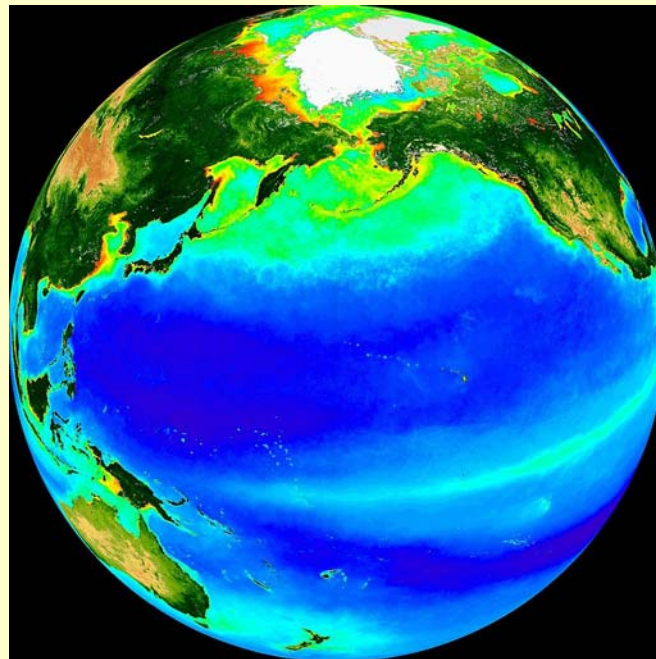


Principles & Practices for Establishing Resilient MPA Networks - Making it Happen

Oceanographic Considerations



David Hyrenbach
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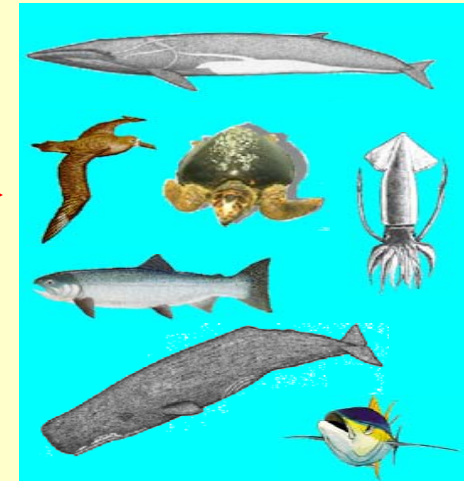
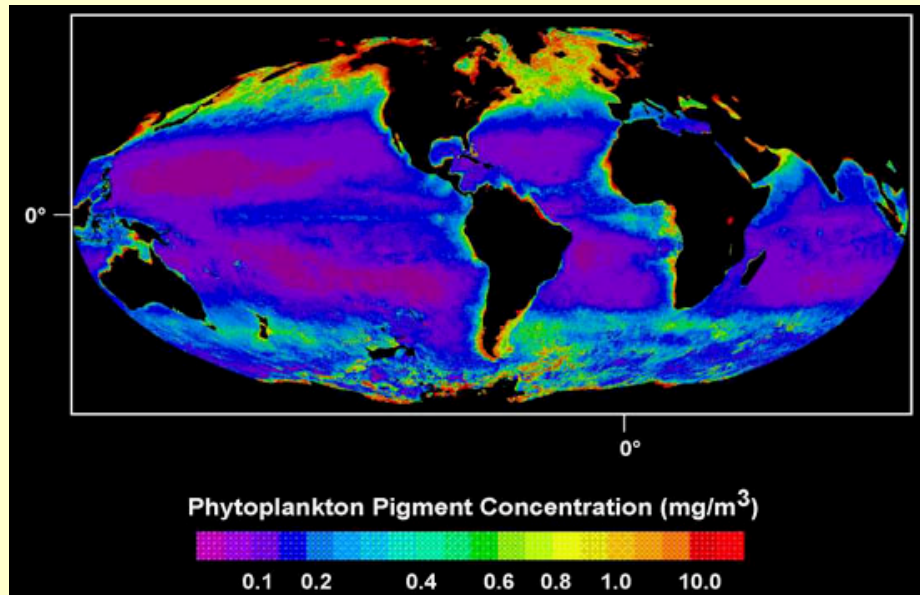
Duke
UNIVERSITY

Focus

- Upper-trophic oceanic predators:
 - Make a living in a vast, dynamic, and heterogeneous environment
 - Respond to changes in water masses, productivity and prey availability
 - Concentrate within smaller-scale foraging areas (10s - 100s km)
- Thus, in principle, MPAs could be designed to protect “predictable” predator concentrations
- Today's Goal:
 - Stimulate discussion of pelagic MPA designs**

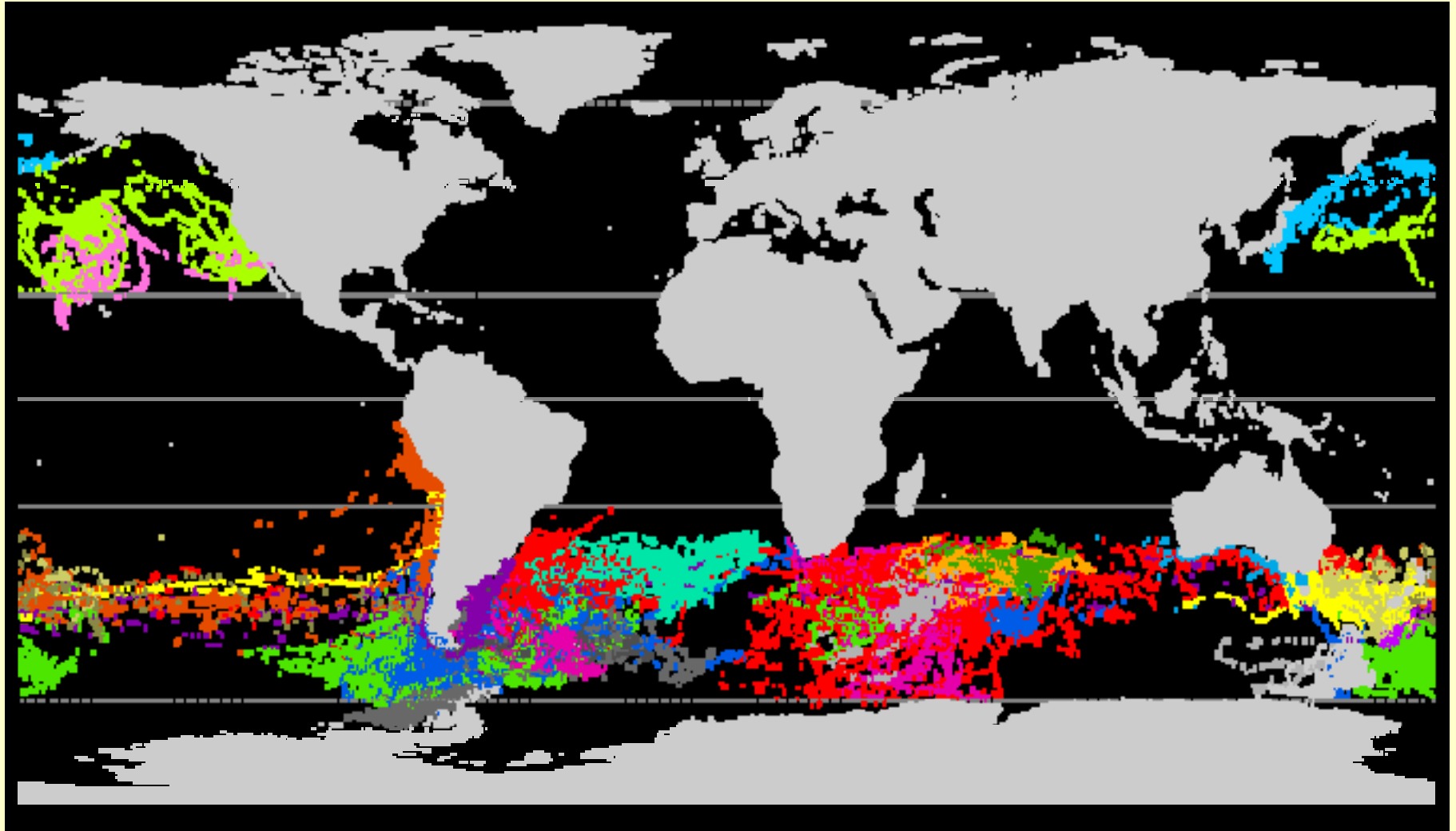


Motivation: Oceanographic Forcing



- Discuss relevant patterns and scales in pelagic systems
- Promote discussion:
 - Reserve design concepts for pelagic MPAs
 - Research needs to assess effective designs

Pelagic Conservation - One Ocean



Procellariiformes Tracking Database

21 species & 30 researchers

Far-ranging Predators



Photo: Ian Jones

Concentrate in Dense Aggregations



Photo: Brittain

With 2 - 4 birds m^{-2} , this flock off Unimak Pass contained 5 - 9 million shearwaters (~ 20 - 50 % of world population)

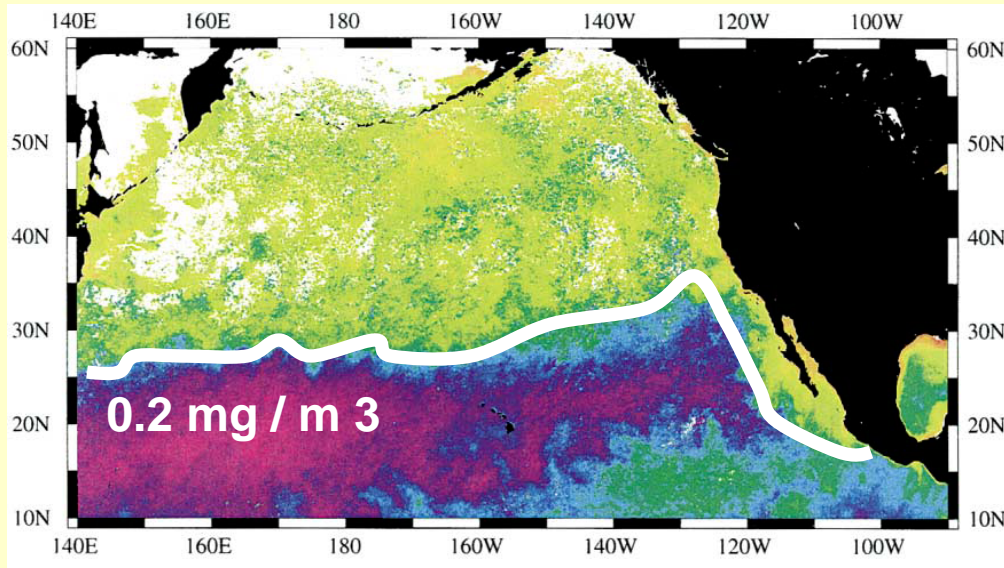
Dynamic Hotspots



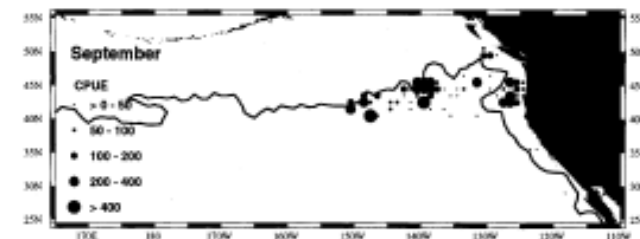
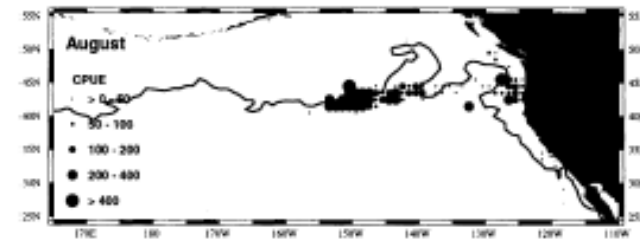
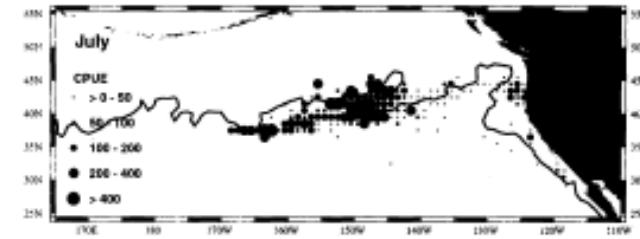
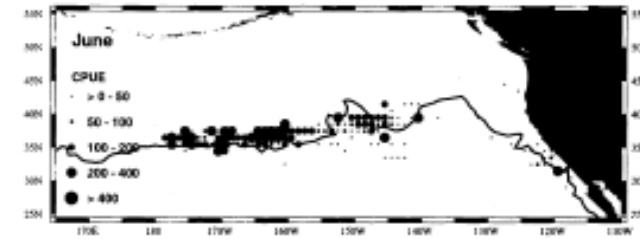
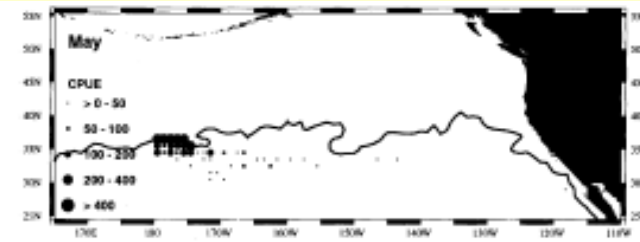
Loggerhead turtles migrate across Pacific along dynamic front



