Spatial models of Antarctic whale distribution in relation to prey and oceanographic processes: CART, GAM, and Mantel's tests

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Quick Outline

- Research objectives & hypotheses
- Cetacean & environmental data
- Analytical tools and methods
  - CART & GAM
- Results
- Cetacean-ecosystem relationships
- Spatially-explicit analysis
  - Mantel's Test
- Looking ahead
  - Hypotheses
  - Data
  - Models

IWC- SO GLOBEC Collaboration

Investigate how spatial & temporal variability in the physical and biological environment influence cetaceans

Understand the physical and biological factors that contribute to enhanced Antarctic krill growth, reproduction, recruitment and survivorship

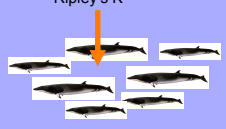
- Study cetacean patterns of occurrence concurrent with data collected across physical and biological domains
- Model potential effects of climate change and variability on cetacean distribution and environment

Objectives

- Quantify & describe ecological relationships between cetaceans, physical and biological environment
- Explore spatially-explicit distribution patterns of whales in relation to prey
  - Provide a foundation for predictive habitat modeling and long-term monitoring
  - Study foraging behavior & patch selection at the individual level
    - Concurrent tagging and hydroacoustic sampling

Statistical Tools

1. Spatial structure
   - Ripley's K
2. Relationships
   - Mantel's test
   - CART, GAM

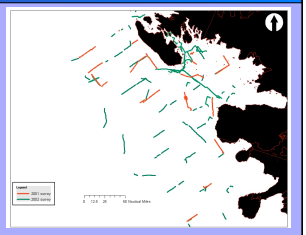


Environmental factors

3. Predictive habitat models
   - Classification and Regression Tree (CART)
   - Logistic regression : probability of occurrence
   - Geographic Information System (GIS)

Cetacean Data

- Visual sightings data from 6 cruises around Marguerite Bay



	2001	2001	2002	2002
Species	Groups	Whales	Groups	Whales
Humpback	32	61	52	162
Minke	22	35	17	44

Environmental Data

Environmental Variable	Sampling Method
Acoustic volume backscatter 25-100m	Continuous along track and interpolated fields
Acoustic volume backscatter 100-300m	Continuous along track and interpolated fields
Chlorophyll a	Interpolated grids from sampling stations
Bathymetry	ETOPO modified bathymetry grid
Slope of bathymetry	Grid cells calculated from bathymetry grid
Water temperature maximum below 200m	Interpolated grids from sampling stations
Distance from coast	Straight line distance grids
Distance from ice edge	Straight line distance grids
Distance from high slope	Straight line distance grids
Distance from inner shelf water boundary	Straight line distance grids from reclassified deep temperature max. (Chapman et al)

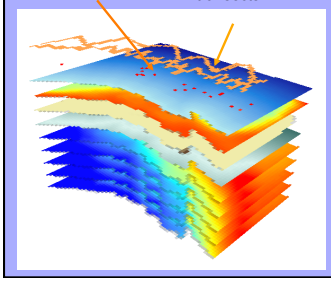
METHODS

sampling

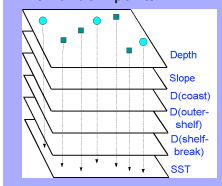
From GIS data layers to model samples…

Whales

Cruise transects



Sample points *vs.* **random** points



Tree-based Models

- Binary partitioning method fitting data into increasingly homogeneous sub-groups
- Hierarchical
- Non-parametric, exploratory
- No a priori assumptions about relationships

- Used as a variable selection tool to identify predictor variables for GAM;
  - Determined by whether the sequential splits reduce model predictive error

