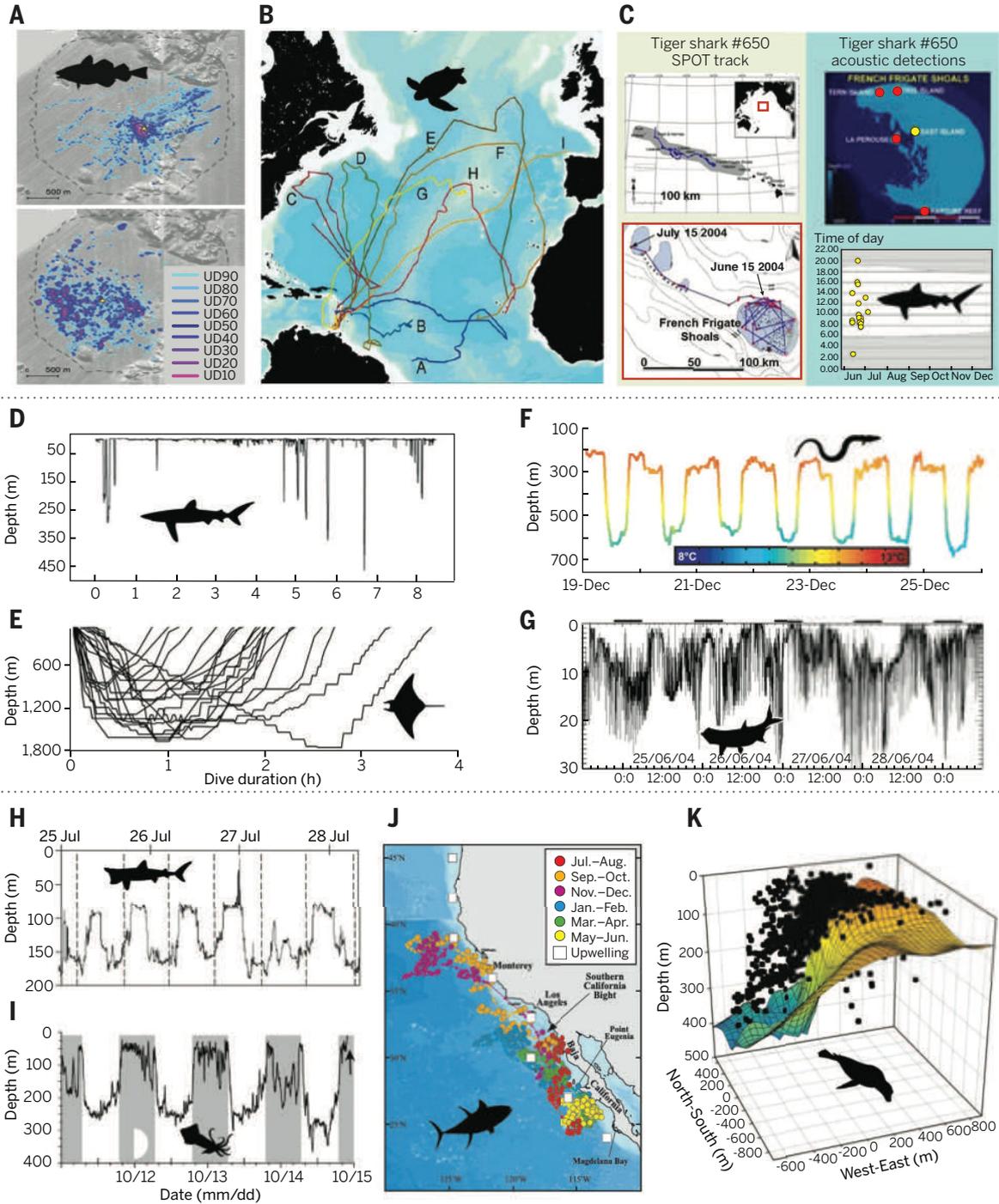
2D

Vertical

3rdD

Time

4thD



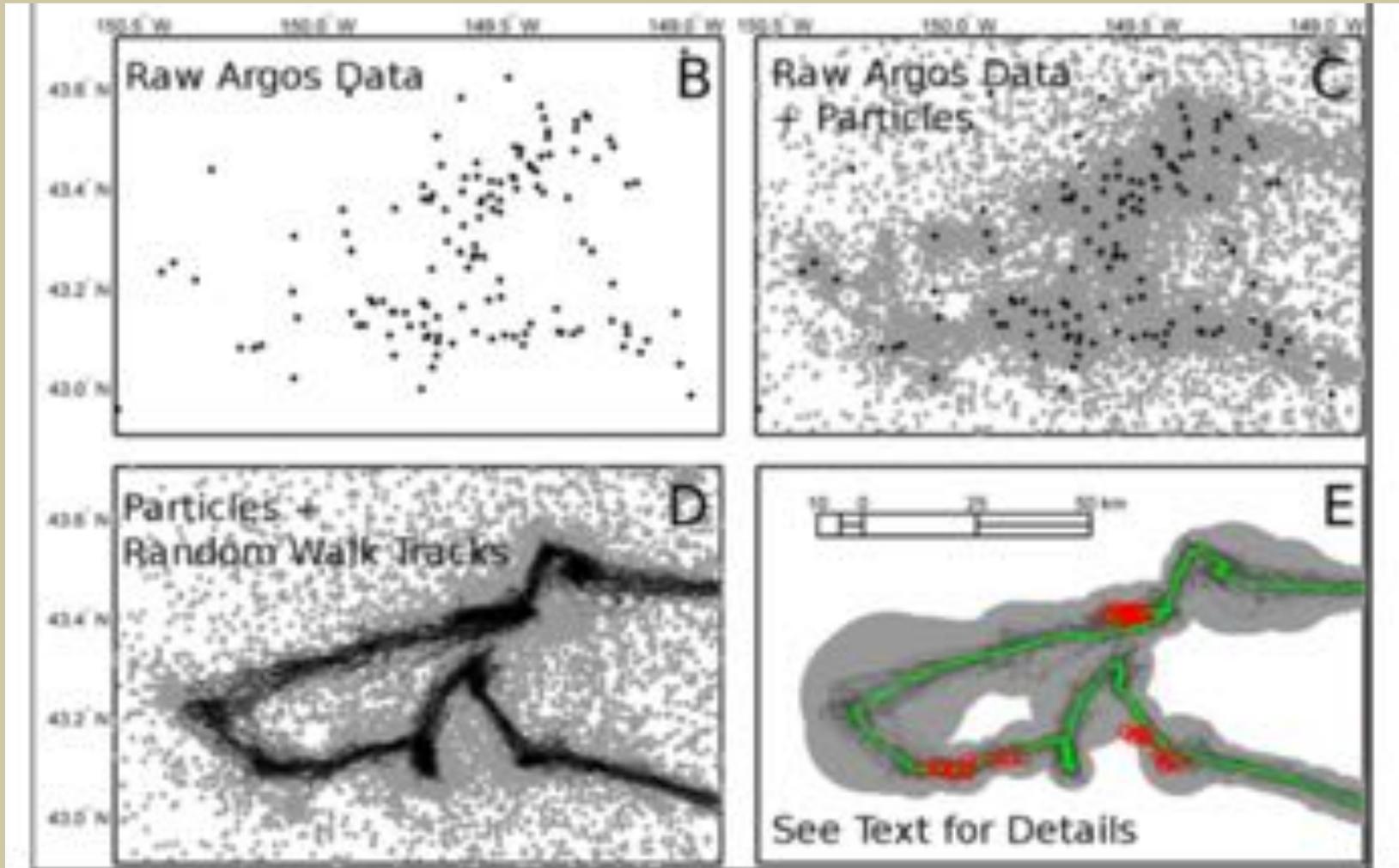
From biologging data to fauna hotspots/coldspots -> Statistical models for movement analysis

