

# Estimating Abundances of Antarctic Ice Seals

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ORIGINAL PAPER

# **Distribution, density and abundance of Antarctic ice seals off Queen Maud Land and the eastern Weddell Sea**

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# TRIBE LOBODONTINI

Sea leopard  
(*Hydrurga leptonyx*)

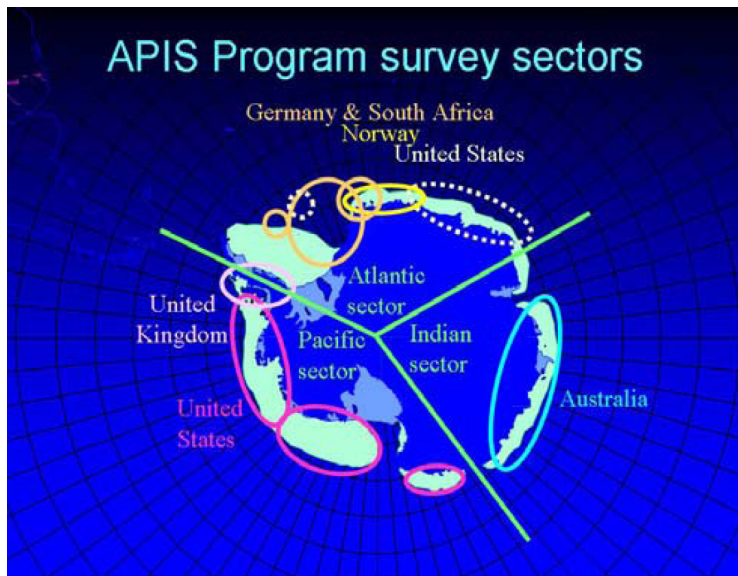
Weddell seal  
(*Leptonychotes weddellii*)

Ross seal  
(*Ommatophoca rossii*)

Crabeater  
(*Lobodon carcinophaga*)



# International APIS Sectors

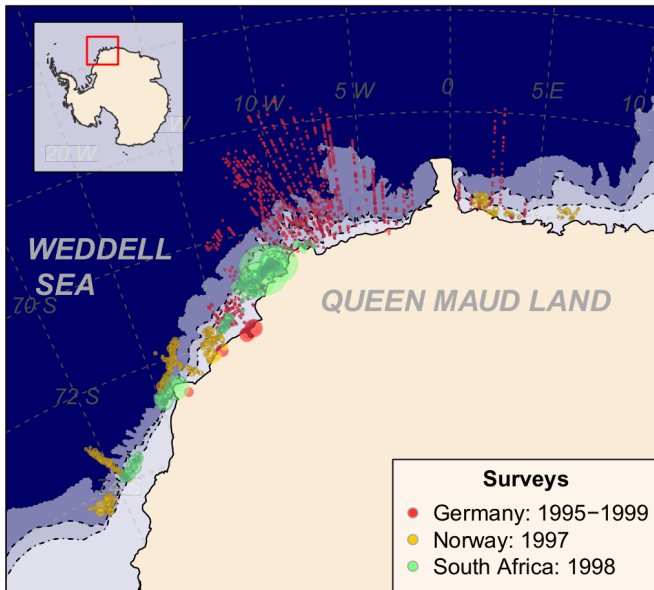




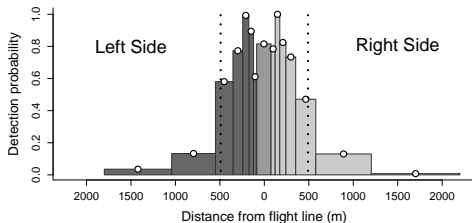
# What is $N_t$ ?

- To estimate global abundances of 4 ice seal species in Antarctica.
- To learn something about habitat preferences, ice-dependence, etc.

