Habitat Associations of Seabirds and Marine Debris in the North East Pacific at Multiple Spatial Scales

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Overview

- Objectives
- Introduction

  - Plastic ingestion by seabirds

  - Oceanic marine debris
- At sea surveys
- Data analyses
- Outcomes and implications

Objectives

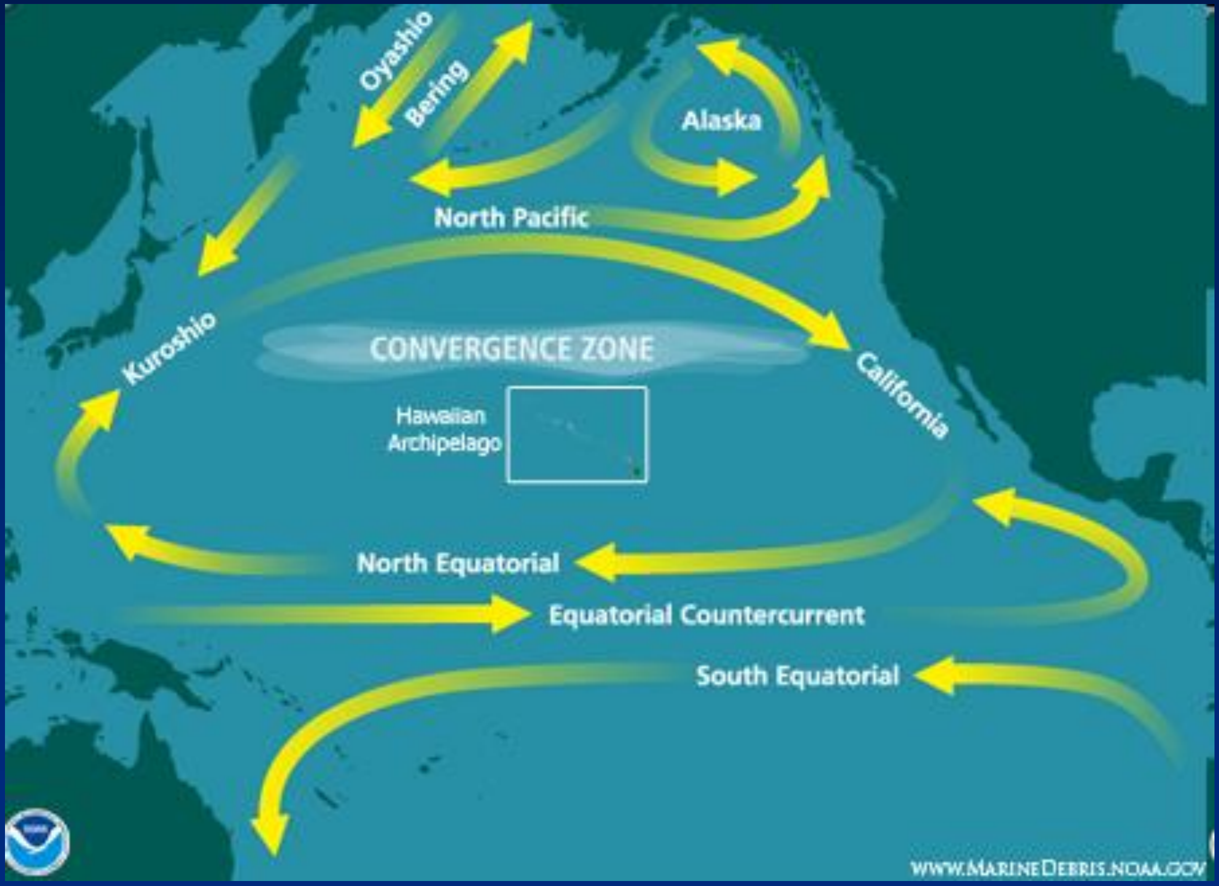
- Survey the amount and characteristics of marine debris over the cruise line
- Determine the seabird communities present over this same extent.
- Examine the spatial overlap between the seabird communities and marine debris

Marine Debris

- Plastic comprises 60-80% of all marine debris
- High input rates
  - Diverse sources
  - Land based
  - Ship based
- Degradation rates unknown
- Indestructible nature

(Derraik 2002, Moore et al. 2005, Moore et al. 2008)

- North Pacific Subtropical Gyre (NPSG)
  - high pressure center (eastern garbage patch)
- extent and scale of accumulation unknown



Plastic Pollution

Ingestion by Seabirds

- Many seabird species in the North Pacific are known to ingest plastic including
  - Albatross
  - Fulmars
  - Shearwaters
  - Storm Petrels
- Albatross and other procellariiform species have a long history of ingestion
- Do not know where seabirds are exposed to the marine debris