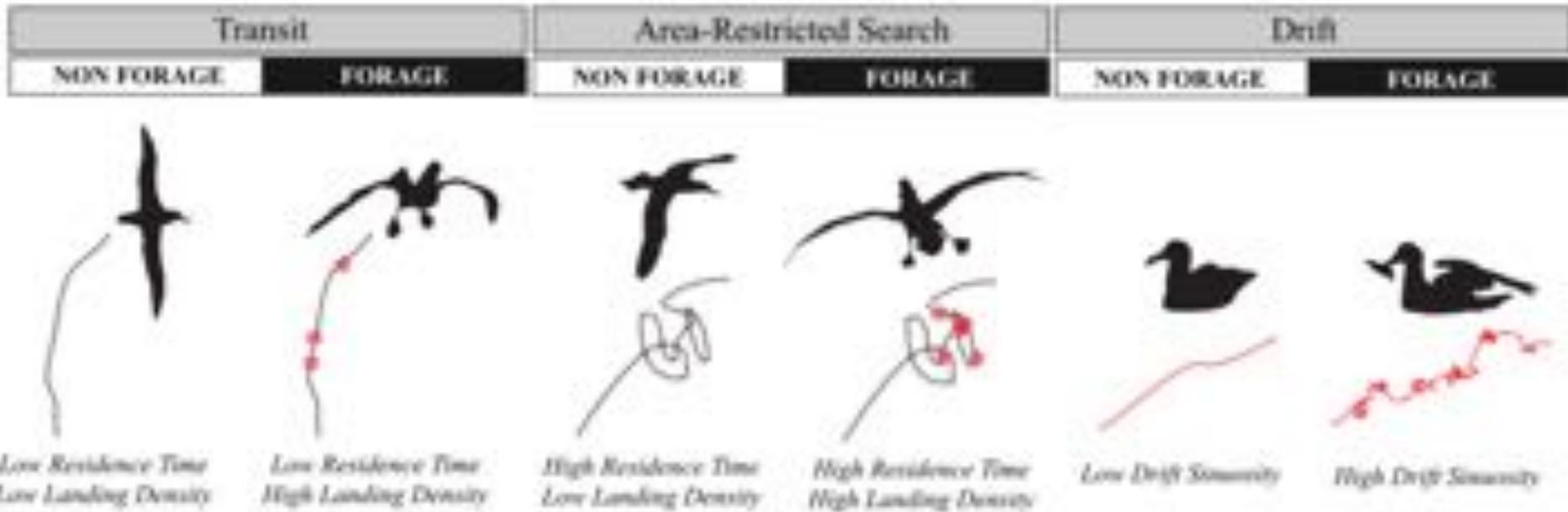
- Trajectory reconstruction
error estimation, interpolation techniques, etc.
- Segmenting a trajectory into behavioural modes
ad hoc methods (speed thresholds, FPT), discriminative models (neural networks, wavelets, random forests, etc.), state-space models (HMM, HSMM)
- From trajectories to habitats and niches,
estimating space occupation from trajectories data
Kernels, Gaussian mixture models, Brownian bridges, etc.
- Habitat modelling

Trajectory reconstruction

Estimation methods for improving position accuracy

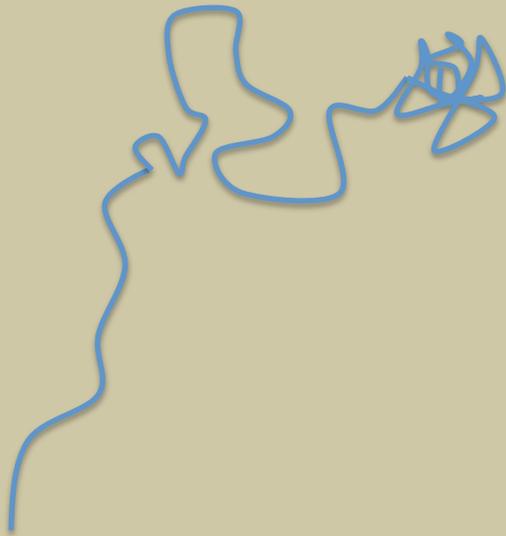
Tremblay et al. 2009



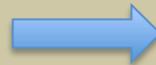


Segmentation : Problem statement

- Identifying geometric pattern
- Identify behavioural events

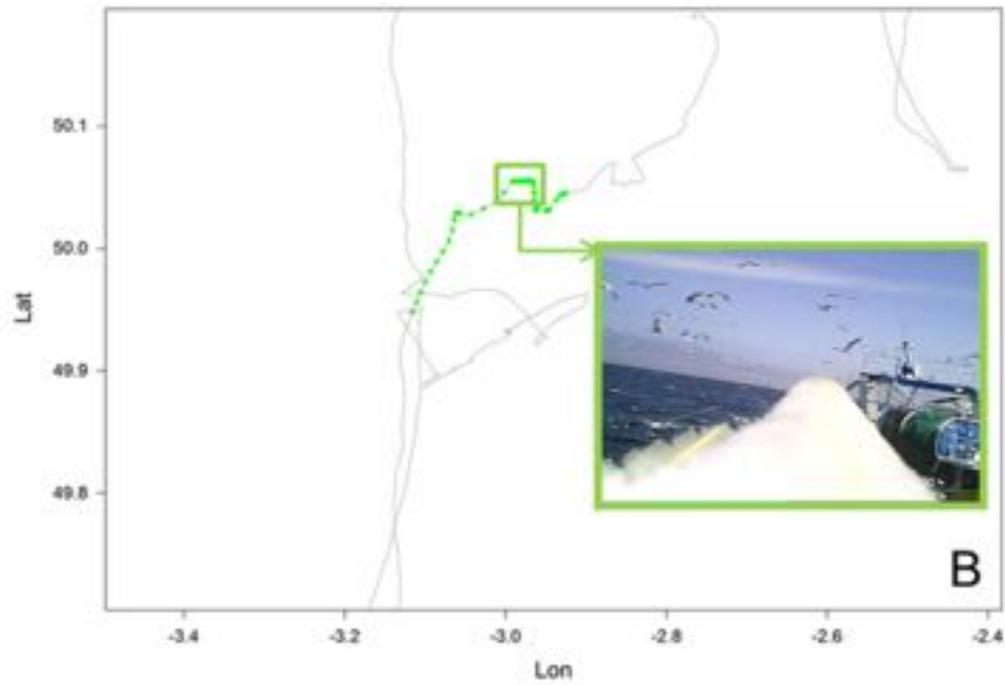
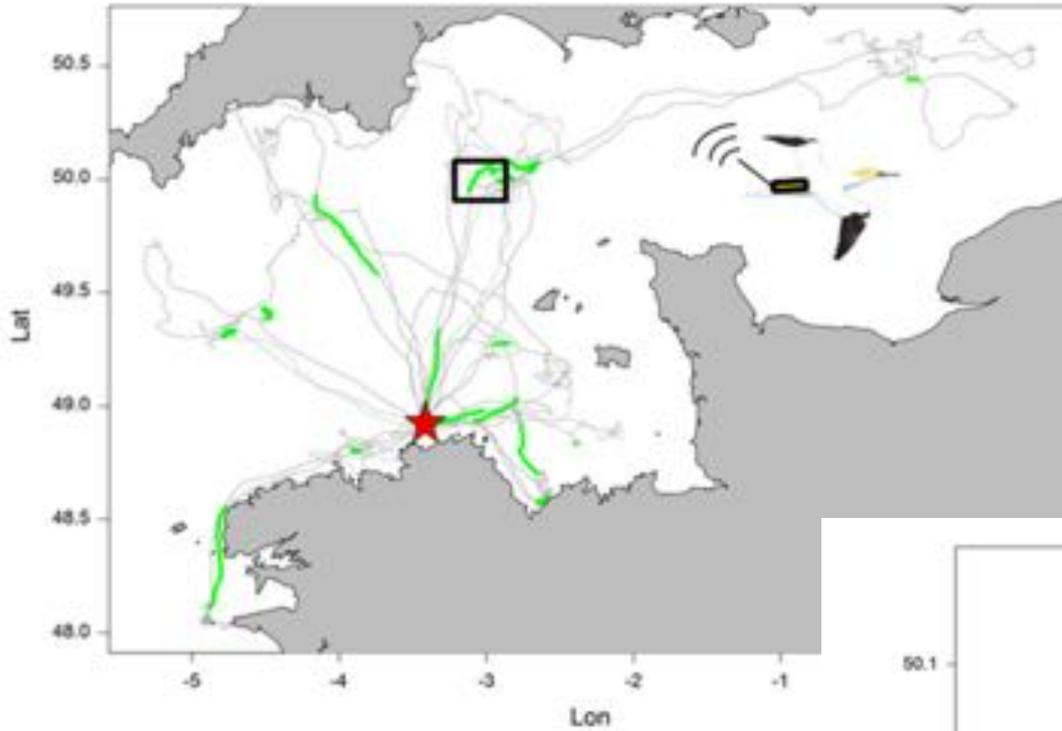