# The Atlantic sector



# Distance-dependent detection: Norway



- Bin-widths reported left and right side
- Central strip

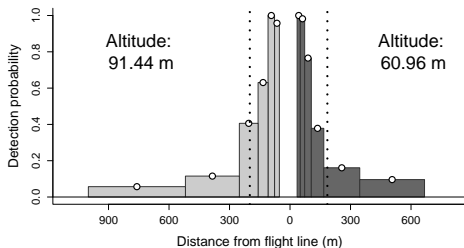
Effective width:

$$N = L \sum_{i=1}^k d_i w_i = LW^* D^*$$

Assumption: Highest bin density represents 100% detection.

**Result:  $W^* = 982.5$  m**

## Distance-dependent detection: South Africa



- Altitude (91.44 m and 60.94 m) and angles ( $10^\circ$ ) reported,
- Bins widths calculated
- Maximum distance assumed: 1000 m and 667 m.

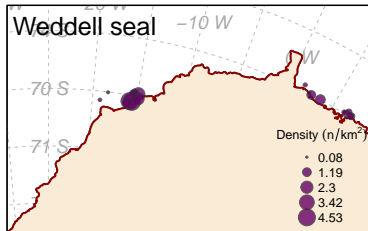
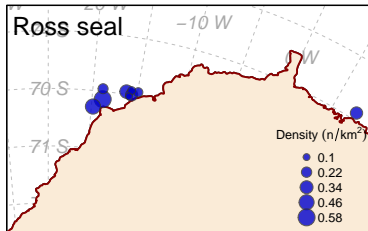
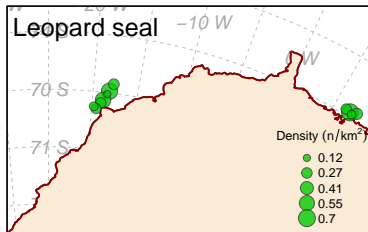
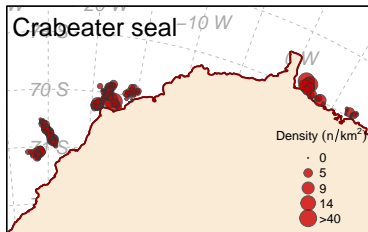
**Result:**  $W^* = 399$  m at 91.44 m; **370.4** m at 60.96 m

# Species!

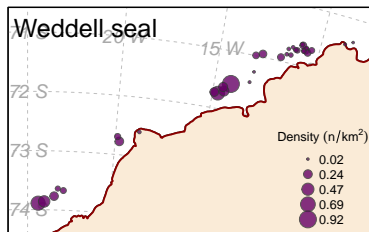
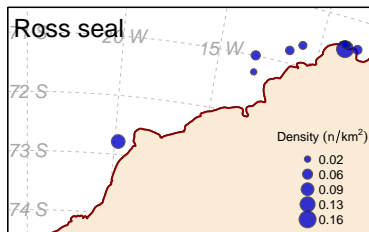
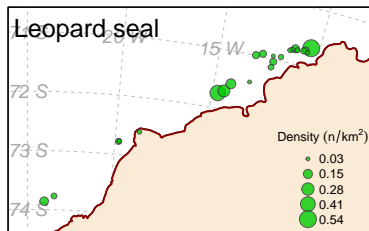
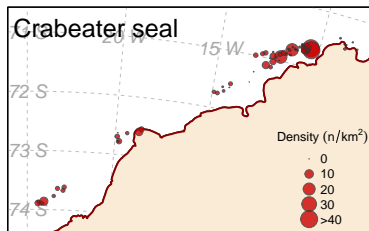
	Norway (1997)			South Africa (1998)		
	N	%	w/o Unid.	N	%	w/o Unid.
Crabeater	1363	84.87	88.45	4157	86.78	96.16
Leopard seal	12	0.75	0.78	42	0.88	0.97
Ross seal	10	0.62	0.65	14	0.29	0.32
Weddell seal	156	9.71	10.12	110	2.30	2.54
Unidentified	65	4.05	-	467	9.75	-



