Meso-Scale Studies

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Biologically Significant Information Needed for Management

- Basic biological information about sperm whales
  - e.g. body length
- Composition – types of whales (sex, age)
- Movements over scales from hours to years
- Reproductive rates – numbers of calves
- Foraging – movement patterns and defecation rates
- Group structure and social organization
- Population structure (cultural, codas)
- Distributions – where are they and why
- Population size

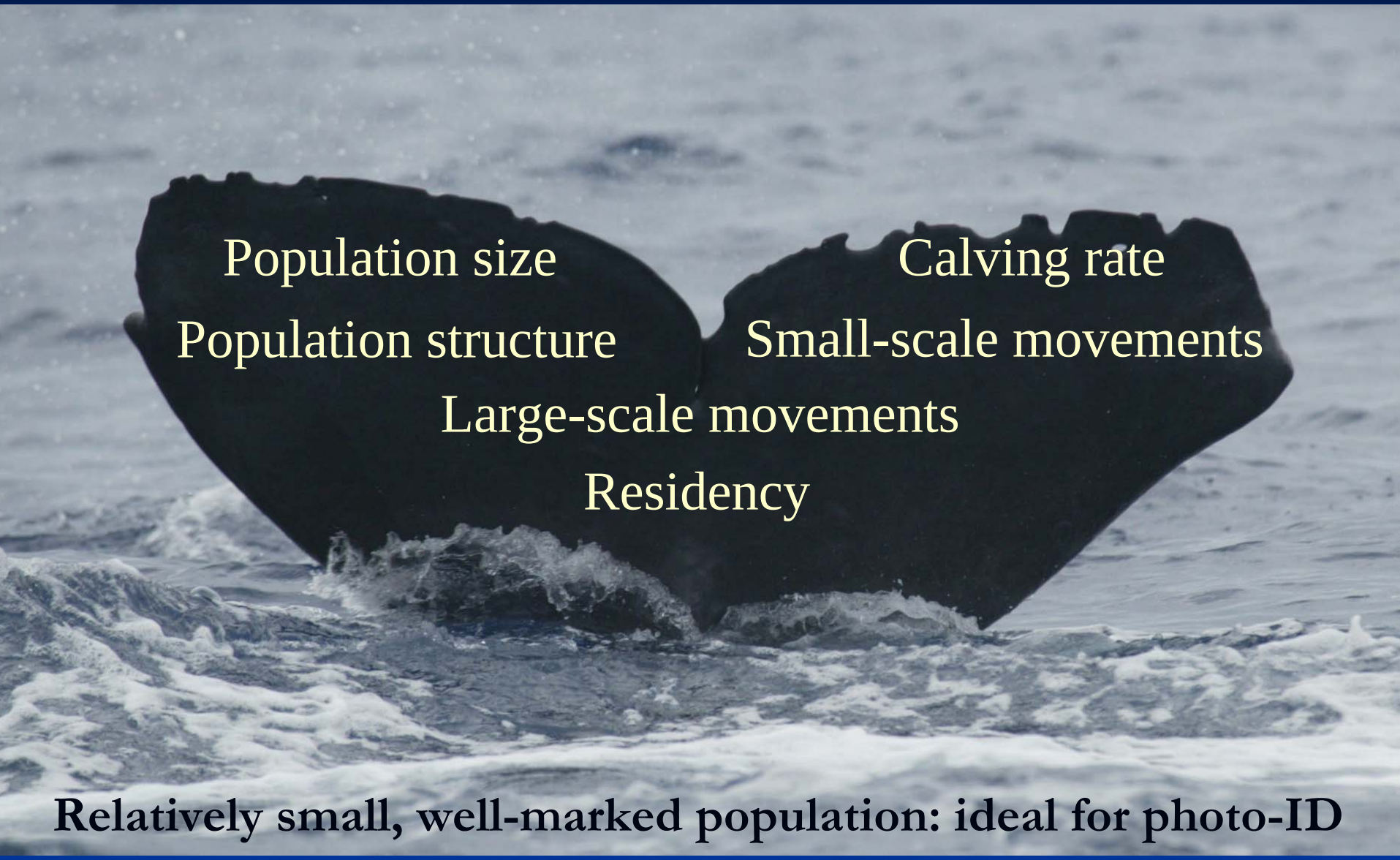
GYRE
GALVESTON

Why a Motor Sailor: Advantages

- Quiet, maneuverable and independent
  - Ideal for observational work
  - Able to work and track whales close to oil platforms
- Sails
  - Safe alternative propulsion
  - Stability
  - Quiet propulsion if necessary
  - Increased range
  - Elevated observational platform
- Operable by a small team of "sailor scientists"
- Cost effective – allows extended field projects
  - Insurance against poor weather etc