Raw location records



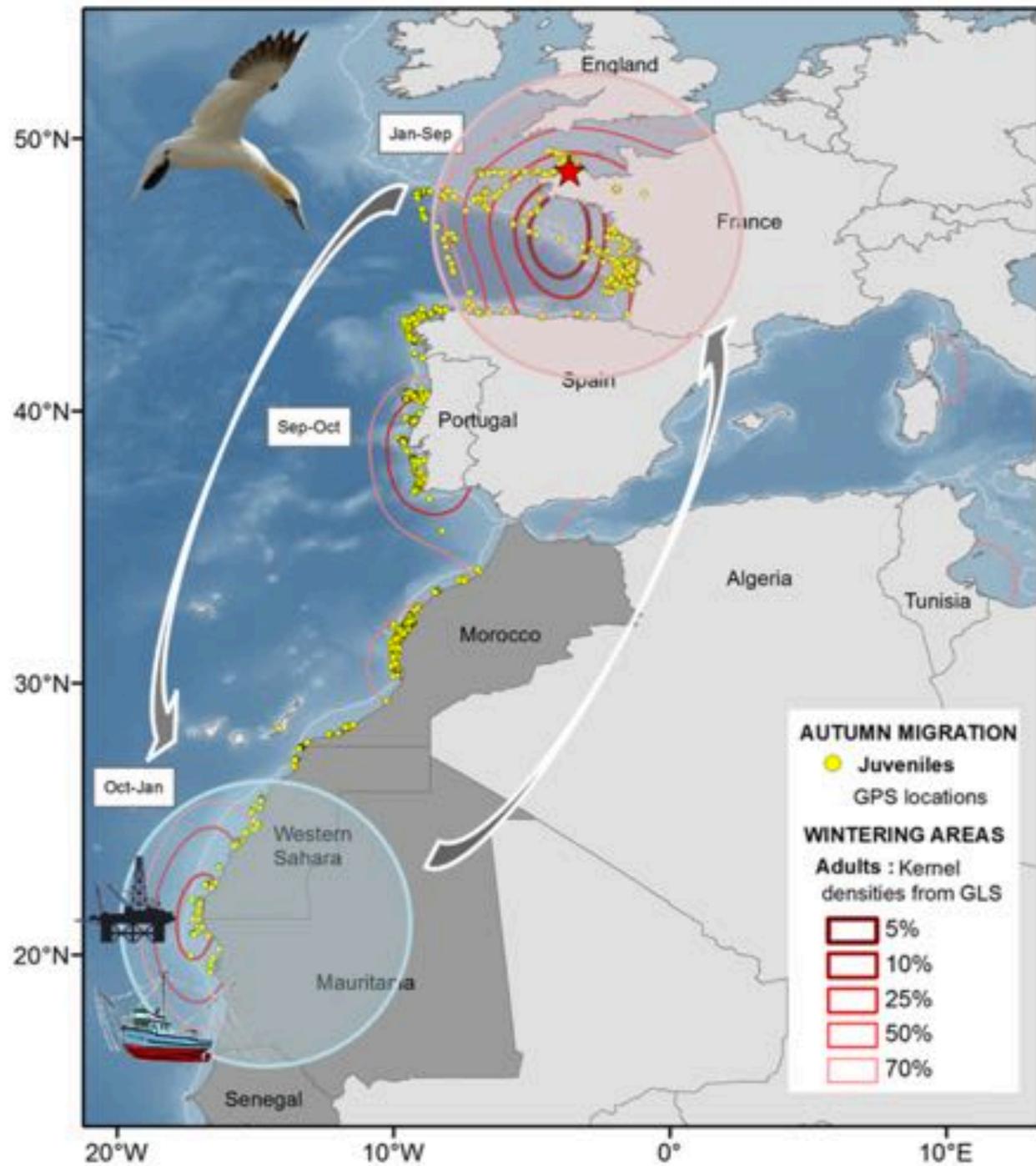
Complete Behavioural sequence

4. Biologging in MSP



Lescroël et al. 2016

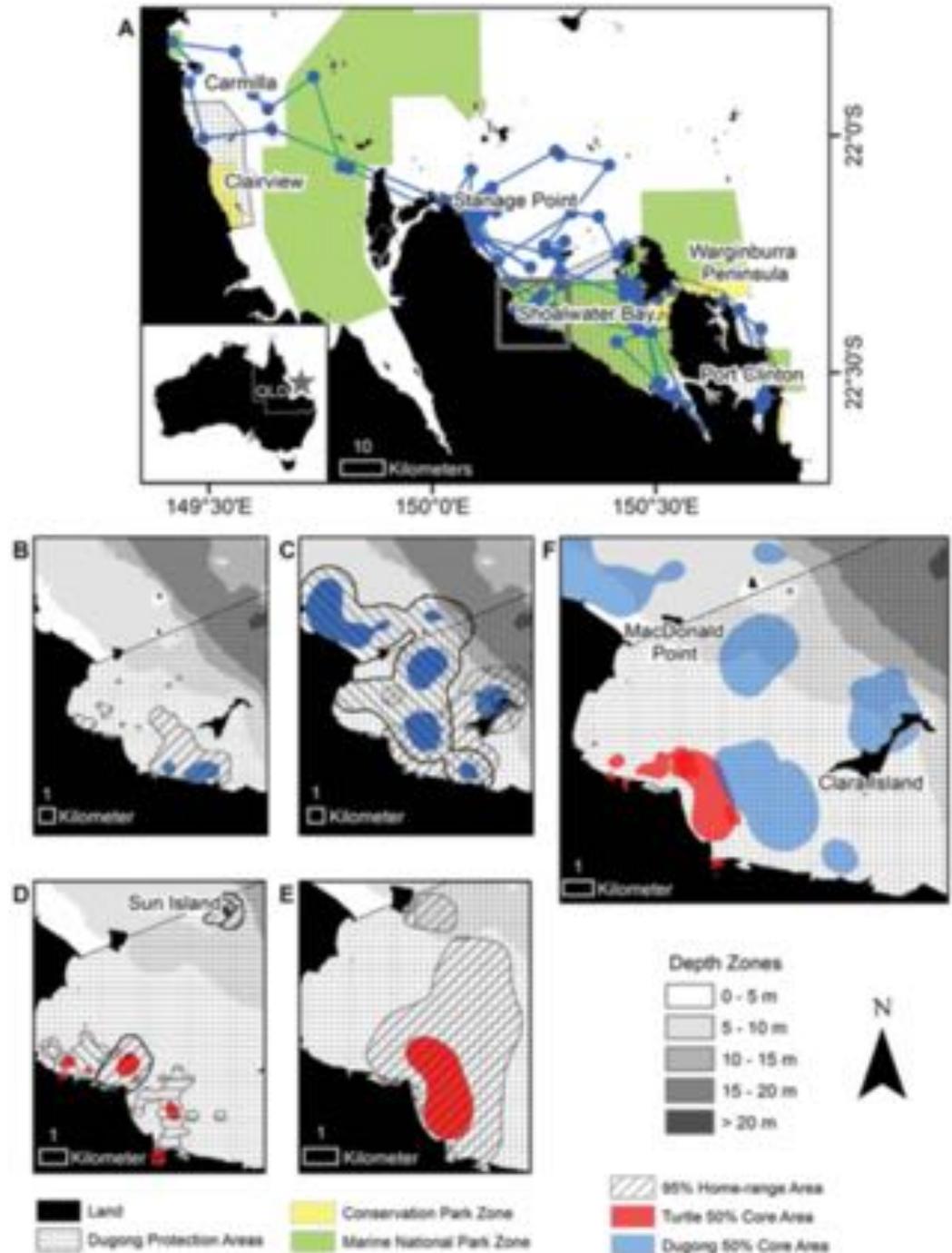
4. Biologging in MSP