# Norway: Species Distribution



# South Africa: Species Distribution

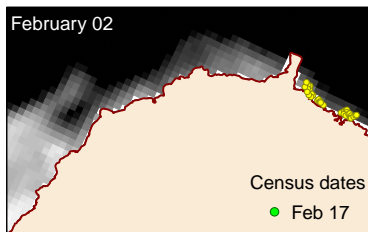
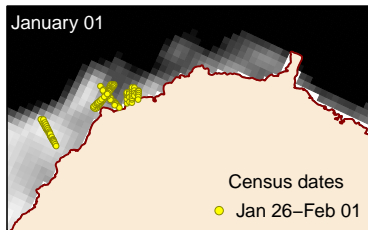
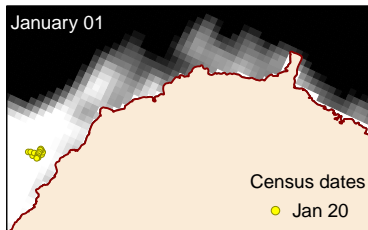


# Covariates

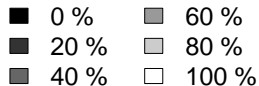
- Distance to shore
- Sea Ice (SSMI)
  - Concentration (%)
  - Distance to 10% ice edge
  - Width of ice platform (km)
  - Change in width of ice platform (km)
- Bathymetry: On/Off shelf ( $< 1000m$ )



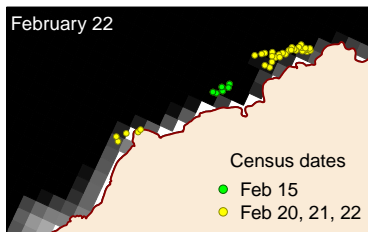
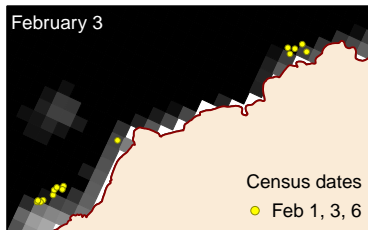
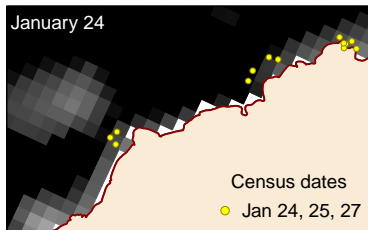
# Norway: Ice concentration (1997)



## SSM/I ice concentrations



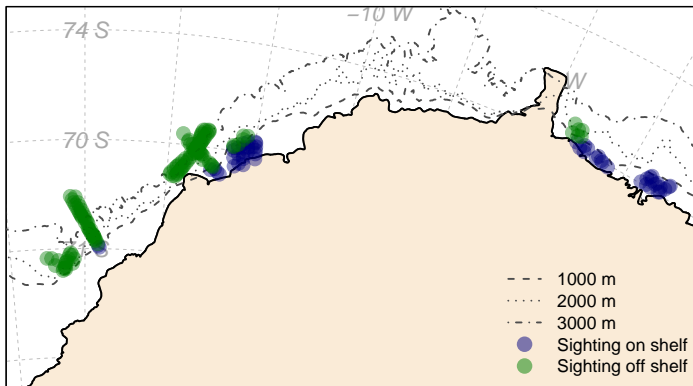
# South Africa: Ice concentration (1998)



