Fourth International Science Symposium on Bio-logging
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Hobart, Tasmania, Australia
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From individuals to populations: movements, foraging, fitness and the comparative method

Sascha K. Hooker

University of St Andrews
Université de La Rochelle (2010-2011)

Overview

Behaviour
Movements, diving

↓

Life function
Feeding

↓

Vital rates
Survival
Reproduction

↓

Population effect

From NRC, 2005 – Characterising biologically significant marine mammal behaviour

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Application to Conservation

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1. Measuring behaviour

Bio-logging

ADVANCES

Resolution
Sensor type
Many parallel sensors
Miniaturisation

LIMITATIONS

Capture / deployment
Attachment
Recovery/ transmission
Expense
Battery life
Memory

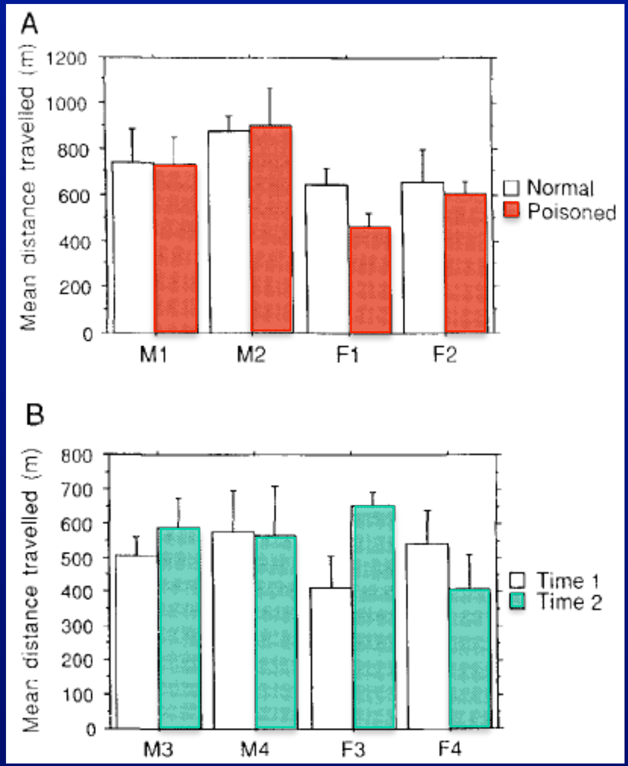
Often….
Small sample sizes
– problems with *representativeness* and *bias*

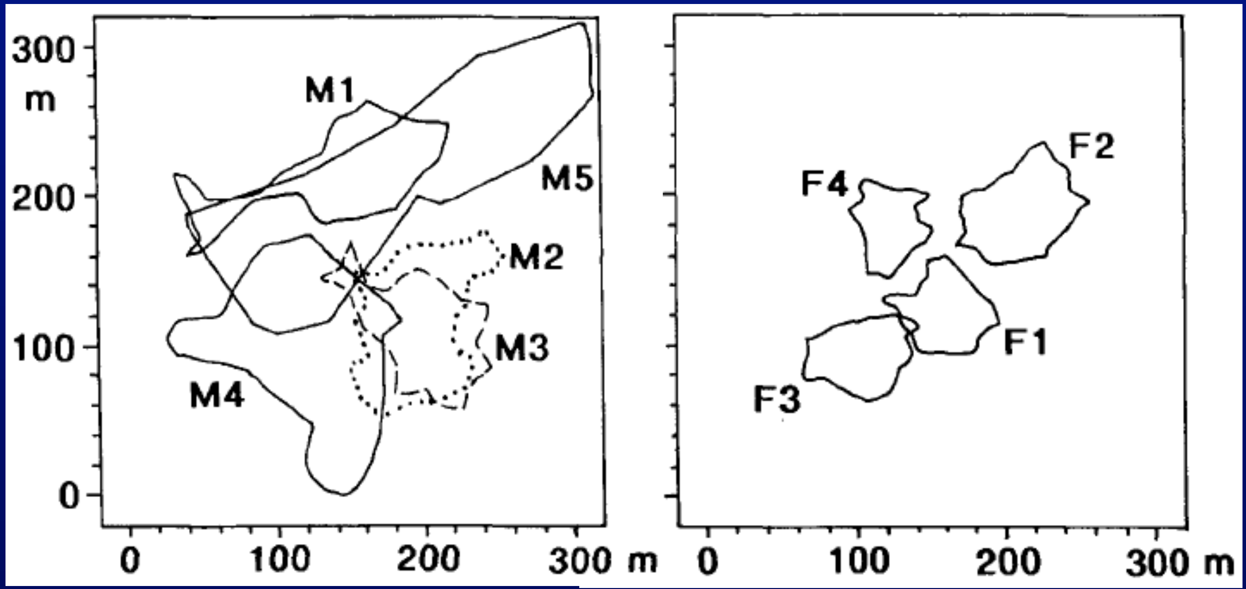
From McConnell et al. chapter 2010. MM Handbook of Techniques

Manipulative experiments

Hooker and Innes. 1995. *NZ Journal of Ecology*

Manipulative experiments



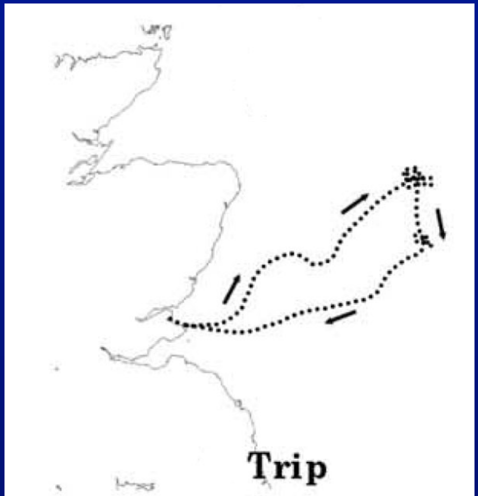


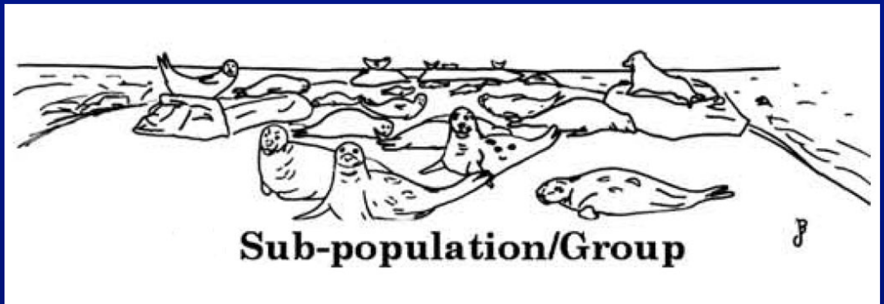
Hooker and Innes. 1995. *NZ Journal of Ecology*

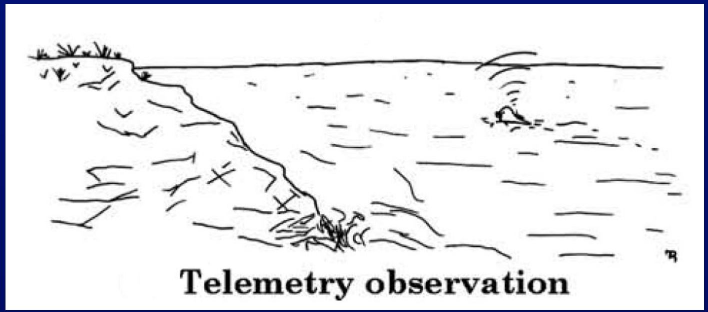
Mensurative experiments

'Measurements taken at points in space or time – not involving imposition by the experimenter of some external factor'

Hurlbert, 1984







From Aarts et al. 2008 *Ecography*

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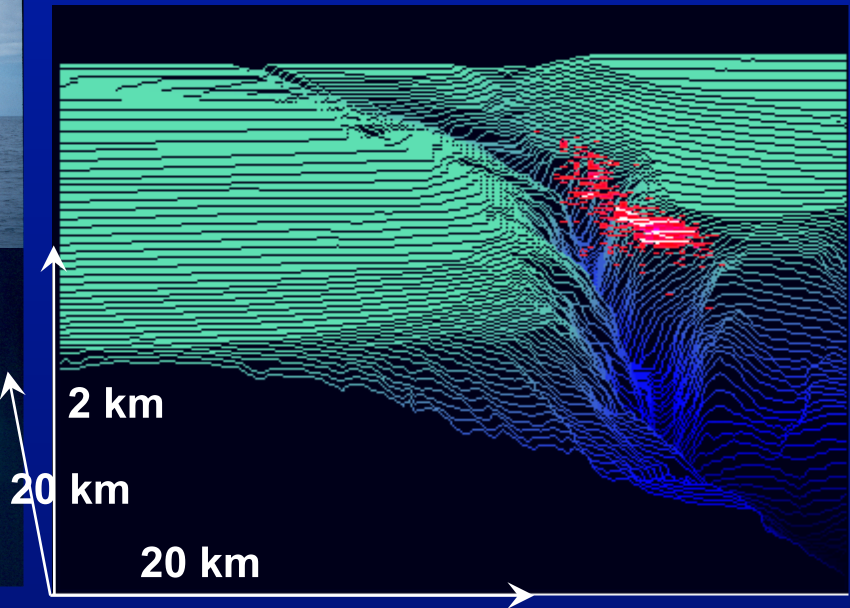
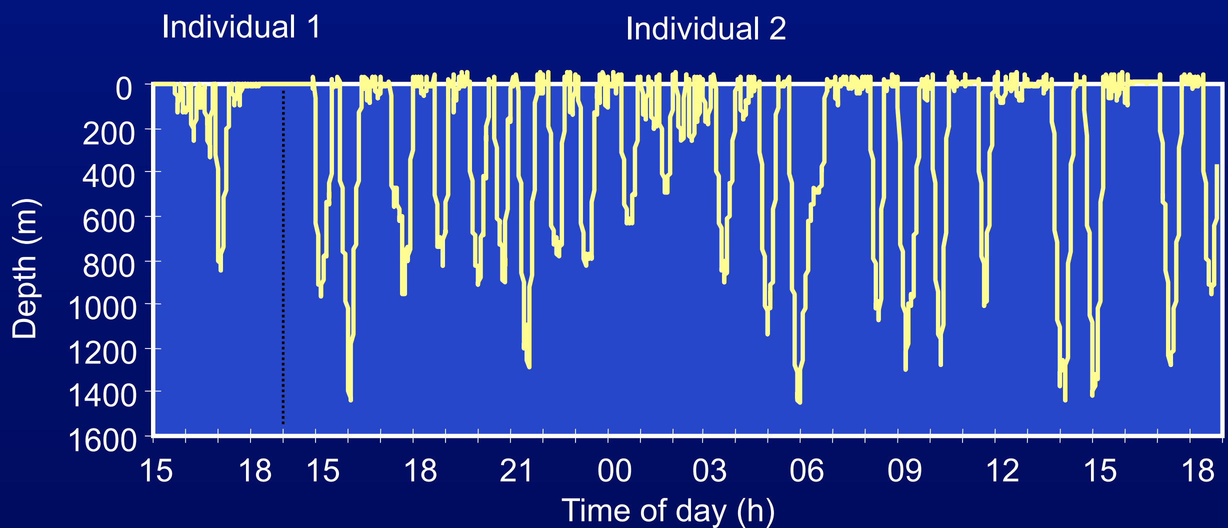
Northern bottlenose whales