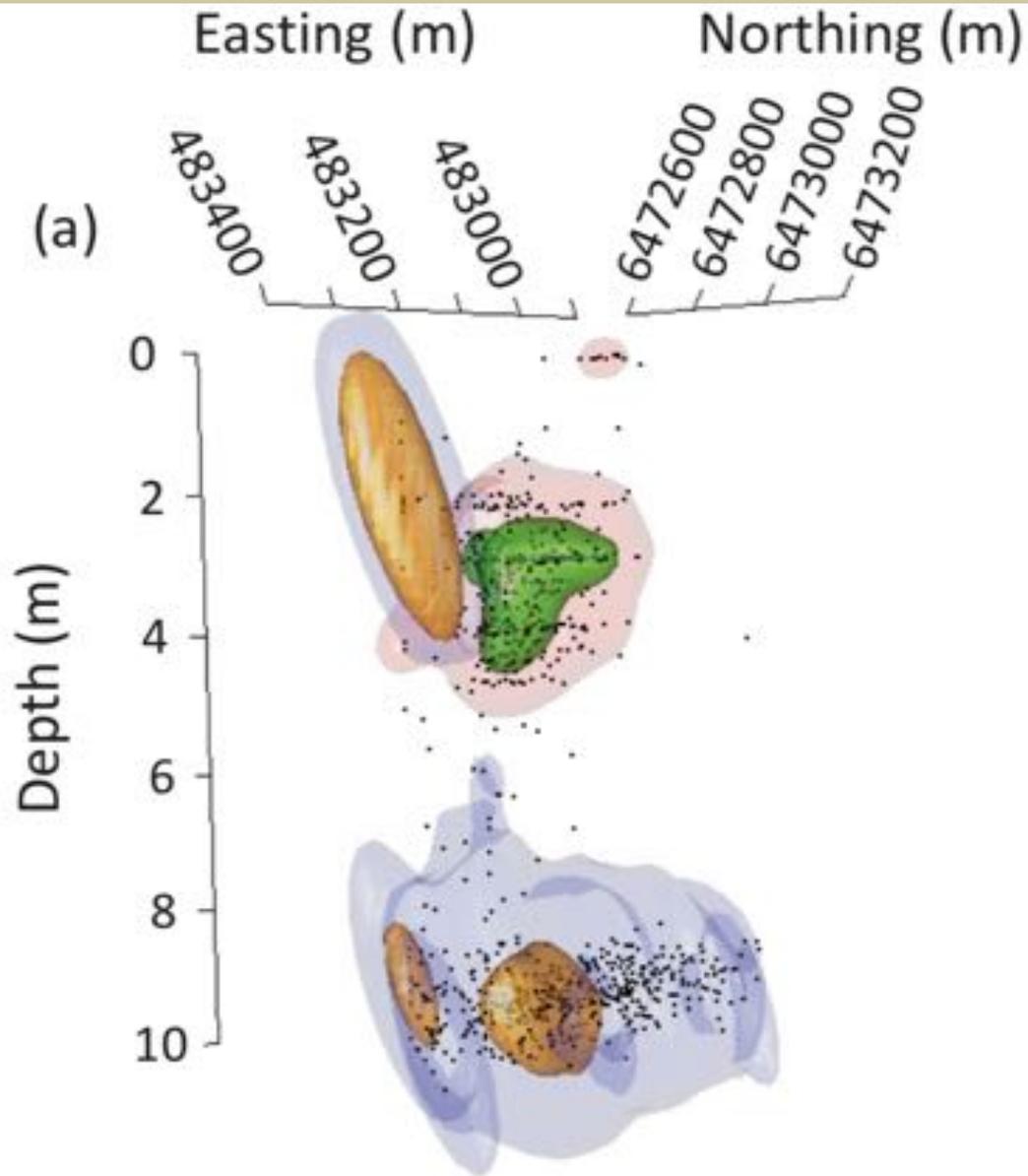
4. Biologging in MSP

Gredzens et al. 2014

Satellite Tracking of Sympatric Marine Megafauna Can Inform the Biological Basis for Species Co-Management