Variable Selection from CART

Rank at primary split	Environmental variable	Improvement to model score (split #)
1	Volume backscatter 25-100m (Av. 100) dB	249.38 (1)
2	Volume backscatter 100-300m (A.v. 300) dB	203.72 (1)
3	Slope of bathymetry	103.47 (1)
4	Distance to ice edge (Dist. ice)	97.42 (1)
5	Distance to inner shelf water boundary (Dist.inswb)	89.41 (1)
6	Chlorophyll a concentration (chla)	102.51 (3)
7	Distance to Coast	132.77 (6)
8	Bathymetry	130.52 (6)

Generalized Additive Model (GAM)

- Exploratory tool to elucidate functional relationships
- Interpret ecological interactions by fitting non-parametric functions relationships between response and predictor variables

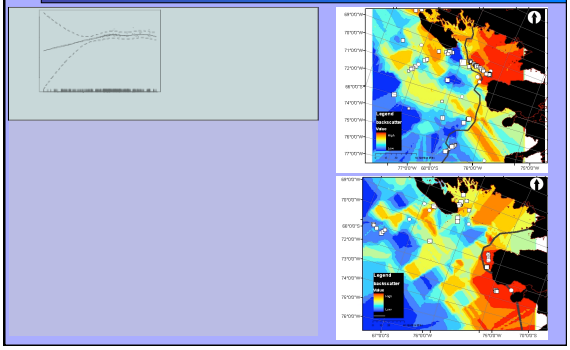
GAM Results

GAM	Pr(>t)	R-sq.	% Dev. Exp.
Full	0.01	0.408	63.1
2001	0.001	0.977	97.7
2002	0.003	0.436	74.1

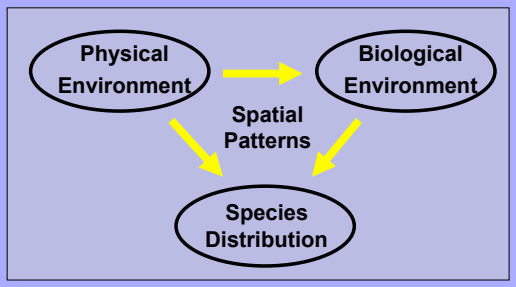
Model Variable	Est. d.f.	Chi-sq.	p-value
Full GAM			
25-100dB	4.028	44.686	<0.00001
Chl_a	5.379	60.304	<0.00001
Bathymetric slope	7.577	42.513	<0.00001
100-300dB	5.924	19.001	0.02
Dist_Ice	3.609	60.641	<0.00001
Dist_INSWB	4.309	23.709	0.004
2001			
25-100dB	4.493	21.792	0.009
Chl_a	<0.00001	0.01	0.92
Bathymetric slope	4.422	18.142	0.01
100-300dB	<0.00001	0.06	0.97
Dist_Ice	5.035	24.614	0.001
Dist_INSWB	4.526	17.931	0.02
2002			
25-100dB	4.763	42.09	<0.00001
Chl_a	5.571	48.395	<0.00001
Bathymetric slope	6.756	35.441	<0.00001
100-300dB	2.054	15.909	0.06
Dist_Ice	0.7126	12.41	0.002
Dist_INSWB	1.897	20.578	0.01

GAM Results

Whale sightings in relation to Zooplankton volume Backscatter



Modeling Habitats



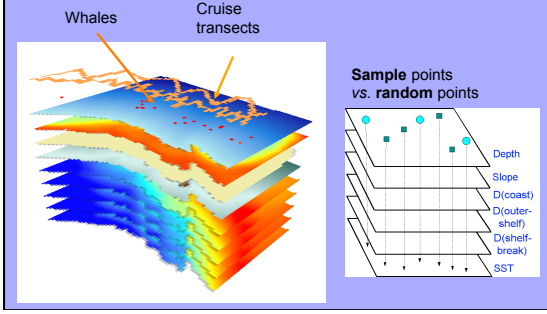
Mantel's Test

- Linear regression applied to distance (dissimilarity) matrices generated from spatially referenced sample locations:
  - Which environmental variables best explain species distributions, once their confounding mutual correlations and spatial structure are accounted