Nevins et al. 2005

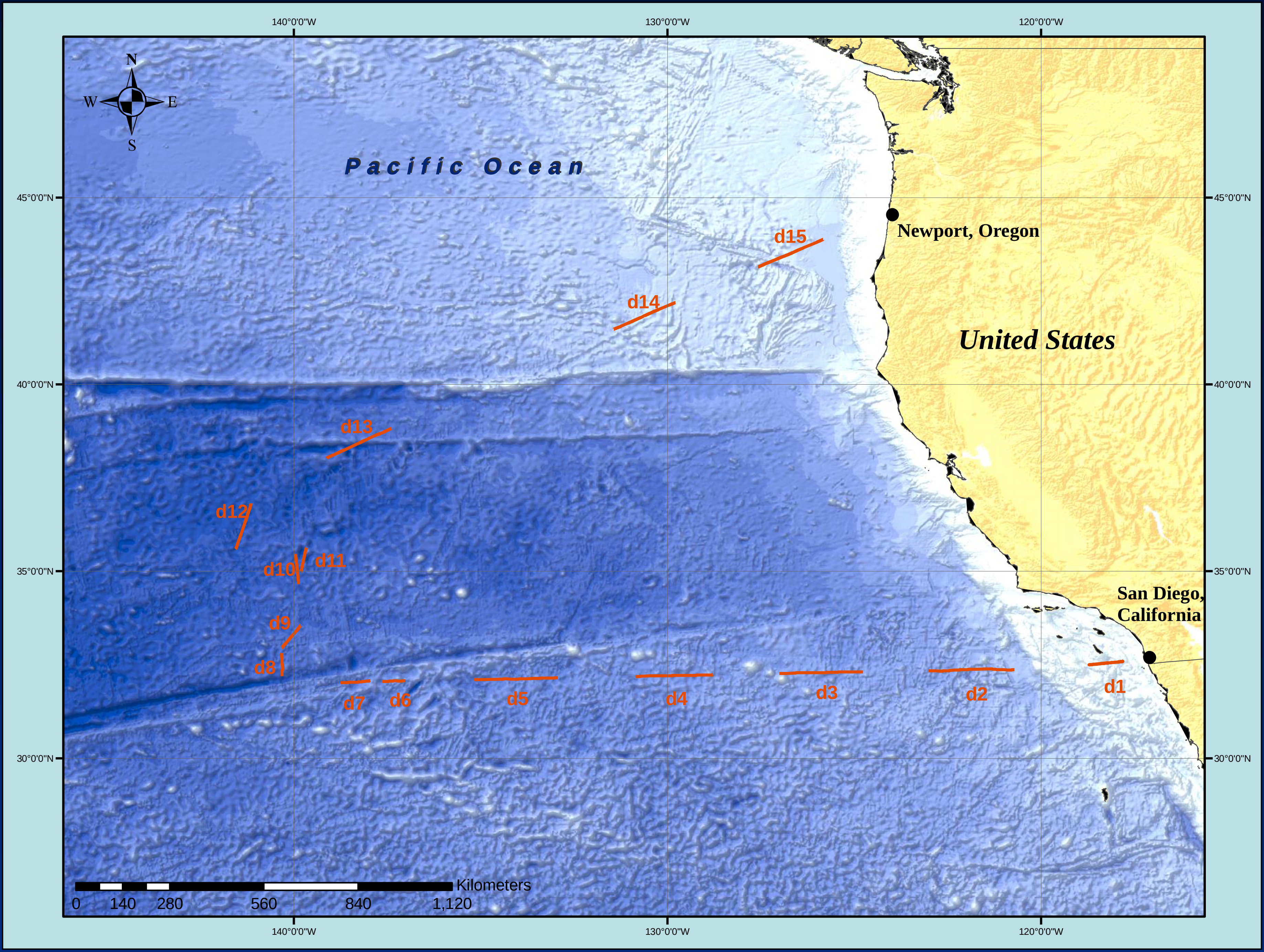
Methods

Study Area

- 20 day cruise (August 2-21, 2009)
- San Diego, California (32°42’N; 117°09’W)

to

- Newport, Oregon (44°36’N; 124°3’W)
- Maximum western extent: 141°W


140°0'0"W
130°0'0"W
120°0'0"W
45°0'0"N
40°0'0"N
35°0'0"N
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N
S
E
W
Pacific Ocean
United States
Newport, Oregon
San Diego,
California
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
Kilometers
0
140
280
560
840
1,120

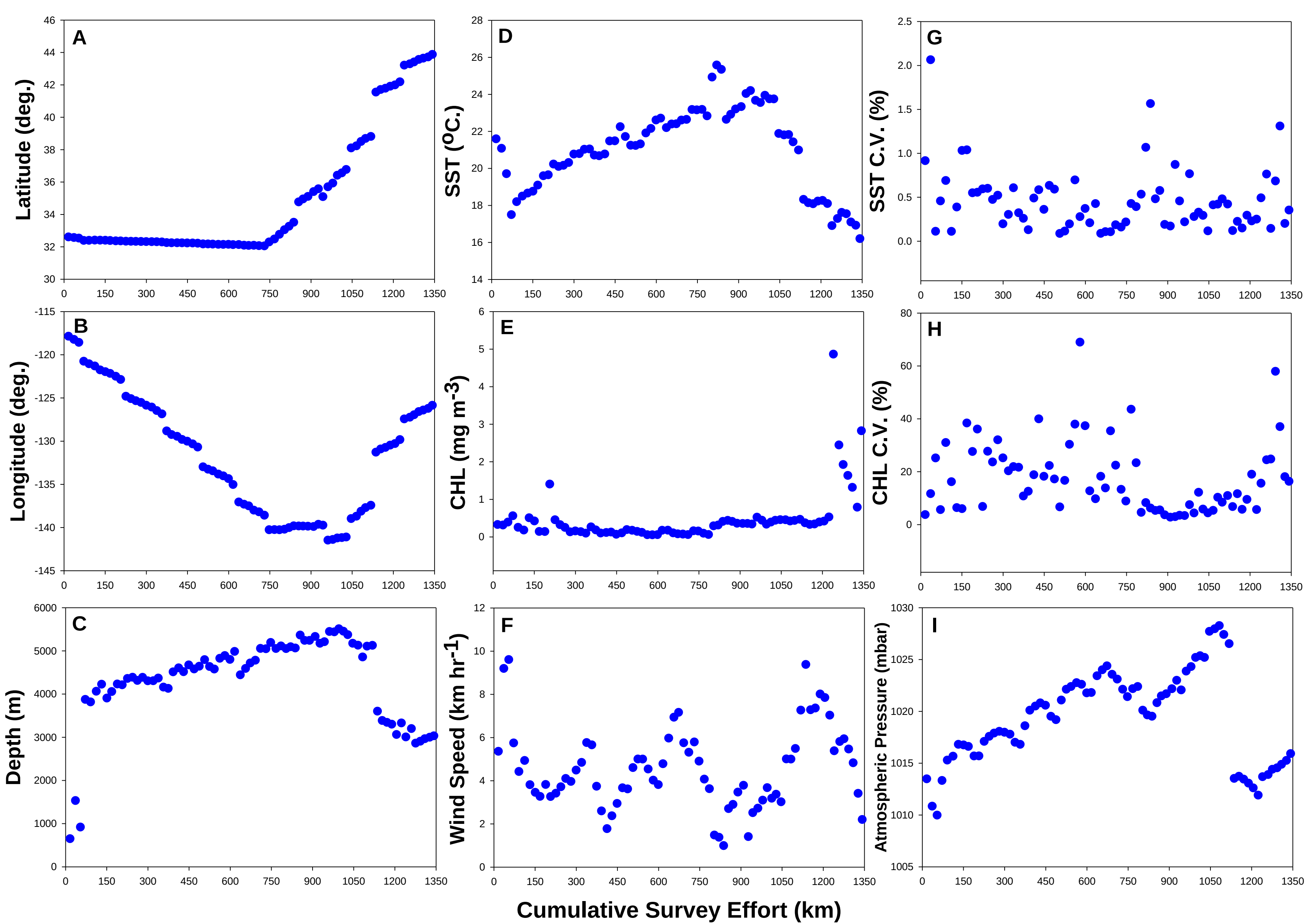
Methods

Oceanographic data

- Temp, Chl, Wind speed, Atm collected continuously underway.