4. Biologging in MSP

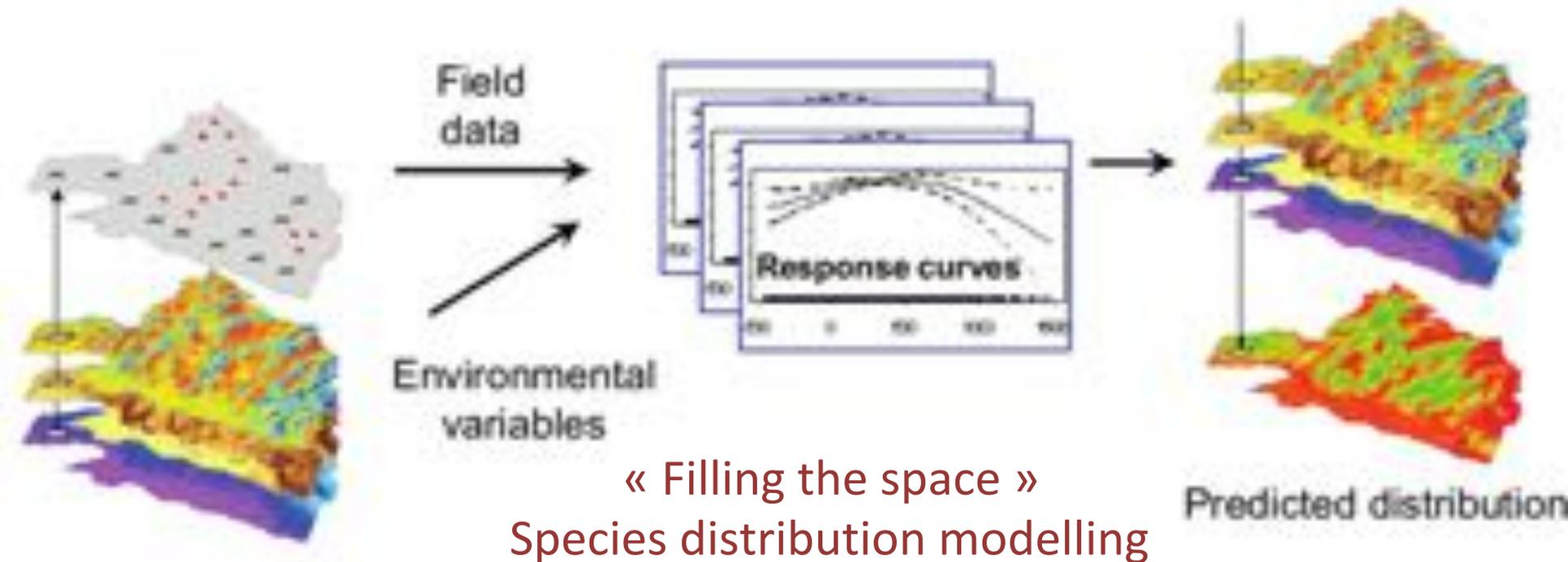


3D Kernel for diving animals

Simpfendorfer et al - 2012

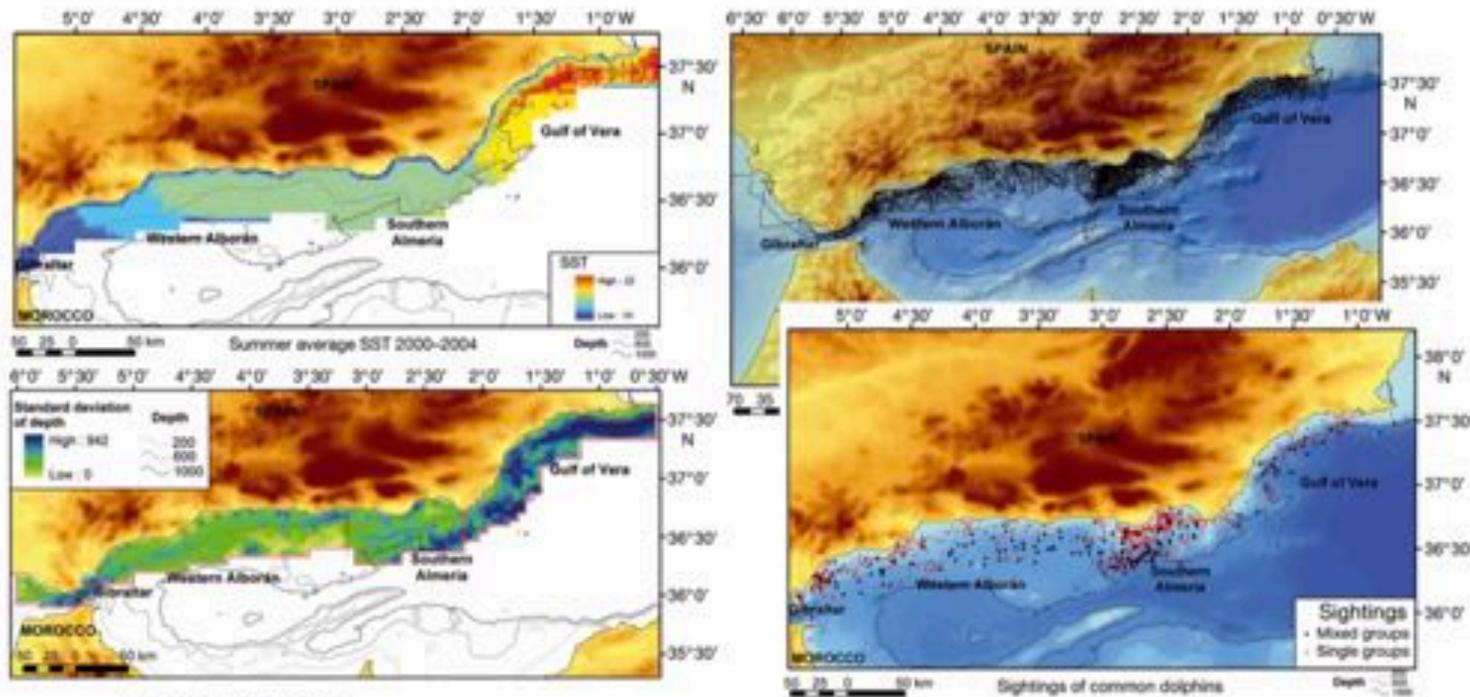
4. Biologging in MSP

Scale and extent of **observation datasets** are often **small** and **patchy**
Unsuitable for large scale MSP endeavors



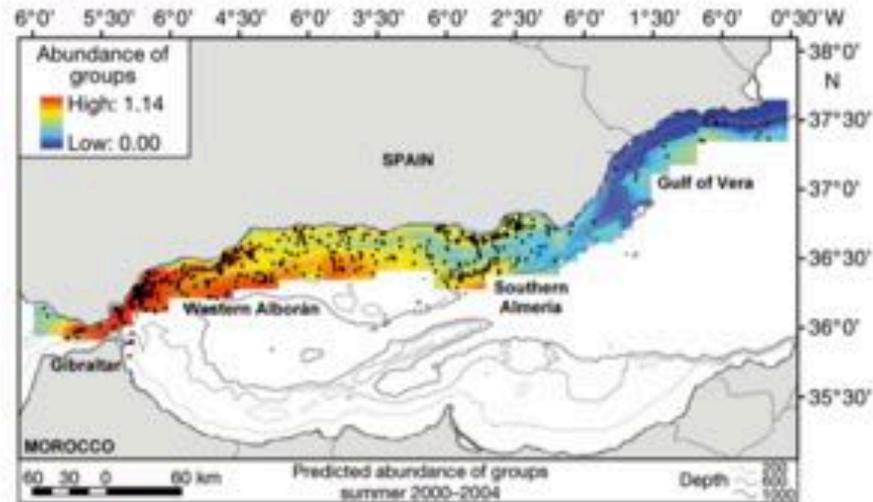
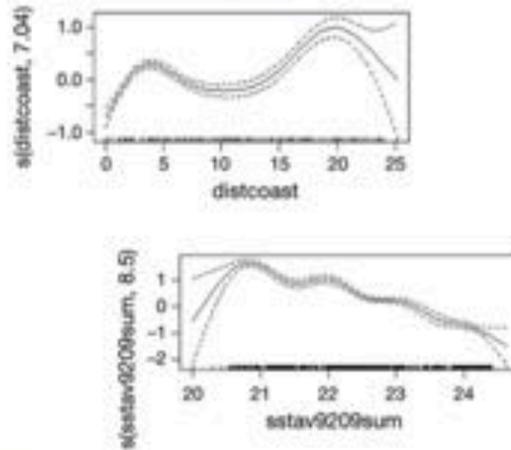
From linear to non-linear modeling and machine learning techniques, coupled with a Geographical Information System (GIS), to **geographically extrapolate in-situ data based on seascape properties**