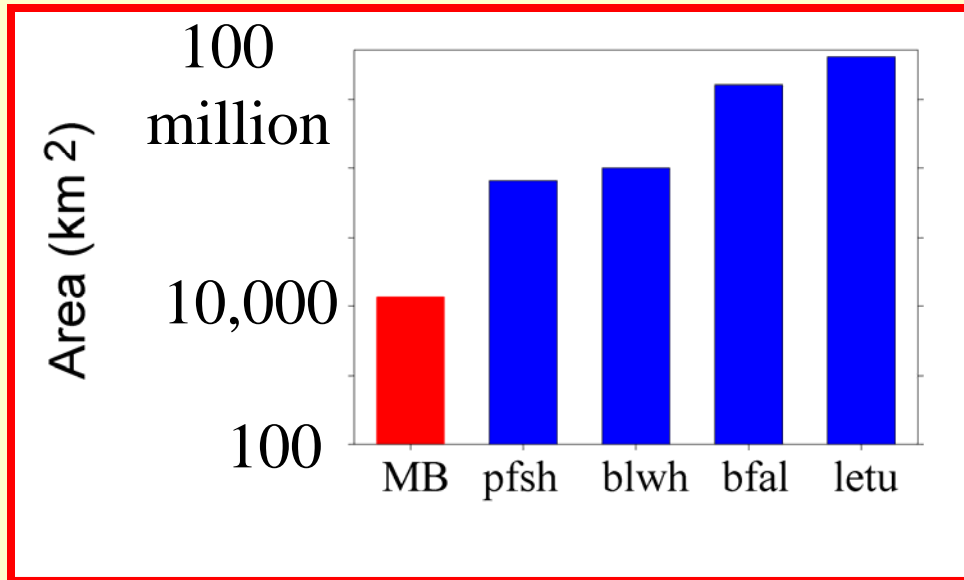
Fisheries target albacore tuna along the same feature



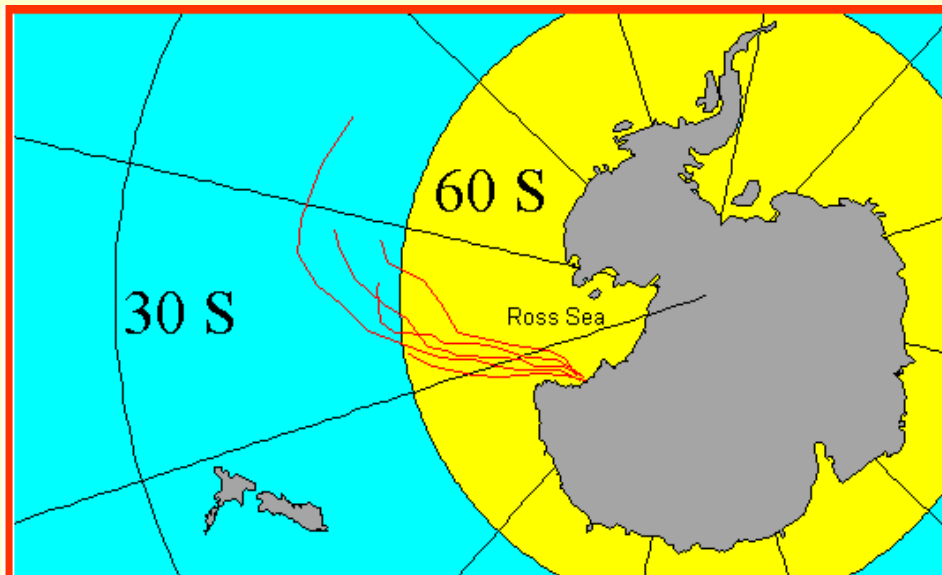
(Polovina et al. 2001)



Pelagic Reserves: Size and Shape Matter



Marine Predators forage over areas 100 - 1000 times bigger than the largest CA MPA

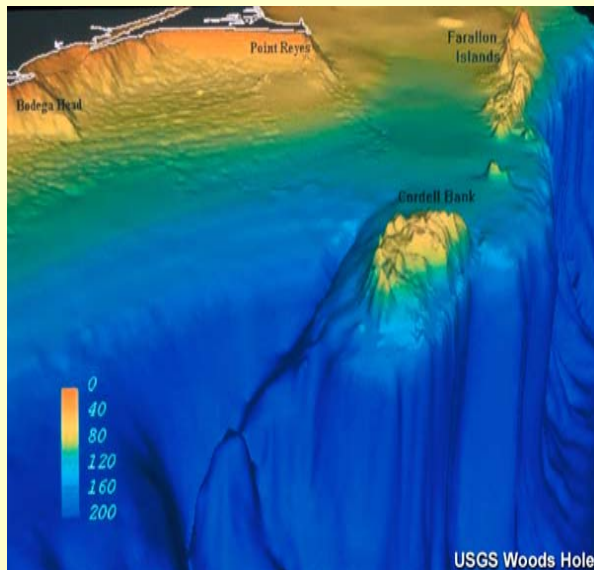


Emperor Penguins forage outside of Antarctic Treaty Waters (> 60° S)

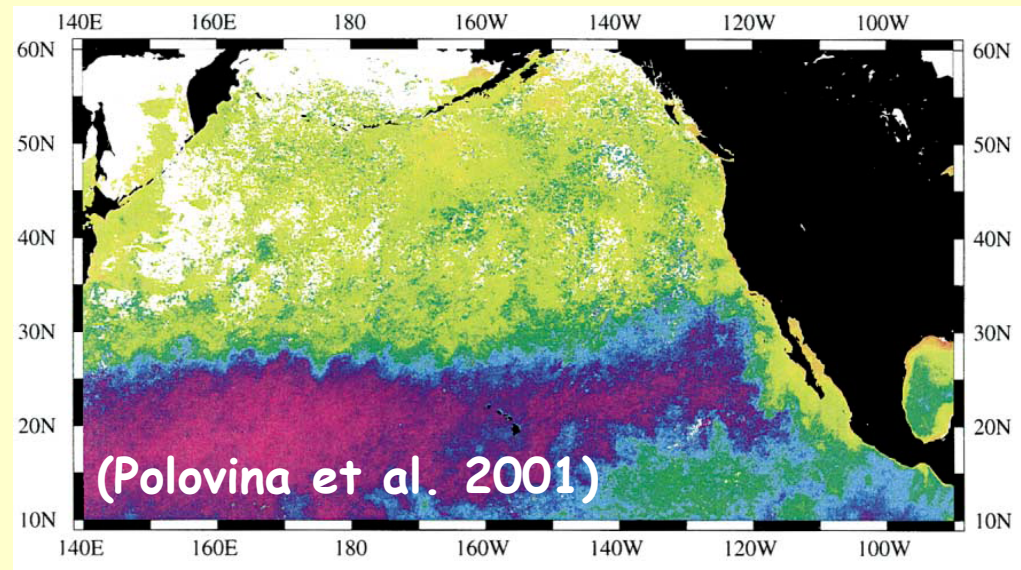
(Kooyman et al. 1996)

Three Oceanographic Habitat Types

- **Static:** Bathymetric features
(e.g., shelf-break, banks)
 - **Dynamic:** Hydrographic features
 - Persistent (e.g., fronts)
 - Ephemeral (e.g., eddies)
- (Hyrenbach et al. 2000)

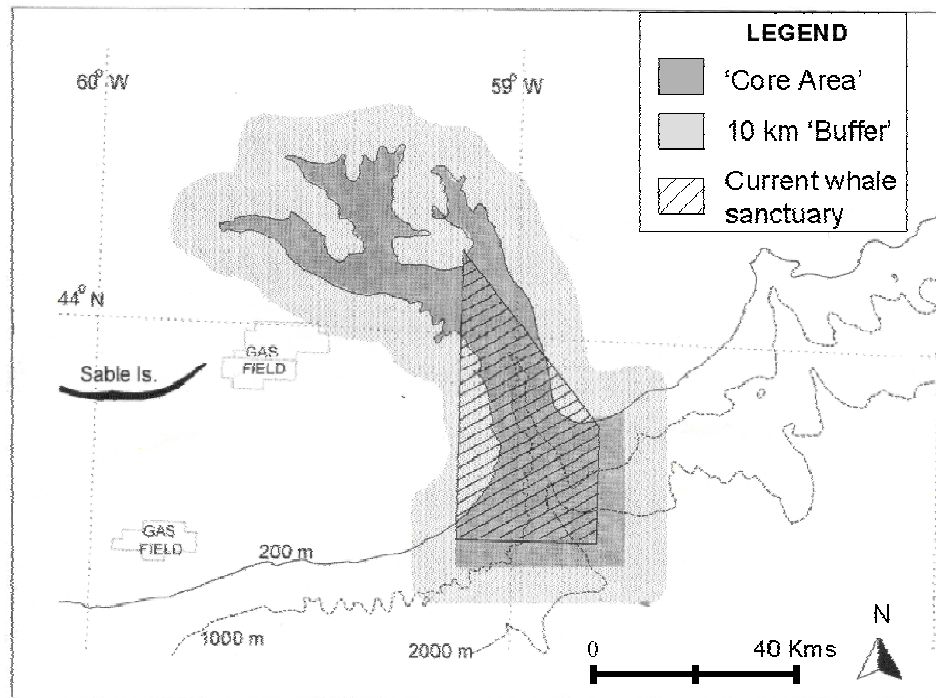


Cordell Bank



Transition Zone Front

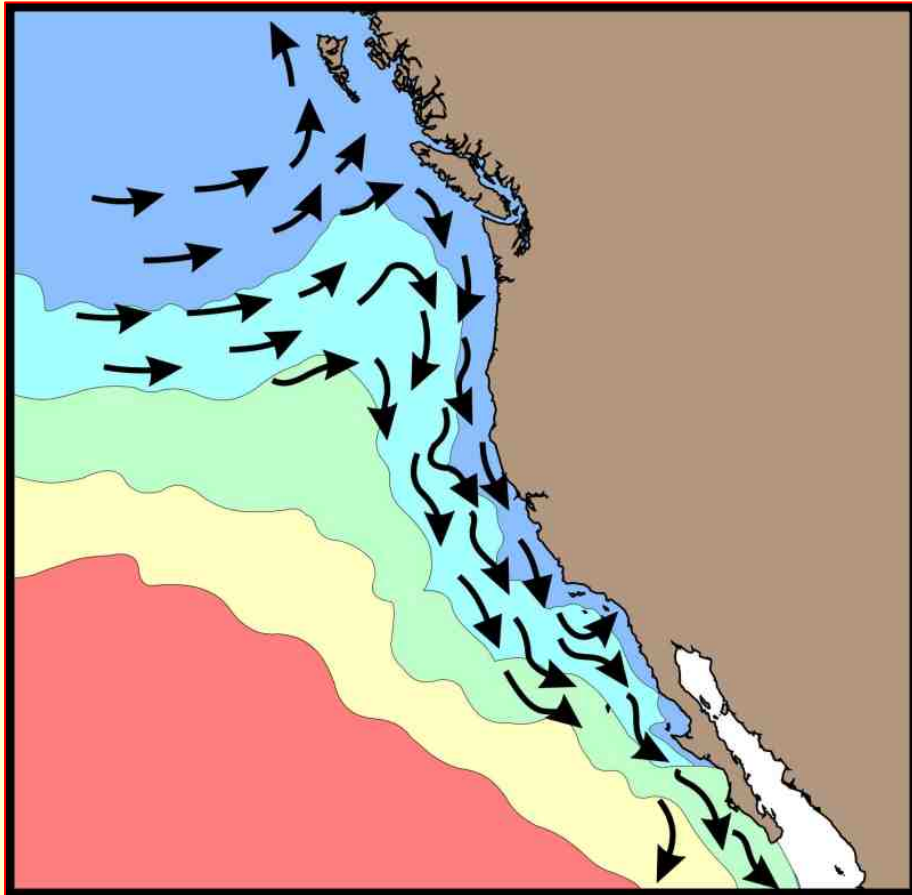
HOTSPOTS: Static Features



- Protection of sessile taxa similar in marine & terrestrial systems
- For mobile species, reserve designs may require extensive buffers around habitat features