  - Two minute averages used based on underway speed
- Depth determined using NOAA Etopo 1’ resolution data
- Cloud cover determined by observer

Spatial distribution of environmental variables



Methods

<u>Seabird Surveys</u>

- Single observer
- 10m eye height outside wheelhouse
- Standardized strip transect methods
  - count all birds within 300m on one side
  - did not recount followers
  - birds ID to lowest possible taxon
- One hour transect length (17.1-20.6 km)

Tasker et al. 1984

Methods

Marine Debris Surveys

- Concurrent with seabird surveys (same observer)
- Standardized line distance sampling
- Counted all visible pieces to the horizon
- Recorded binned perpendicular distance from ship
- Recorded description, size and color for each piece

Buckland et al. 1993

Spatial Scales of Analysis

Coarse Scale

- One hour transects to determine coarse (10s km) scale densities and communities
- 74 total transects (1343km effort)
- Described coarse community using GLM

Daily Scale

- Combined into 15 larger scale daily transects
- Described daily community using NMDS

Seabird abundance

- Densities using 300m strip width
- Coarse scale analysis: all seabirds (235 total birds)
- Larger scale analysis determined habitat of individual species

Marine Debris Abundance

- Probability of detection of marine debris depends on:

  - environmental conditions

  - size and color

- Marine debris split into groups based on size and color

  - S (0-10cm), M (10-30cm) L (>30cm)

  - White, Red, Yellow, Orange, Green, Blue, Brown, Black, Clear

Forney and Barlow 1993

Marine Debris Abundance

Marine Debris Group	Descriptions
1	Large White
2	Large High Vis
3	Large Low Vis
4	Medium White
5	Medium High Vis
6	Medium Low Vis
7	Small White
8	Small High Vis
9	Small Low Vis

- High Vis: Orange, Yellow, Red
- Low Vis: Green, Blue, Brown, Black, Clear

Marine Debris Abundance

- Distance of material from track line used to determine Effective Strip Width
- ESW calculated for each MD group
- Correction factor applied to standardize sightings to the widest width
- Corrected sightings and ESW used to calculate densities

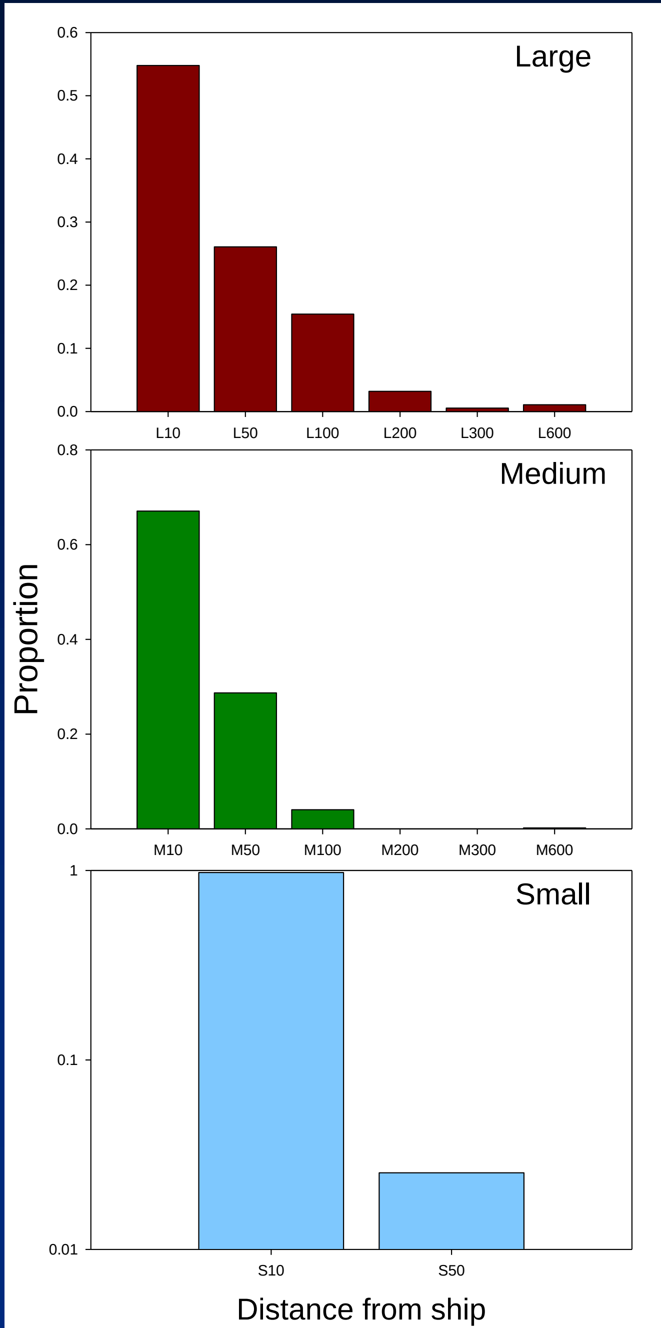
Buckland et al. 1993, Ballance and Pitman 1998