METHODS

sampling

From GIS data layers to model samples…

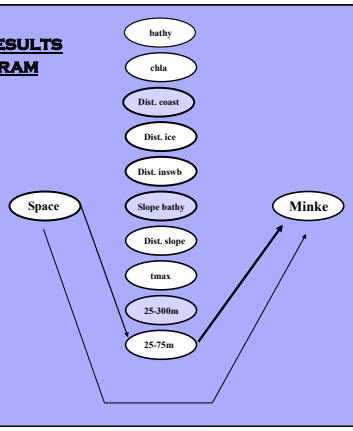


Mantel Data Table

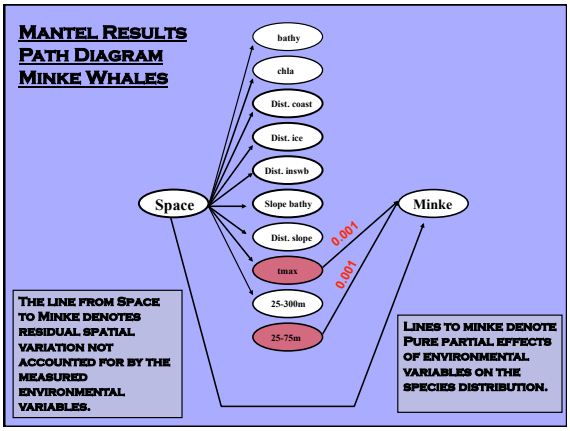
	minke (y)		Space	Pyx/space	Pyx/**
Minke			-0.075(0.983)		
Tmax	-.02528		0.329(0.001)	0.197(0.001)	0.187(0.001)
Slope.bathy	-.01744		0.196(0.002)	-0.095(0.987)	-0.085(0.949)
Chla	0		0.217(0.001)	0.0127(0.340)	-0.017(0.503)
Dist.inswb	0		0.214(0.001)	-0.055(0.907)	-0.084(0.994)
Dist.slp	0		0.213(0.001)	-0.003(0.499)	0.028(0.194)
Bathy	0		0.149(0.014)	-0.010(0.502)	-0.001(0.482)
Dist.ice	-0.206		0.522(0.001)	0.124(0.006)	0.055(0.117)
Dist.coast	-0.263		0.392(0.001)	0.004(0.400)	-0.026(0.789)
X25-75db	0.346		-0.026(0.747)	0.187(0.002)	0.213(0.001)
X25-300db	0		0.100(0.007)	-0.053(0.897)	-0.091(0.991)

Simple correlations | Mantel autocorrelation | Partial Mantel | Pure Partial

Mantel Results Path Diagram



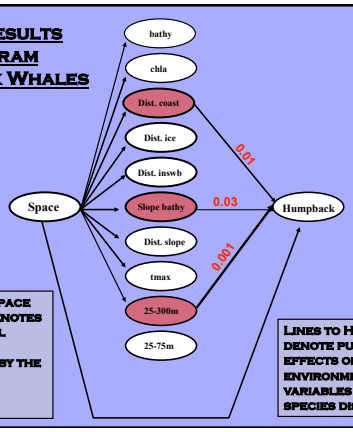
Mantel Results Path Diagram Minke Whales



The line from Space to Minke denotes residual spatial variation not accounted for by the measured environmental variables.

Lines to Minke denote pure partial effects of environmental variables on the species distribution.

Mantel Results Path Diagram Humpback Whales



The line from Space to Humpback denotes residual spatial variation not accounted for by the measured environmental variables.

Lines to Humpback denote pure partial effects of environmental variables on the species distribution.

Take-Home

- Concurrent measurements of cetaceans, environmental variables, and prey allow for ecological insights
- Multiple techniques to test hypotheses regarding Species/Environment relationships
  - Functional response
  - Pure spatially explicit relationships
- This knowledge allows for model building
  - Habitat envelopes
  - Environmental variability
  - Species-specific/individual foraging behavior

Questions?