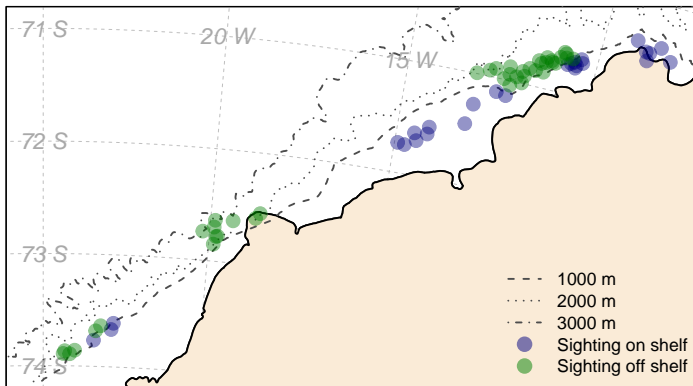
## SSM/I ice concentrations



## Norway: Bathymetry



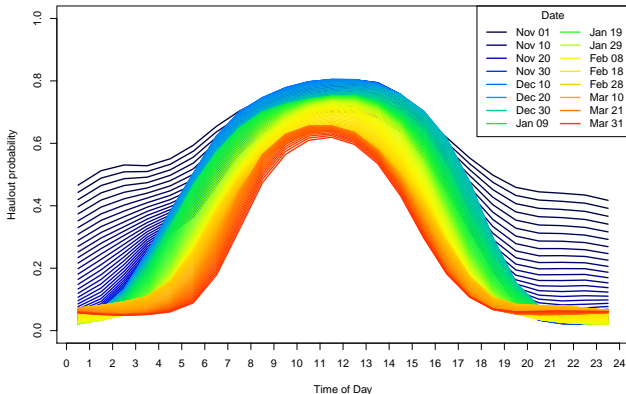
## South Africa: Bathymetry



# Time of day affects probability of sighting

$$D_{ij}^* = \frac{D_{ij}}{P_s(\text{day, time of day})}$$

Modeled crabeater haulout probabilities



$P_s$  correction factor, derived from other studies of diving behavior of seals  
(Bengtson et al. 2011)

## Modeling strategy

- Fit Density with respect to Covariates as well as possible with GLM.
- Use GLM to extrapolate over entire region of survey.

# Raw Densities

## Norway, 1997

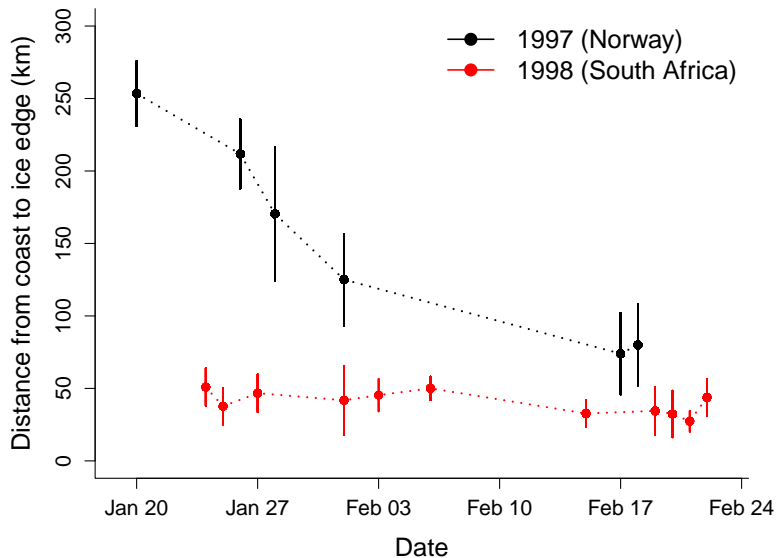
Survey	Area (km <sup>2</sup> )	N	Density (ind./km <sup>2</sup> )
3	103	112	1.09
4	96	148	1.55
5	246	275	1.12
6	157	123	0.78
7	260	360	1.39
9	266	328	1.23
10	237	203	0.85
11	113	57	0.51
Total:	1479	1606	<b>1.09</b>

## South Africa, 1998

Survey	Area (km <sup>2</sup> )	N	Density (ind./km <sup>2</sup> )
2	21	98	4.62
3	32	38	1.19
4	26	8	0.31
5	38	154	4.03
6	9	34	3.92
7	35	388	10.96
8	35	225	6.42
9	16	360	22.01
10	11	163	14.57
11	55	2591	47.36
12	12	195	15.97
13	36	536	14.80
Total:	327	4790	<b>14.66</b>

Order of magnitude difference! ... (explained entirely by availability of ice).