Bottlenose whales in the Gully
(Hooker et al. 1999)

HOTSPOTS: Dynamic Habitats

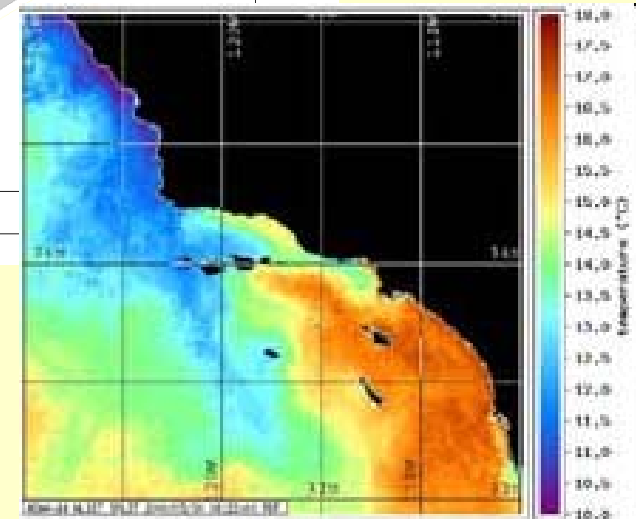
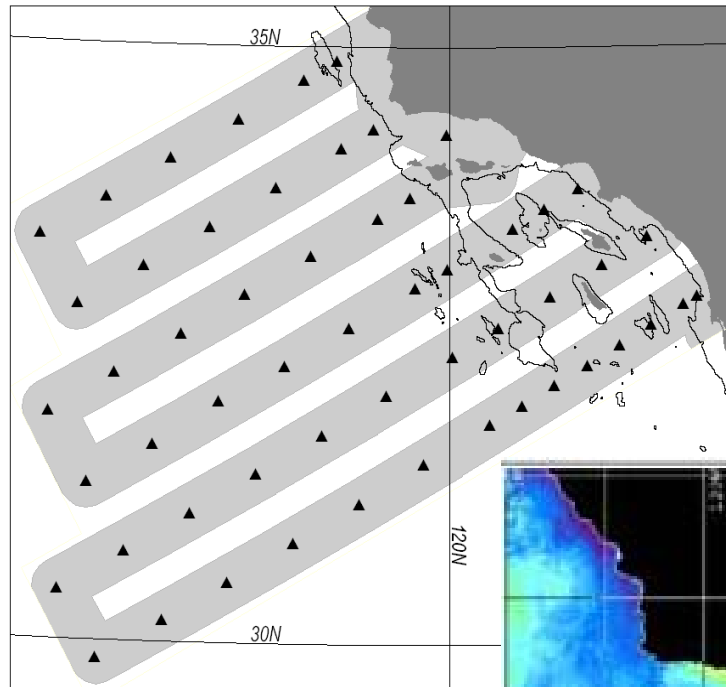


- Spatially predictable ("on average")
- Some are Persistent
- Others are Recurrent
- The size and shape varies temporally

Case Study I: Upwelling Plumes

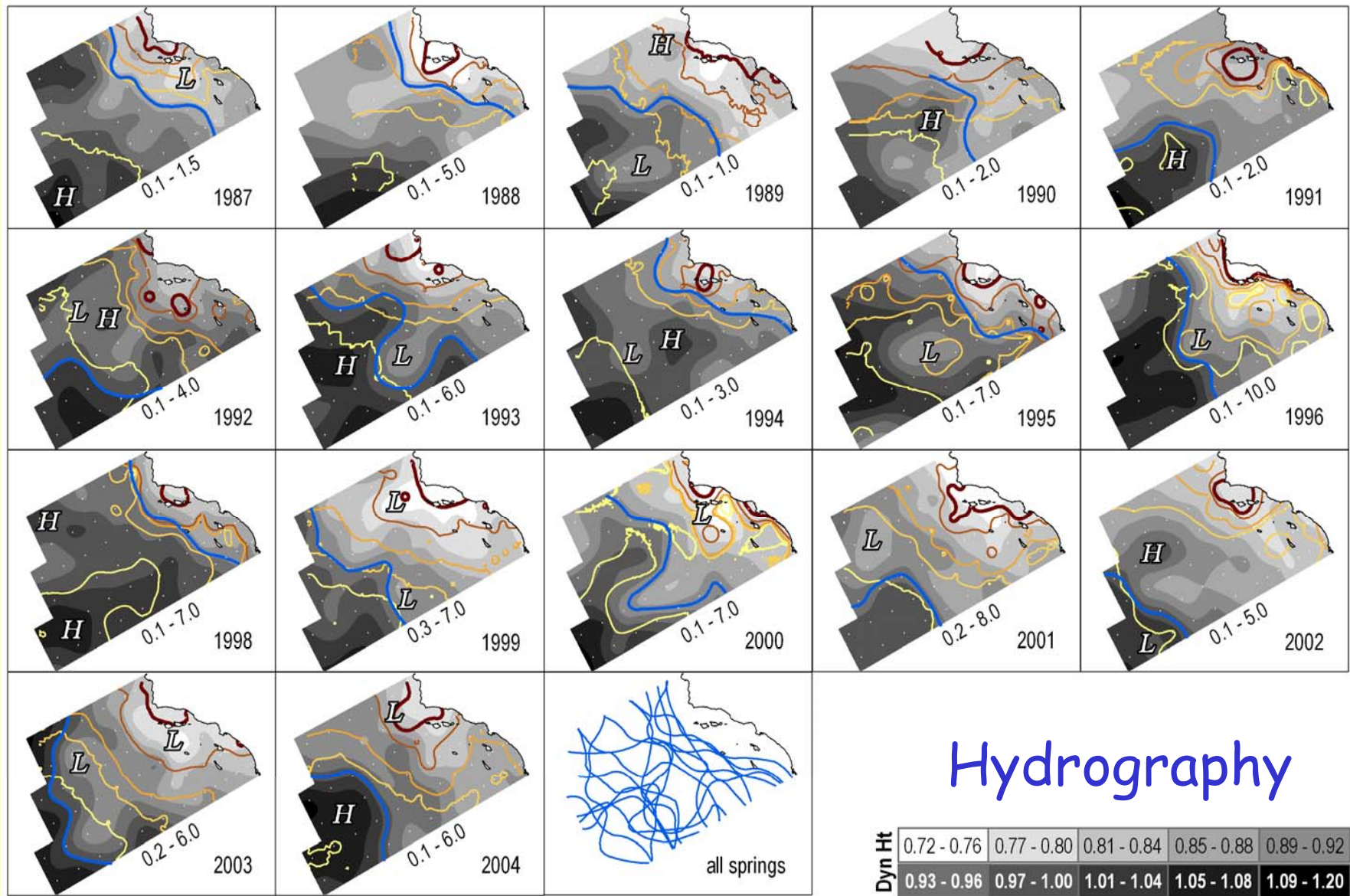


- Spring cruises
(late Feb - early May)
- 17 years (87 - 04)
(no data for 1999)
- 1600 km / cruise
- 66 CTD stations
(Chl a, nutrients)



(Yen et al., 2006)

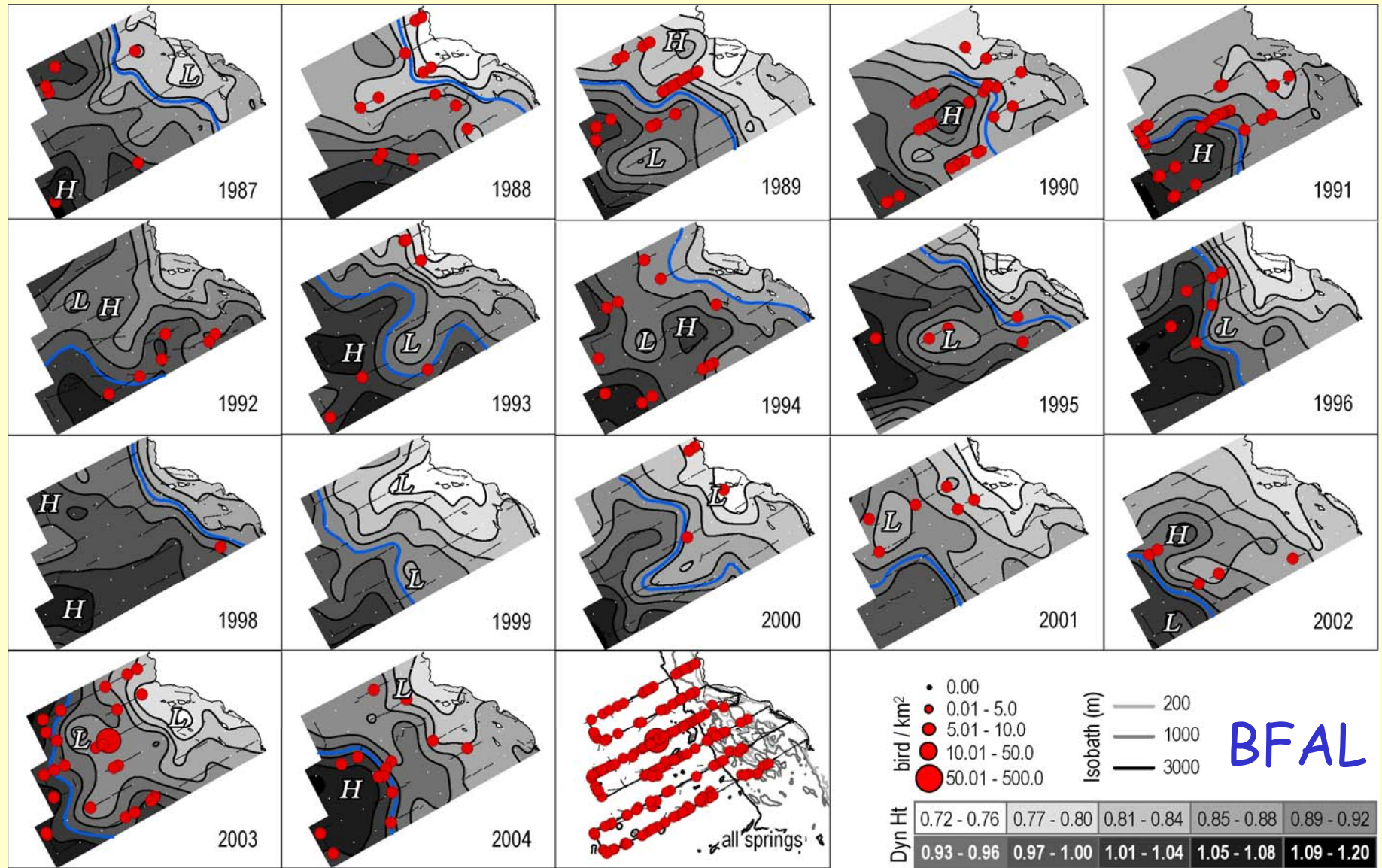
A Complex and Dynamic Seascape



(Yen et al., 2006)