Hooker and Baird. 1999. *Proc. Roy. Soc. Lond. B.*

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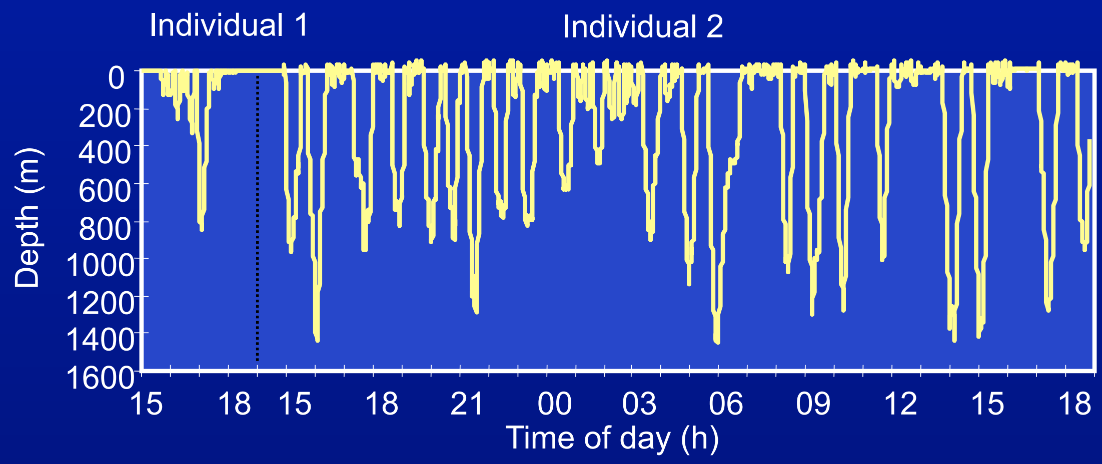
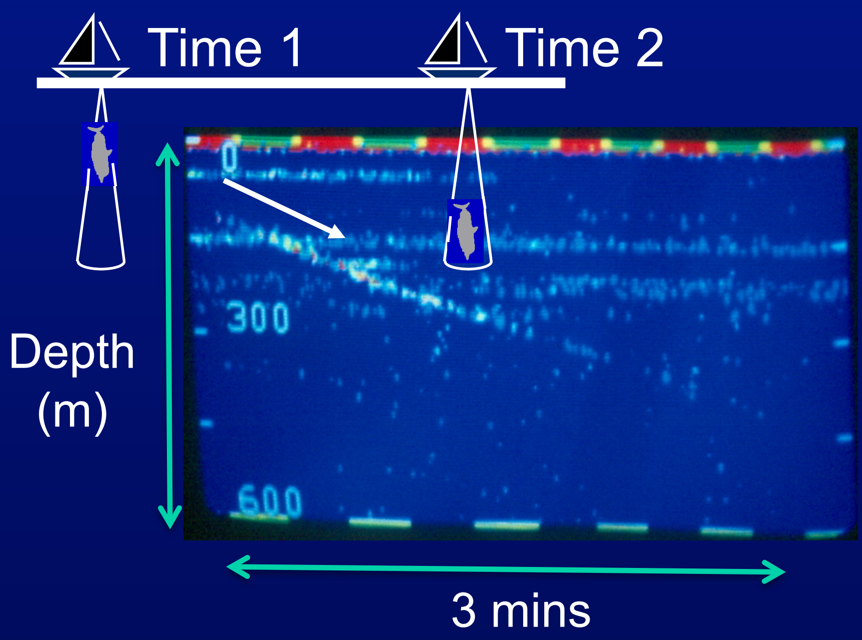
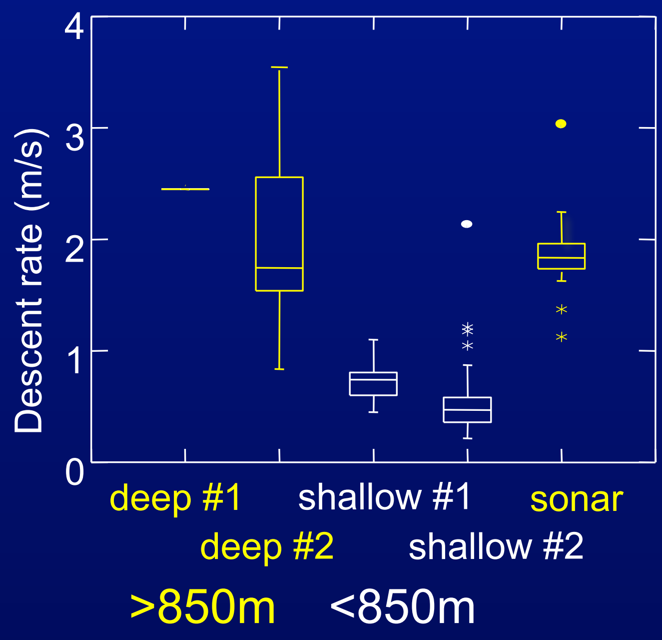
Representativeness

Using sonar traces to verify deep dives based on descent rates







Hooker and Baird. 1999. *Proc. Roy. Soc. Lond. B.*

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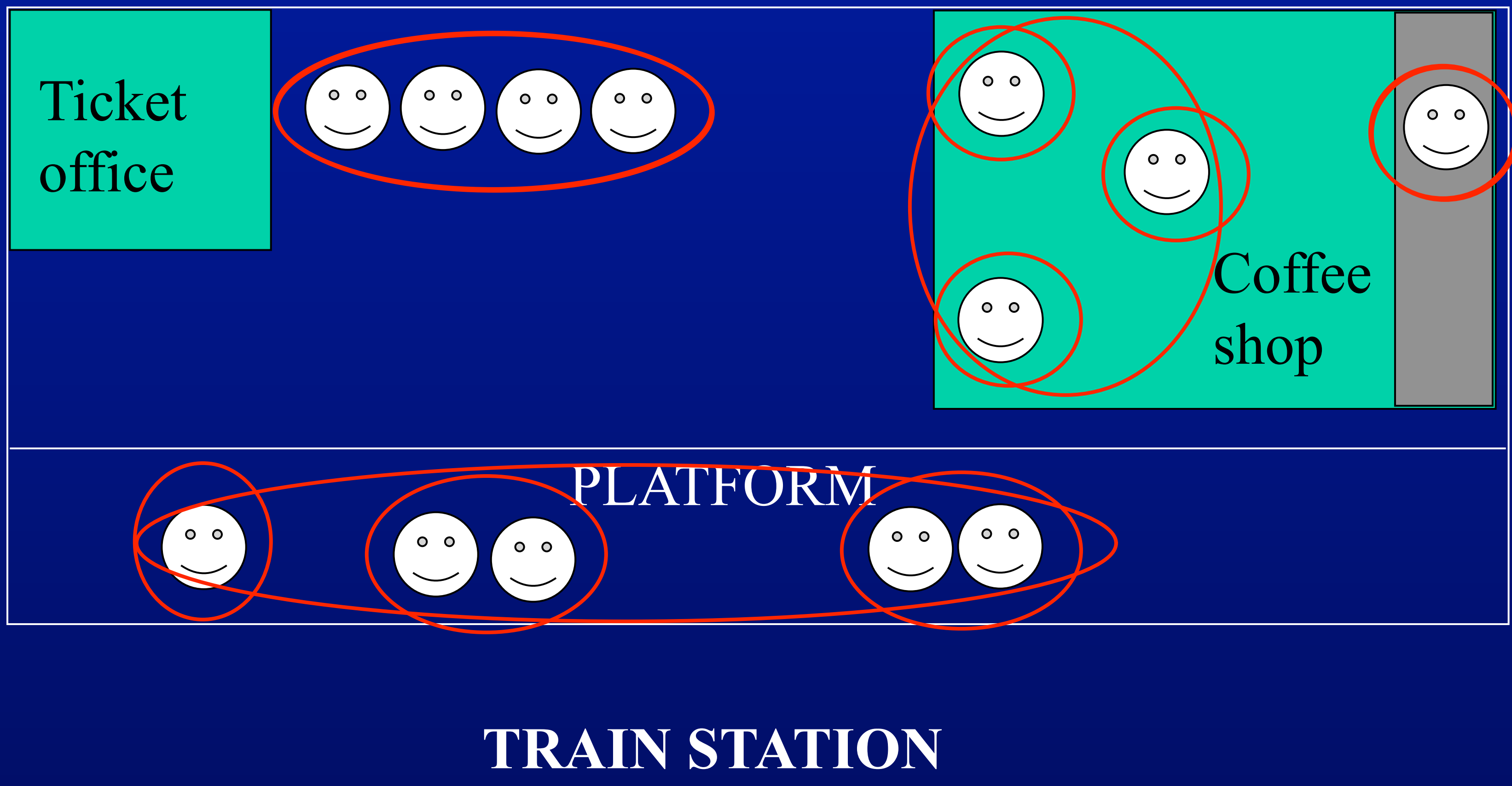
2. Measurement of foraging

- How can we maximise broad-scale inference

Environmental Context



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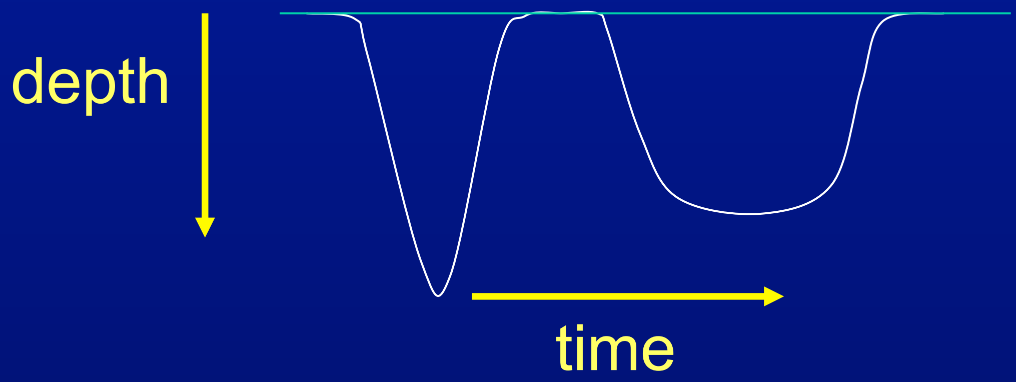
TDR: the biologging workhorse

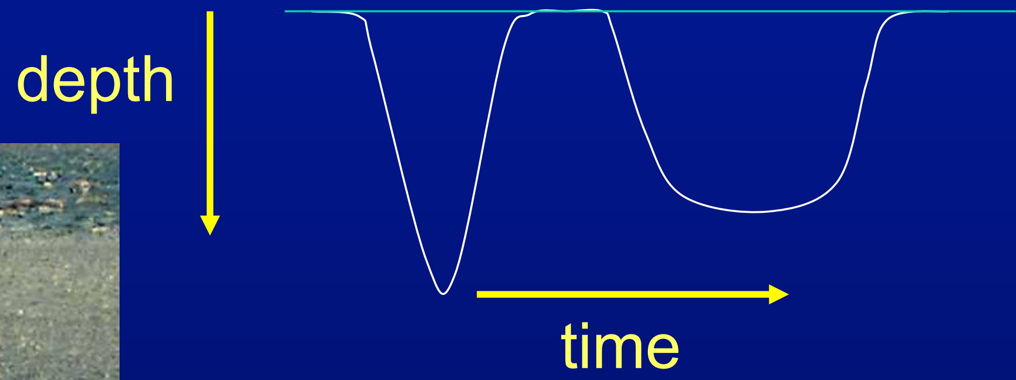
Time-depth recorder (TDR) - samples depth at set time-intervals



Categorising behaviour?

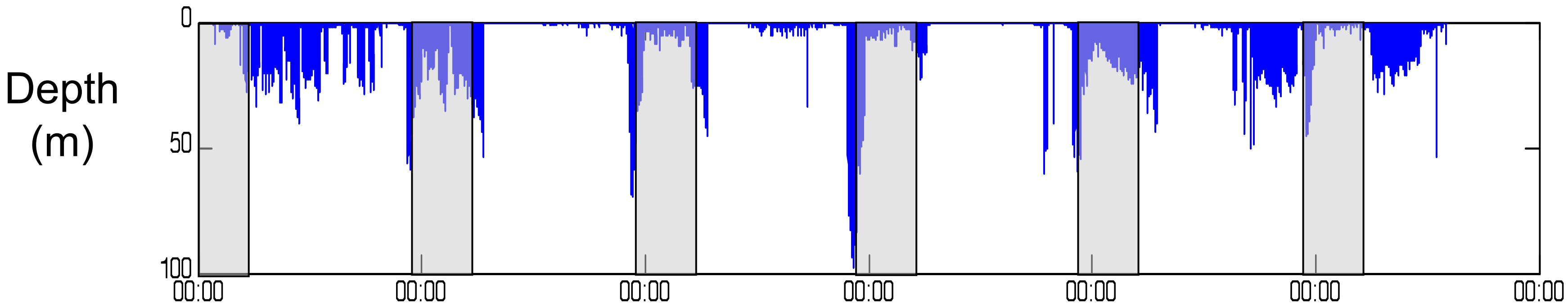
Bird Island, South Georgia, 1979 - mechanical TDR

TDR: the biologging workhorse



Bird Island, South Georgia, 2002 – seals get wise!