4. Biologging in MSP



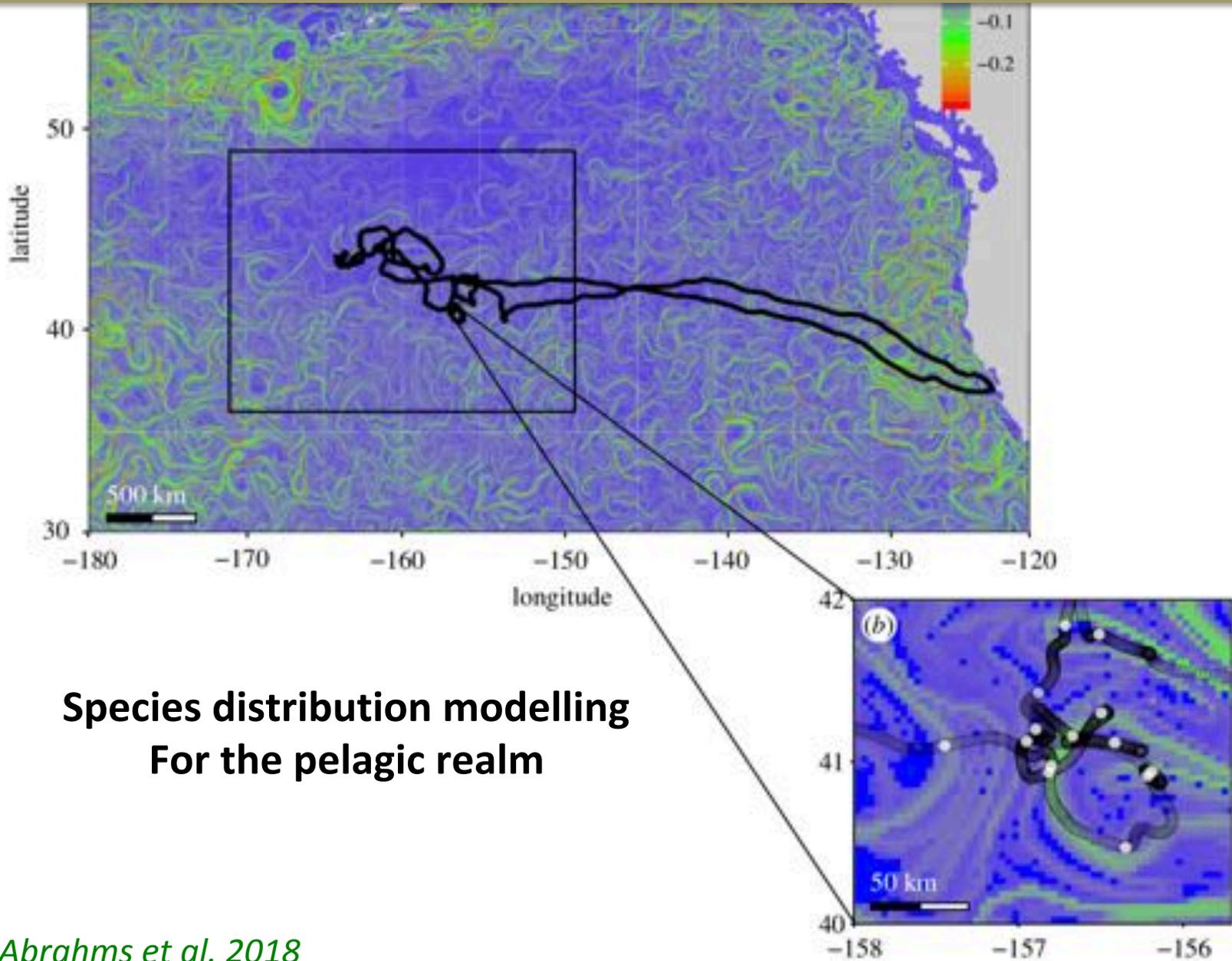
Habitat features

Effort and sightings data



Models of species-habitat relationships → Spatial prediction of species density

4. Biologging in MSP

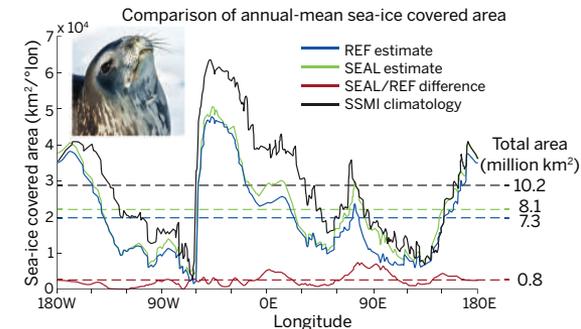
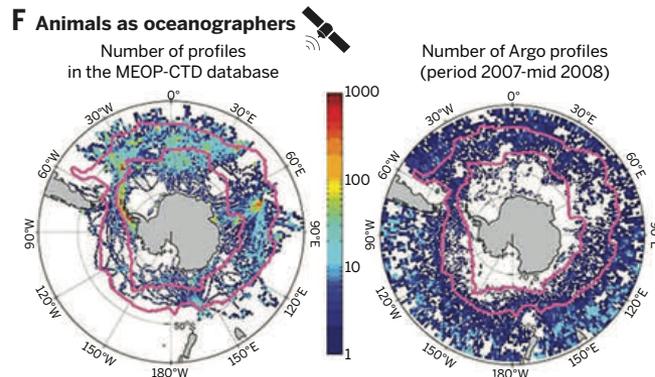
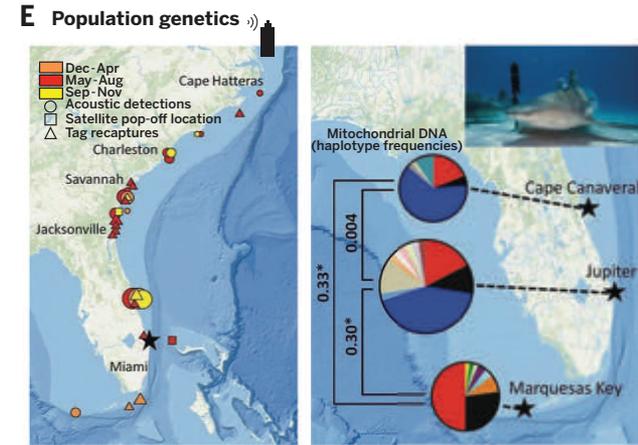
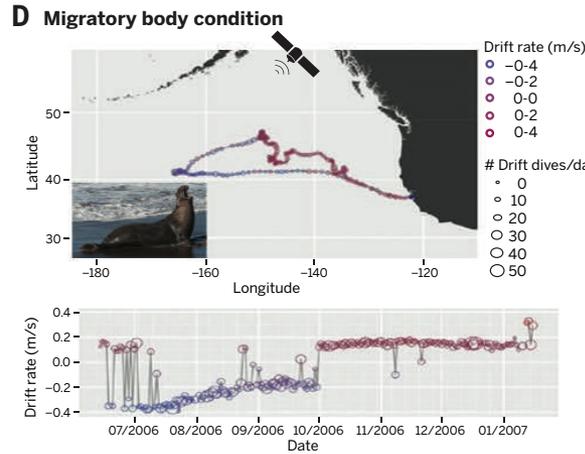
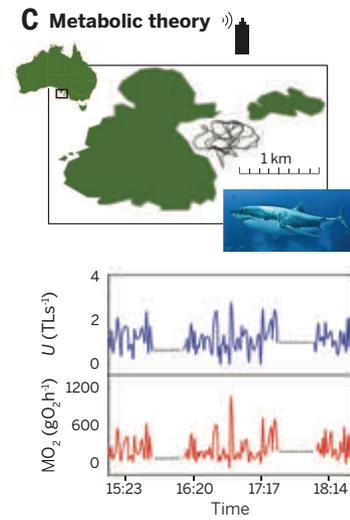
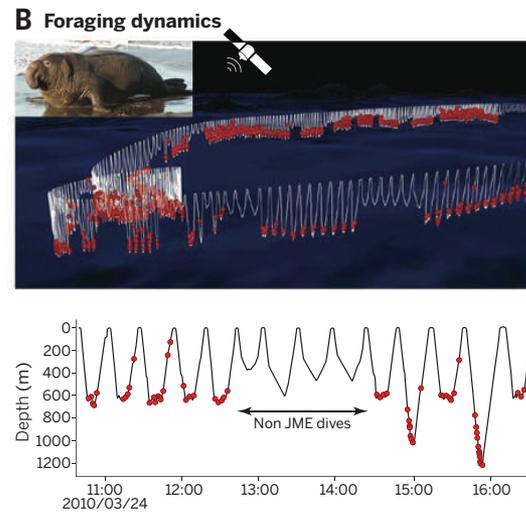
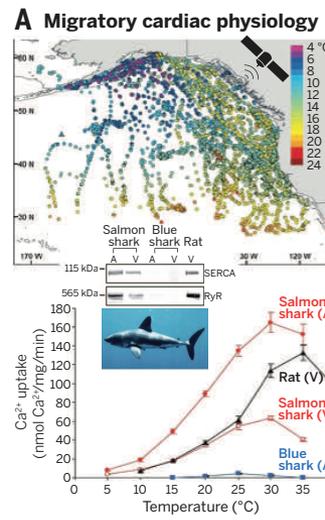


Perspectives biologging

Hussey et al - 2015

Perspectives
Where we could go?

1. Scaling up from individuals to groups and multispecies
2. Integrating loggers (telemetry + physiology + environment)
3. Integrating databases
Rodriguez et al. 2017
4. Animals, ships and bouys as opportunistic oceanographers