# Ice Extent Index (MID)





## Complete Model

$$Y \sim \text{OnShelf} \times (\text{Ice} + \sqrt{\text{Ice}}) \times (\text{DEdge} + \sqrt{\text{DEdge}}) \\ \times (\text{IceExtent} + \text{dIceExtent}).$$

## Model parameter estimates

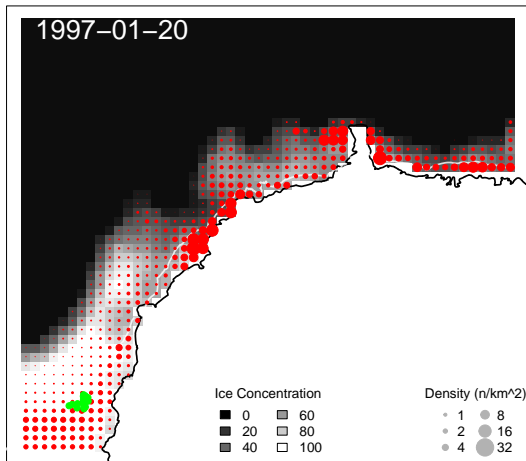
Factor	Norway	South Africa	Germany ( <i>all seals</i> )		
			<i>Crabeater seals</i>	<i>High ice</i>	<i>Medium ice</i>
OnShelf	-1.72***	-0.85*			-1.5319***
DEdge			-1.30**	-0.38**	
$\sqrt{\text{DEdge}}$			-0.85*		
IceExtent	-0.43***	-0.86**	-0.40**	0.104	
dIceExtent	-0.30***		-0.21**		
Ice			0.50		
$\sqrt{\text{Ice}}$			-0.25	-0.585***	
DEdge:IceExtent			1.17***	**	
dIceExtent:Ice			-0.95**		
dIceExtent: $\sqrt{\text{Ice}}$			-1.22***	-0.40**	
OnShelf:IceExtent	-1.36**	0.78			
OnShelf:dIceExtent	-1.99***				
$R^2$	0.317	0.17			
$\hat{\theta}$			0.78 (0.07)	0.53 (0.15)	0.055 ( $5e-3$ )
$\Delta\text{BIC}$	36.2	6	38.3	9.06	1.6

All parameter estimates are given for standardized covariates (except the binomial OnShelf variable)

The significances are coded according to  $p$ -value: \*\*\* <0.001 ≤ \*\* <0.01 ≤ \* <0.05 ≤ - <0.10

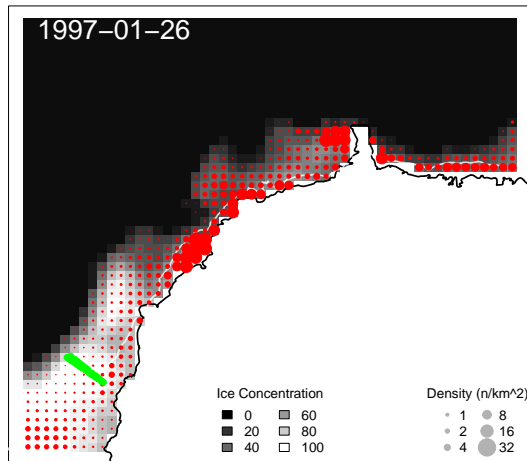
# Norway Results (crabeater)

409000 (188000, 2083000)



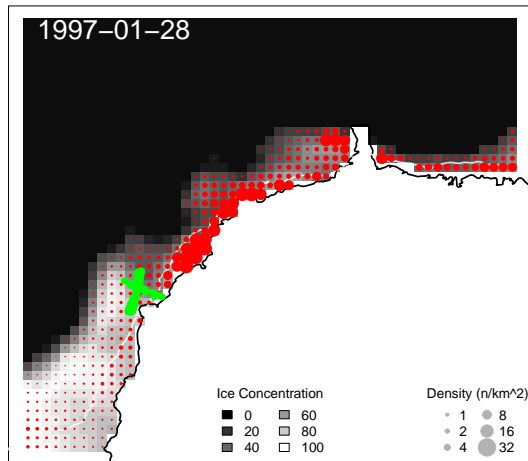
# Norway Results (crabeater)

424000 (185000, 12284000)