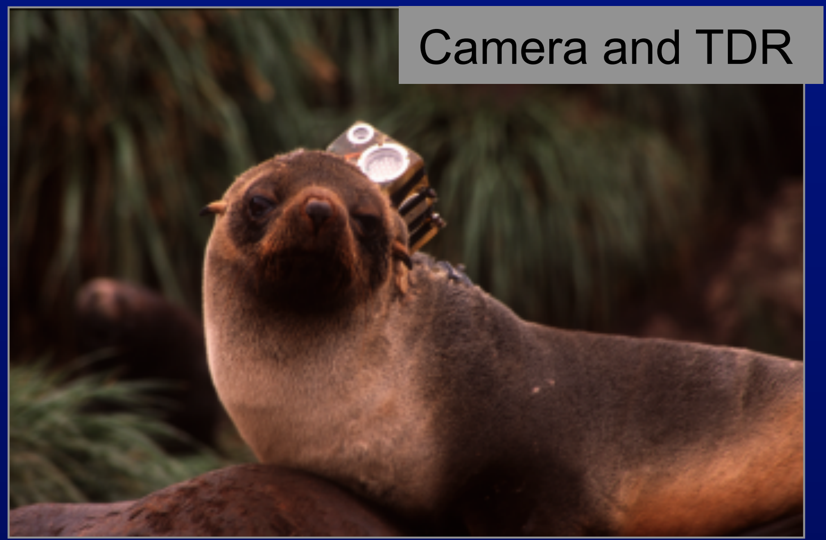
Inferring foraging



Time (shaded areas show night)

What are the proxies for foraging?
-all dives?
-all time below 10m depth?

Where in a dive does foraging take place?



Hooker et al. 2002. *Marine Mammal Science*

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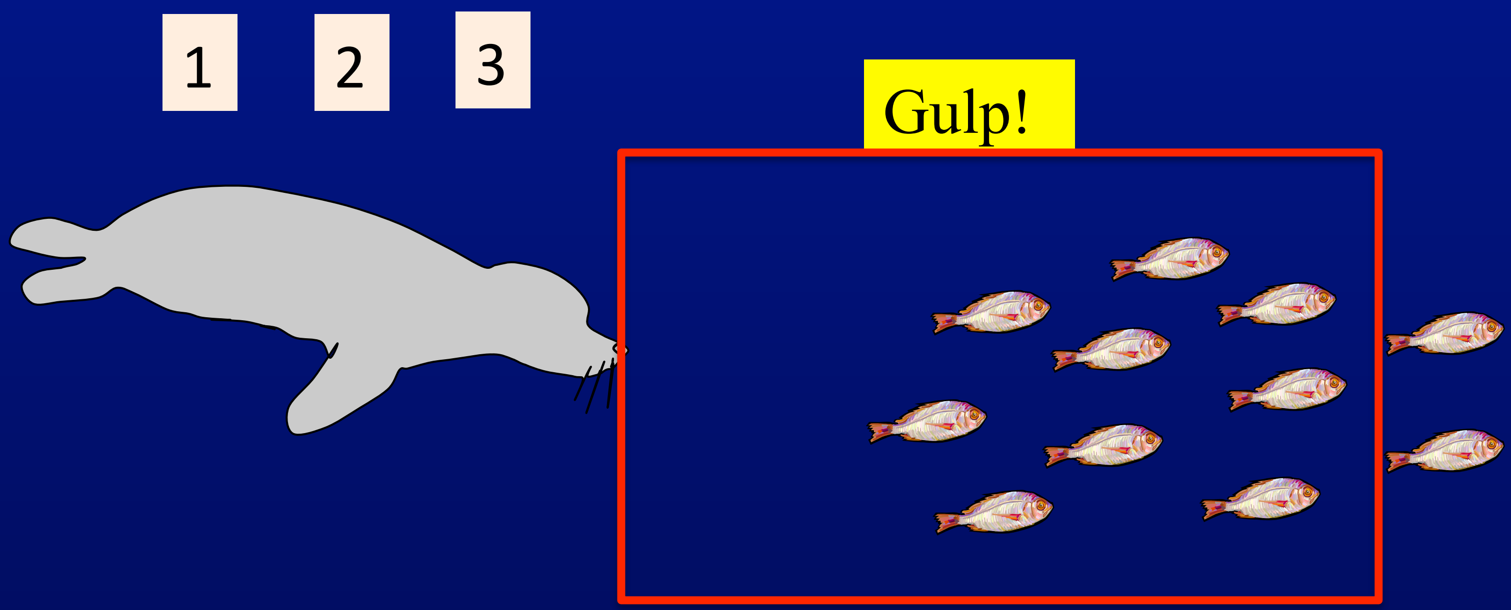
Foraging

Foraging signatures

1. Camera results – show prey availability
2. Accelerometers / Hall sensors – show prey capture attempts
3. Stomach temperature sensors – show prey ingestion



Camera

Another foraging seal 10 m away

Camera

Antarctic krill

Camera

Krill illuminated
by flash at night

Camera

High density krill

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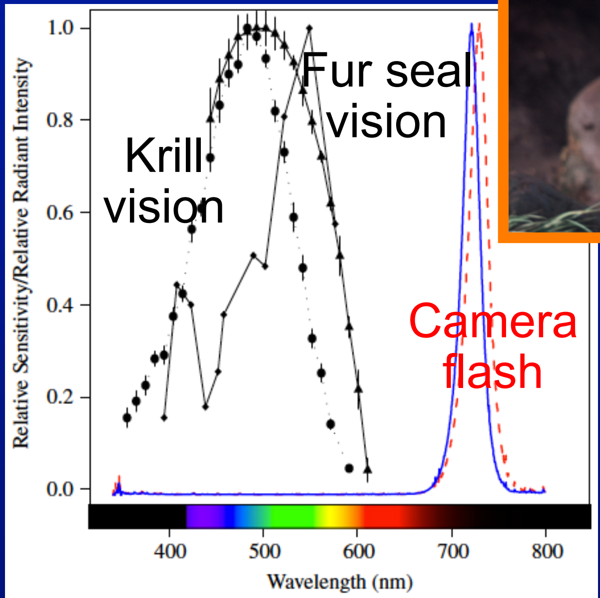
Representativeness