MD size distribution

Large, >30cm

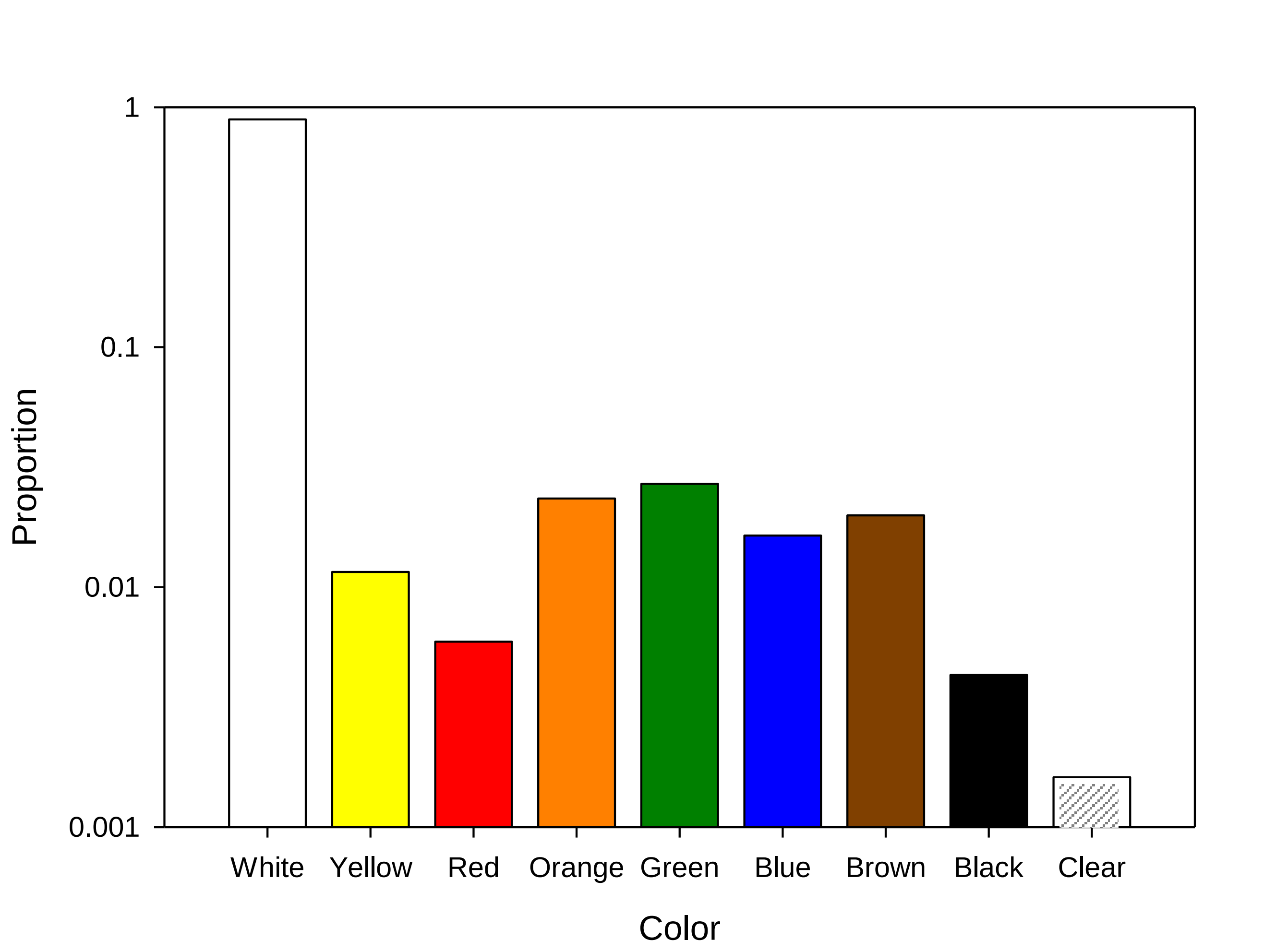
Medium, 10-30cm

Small, 0-10cm

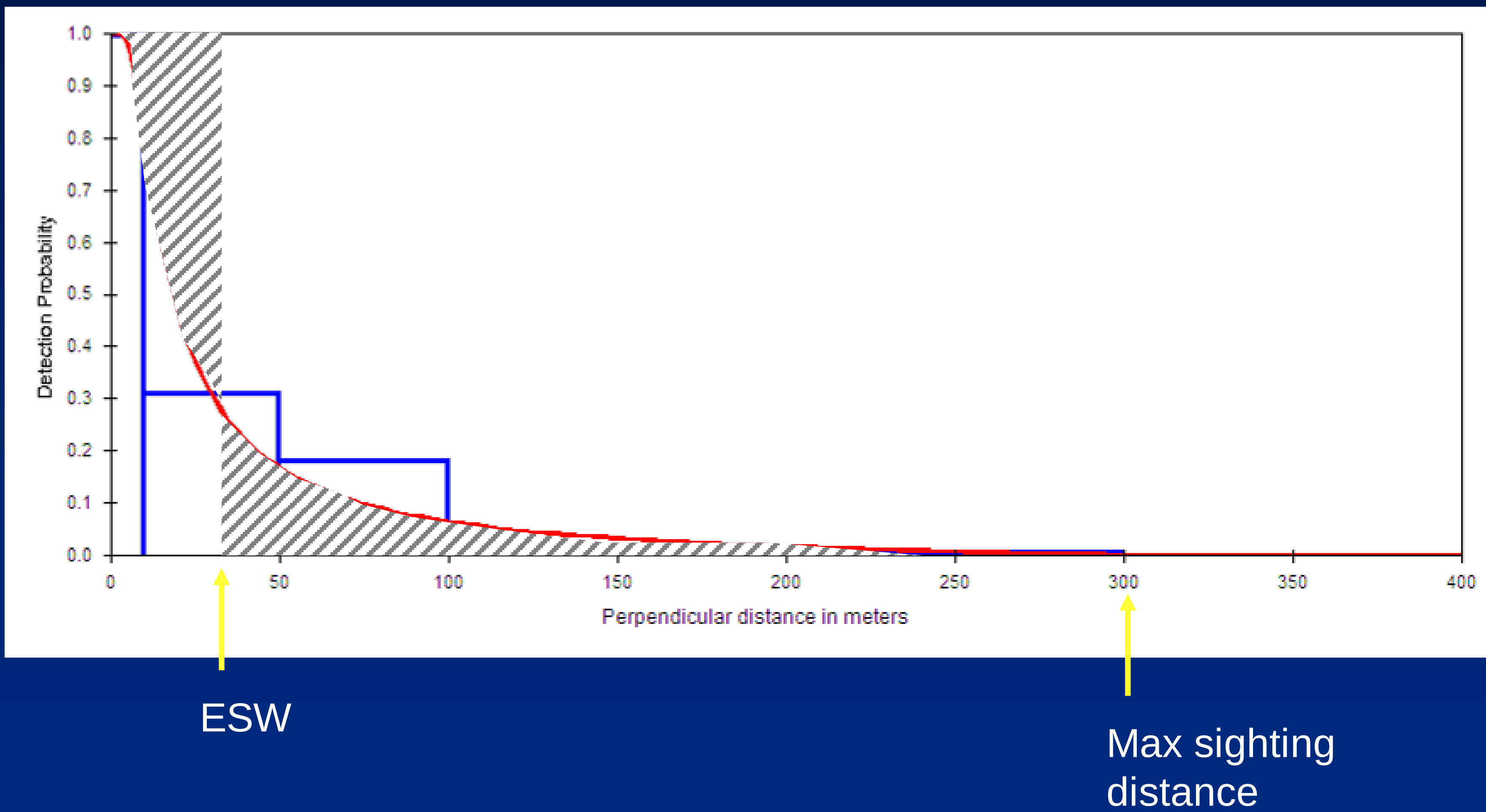


Increasing loss in detection

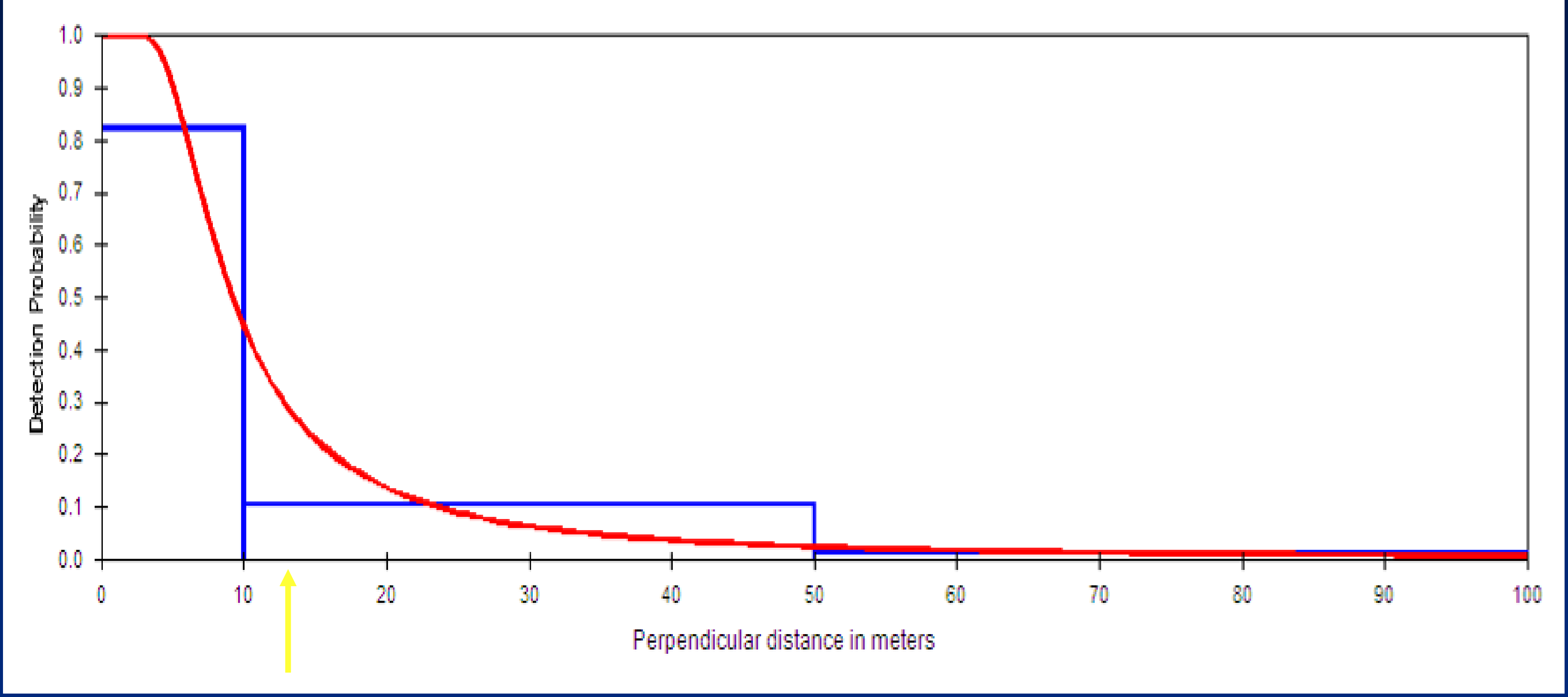
MD Color distribution



Large White
ESW = 33.2m

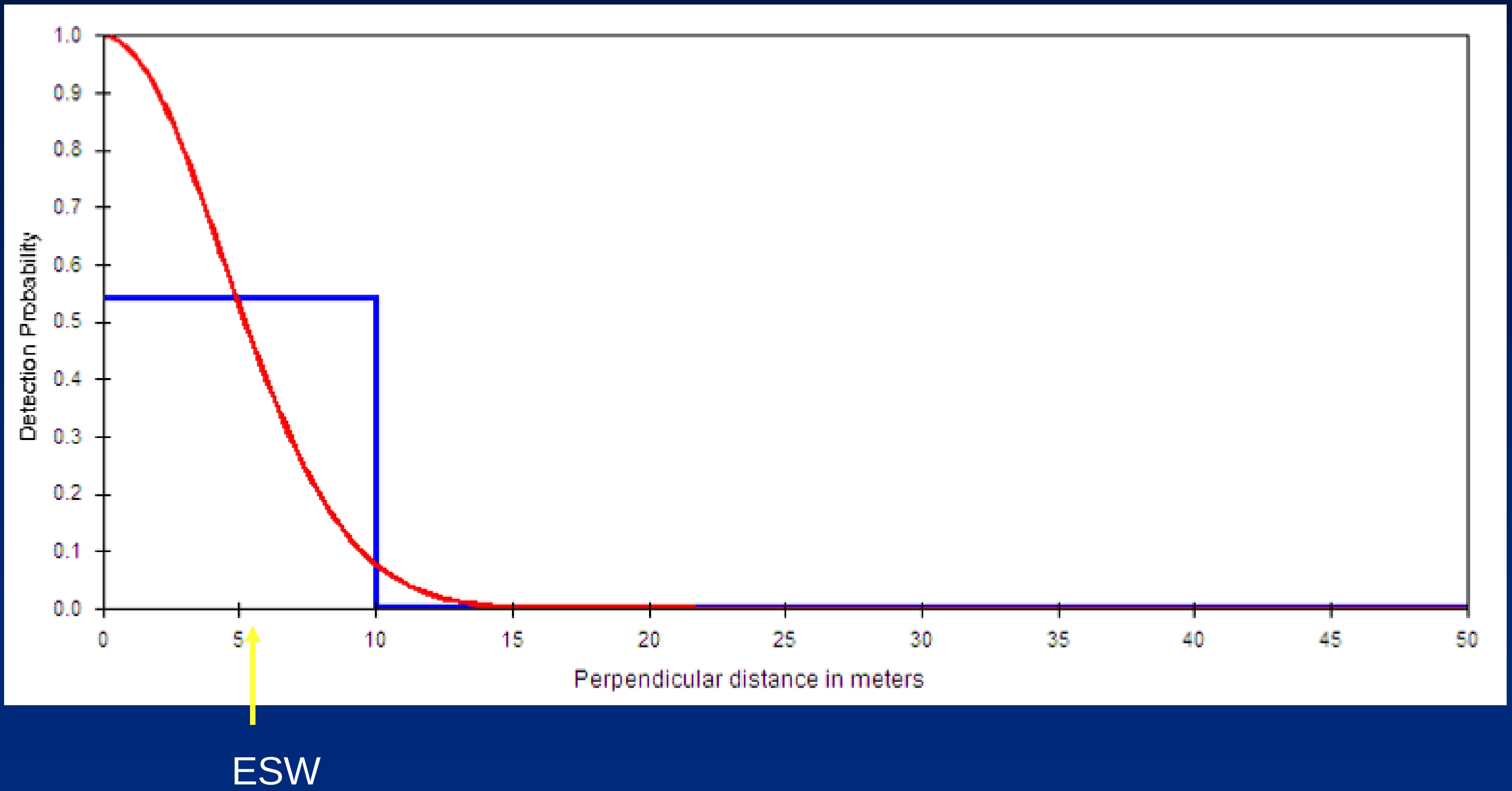


Medium White
ESW = 13.0m



ESW

Small White
ESW = 5.5m



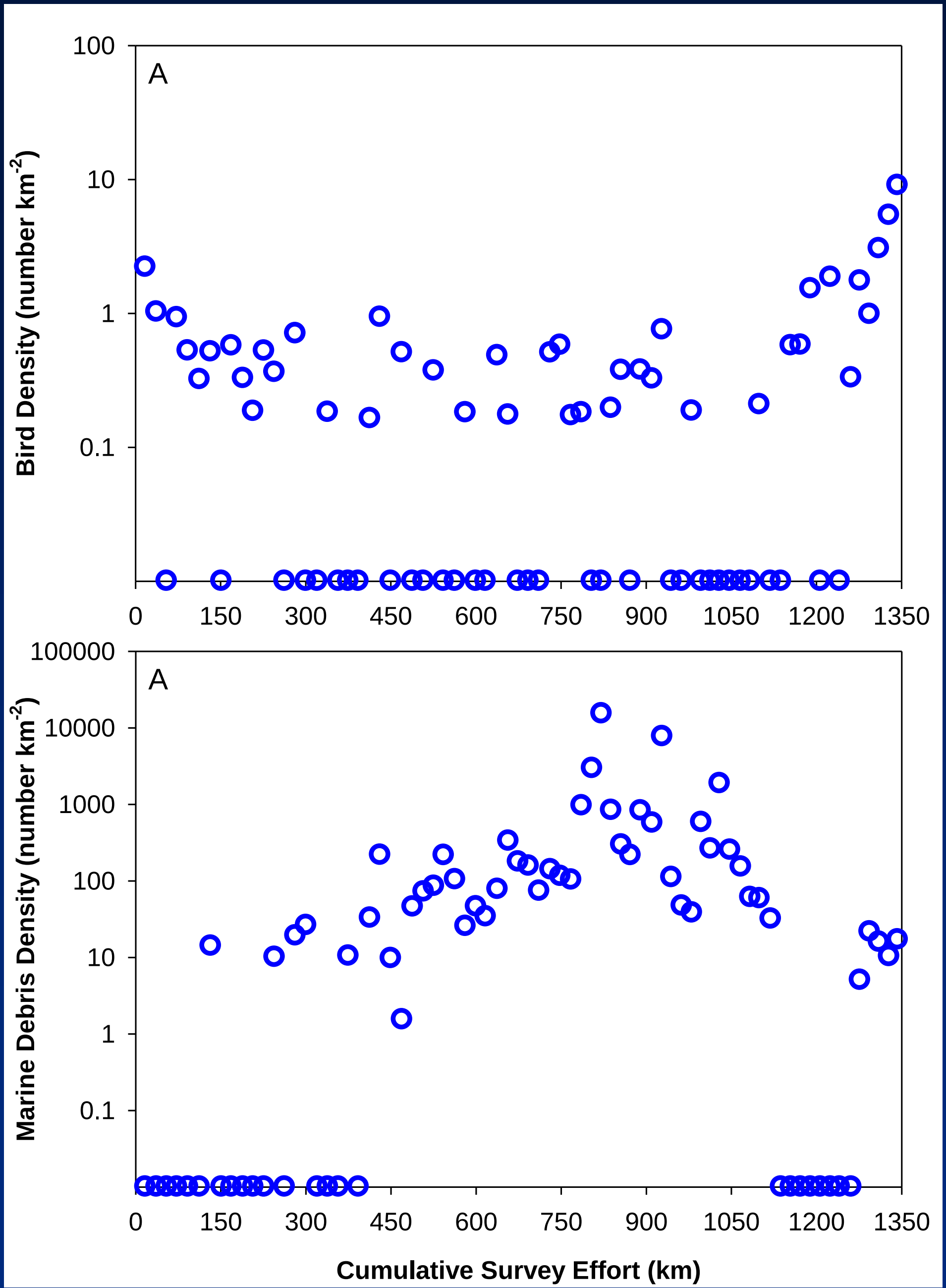
ESW Model Parameters

MD Group	Sightings	Model	Truncation (m)	α ± S.E.	β ± S.E.	ESW ± S.E.	AIC
1	70	Hazard Rate	400	14.28 ± 6.49	1.33 ± 0.25	33.20 ± 8.58	193.92
2	32	Hazard Rate	300	3.00 ± 3.52	1.59 ± 0.41	6.86 ± 5.66	62.31
3	83	Hazard Rate	200	2.00 ± 3.47	1.37 ± 0.48	5.44 ± 6.19	145.95
4	410	Hazard Rate	100	7.67 ± 1.58	1.99 ± 0.24	13.02 ± 1.63	496.73