Key components of traditional approach are acoustic monitoring and tracking and photo-identification

Photo-Identification



Population size

Calving rate

Population structure

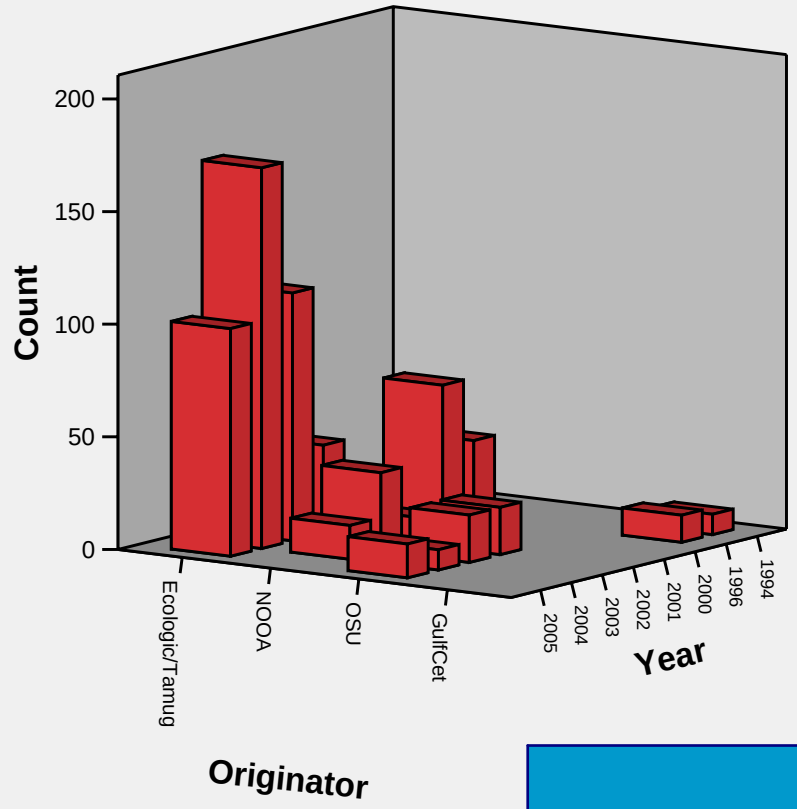
Small-scale movements

Large-scale movements

Residency

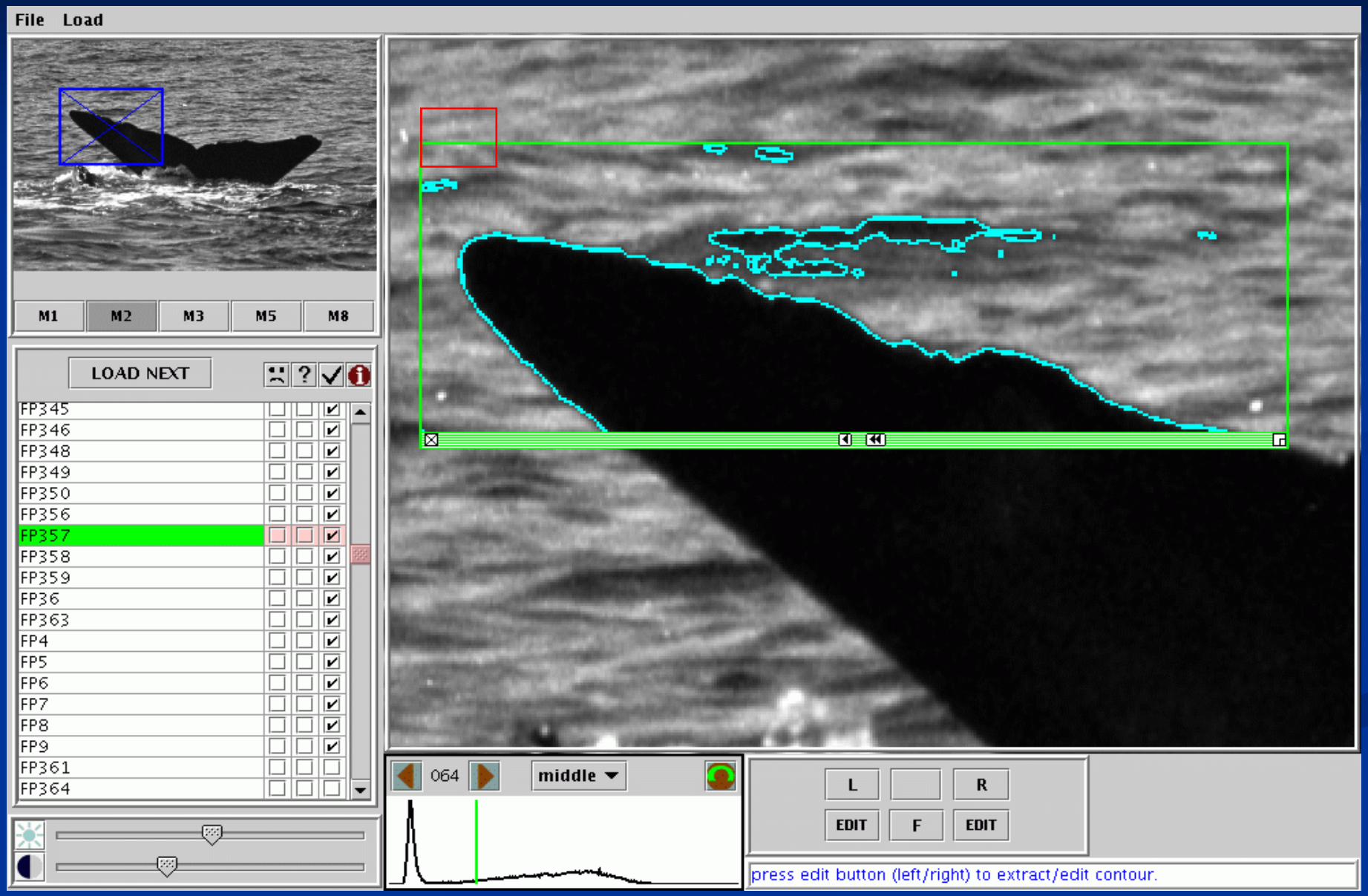
Relatively small, well-marked population: ideal for photo-ID