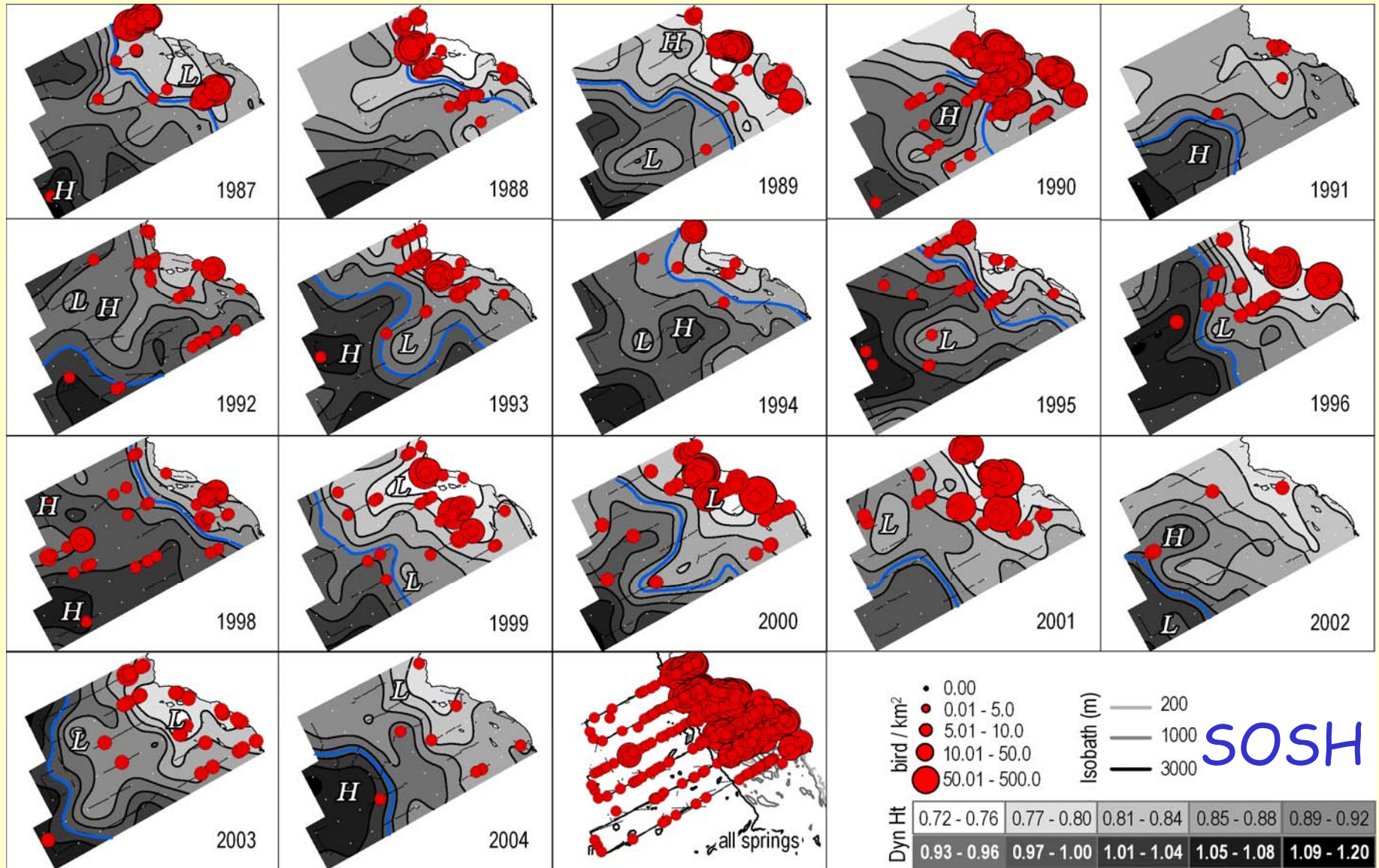
Albatross - Offshore Distribution



(Yen et al., 2006)



Shearwater - Onshore Distribution



(Yen et al., 2006)

Results - Presence / Absence

➤ Logistic Regression: Encounter Probability

Albatross (Oceanic)

Convergence Zones

Close - California Current
Close - high SSH regions

Shearwater (Coastal)

Upwelling Plumes

Far - California Current
Far - high SSH areas

In - low SSH regions

In - "green" water

In - nutrient-rich water

Variable	Interpretation		Result	
	BFAL	SOSH	BFAL	SOSH
CC jet	Closer	Farther	-	+
Dyn ht		Lower	+	-
Dyn ht CI			+	+
Chl a		Greener	-	+
NO ₃		Higher	-	+
L eddy			-	+
H eddy	Closer	Farther	-	+

(Yen et al., 2006)

Results - Density (when present)

➤ Ordered Logistic Regression: Aggregation

Albatross (Oceanic)

No Aggregations

Shearwater (Coastal)

Upwelling Fronts

In - nutrient-rich water

In - low SSH waters

In - high SSH gradients

Variable	Interpretation		Result	
	BFAL	SOSH	BFAL	SOSH
CC jet			-	+
Dyn ht		Lower	+	-
Dyn ht CI		Steep	-	+
Chl a			-	+
NO ₃		Higher	-	+
L eddy			-	+
H eddy			-	+

(Yen et al., 2006)



Case Study II: Seasonal Migration

- Cross- correlations with environmental conditions



©Mike Danzenbaker

Sooty Shearwater

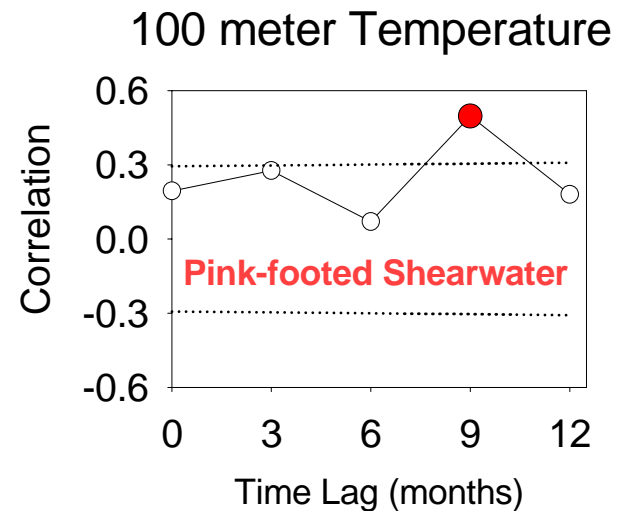
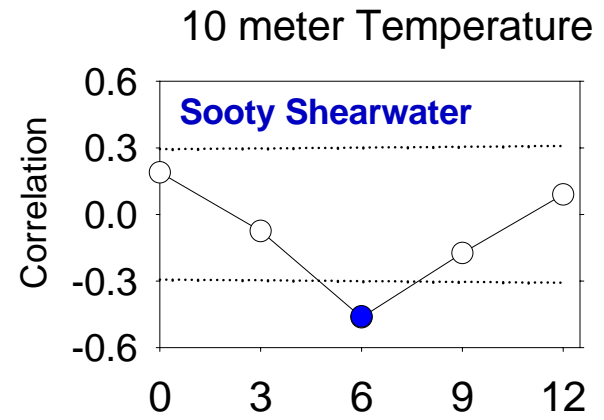
**Avoids
Warming**



©Mike Danzenbaker

Pink-footed Shearwater

**Follows
Warming**



(Hyrenbach & Veit, 2003)

Movement Corridors

➤ Pink-footed Shearwaters more frequent on shelf-break, during oceanic season



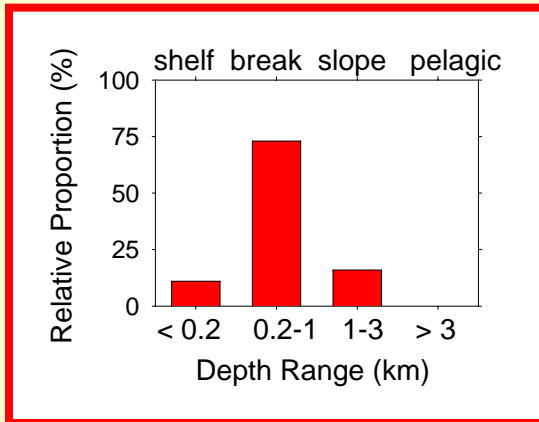
- MMS dataset (1975 - 1997)
- Step-wise logistic regression

<u>Parameter</u>	<u>p-value</u>	<u>Effect</u>
BATH_pelagic	< 0.001	-
BATH_slope	< 0.001	-
BATH_shelf-break	0.031	+
SEASON_CC	< 0.001	-
SEASON_UP	< 0.001	-
EFFORT	< 0.001	+

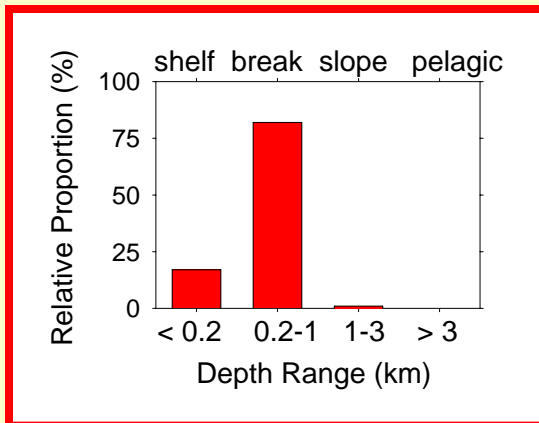
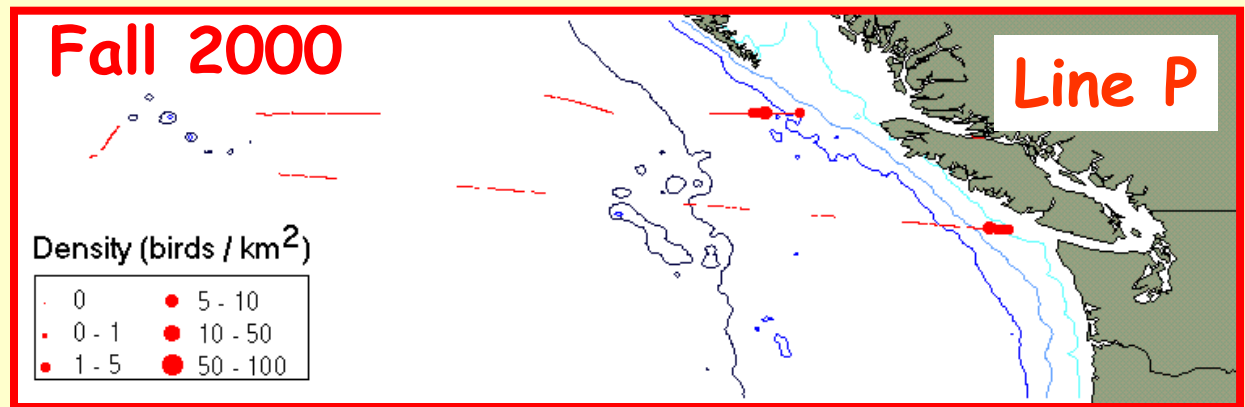
(Freeman & Hyrenbach)

Movement Corridors

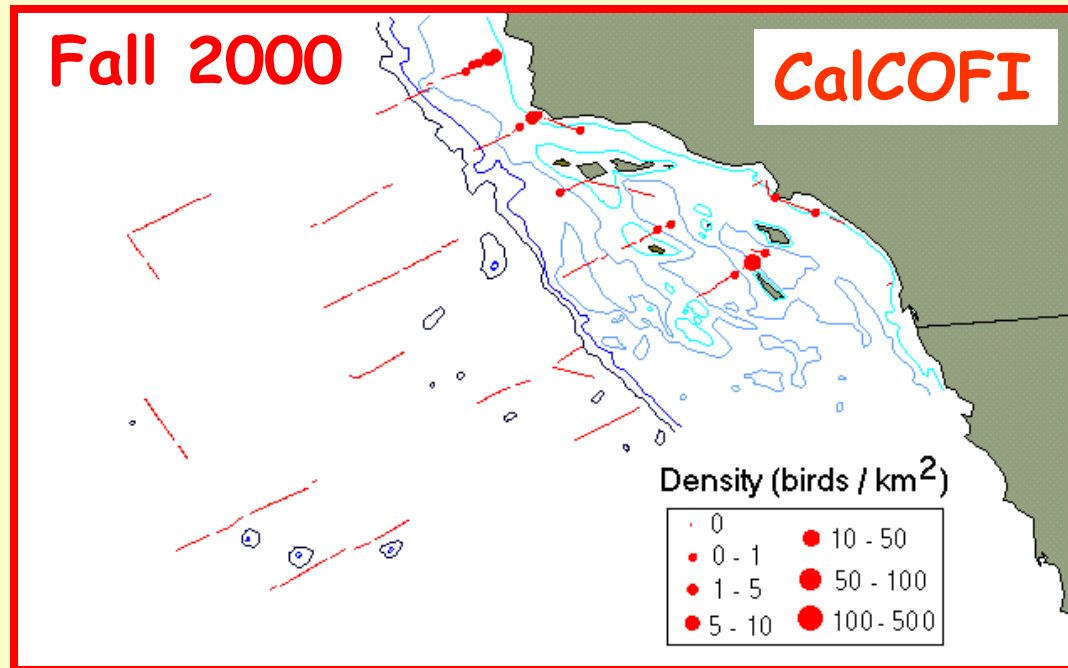
➤ Shearwater distribution in different regions