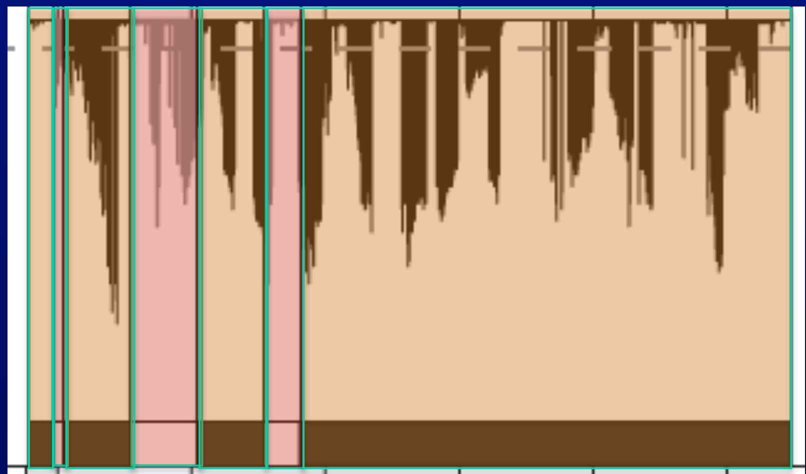
<u>Comparing:</u>

TDR & PTT

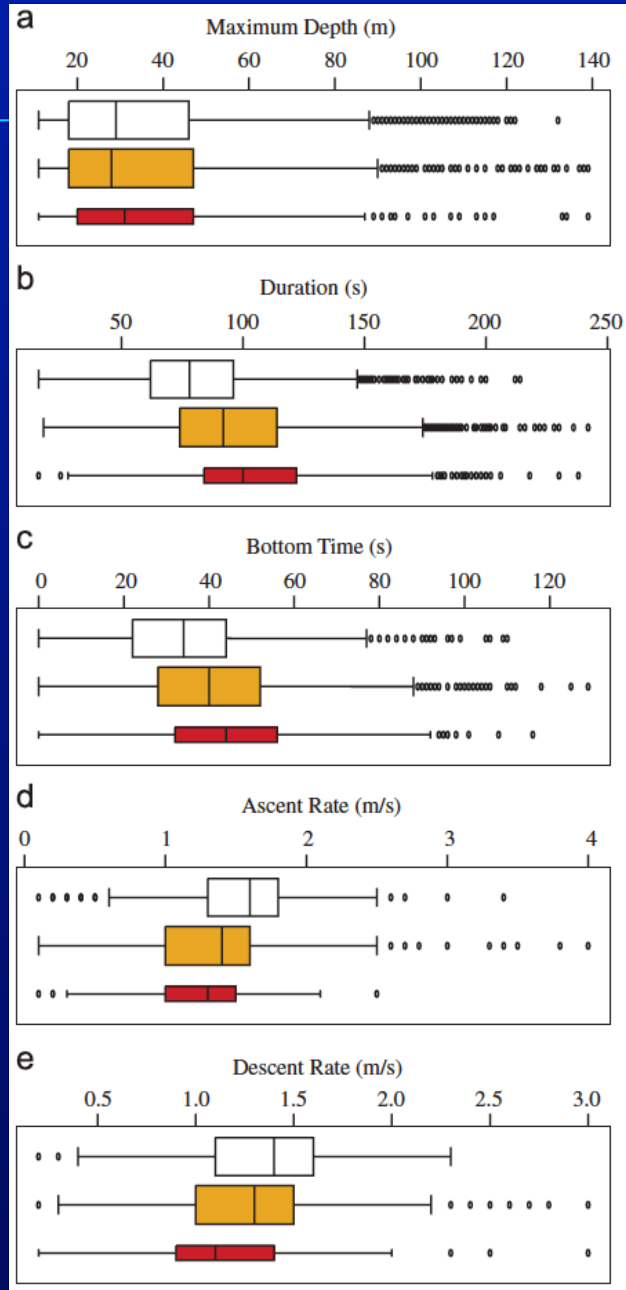
Camera no flash

Camera flash

depth



time



Heaslip & Hooker 2008. *Deep-Sea Research*

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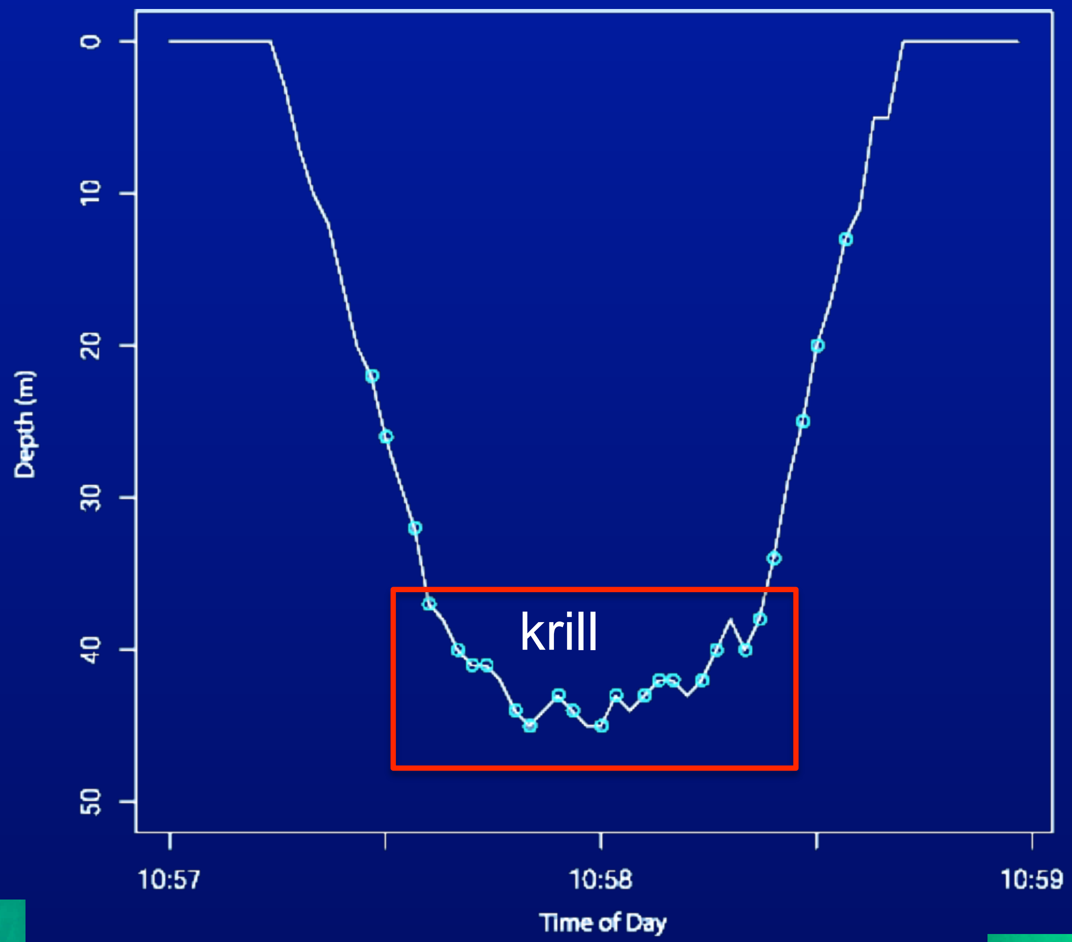
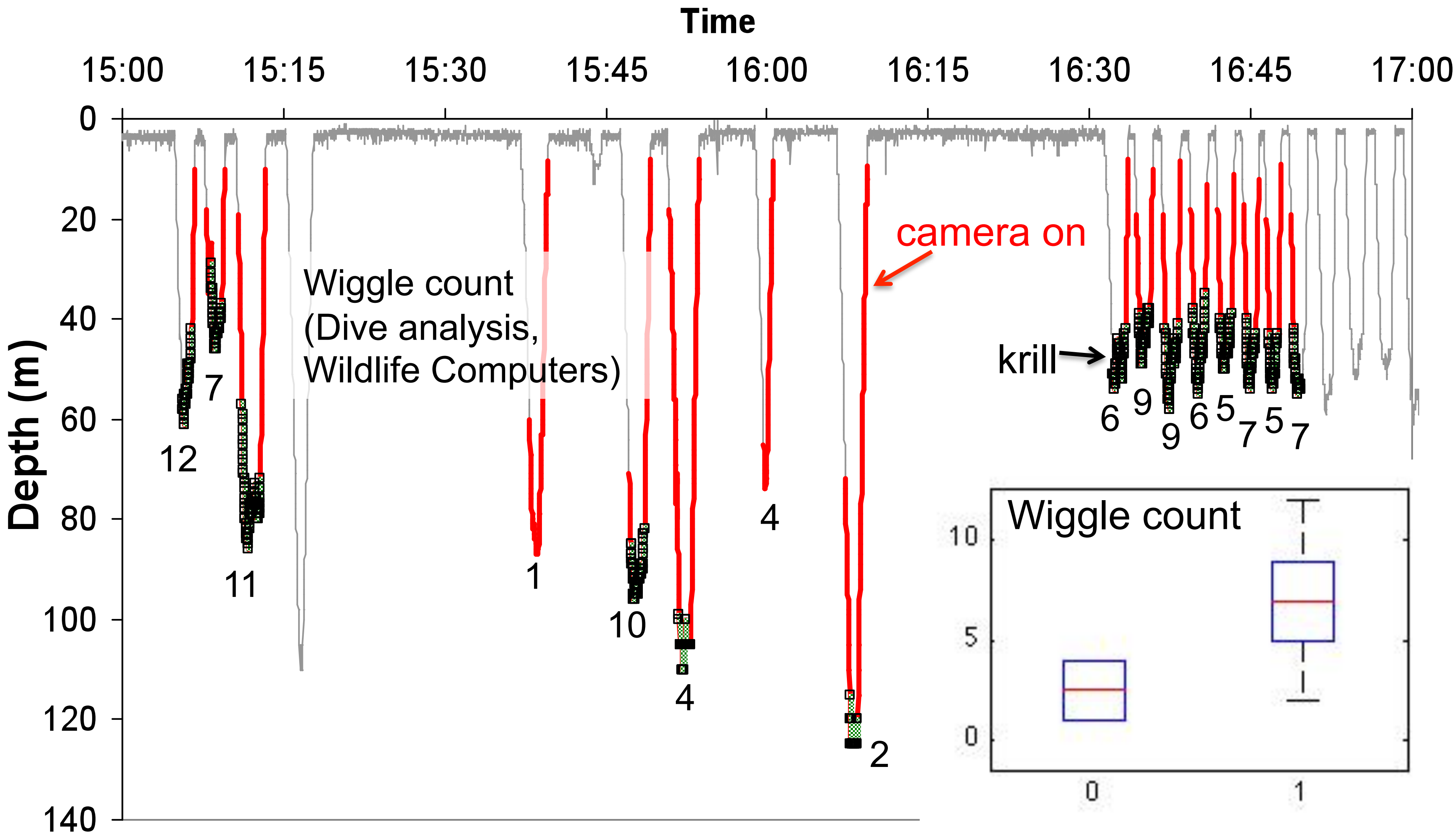
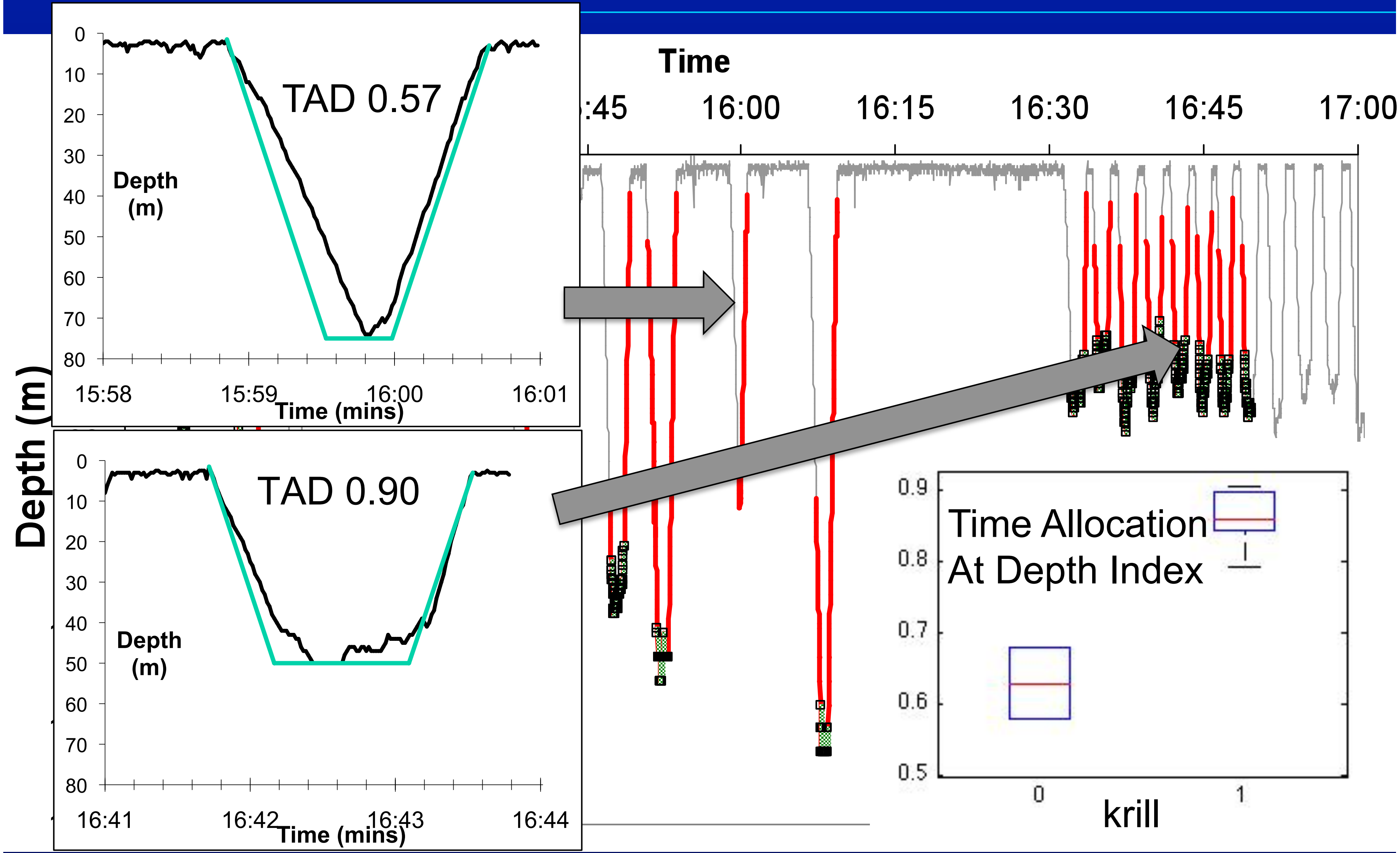
Proxies for prey availability?



Identifying foraging proxies



Identifying foraging proxies

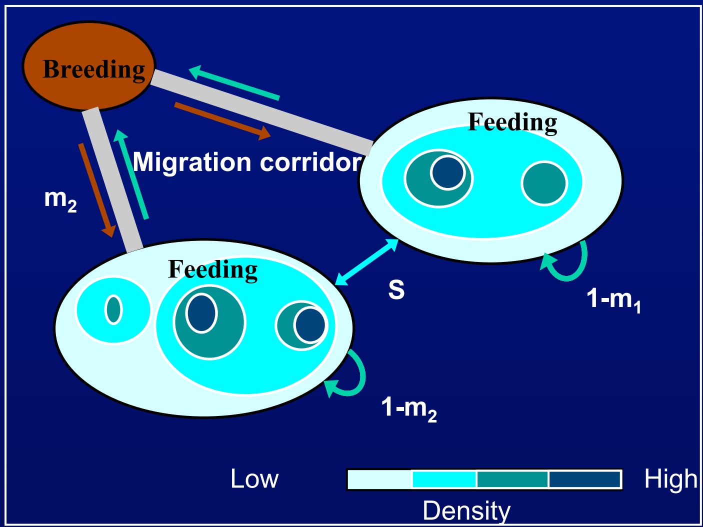


Marine Protected Areas

"Reserves…can help to overcome a key weakness of conventional management: its failure to account for ecological complexity" *Roberts (1997)*

Identification of foraging

- Most threats occur during foraging
- Most can be mitigated by spatial protection



Hooker & Gerber 2004. *BioScience*



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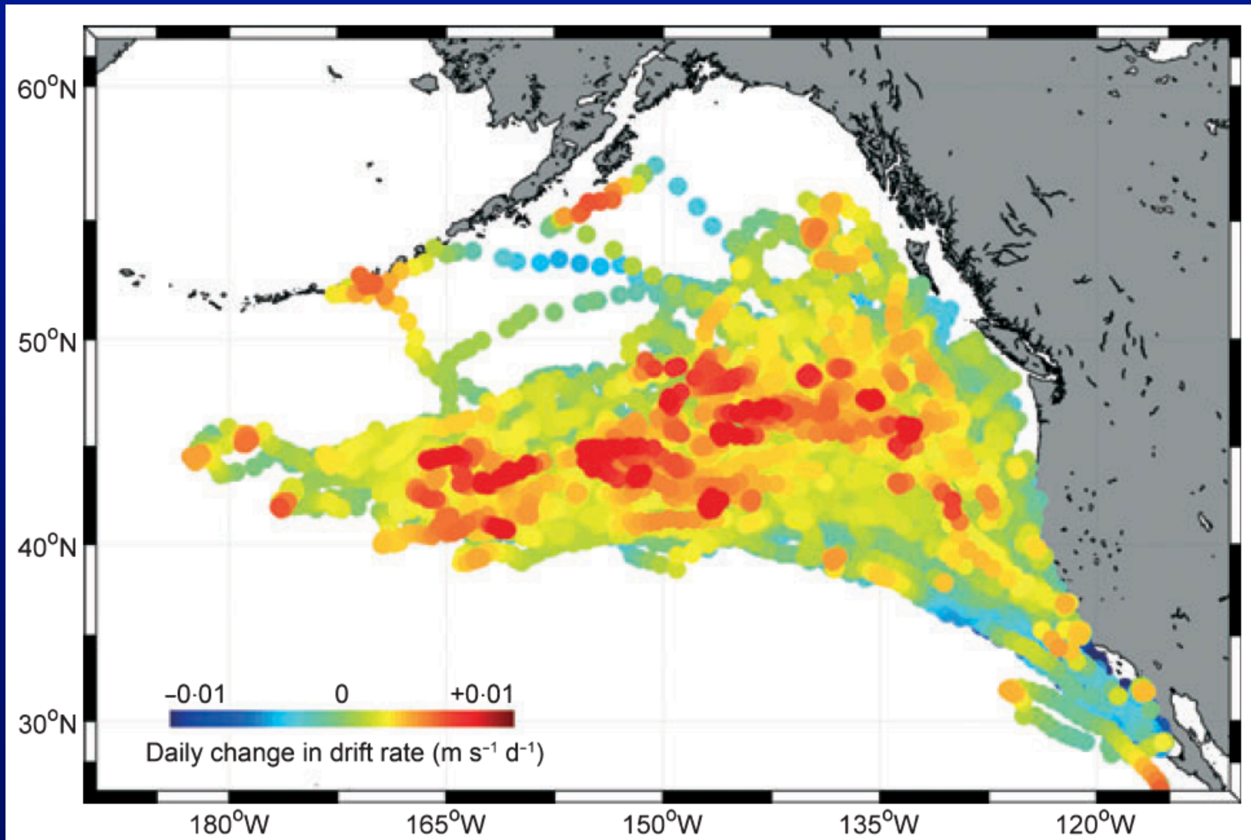
Conservation Decision Making