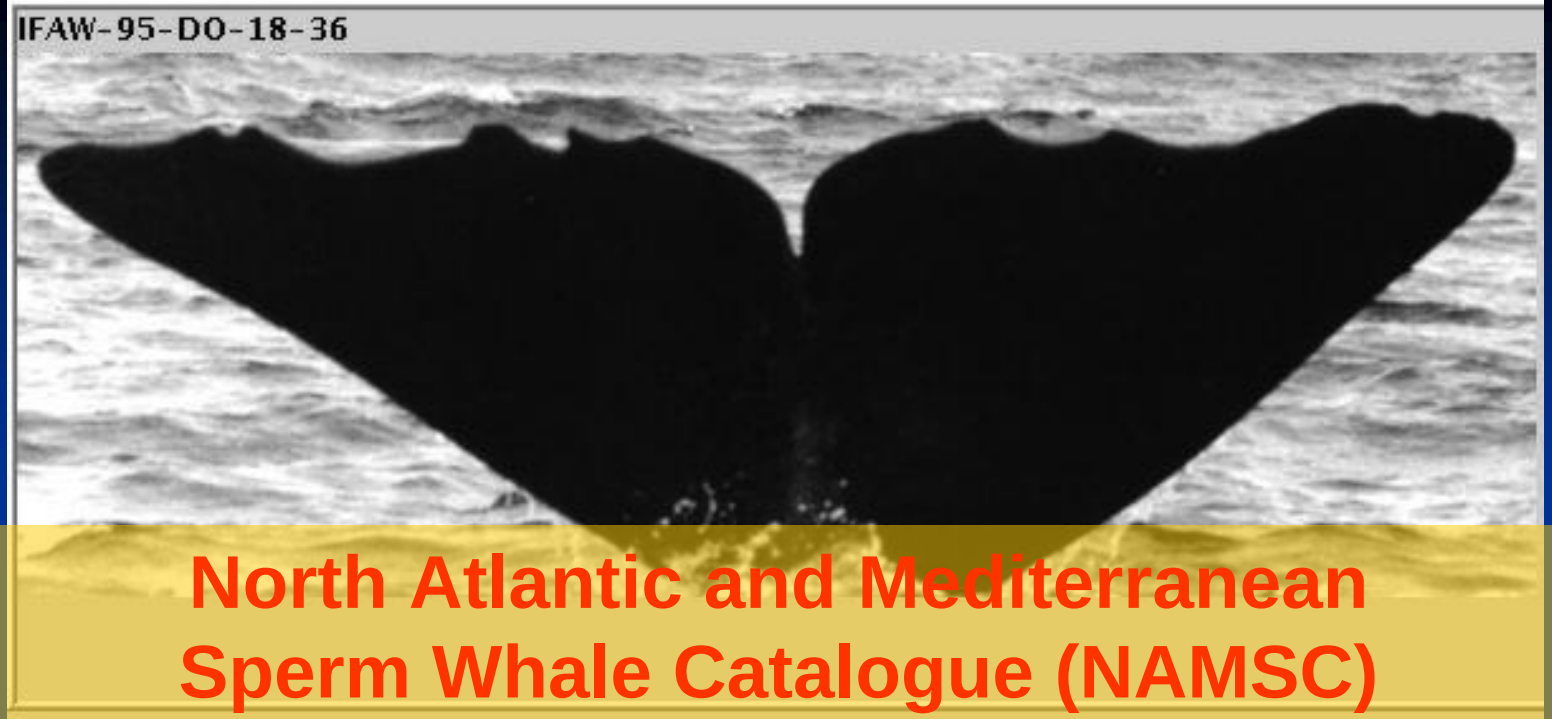
Photo-ID Sequences Collected in the GOM



	1994	1996		2000	2001	2002	2003	2004	2005
Gulf Cet	33 (9)	21 (12)							
NOAA				54 (39)	92 (67)	20 (12)	57 (35)	18 (15)	