($p < 0.001$)



($p < 0.001$)





Case Study III - Balearic Shearwater

➤ Approach:

- Range (Pres / Abs)
- Concentration (> 0)

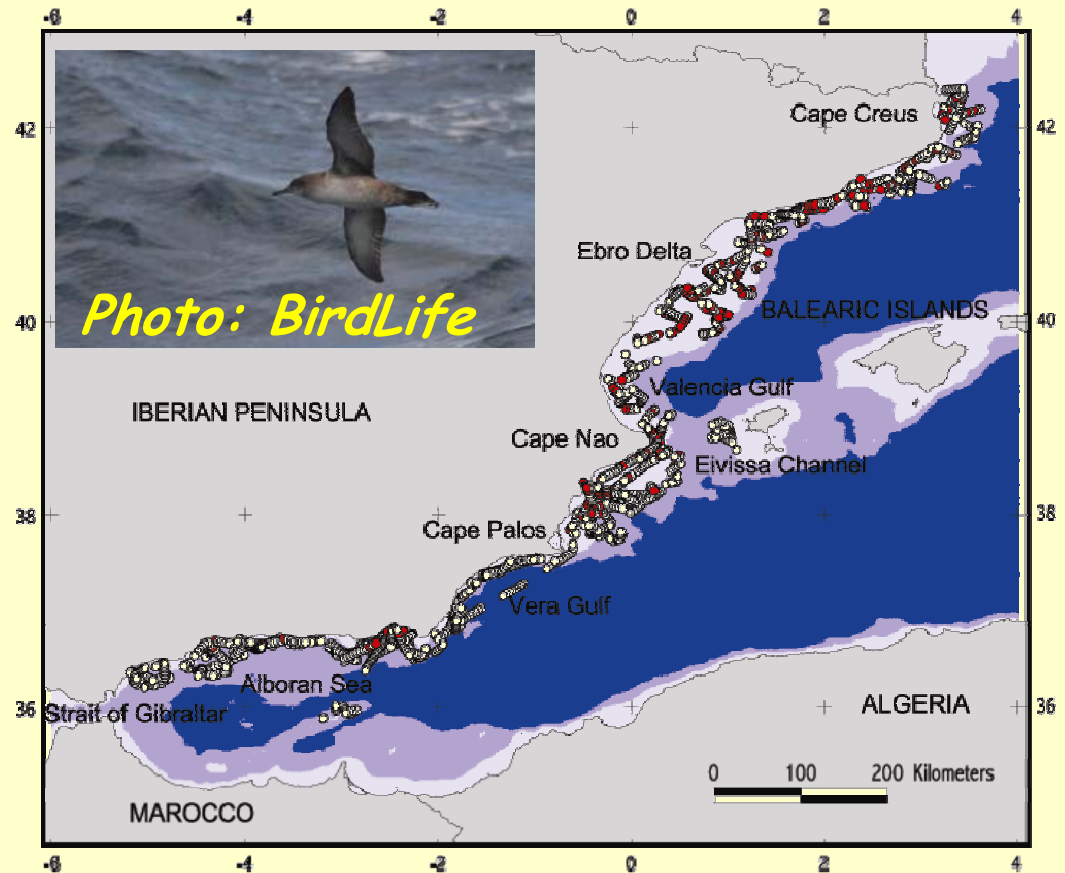
➤ Eight variables

Distance to Shore
Distance to Colony
Median Depth
Depth Gradient

Median Chl a
Chl a Gradient

Median SST
SST Gradient

(Louzao et al., 2006)



- MEDITS (99, 00, 02) (May - June)
- 567 grid cells (9 x 9 km)
- 657 birds, 140 presences (24.7 %)

Shearwater Concentrate at Color Fronts on the Shelf

- Density: up to 500 birds/km²
- Higher densities in areas of strong Chl-a gradients

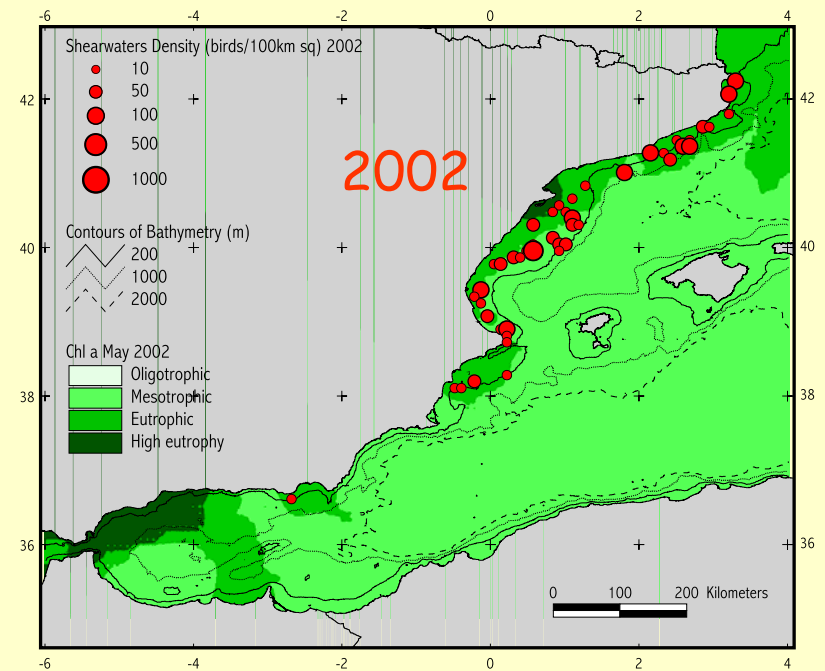
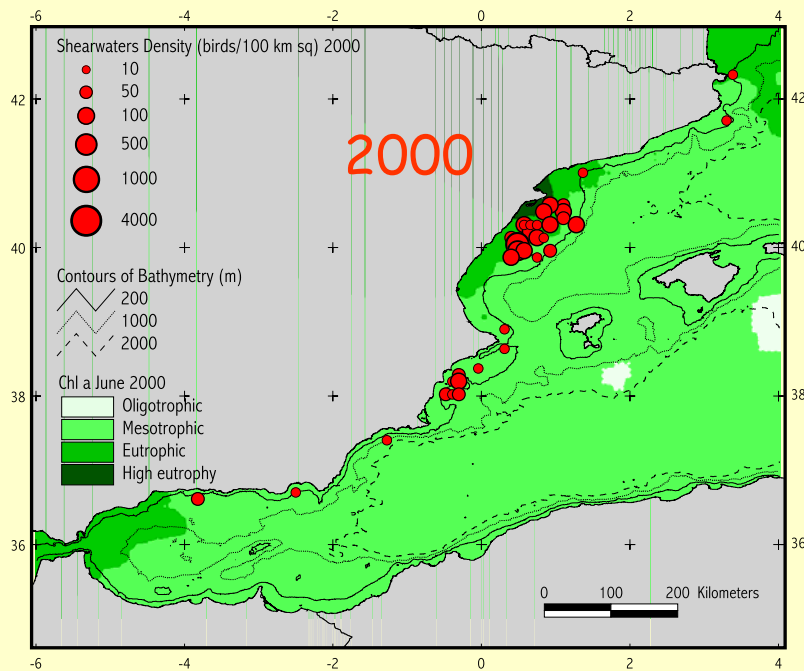
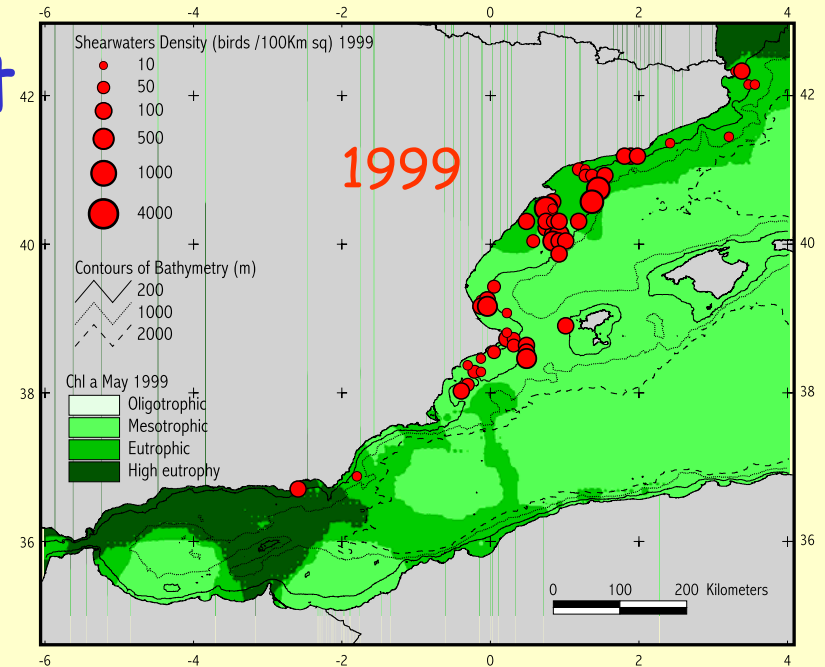




Photo: Webb

Recommendation - 1

Address a Hierarchy of Scales



Scale-Dependent Patterns in Zooplankton

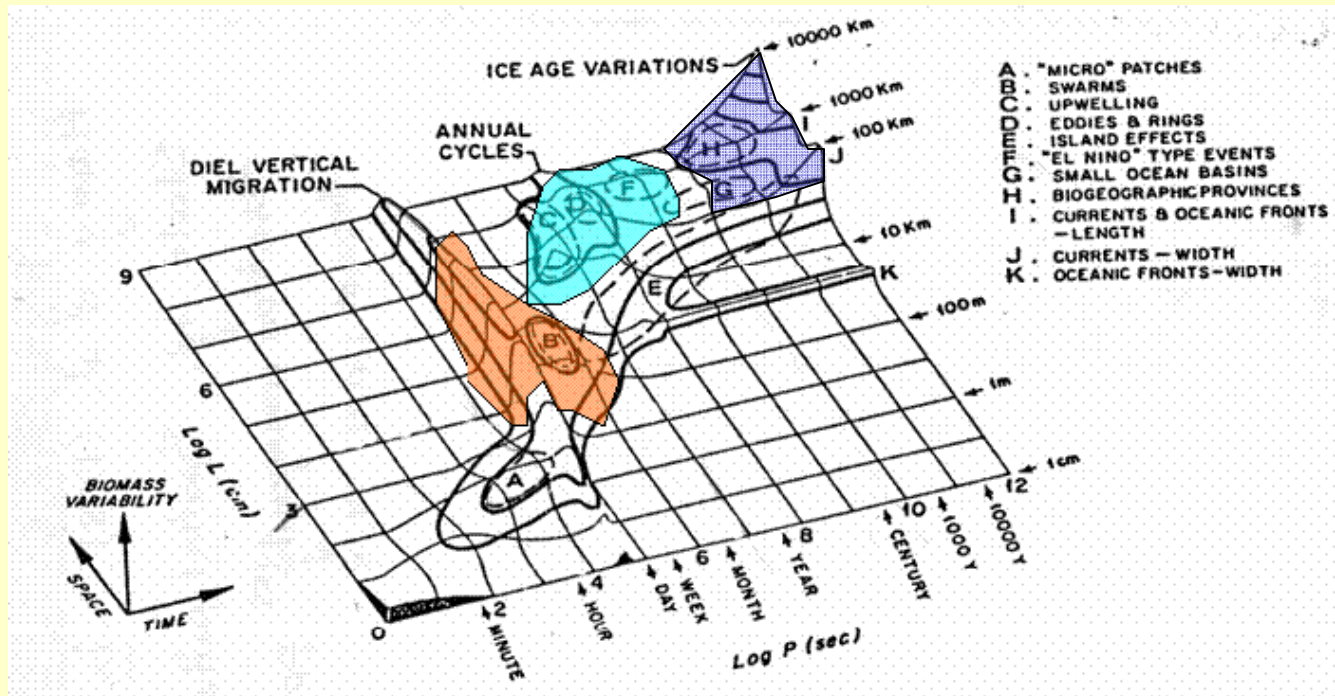


Diagram of plankton abundance variation (Haury et al. 1978)

the orange area shows the scales at which individuals vary
the blue area shows the scales at which populations vary
the purple area shows the scales at which species vary

Spatial Scaling in Seabirds

Scale of Analysis

Macro (1000s km)
(Standing Stocks)

Meso (100s km)
(Community Structure)

Coarse (10s km)
(Abundance)

Process

Ocean
Productivity

Water Mass
Distributions

Prey Availability
and Concentration



Hunt, G.L., Jr., and D.C. Schneider. 1987. Scale dependent processes in the physical and biological environment of seabirds. Pages 7-41 in J.P. Croxall, editor. The feeding ecology of seabirds and their role in marine ecosystems. Cambridge University Press, Cambridge, USA.