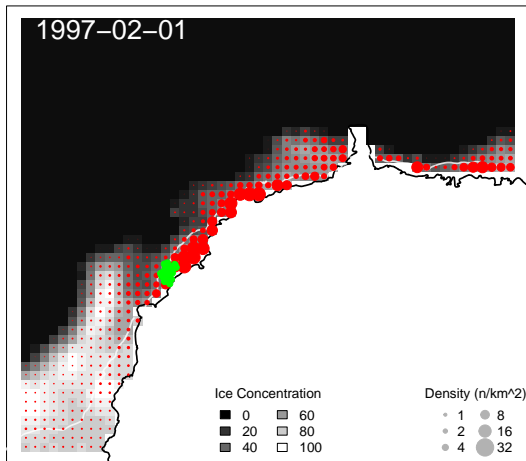
# Norway Results (crabeater)

407000 (174000, 1562000)



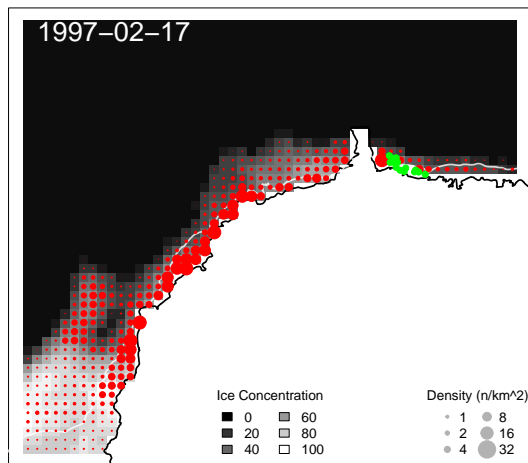
# Norway Results (crabeater)

359000 (164000, 1919000)



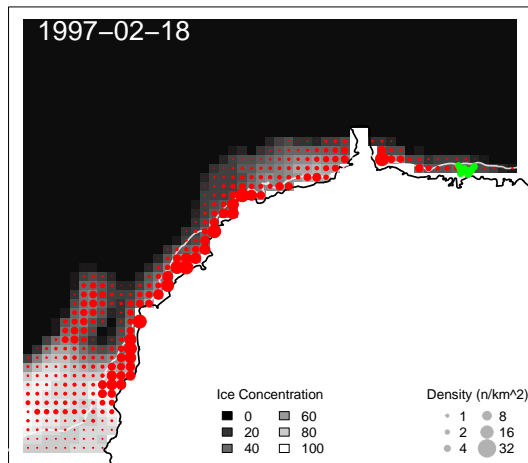
# Norway Results (crabeater)

438000 (198000, 2291000)



# Norway Results (crabeater)

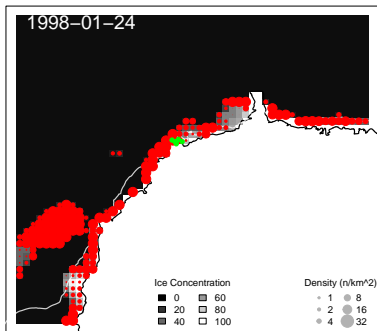
458000 (204000, 5758000)



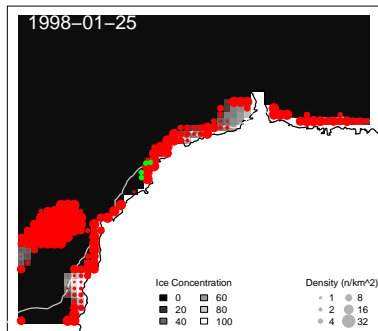


# South Africa Results (crabeater)

1111000 (510000, 6748000)

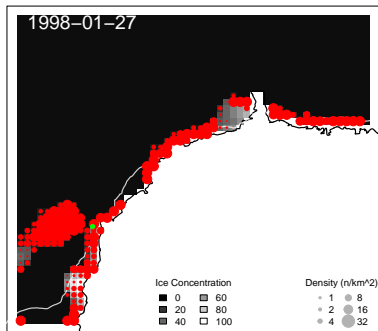


1129000 (526000, 6775000)