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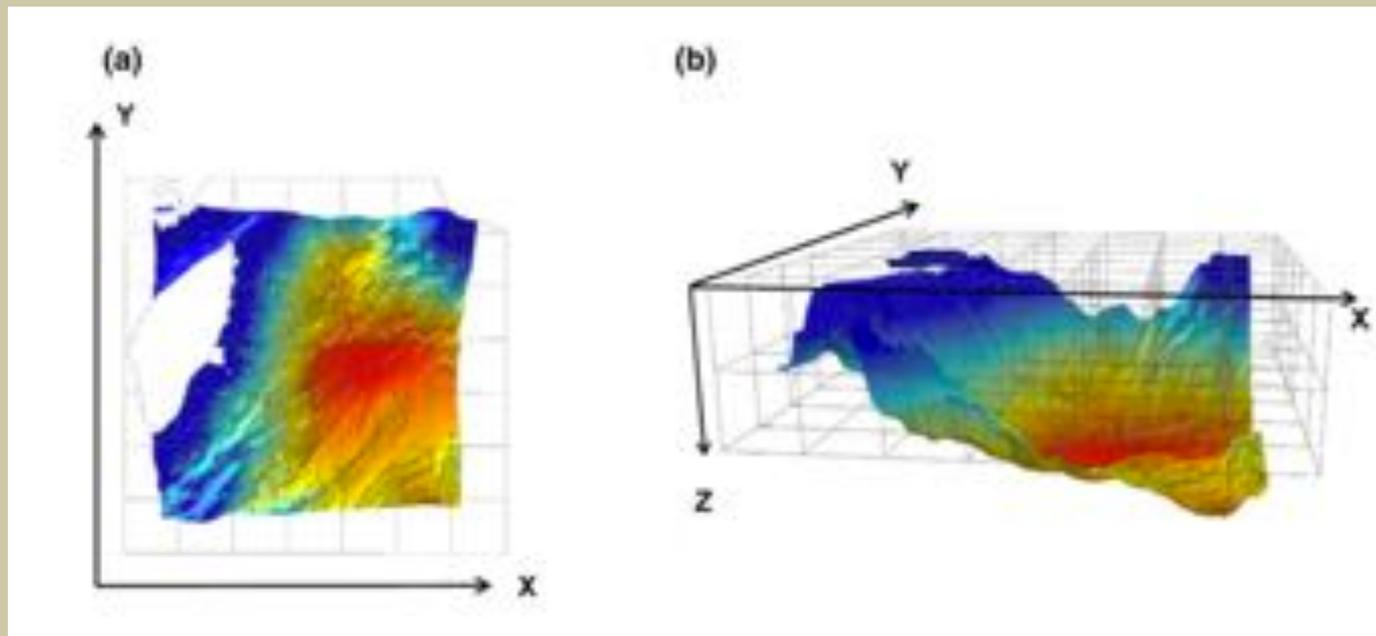
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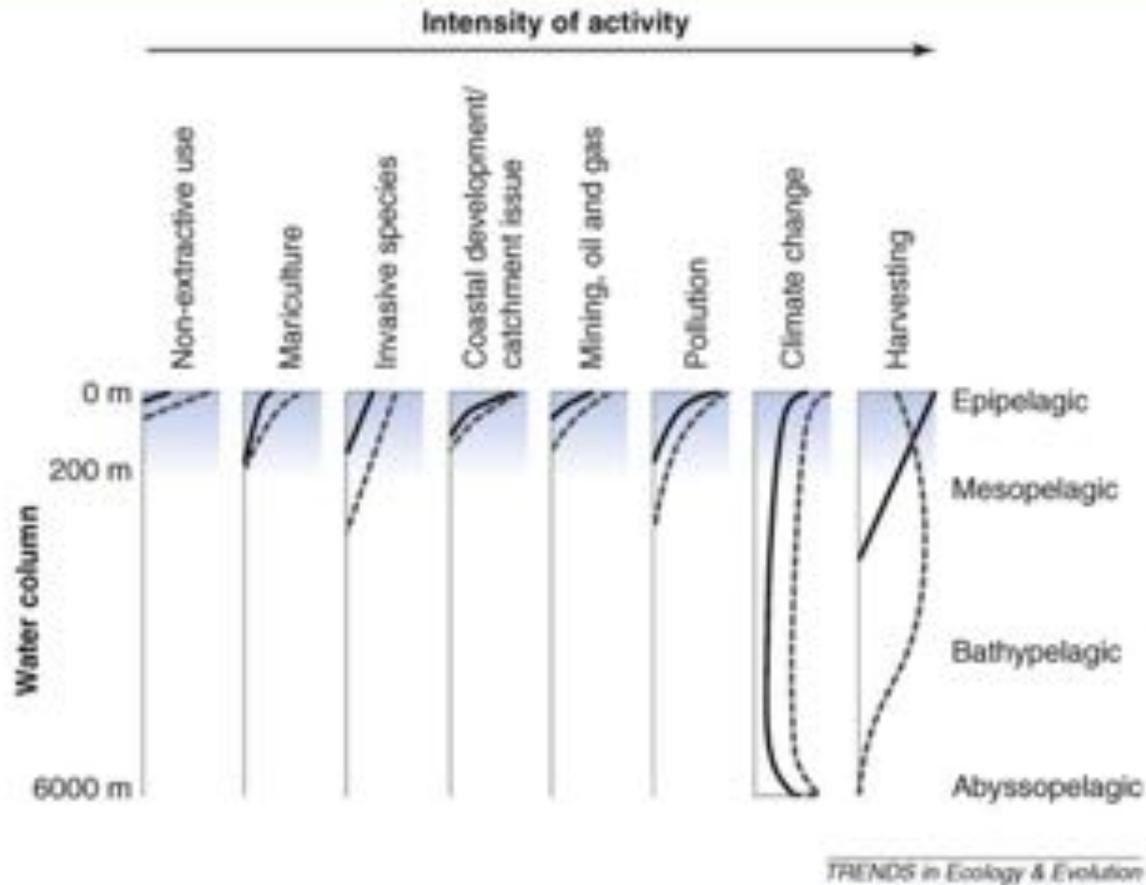
RESEARCH ARTICLE



3D spatial conservation prioritisation: Accounting for depth in marine environments

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TRENDS in Ecology & Evolution

Figure 1. Schematic of the intensity of the eight largest threats in the pelagic ocean as a function of depth. Blue shading indicates the penetration of light (euphotic zone) into the water column. The solid line is the current intensity of these threats, while the dashed line indicates the potential change in intensity over the next 50 years (generally increasing and moving deeper). The assessment contained in this figure is a combination of the authors' collective experience and views and interpretation of published studies, particularly Refs [2,17,26,38,75].

Perspectives modelling

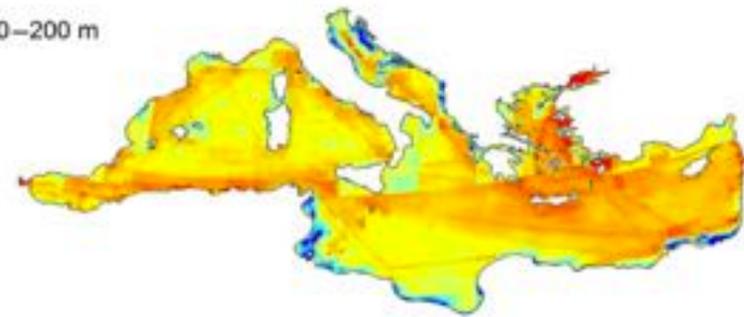
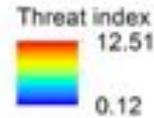
Marxan

Cumulative threat maps

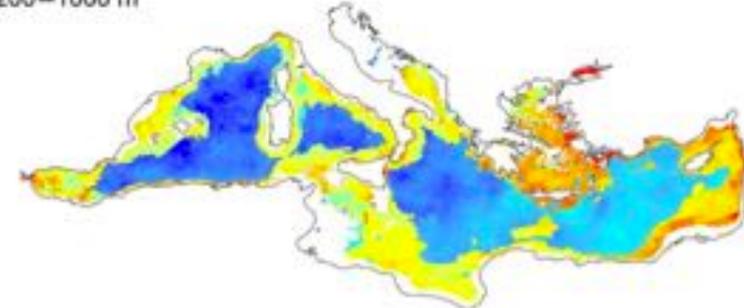
Depth class

Prioritising in 3D opens the possibility of targeting specific threats to specific features of conservation interest at specific depths

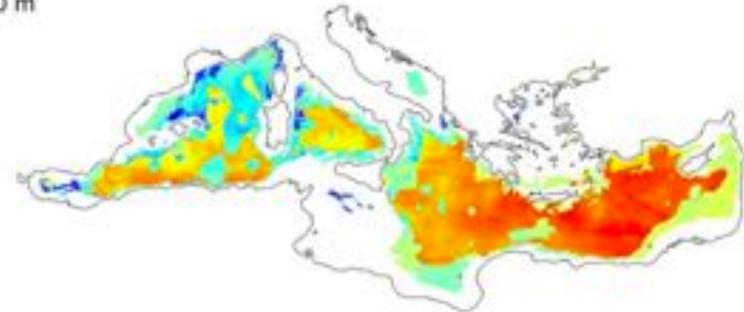
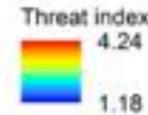
(a) Depth range 0–200 m