Application

➤ Analysis Approach:

- Range: Presence / Absence (All Data)
- Concentrations: Abundance (Present-Only Data)



Range:

Where the species occurs

Diffuse Mgmt: monitoring, gear

Concentrations:

Where the species aggregates

Focused Mgmt: MPAs, closures

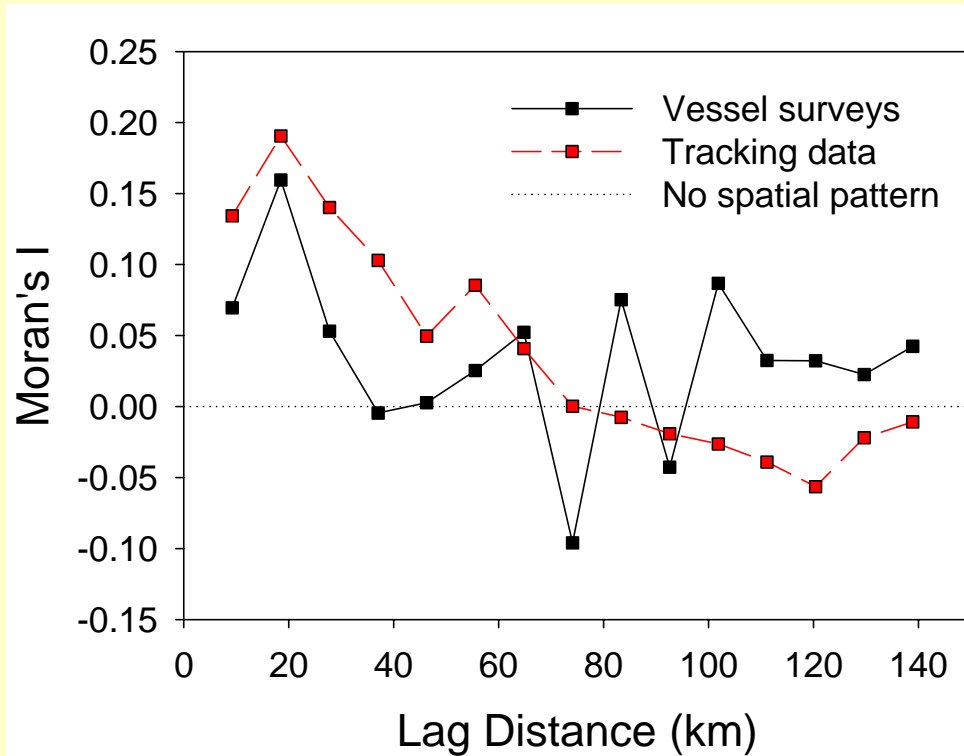
Recommendation - 2

Consider the Spatial Context

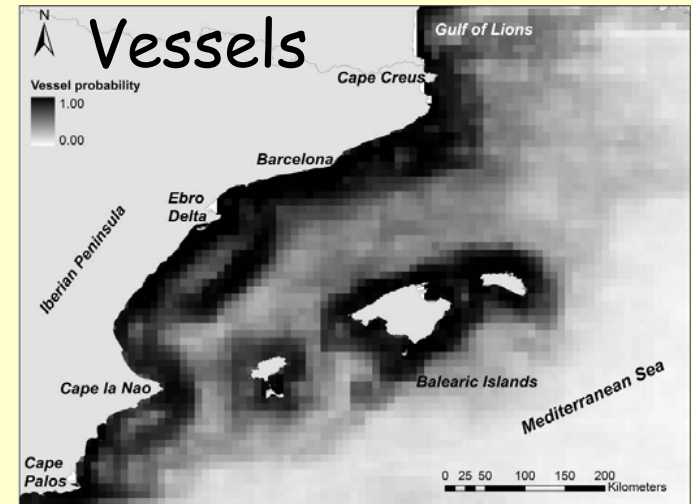


Scales of Aggregation

➤ Individuals vs. Populations

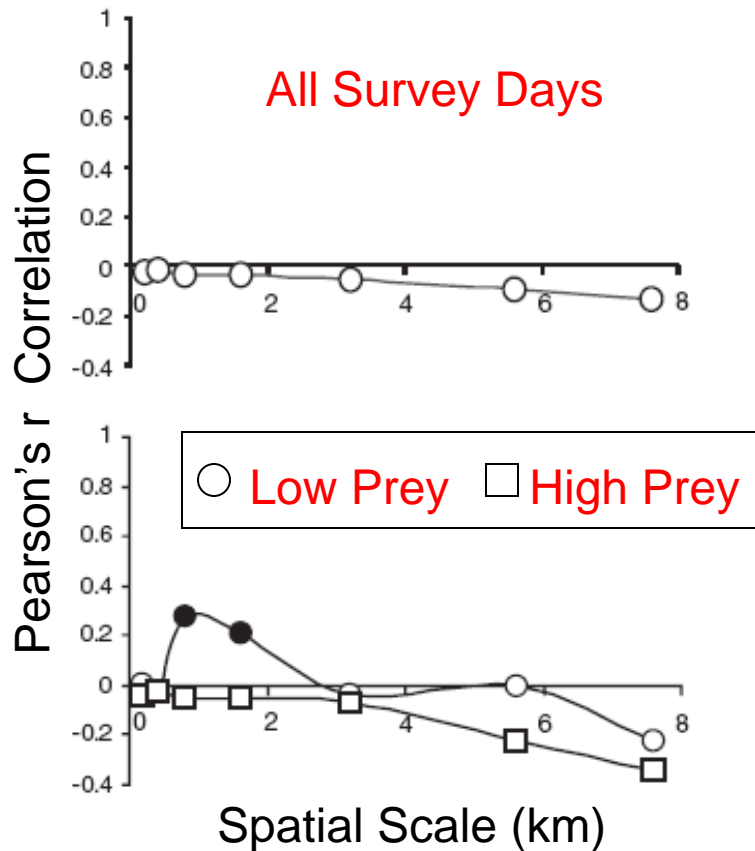


(Louzao, Bécaries, Rodríguez, Hyrenbach, Ruiz, Arcos)

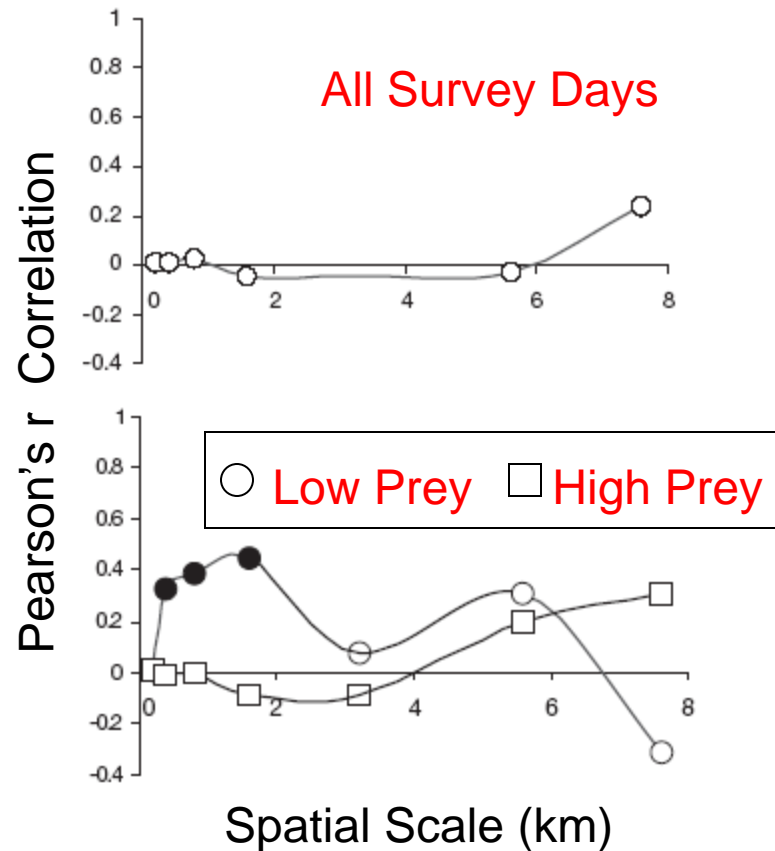


Influence of Prey Resources

Pacific Loon



Rhinoceros Auklet

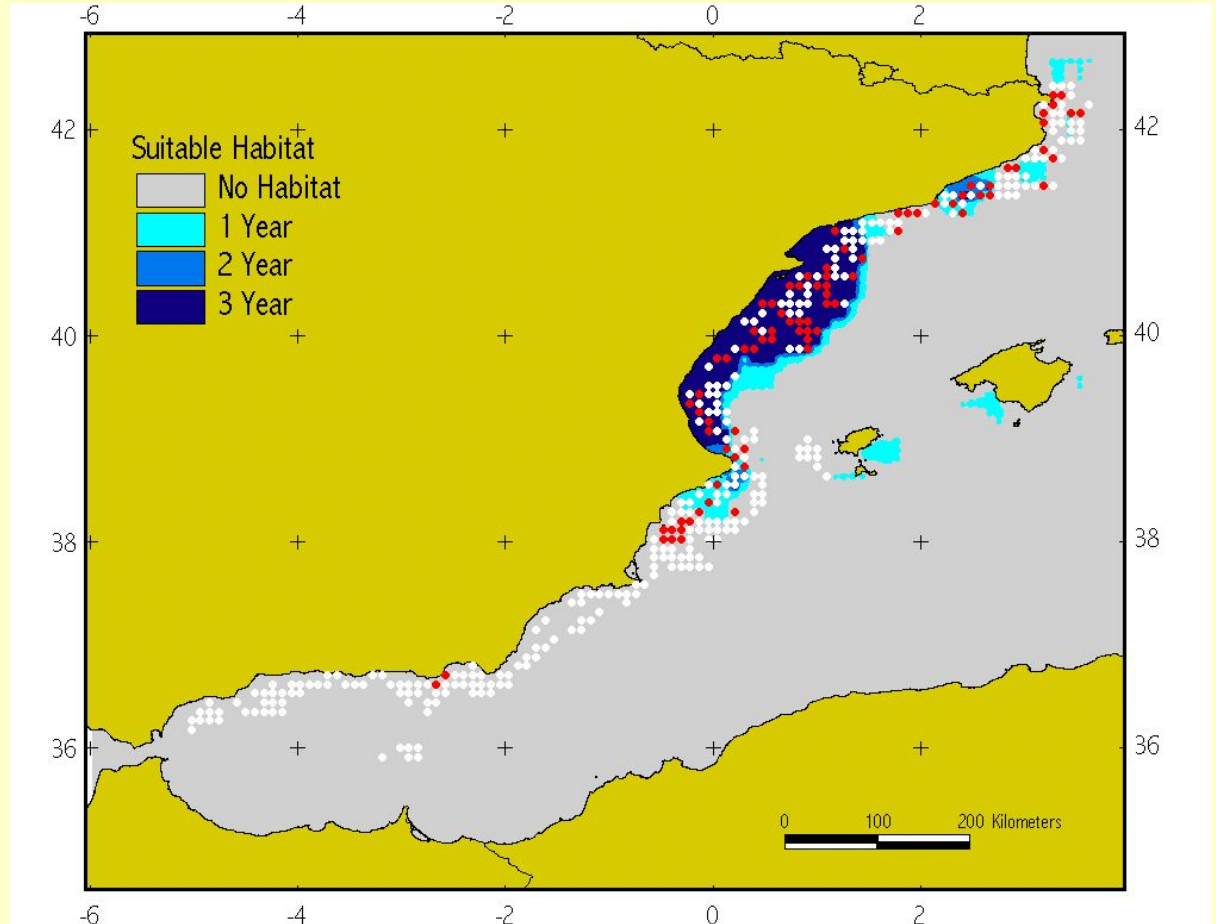


(Vlietstra 2005)