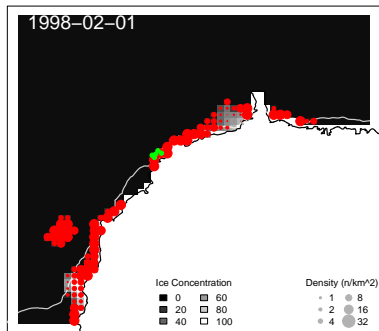


# South Africa Results (crabeater)

1020000 (473000, 6317000)

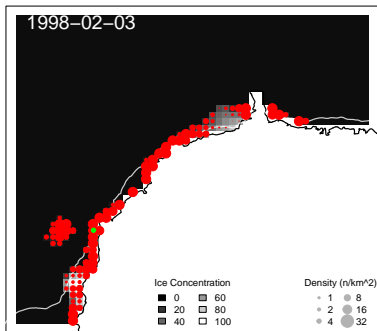


609000 (277000, 2472000)

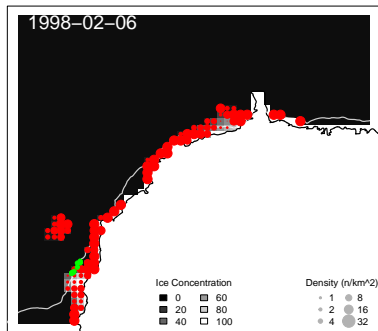


# South Africa Results (crabeater)

580000 (259000, 3960000)

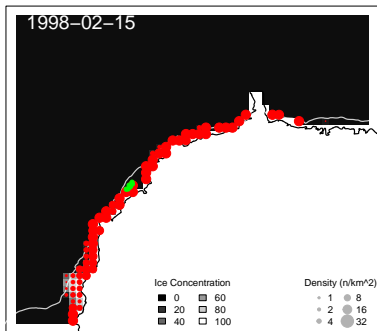


582000 (260000, 3316000)

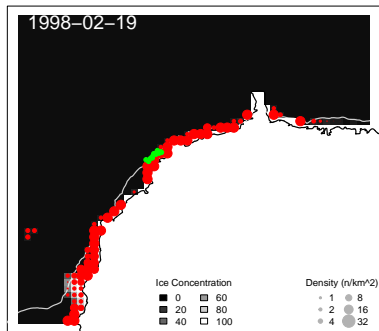


# South Africa Results (crabeater)

558000 (252000, 3056000)

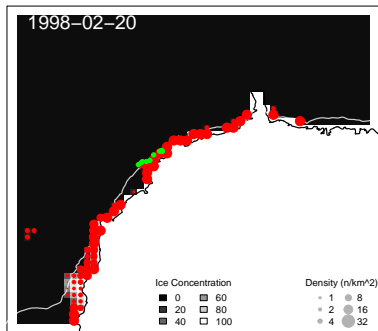


5e+05 (227000, 3229000)

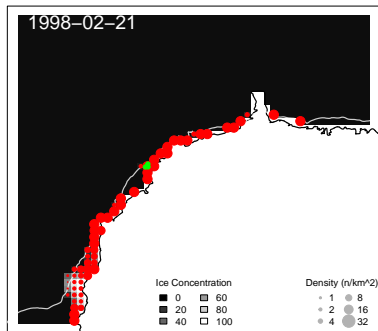


# South Africa Results (crabeater)

454000 (208000, 3916000)

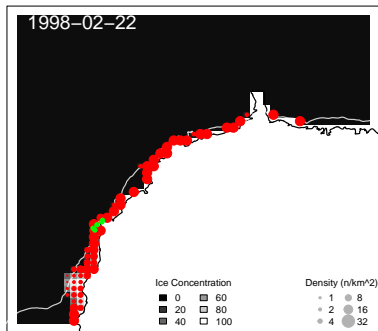


448000 (205000, 3063000)



# South Africa Results (crabeater)

447000 (203000, 2923000)





What is  $\hat{N}$  (and 95% C.I.)?

- Crabeater seals,  $514 (337-886) \times 10^3$
- Weddell seals,  $60.0 (43.2-94.4) \times 10^3$
- Leopard seals,  $13.2 (5.50-39.7) \times 10^3$
- Ross seals - only 24 observed - conservatively 830 (119-2894)