5	72	Hazard Rate	100	6.38 ± 3.24	2.15 ± 0.59	10.37 ± 3.36	102.08
6	111	Hazard Rate	100	3.96 ± 2.83	1.81 ± 0.44	7.48 ± 3.56	152.35
7	2925	Half Normal	100	4.42 ± 0.88	-	5.54 ± 0.11	632.96
8	47	Half Normal	100	6.59 ± 0.84	-	8.25 ± 1.05	37.90
9	62	Half Normal	100	5.75 ± 0.65	-	7.20 ± 0.81	36.76

Corrected MD Densities

Group	Description	Sightings	Effective Strip Width (ESW)	Correction Factor	Corrected Sightings	Corrected Encounter rate (pieces/km)	Corrected Density (pieces/km2)
1	Large White	70	33.20	1.00	70.00	0.05	1.57
2	Large High Vis	32	6.86	4.84	154.87	0.12	3.47
3	Large Low Vis	83	5.44	6.10	506.54	0.38	11.36
4	Medium White	410	13.02	2.55	1045.47	0.78	23.44
5	Medium High Vis	72	10.37	3.20	230.51	0.17	5.17
6	Medium Low Vis	111	7.48	4.44	492.67	0.37	11.04
7	Small White	2925	5.54	5.99	17528.88	13.05	392.94