SWSS OSU						29 (21)	30 (21)	19 (9)	23 (15)
SWSS Ecologic/TAMUG						64 (39)	167 (110)	324 (169)	191 (101)

Phlex Automated Fluke Matching





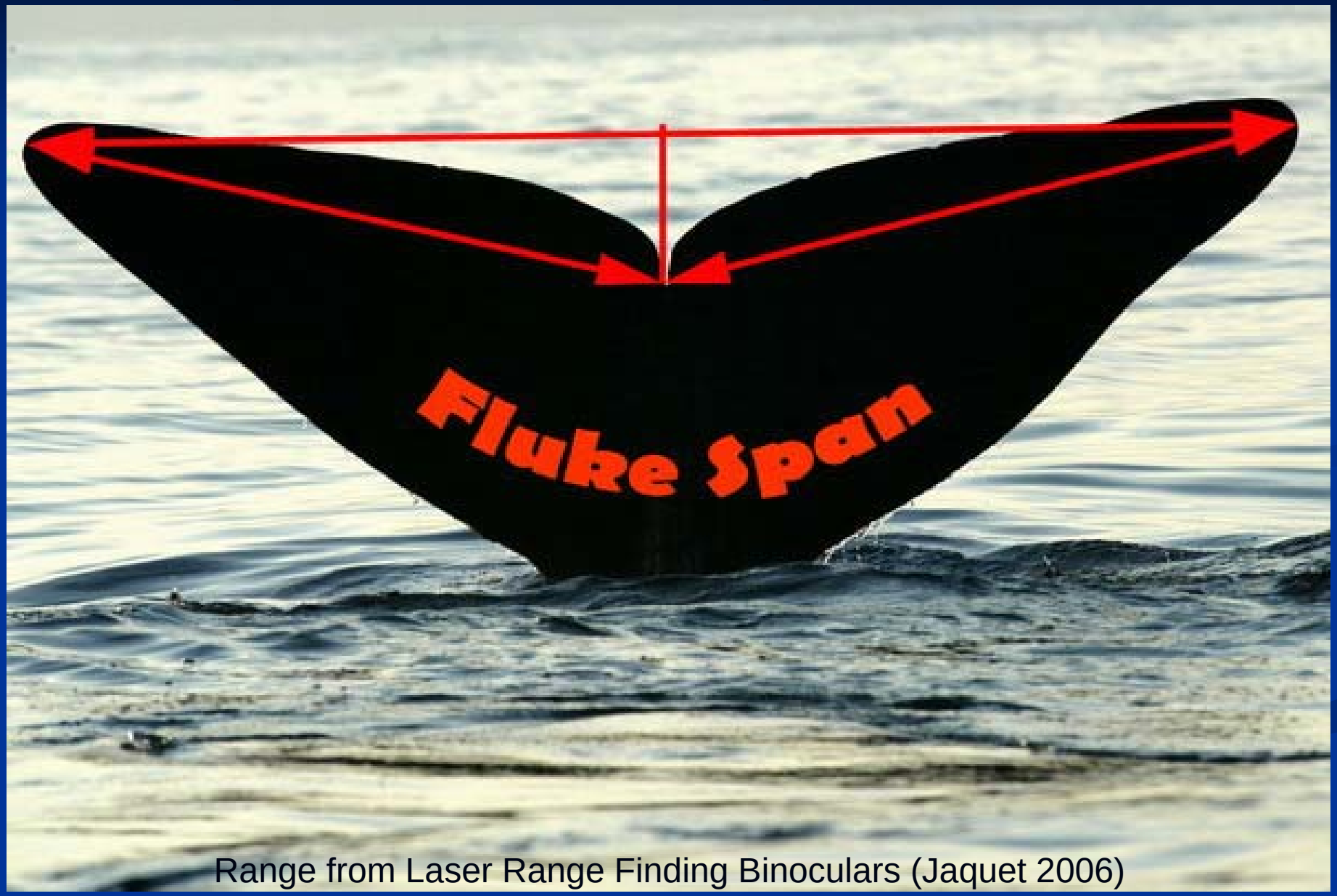
North Atlantic and Mediterranean Sperm Whale Catalogue (NAMSC)