Generation of maps based on foraging success

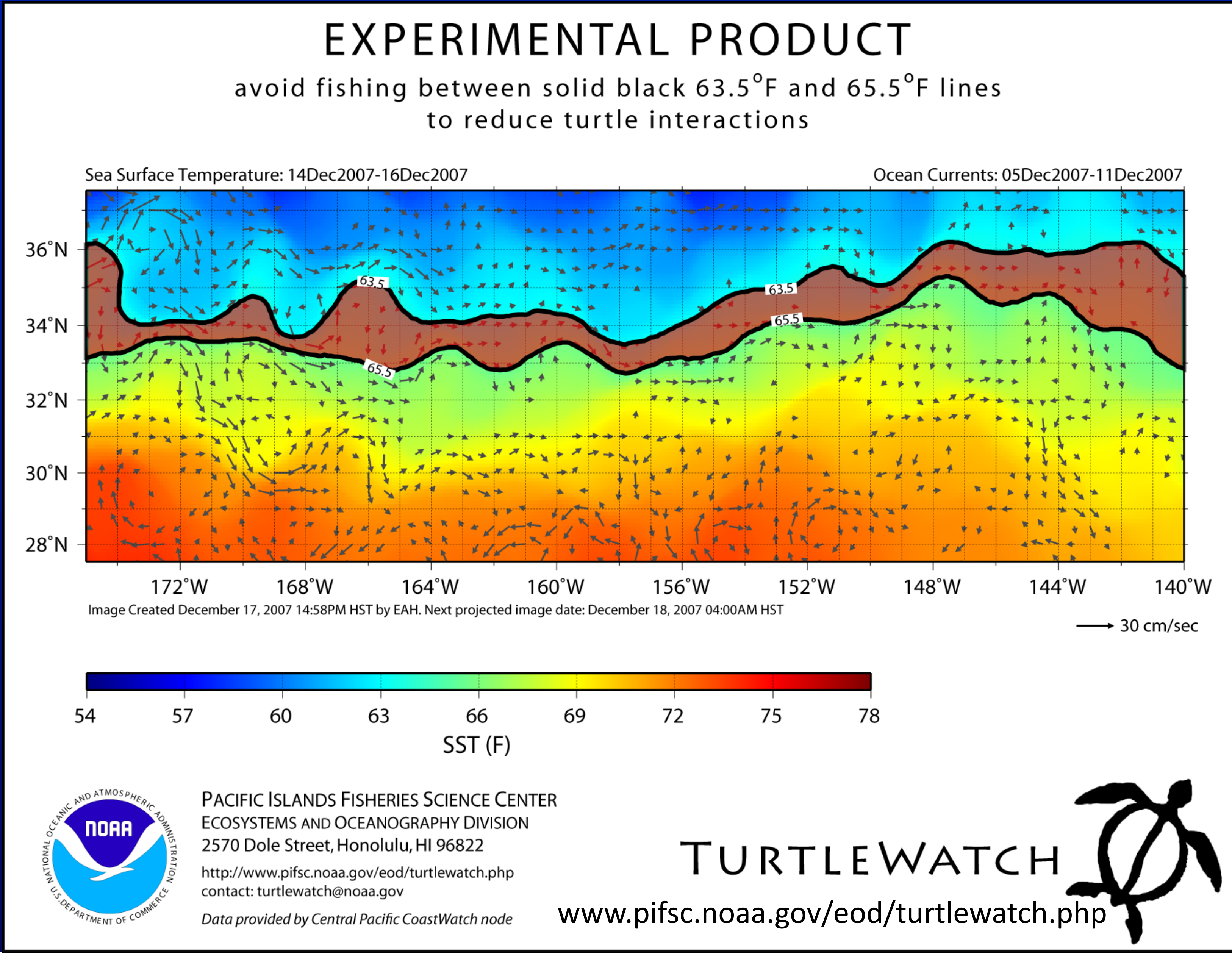
Relationships between these and habitat features

-provides predictive power to anticipate temporal changes



Daily estimates of change in drift rate for 79 elephant seals.
From Robinson et al. 2010. J. Anim. Ecol.

Dynamic MPAs



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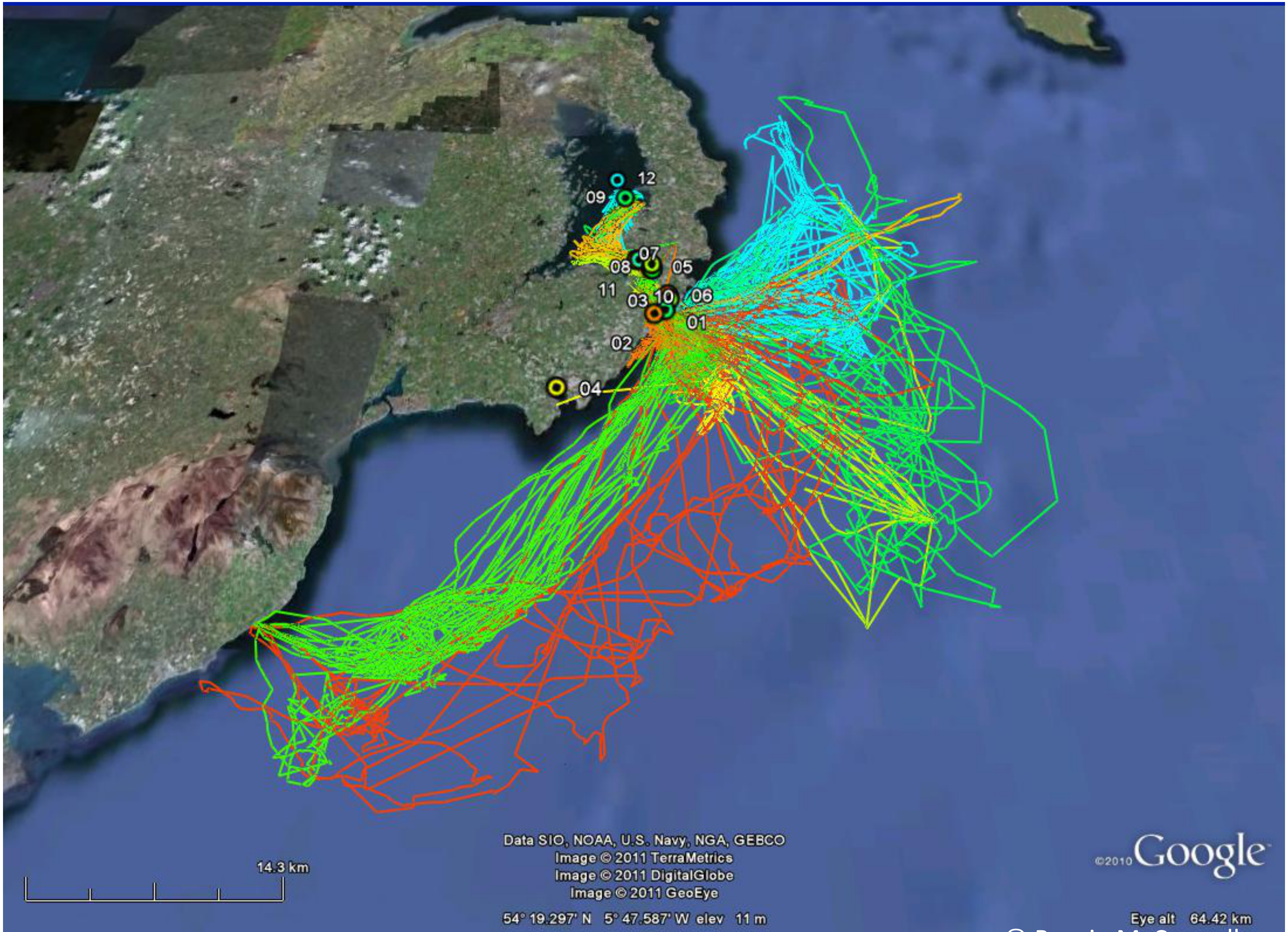
3. Individual fitness

- Are there successful individual strategies?


12
09
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01
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2011 TerraMetrics
Image © 2011 DigitalGlobe
Image © 2011 GeoEye
14.3 km
54° 19.297' N 5° 47.587' W elev 11 m
©2010 Google
Eye alt 64.42 km

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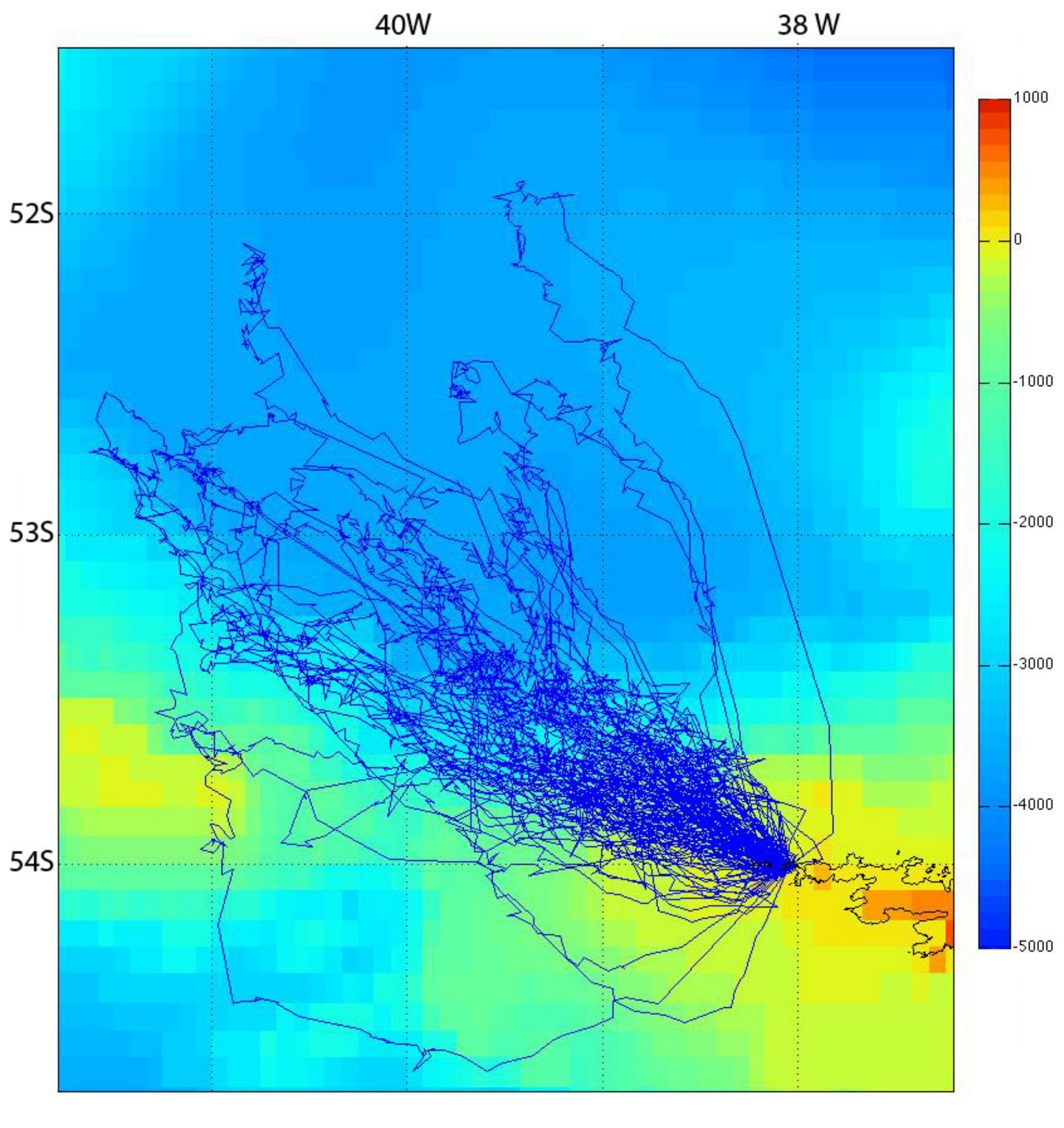
'Three-dimensional' movements