8	Small High Vis	47	8.25	4.02	189.14	0.14	4.24
9	Small Low Vis	62	7.20	4.61	285.89	0.21	6.41

Seabird and Marine Debris densities



Coarse Scale Community Analysis

- General Linear Model (GLM)

  - First examined the location effect and removed from analysis

  - Related density to concurrent environmental variables using step-wise model to determine variables with the highest explanatory power

Marine Debris community

(A) Location GLM, $r^2 = 0.68$, n=74				
Variable	Coefficient	*t* statistic	*p* value	Effect
Latitude	-0.049	-2.622	0.011	Higher MD densities in the southern study area
Longitude	-0.132	-12.212	<0.001	Higher MD densities in the western study area
(B) Environmental GLM, residuals, $r2 = 0.25$, n=74				
Variable	Coefficient	*t* statistic	*p* value	Effect
Wind speed	-0.206	-4.948	<0.001	Higher MD densities in low wind areas
Barometric pressure	0.062	2.402	0.019	Higher MD densities in higher pressure areas
Depth	0.461	-3.649	0.001	Higher MD densities in deeper areas

Wind Speed, Barometric Pressure and Depth explain distribution

Seabird Community

(A) Location GLM, $r^2 = 0.341$, n=74				
Variable	Coefficient	*t* statistic	*p* value	Effect
Latitude	0.022	5.001	<0.001	Higher bird densitites in the northern study area
Longitude	0.010	3.950	<0.001	Higher bird densitites in the eastern study area
(B) Environmental GLM, residuals, $r^2 = 0.111$, n=74				
Variable	Coefficient	*t* statistic	*p* value	Effect
Wind speed	-0.035	-3.253	0.002	Higher bird densities in low wind areas
Depth	-0.048	-2.412	0.018	Higher bird densities in shallower areas