Analysis SOCPROG – Hal Whitehead

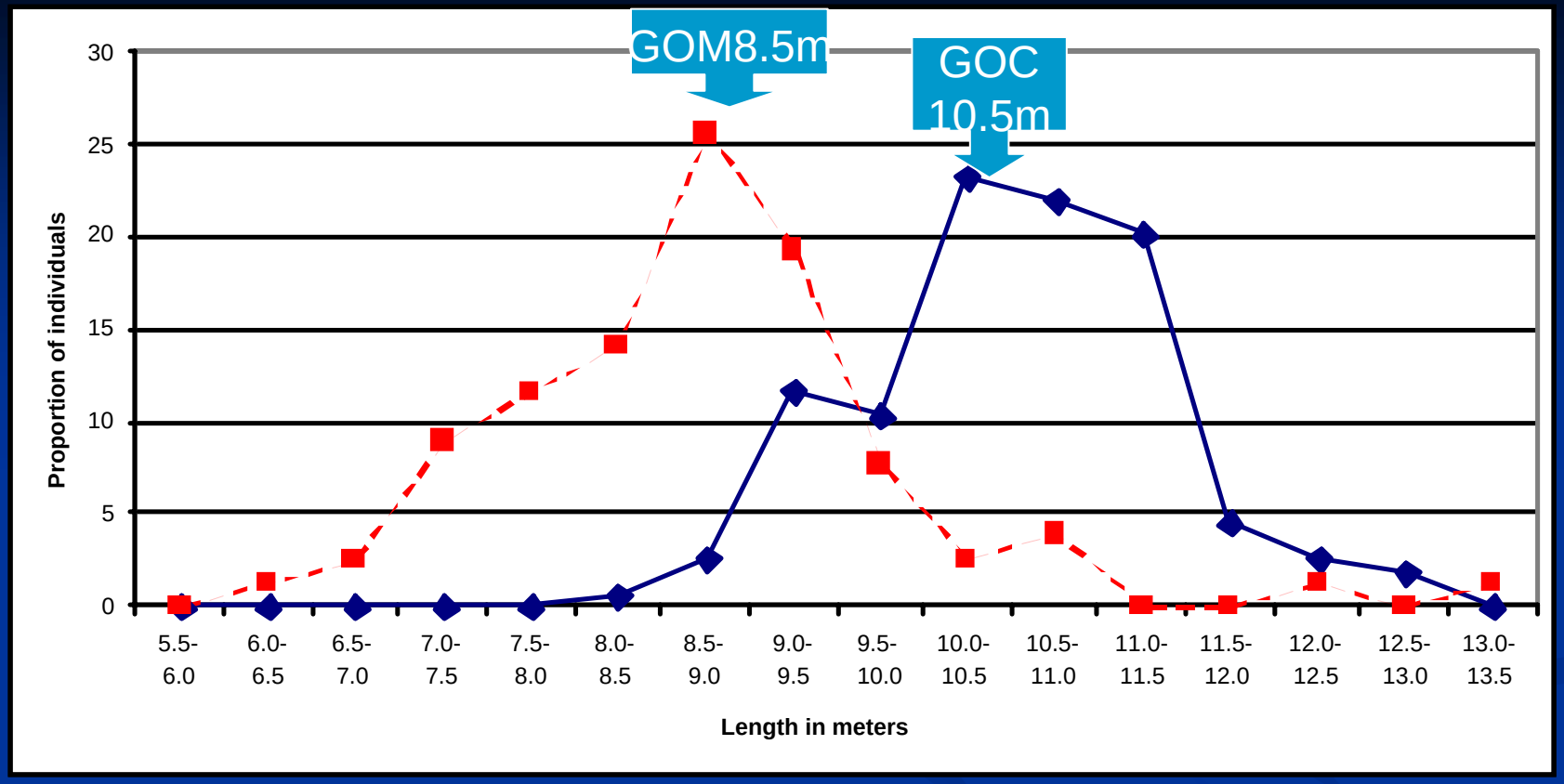
Dorsal Fin Callus: Indicative of Maturity in Females, Puberty in Males