Application



➤ The Balearic Shearwater occurs over shallow and productive shelves (flat, high Chl a)



➤ The spatial extent of this "habitat" varies from year to year and can be defined probabilistically

(Louzao et al. 2006)

Recommendation - 3

Develop Dynamic Measures



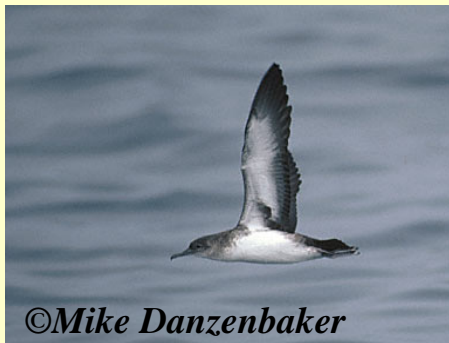
Antecedent Conditions

- Cross- correlations with environmental conditions



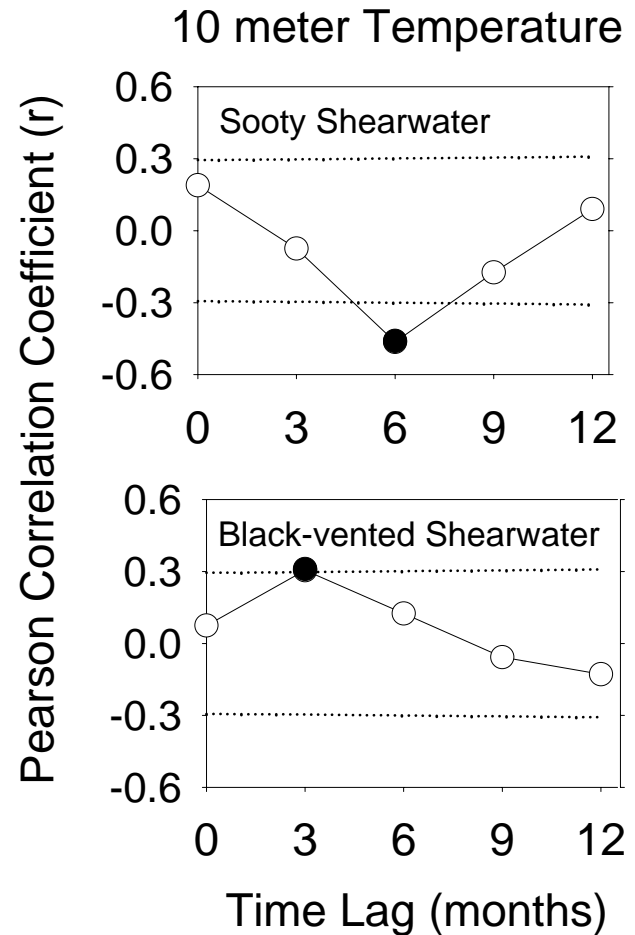
Sooty Shearwater

Avoids
Warming



Black-vented
Shearwater

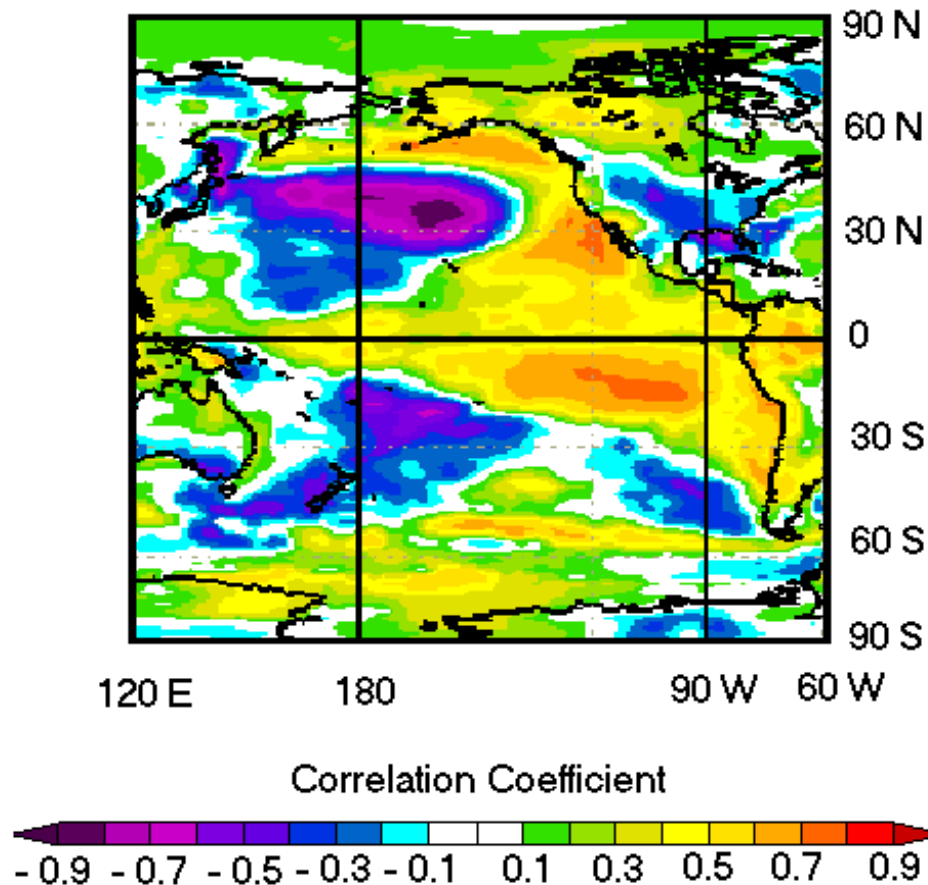
Follows
Warming



(Hyrenbach & Veit, 2003)

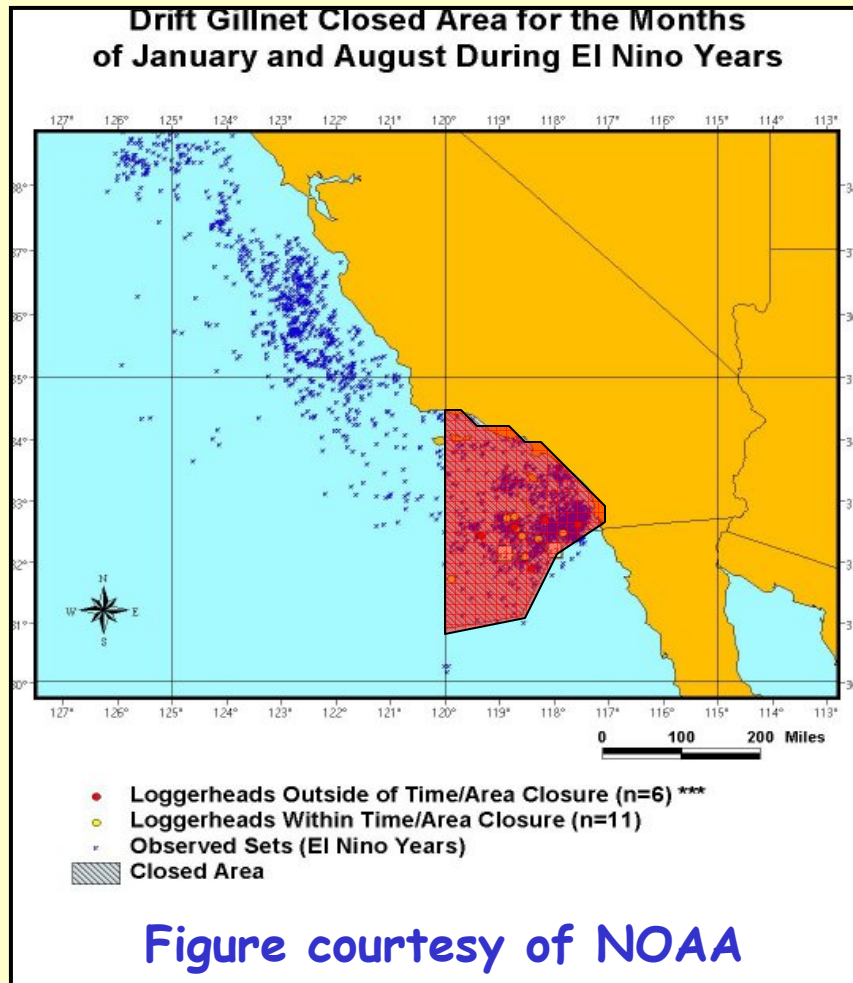
Remote Forcing

Surface Temperature / PDO Correlation
(January 1958 - December 1999)



Application

Drift gillnet closures off southern California during El Niño to mitigate loggerhead turtle gillnet bycatch



Conclusions

- In principle, MPAs could be designed to protect “predictable” predator concentrations
- Large MPAs May Not Suffice
- Effective MPAs Require Careful Design and a Broader Scale-Explicit Management Scheme:
 - Address a Hierarchy of Scales
 - Consider the Spatial Context
 - Develop Dynamic Metrics

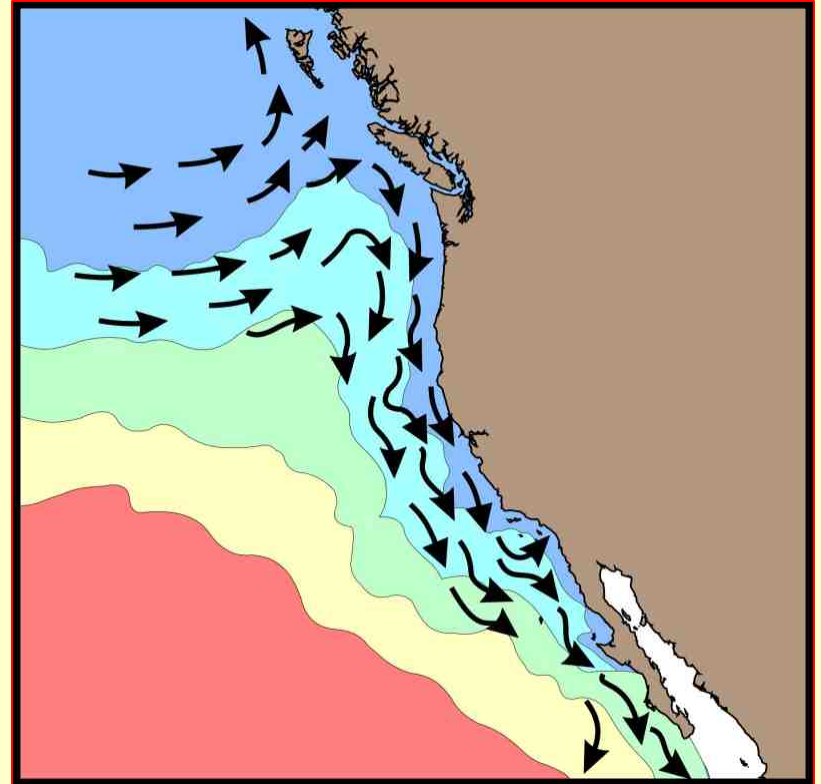


Conclusions: Pelagic Systems

- MPA designs must incorporate an understanding of natural history and habitat variability
- Dynamic pelagic systems differ from terrestrial / benthic ecosystems in scale and predictability
- Yet, as in static systems, many pelagic species use predictable habitats to breed and forage. Thus, MPAs could be designed to protect these aggregations
- While "terrestrial" designs are effective in static systems, many marine habitats are not fixed in space