<u>2000-2001</u>

64 trips recorded from 47 individuals

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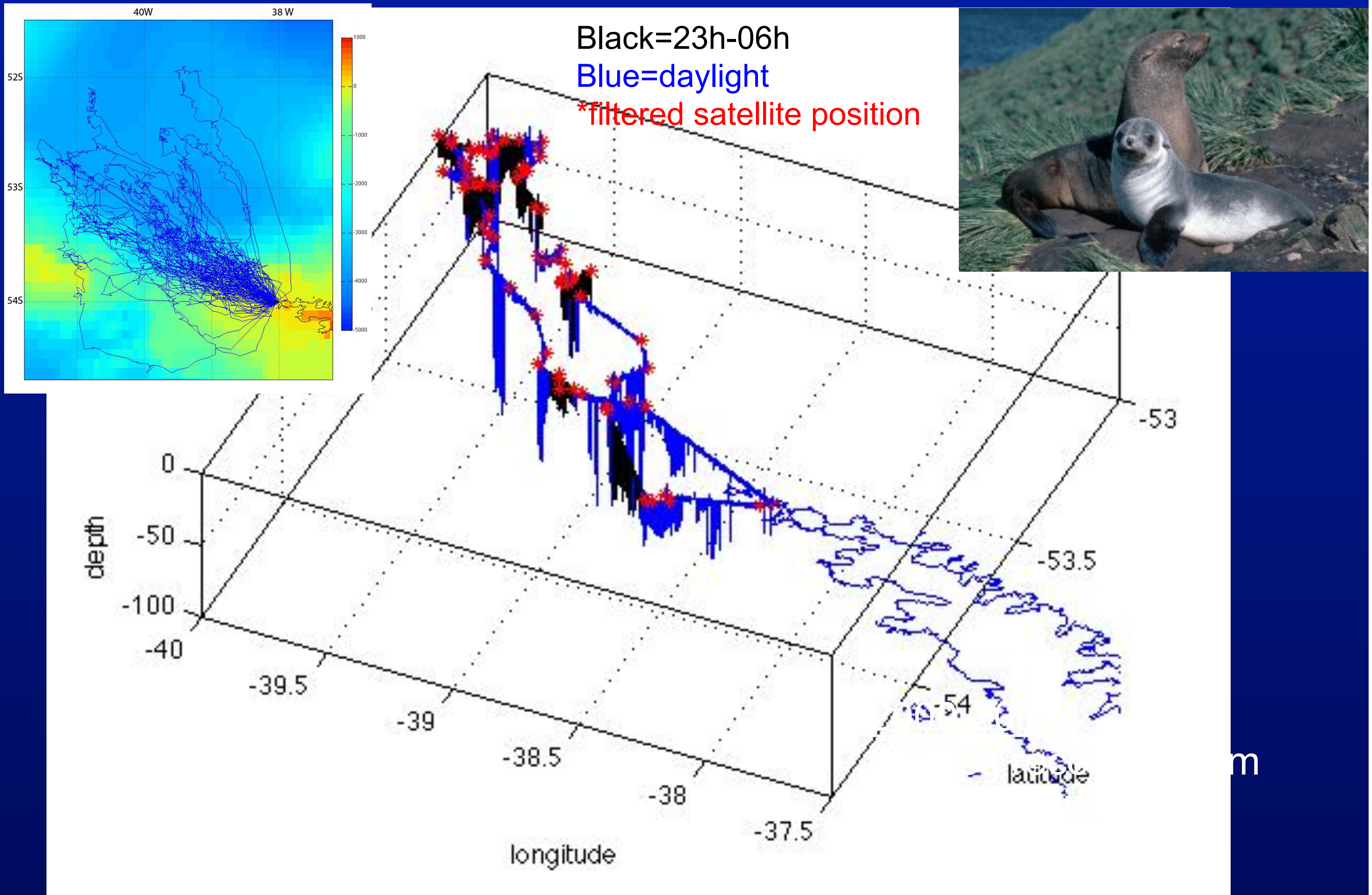
‘Three-dimensional’ movements



Telemetry data

"Wildlife telemetry data are
spatio-temporally autocorrelated,
often unbalanced,
presence-only observations
of behaviourally complex animals,
responding to a multitude of
cross-correlated environmental variables."

Aarts et al. 2008. *Ecography*

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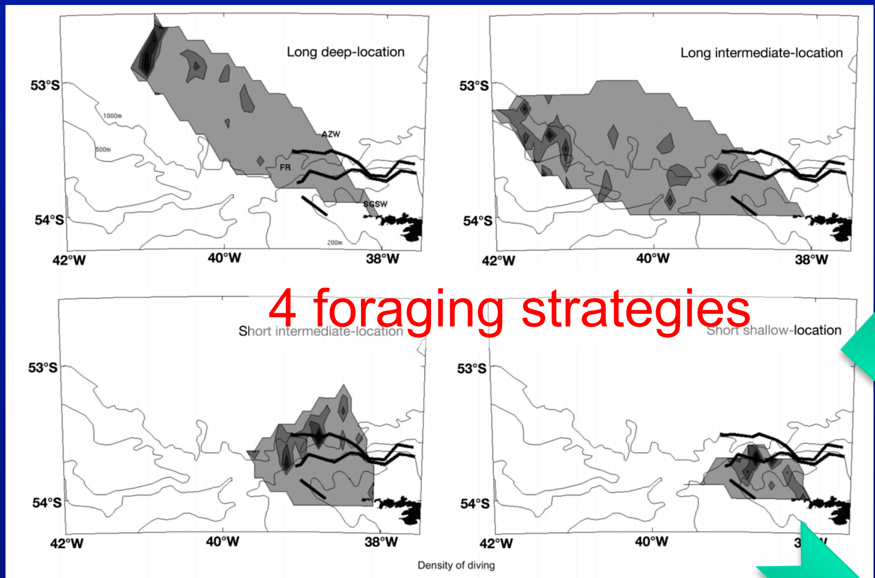
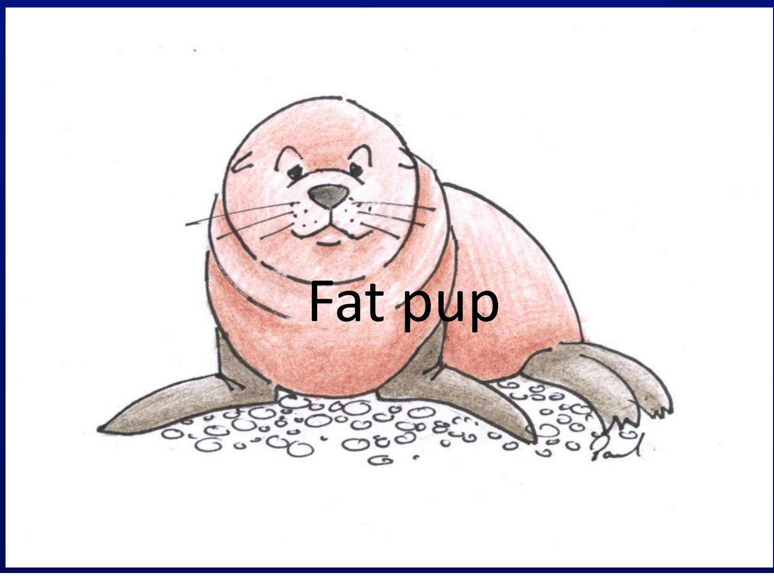
Individual strategies



Staniland et al. 2004.

Oceanographic variation



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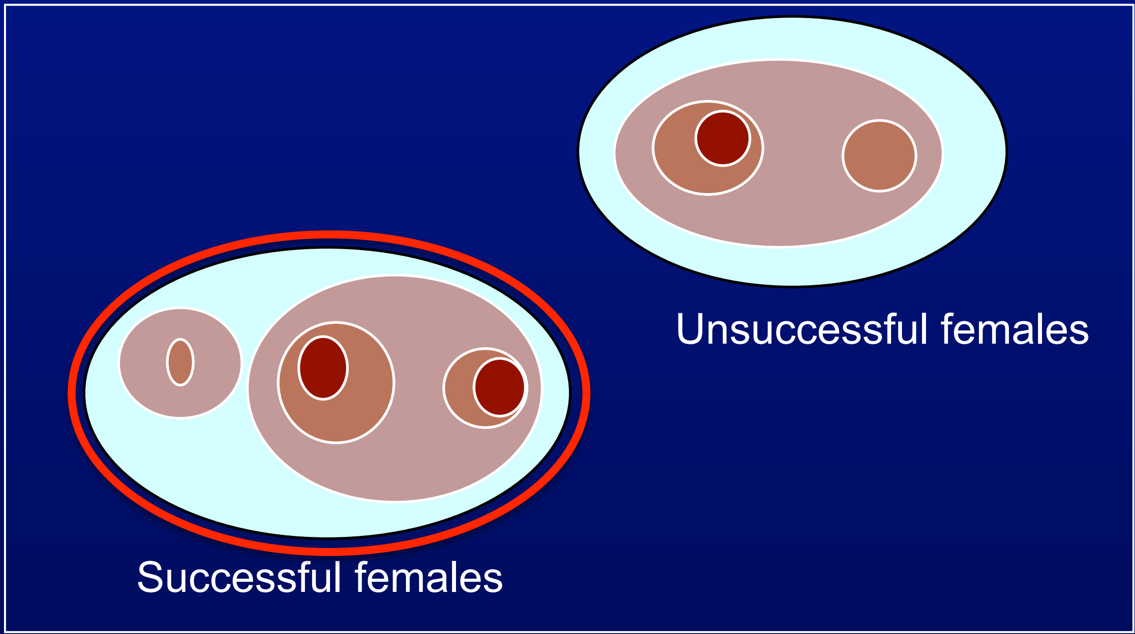
Marine Protected Areas

Critical habitat: *that which when changed affects rate of population increase* (Harwood, 2001)

<u>Demographic assessment in MPA planning</u>

- Which animals?
- What risk?
- What affect on rate of population increase?



Hooker et al. In press. *ESR*

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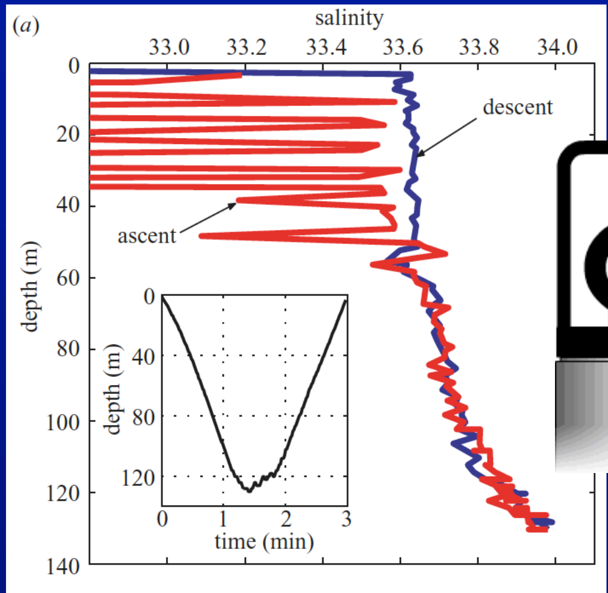
From NRC, 2005 – Characterising biologically significant marine mammal behaviour