	Biopsy		Observation	
	Females	Males	Medium Males	Nursing Females
No Callus	2 (52.5%)	10 (100%)	1 (12.5%)	12 (100%)
Small Callus	5 (12.5%)	0	2 (25%)	0
Medium Callus	9 (22.5%)	0	03 (37.5%)	0
Large Callus	5 (12.5%)	0	2 (25%)	0
Total	40	10	9	12

Photogrammetric Length Measurement



Range from Laser Range Finding Binoculars (Jaquet 2006)

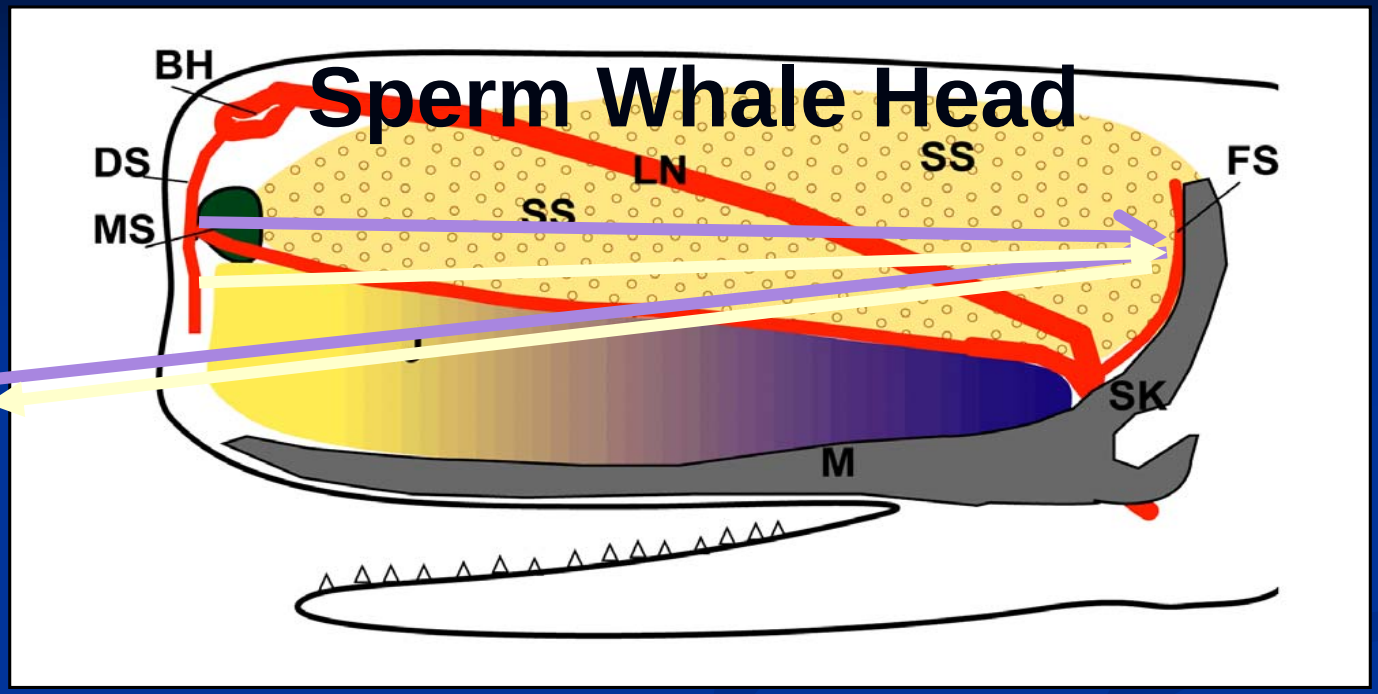


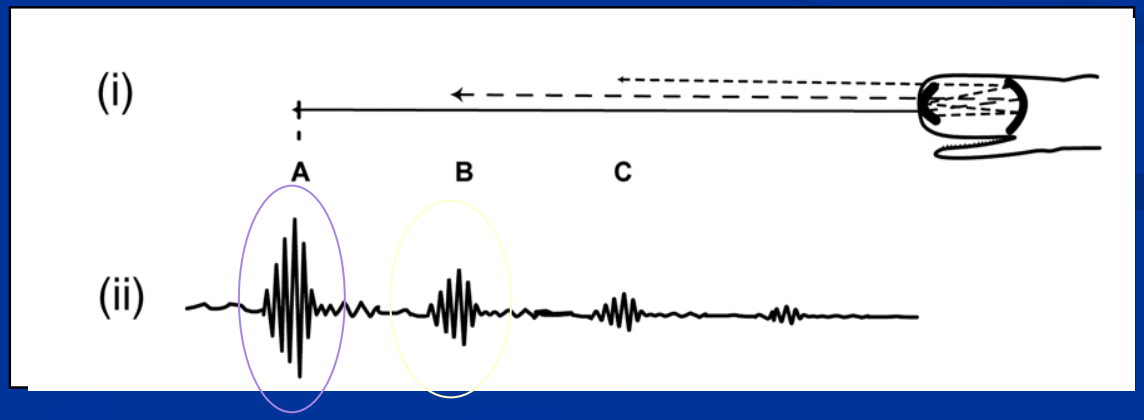
Gulf of Mexico sperm whales are smaller than those measured in similar populations elsewhere

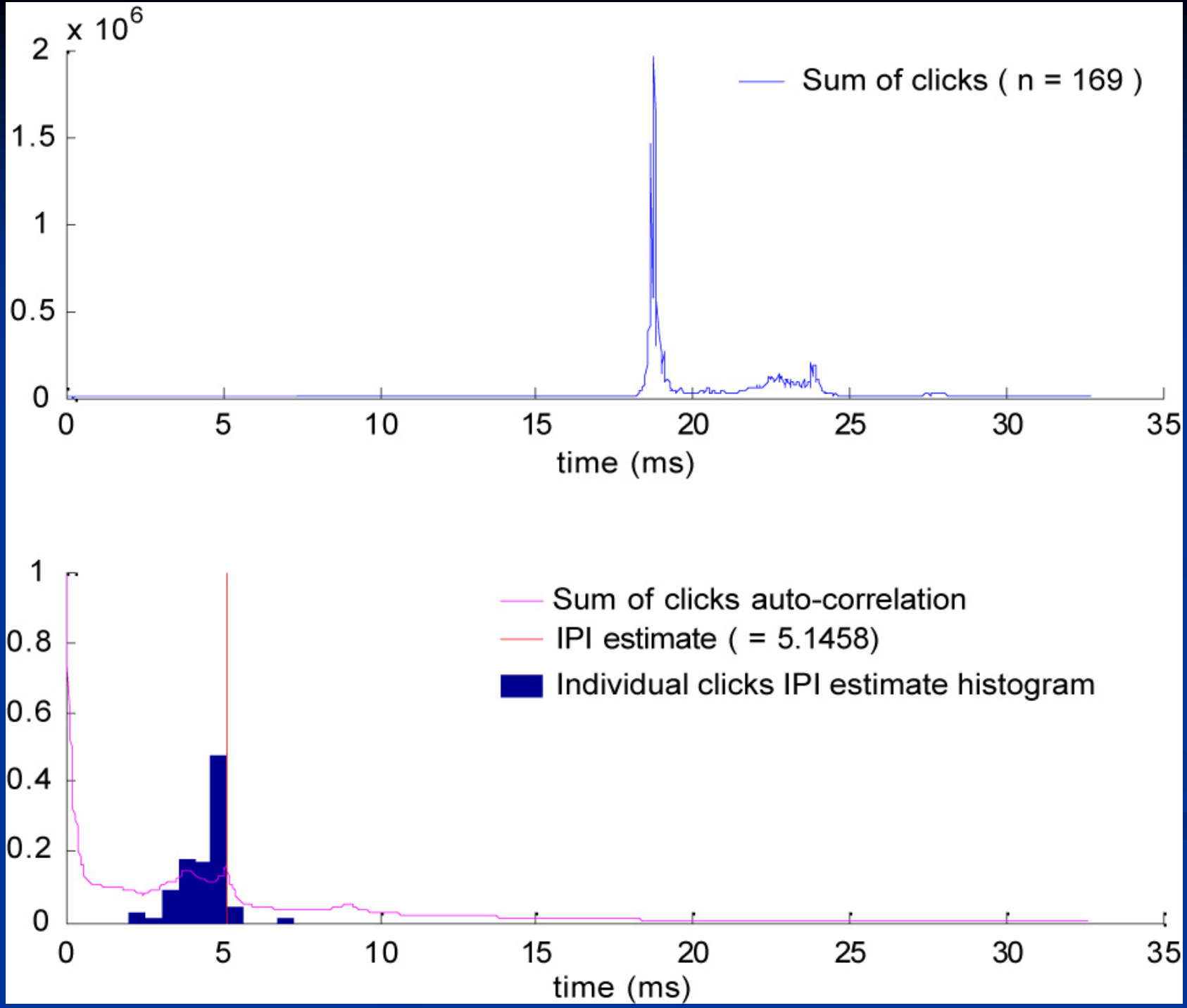
– in fact, the smallest reported from any location

– should this be a cause for concern?