Conclusions: MPA Designs

- Essential to understand the physical mechanisms influencing formation and persistence of "hotspots"
- Focus research efforts on pattern and process:
 - Retention zones downstream from upwelling centers
 - Bathymetric / hydrographic gradients
- New design concepts necessary:
 - Dynamic boundaries (real-time)
 - Extensive buffers (statistics)



Challenges: New Design Concepts

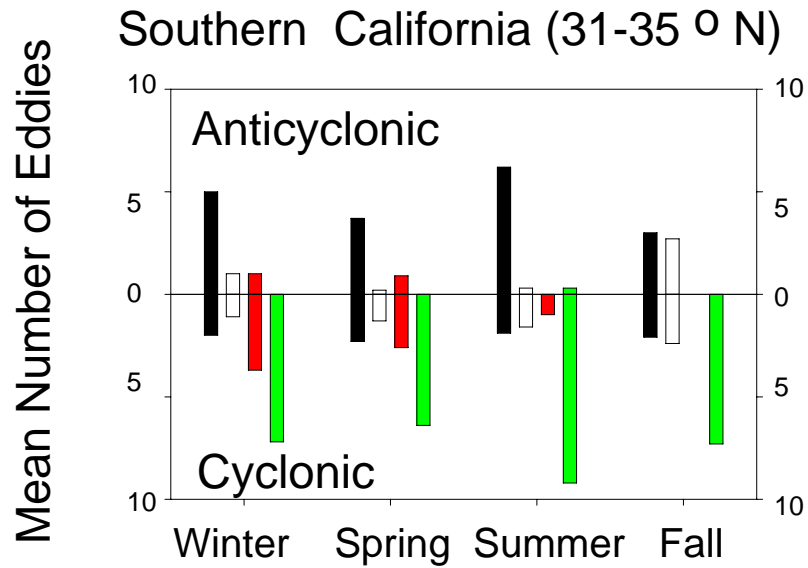
Conceptual

- MPAs better suited for taxa which concentrate in large densities - *Need to deal with "corridors"*
- For HMS, range area will exceed sanctuary extent - *Need to link MPAs with regional monitoring / mgmt.*

Methodological

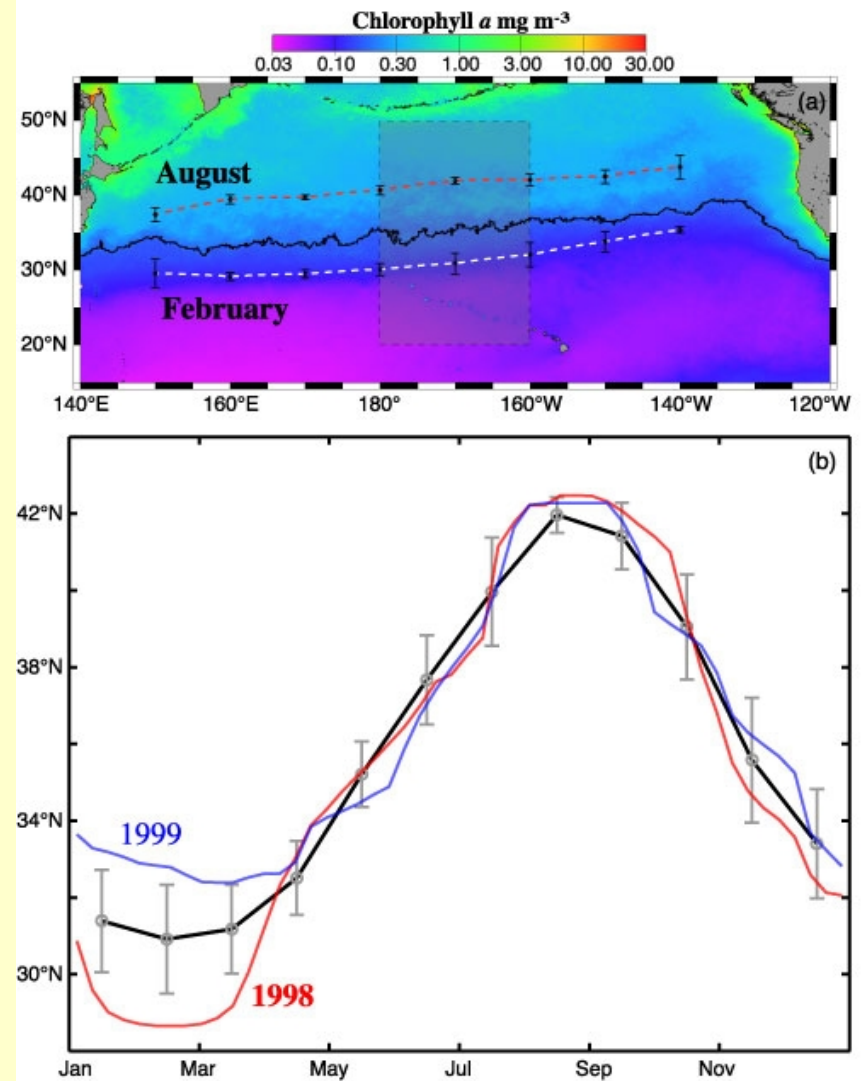
- Accommodate Dynamic Features: Need to characterize the dynamics / predictability of habitat features
- Accommodate Dynamic Distributions: Mobile predators shift distributions across seasons, years, decades...

Increased Sophistication



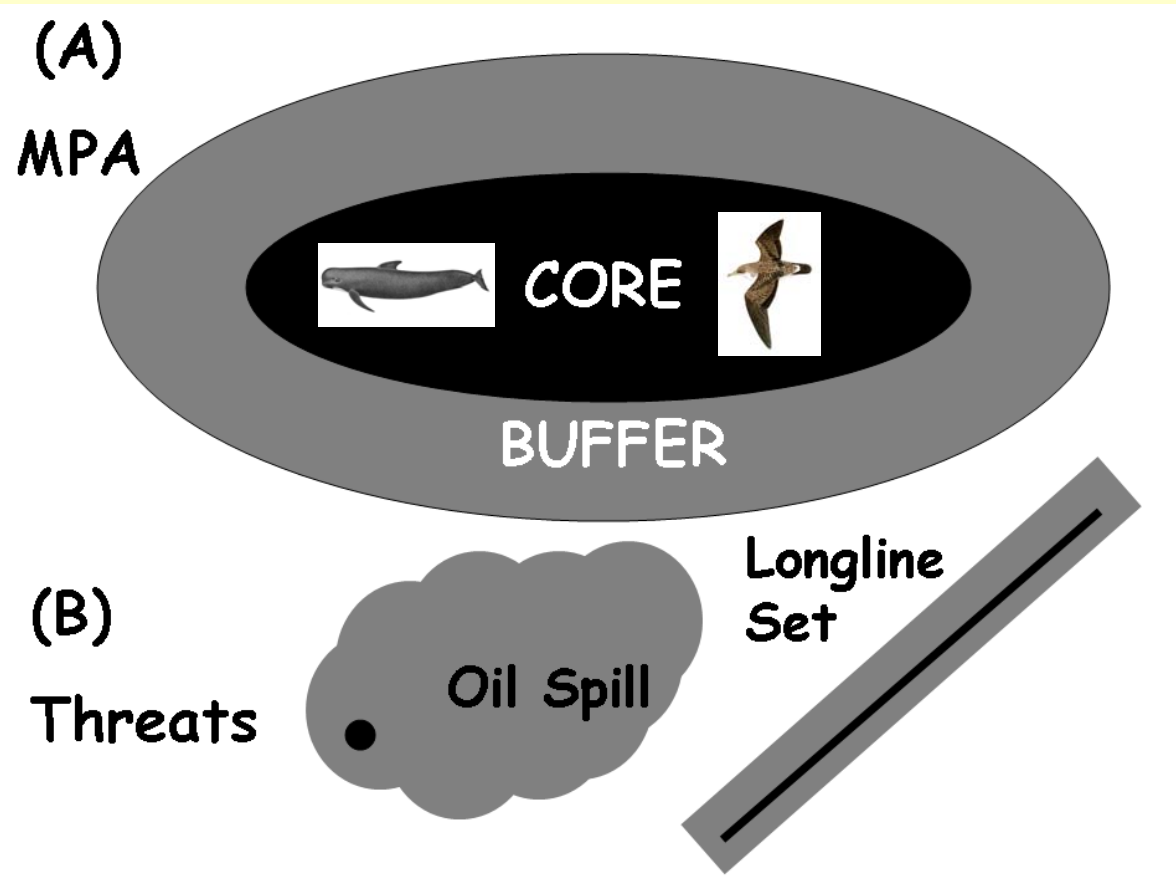
10-year incidence of eddies
(All Seasons, 1949 - 65)

(Owen, 1980)



(Bograd et al., 2001)

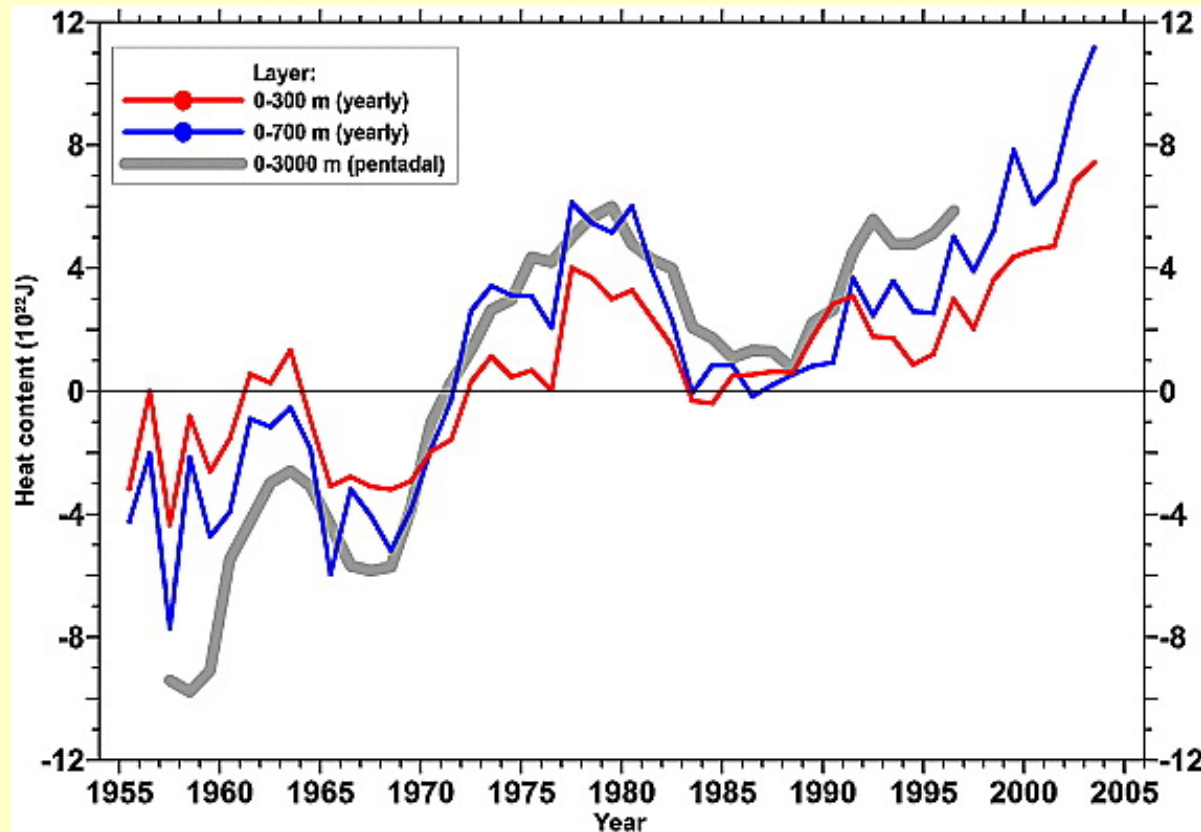
Challenges: Accommodate Threats



Conceptual diagram of a core- buffer MPA (A)
and the "footprint" of different threats (B)

(Hyrenbach 2008)

Challenges: Accommodate Climate



Yearly ocean heat content for the **0-300 m** and **0-700 m** layers and 5-year composites (from 1955-59 to 1994-98) of ocean heat content for the **0-3000 m** layer

(Levitus et al. 2000, 2005)



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Acknowledgements