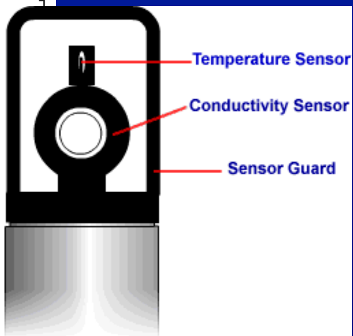
4. Beyond populations

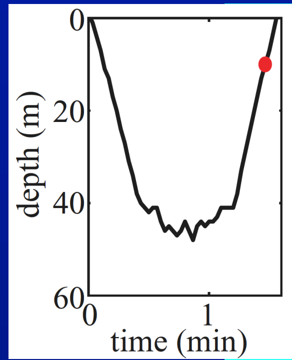
- The comparative approach

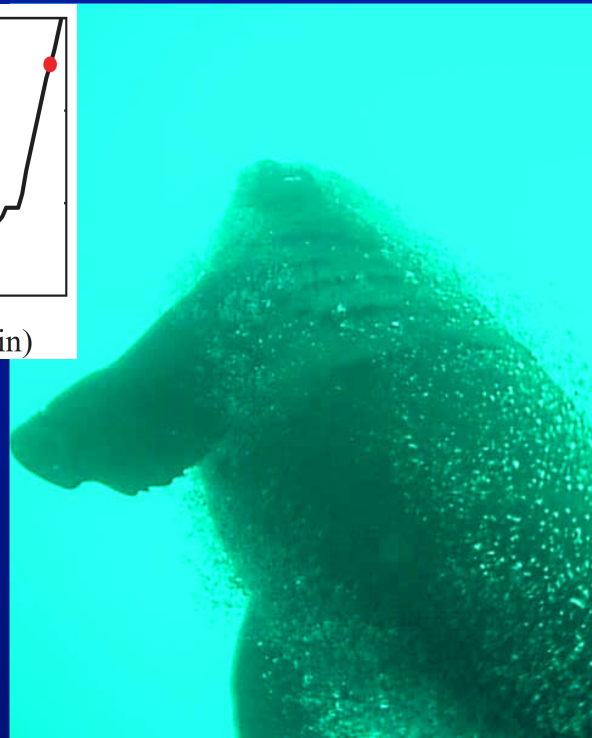
Image from Berta et al. 2005 Marine Mammals: evolutionary biology

The puzzle of ascent exhalations in fur seals









- 29 individuals: every dive (over 12,000 dives)
- Range of dive depths (10 – 160 m)

- Diving on inhalation and exhaling expanding air on ascent
  - maintains constant minimal lung volume
  - preventing reduction in lung partial pressure
  - minimises reduction in blood O2 (minimises shallow-water blackout)

Hooker et al. 2005. *Proc Roy Soc Lond B*

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Other pinnipeds





Phocids – exhalation divers

No Harbour seals, Grey seals (Bowen et al.)

No Weddell seals (Davis et al)

No Northern elephant seals (Costa; Tyack) ♪

Otariids – inhalation divers

No Australian sea lion (Goldsworthy)

No Hooker's sea lions (Gales)

No Steller sea lions (Davis, Andrews)

Yes Northern fur seals (Insley; Andrews) ♪ ⌫

Yes Sub-antarctic fur seals (Bester) ⌫

Yes Australian fur seals (Arnould)

Yes Male antarctic fur seals (Davis)

Key: ⌫ CT ♪ Acoustic Camera (forwards)

Species Comparison

Species	Dive frequency (dives/h at sea)	Dive depth (m)	Dive duration (min)
Subantarctic fur seals			
Arctocephalus tropicalis[a]	3.7 ± 0.5 (10)	19 ± 0.4	1.1 ± 1.0
A. tropicalis[b]	7.9 ± 0.6 (4)	12 ± 6	0.7 ± 0.3
Northern fur seals			
Callorhinus ursinus[c]	1.5 ± 0.2 (7)	68 ± 20	2.2 ± 0.5
Antarctic fur seals			
A.gazella[d,e,f]	3.4 ± 0.5 (17)	30 ± 2	0.9
A.gazella[g]	18.1 (385)	12.7	1.1
South African fur seals			
A. pusillus[h]	2.7 (2)	45	2.1
Galapagos fur seals			
A. galapagoensis[i,j]	5.6 ± 1.4 (3)	26 ± 4.0	1.3*
Juan Fernandez fur seals			
A. phillipi [k]	0.6^1 (9)/1.9^2 (6)	26 ± 2/12 ± 3	1.8 ± 0.2/0.8 ± 0.1
Steller sea lions			
Eumetopias jubatus[l]	17.5 ± 1.2 (5)	21*	1.3
California sea lions			
Zalophus californianus[m]	16.4 ± 0.8 (17)	61.8 ± 5.9	2.1 ± 0.1
Galapagos sea lions			
Z. wollebaeki [n,f]	8.0 (3)	37	2.0
Northern elephant seals			
Mirounga angustirostris[o]	2.7 ± 0.1 (7)	400 ± 59	19.2 ± 1.6
Southern elephant seals			
M. leonina[p]	2.3 ± 0.1 (8)	493 ± 20	24.4 ± 1.5

Georges *et al.* 2000 Polar Biol.

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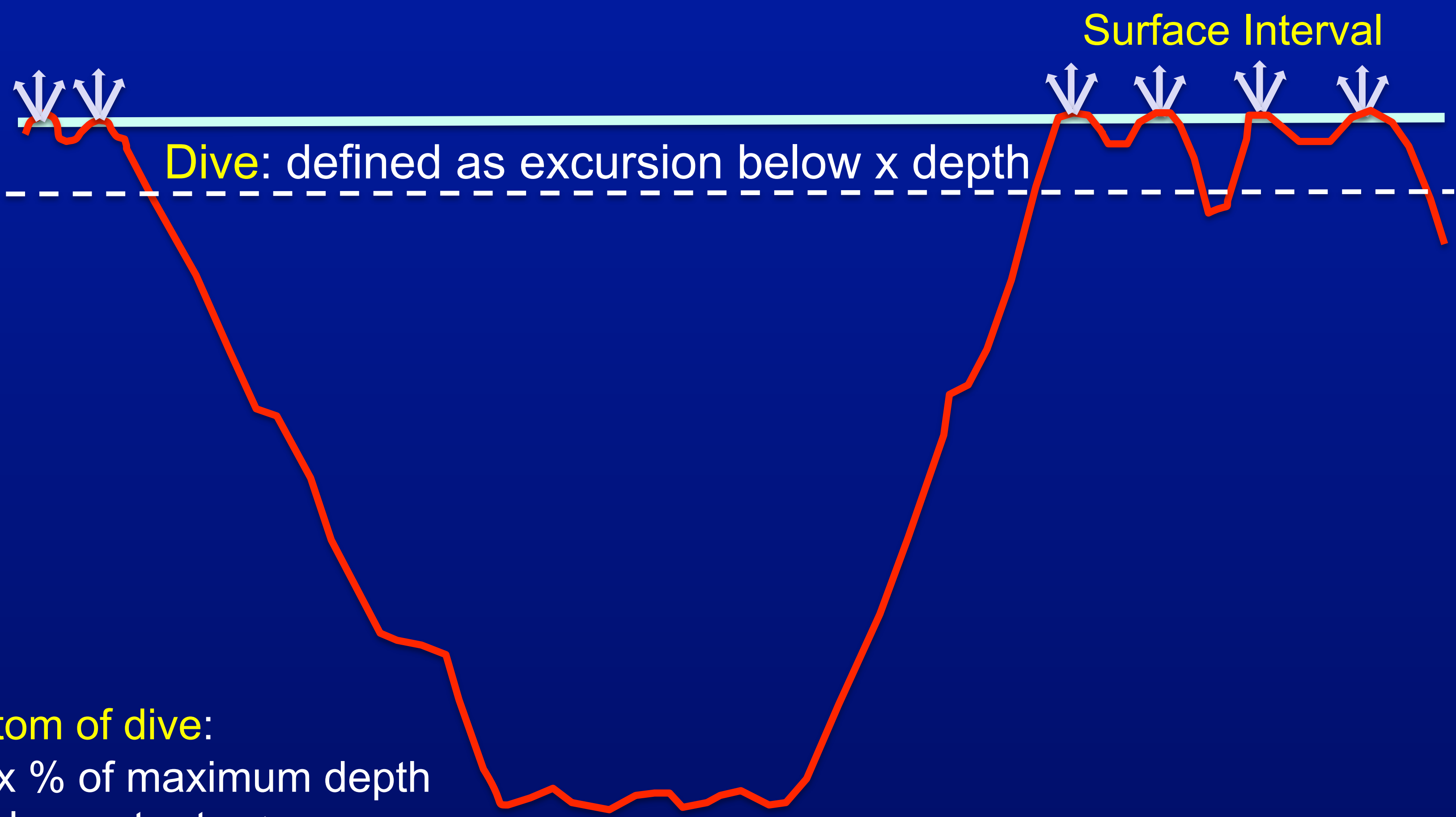
Dive Analysis - Subjectivity



Bottom of dive:

- x % of maximum depth
- descent rate < x
- descent rate < average descent to max depth

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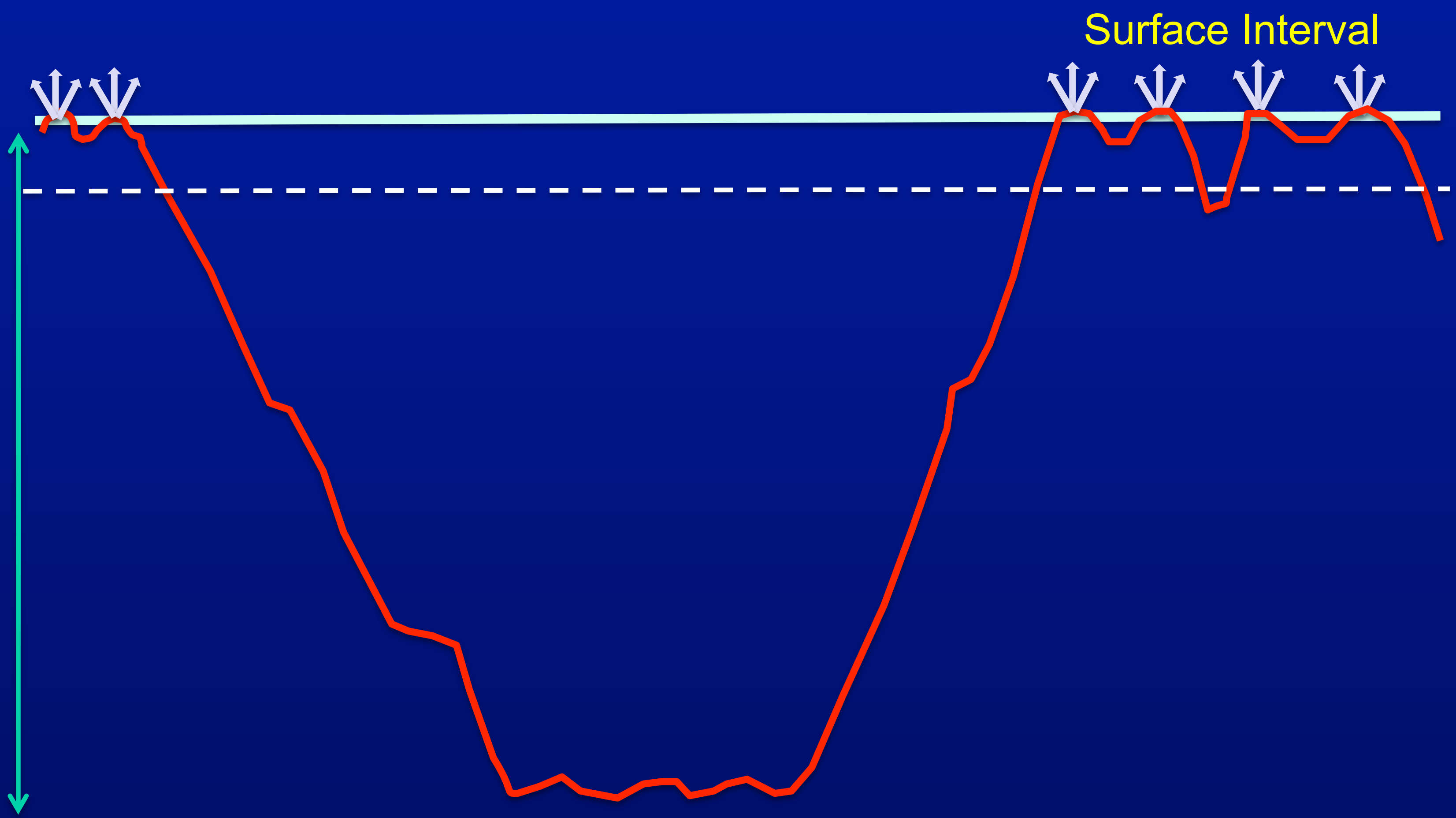
Dive Analysis – Scale and Resolution



Depth 1000 m - less relative error (in descent/ascent)
Depth 10 m – more relative error