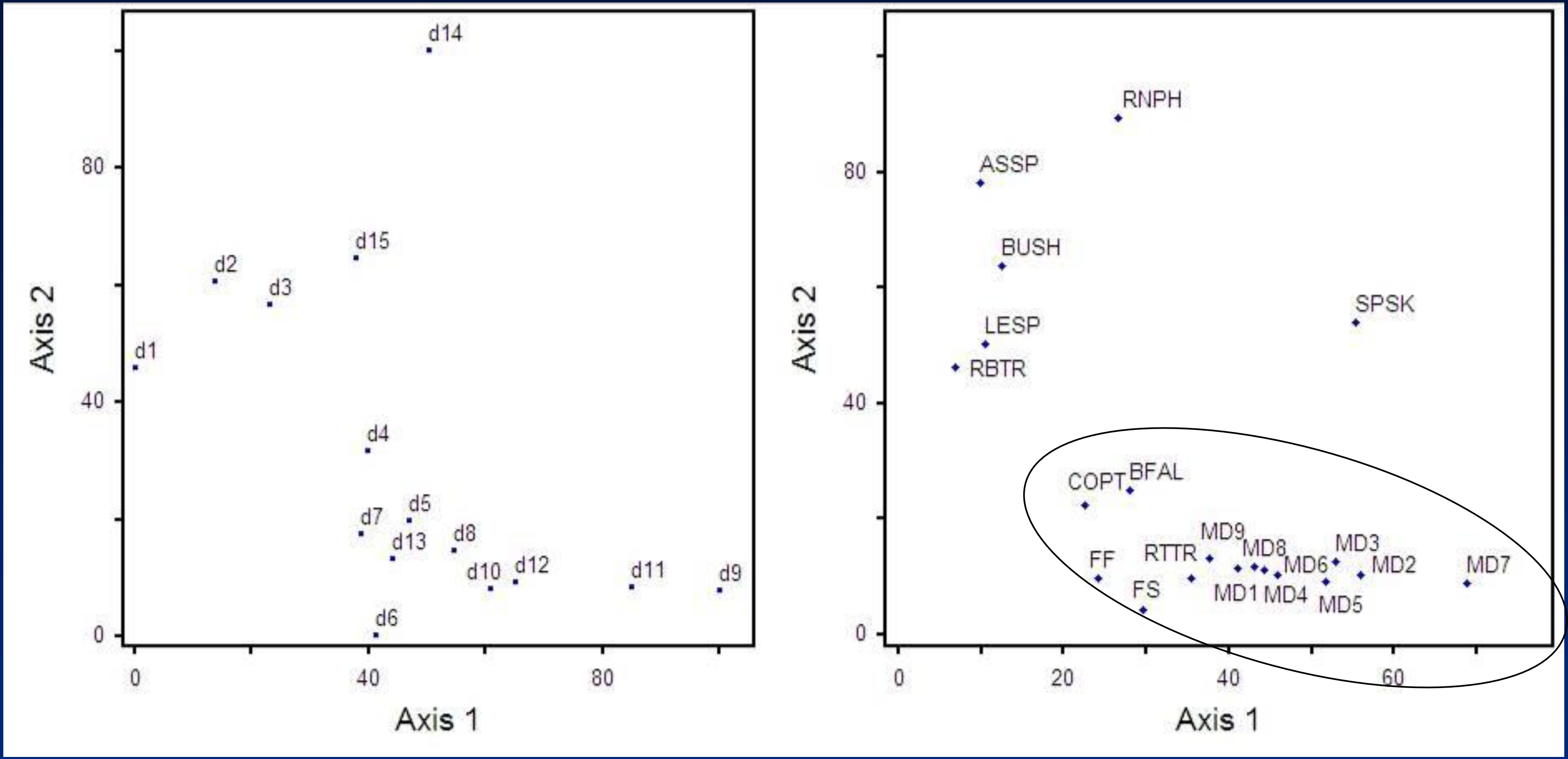
Wind Speed and Depth explain seabird distribution

At this scale (10's km) birds and marine debris are found in different areas (based on depth)

Large Scale Analysis

- Grouping transects by day allows separate analysis of different seabird species and marine debris groups in relation to environmental variables
- Non-metric Multi Dimensional Scaling (NMDS) allows for a large number of variables to be examined

NMDS Results



Warmer, lower wind to the right

Lower chlorophyll, higher pressure towards the bottom

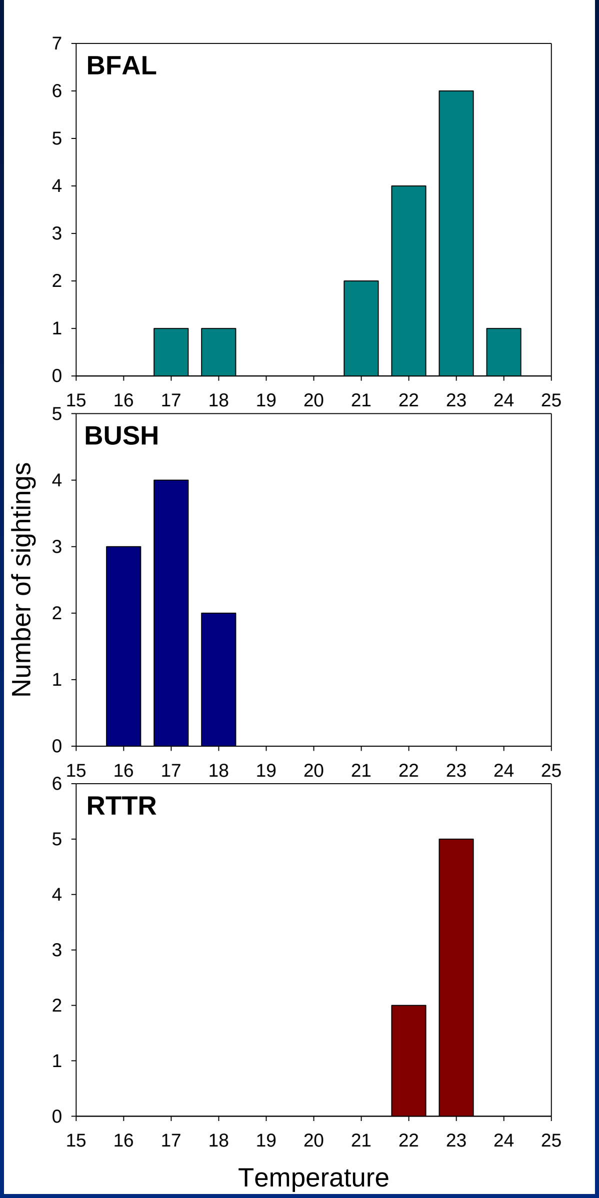
Marine debris, BFAL, COPT found together

Axis Parameters

Environmental Variable	Axis 1	Axis 2
Wind Speed (WSP)	-0.429	0.295
Depth (DPT)	0.6	-0.581
Temperature (SST)	0.619	-0.752
C.V. Temperature (TCV)	-0.41	0.352
Chlorophyll-a concentration (CHL)	-0.067	0.238
C.V. Chlorophyll-a (CCV)	-0.524	0.429
Barometric Pressure (ATM)	0.295	-0.505
Cloud Cover (CC)	0.01	0.162
Latitude (LAT)	0.162	0.162
Longitude (LON)	-0.695	0.524

Some variables load on both axis however a clear pattern is present along with a split in the seabird community

Seabird species distribution



BFAL found throughout a wide range of temperatures

BUSH found only in colder waters close to coast

RTTR found only in warmer sub-tropical waters

Conclusions

- Many of the same environmental parameters explain seabird and MD distribution (wind speed, depth) at the coarse scale, indicating separation

- Marine Debris concentrations are found in a distinct area that overlaps with the presence of far ranging procellariiform species (Black-footed albatross, Cook's Petrel) when examined at a larger scale

Implications

- Although this concentration of marine debris is not the main foraging area for these far ranging pelagic species, they are exposed to it while traveling

- Many other petrels may be ingesting plastic that travel over this area

Acknowledgements

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Questions?