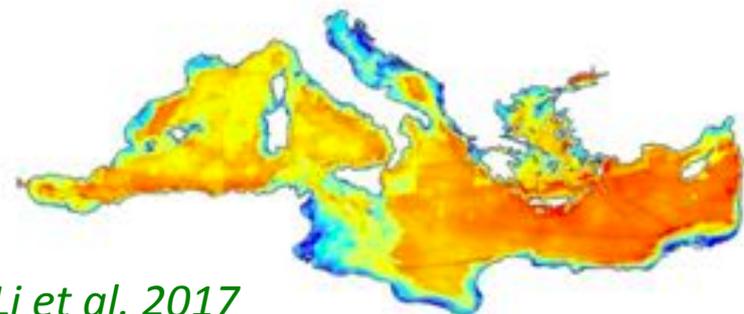
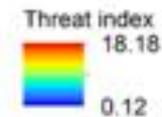
(b) Depth range 200–1000 m



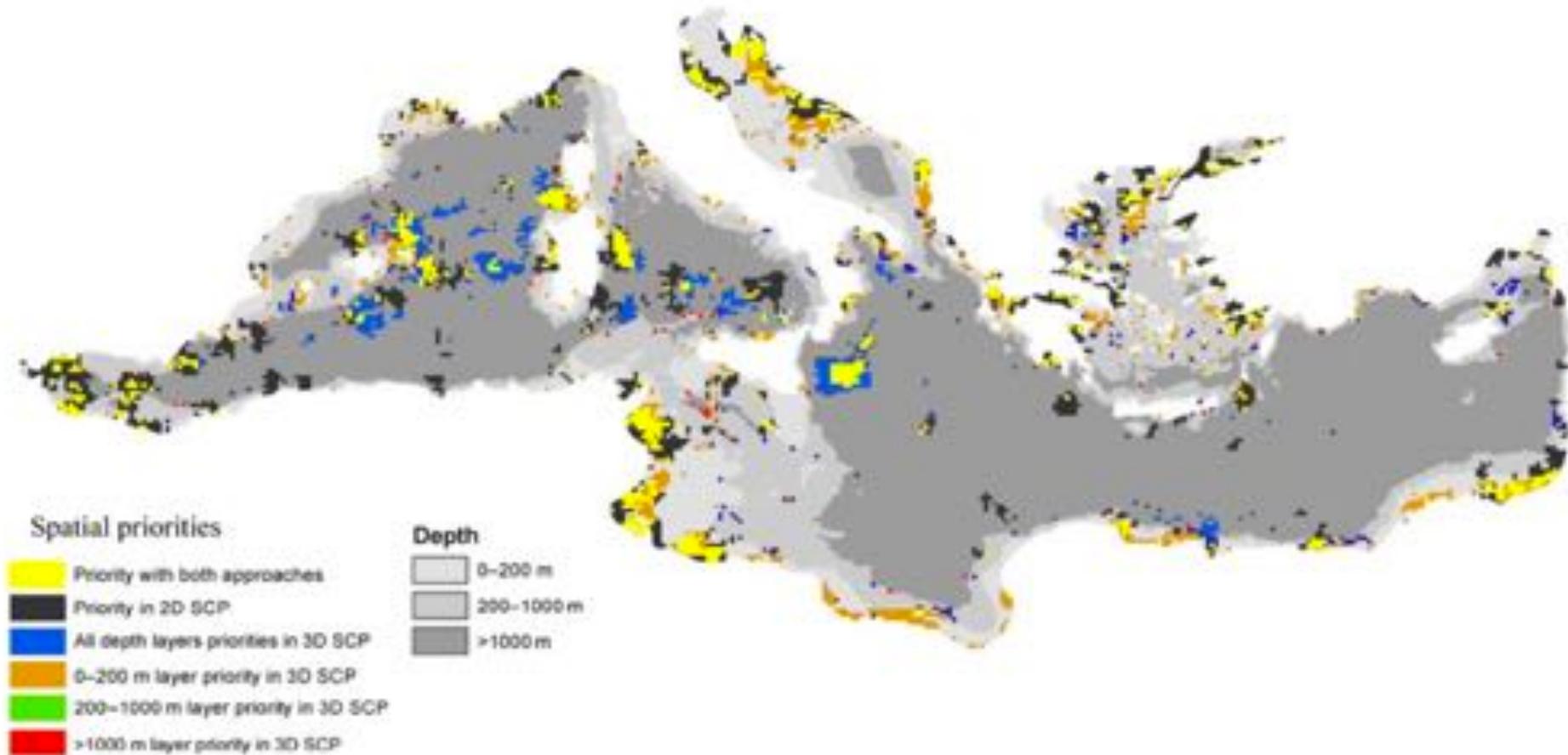
(c) Depths >1000 m



(d) All depths



Venegas Li et al. 2017



Venegas Li et al. 2017

Comparison of spatial priorities through a 3D and a 2D spatial conservation prioritisation

Time variability

Short term time variability in the pelagic realm

Long term trend variability with climate change

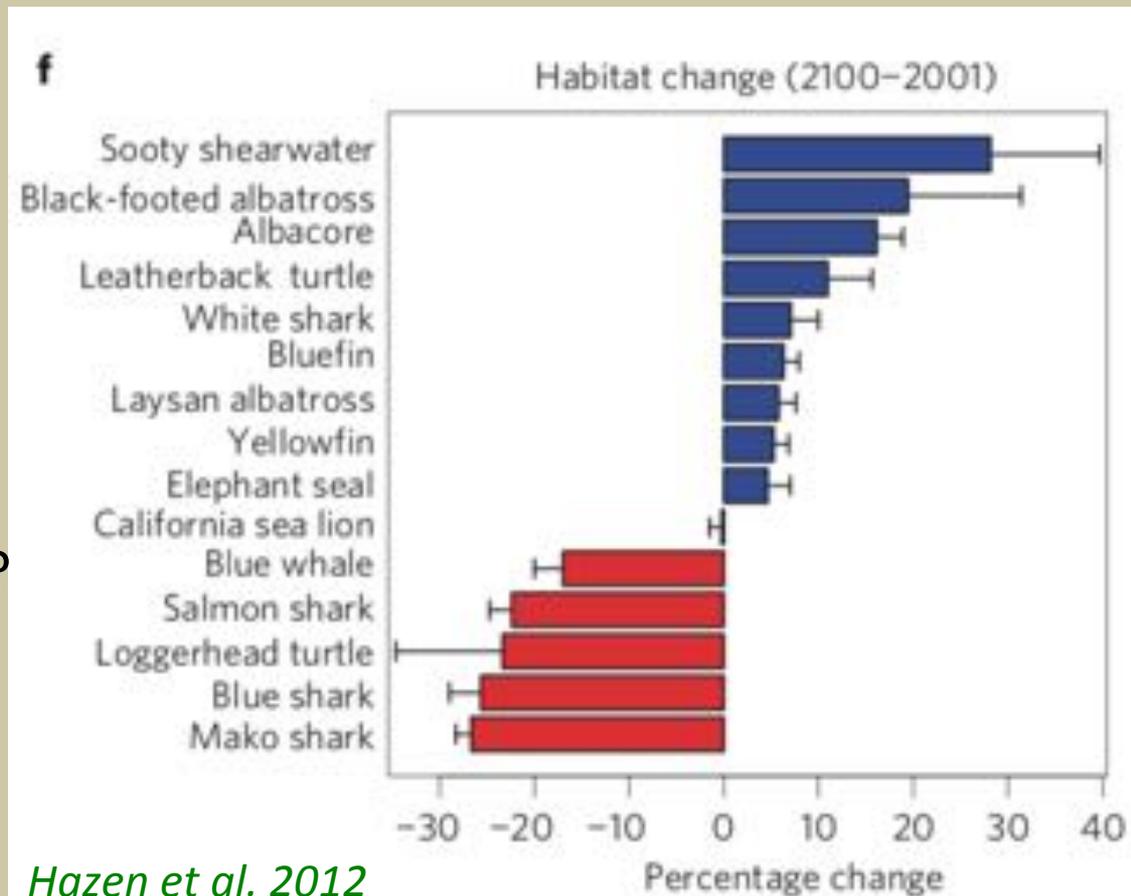
Real time monitoring

Dynamic boundaries

Adaptive management

How do we **plan variability**?

How do we **plan uncertainty**?



The odd species within megafauna