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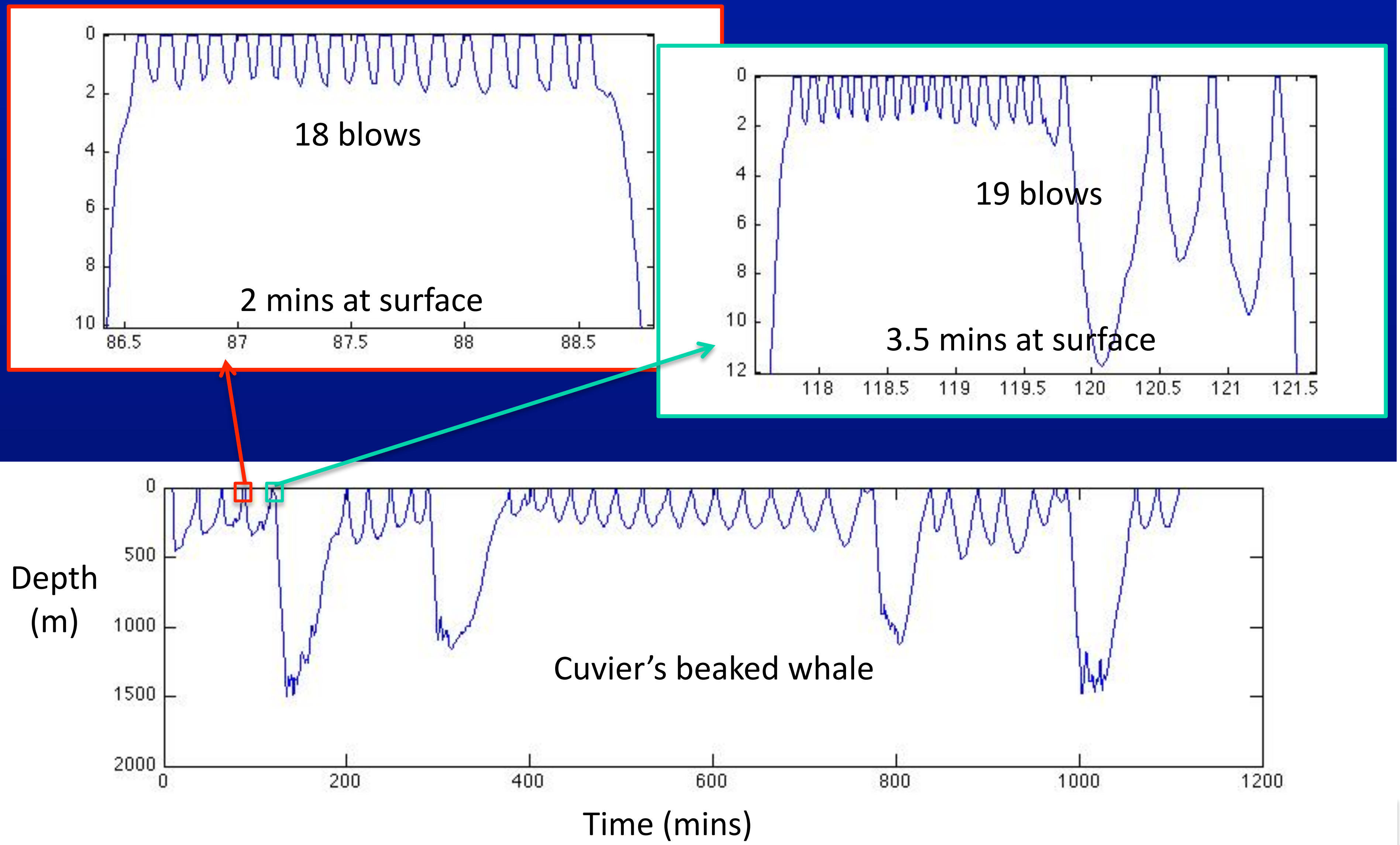
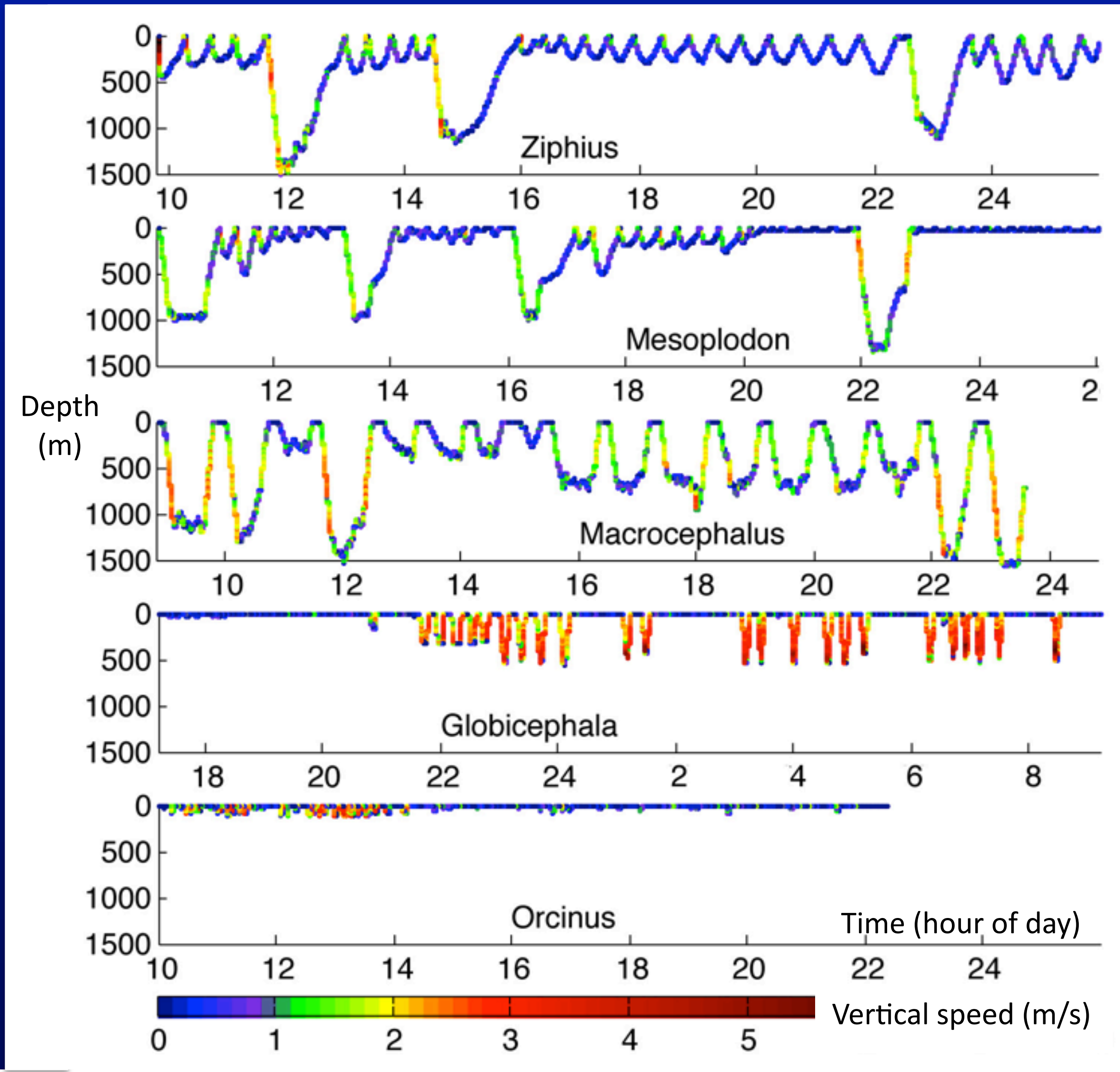
Scale – respiration “dives”



Data © Peter Tyack

Pattern not captured by standard metrics



Data © Peter Tyack

Gas Kinetic Modelling

Sealion dive profiles

Fur seal dive profiles

Gas Kinetic Model

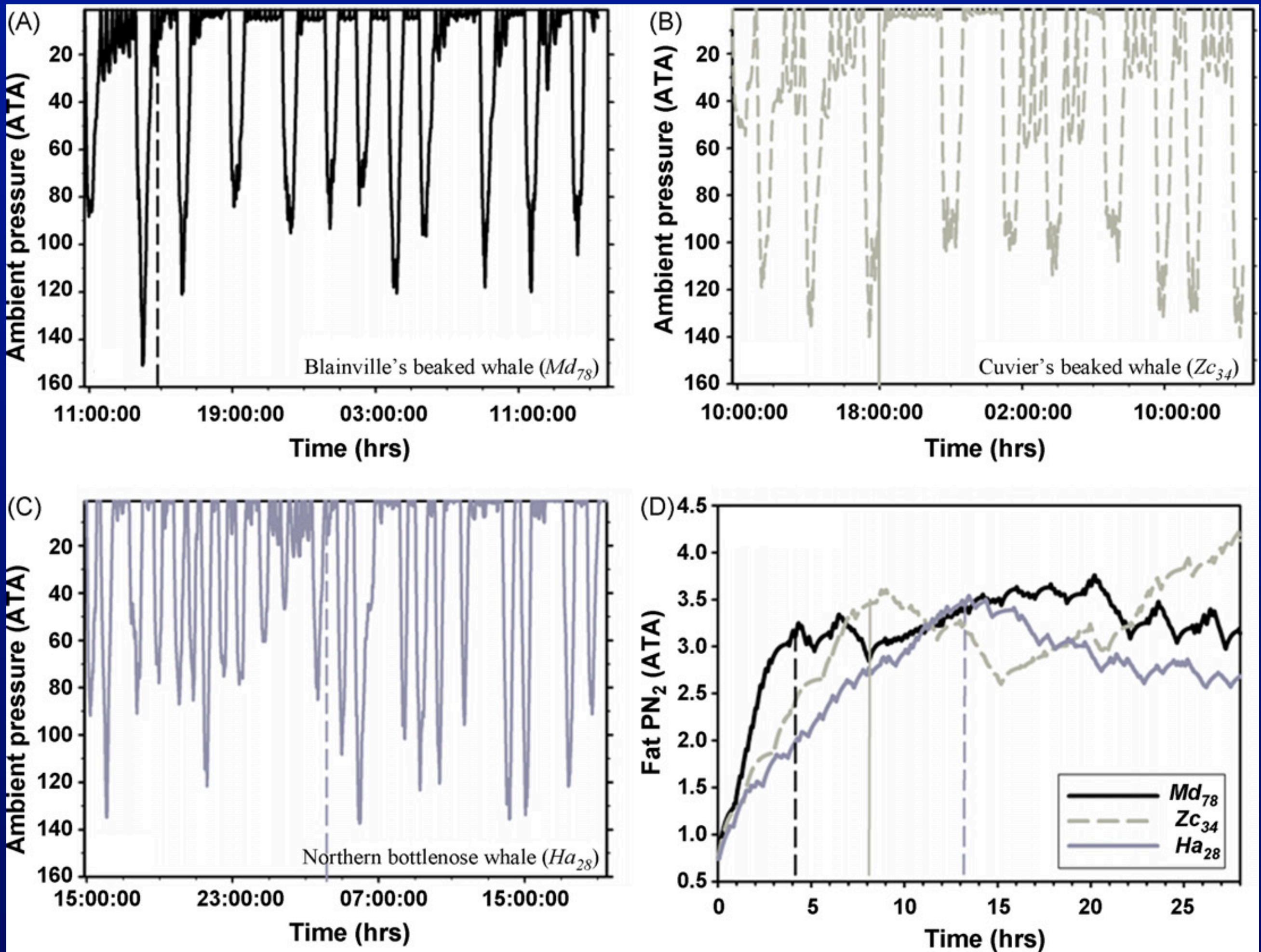
(lung volume, dive response, body size)

Higher blood O_2 at end of dives?

Lower blood O_2 at end of dives?

Gas Kinetic Modelling

Physiological models run on dive traces



Hooker et al., 2009 *Resp Physiol Neurobiol*

Recommendations

1. Use high-resolution or novel sensor tag data to derive more accurate dive metrics (e.g. identifying foraging) and thus make better use of low-resolution (often historic) datasets

2. Consider scale in terms of relating biologging data to the population - from life functions (foraging success) to vital rates (individual success)

3. Improvement of metrics and analytical techniques to describe and differentiate behaviour, enabling better comparison between populations and species.

Acknowledgements

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NZ rat work: John Innes (FRI)

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Diving Physiology: Andreas Fahlman, Peter Tyack, Michael Moore (WHOI)

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