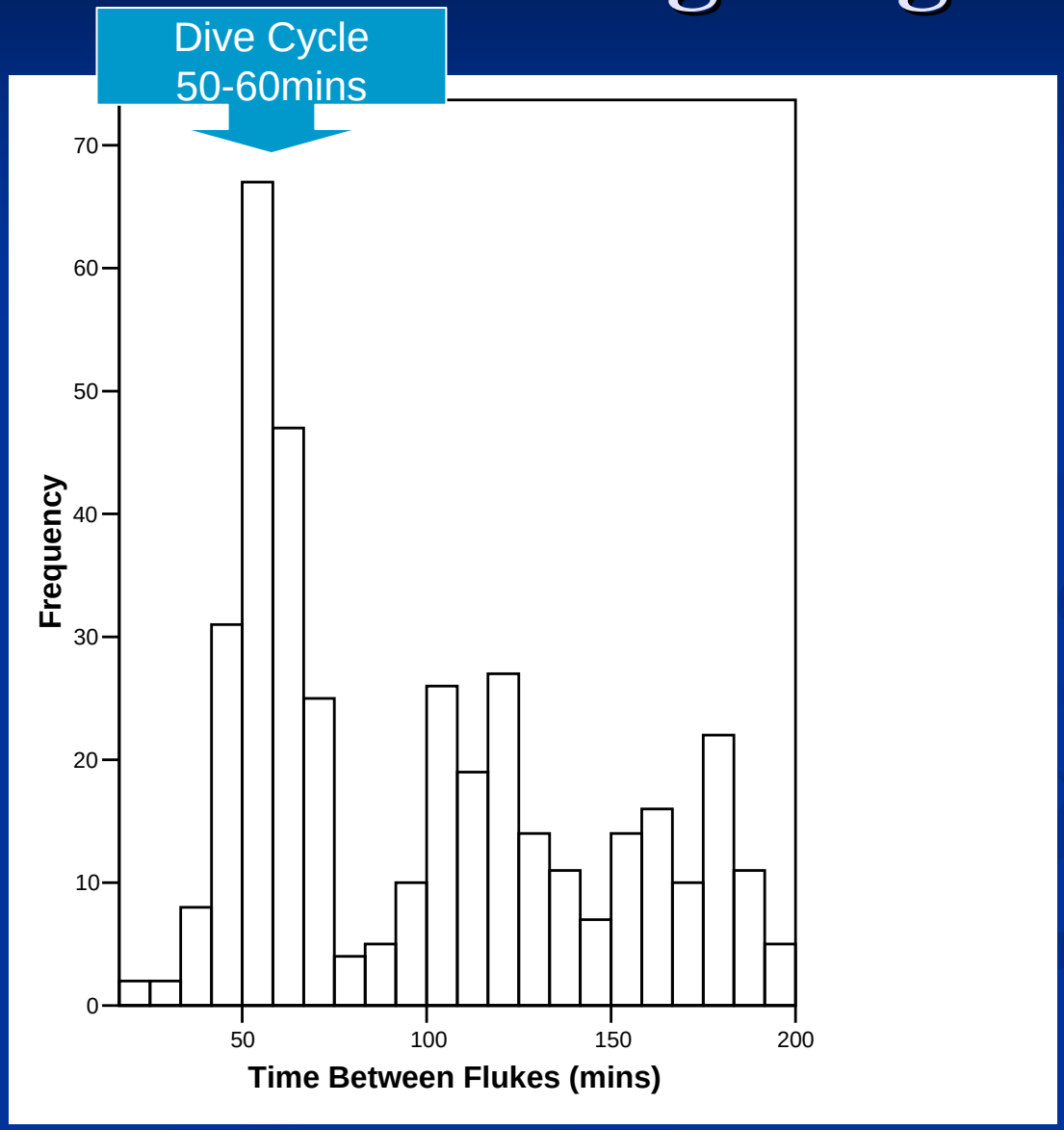
Length Measurement Acoustic





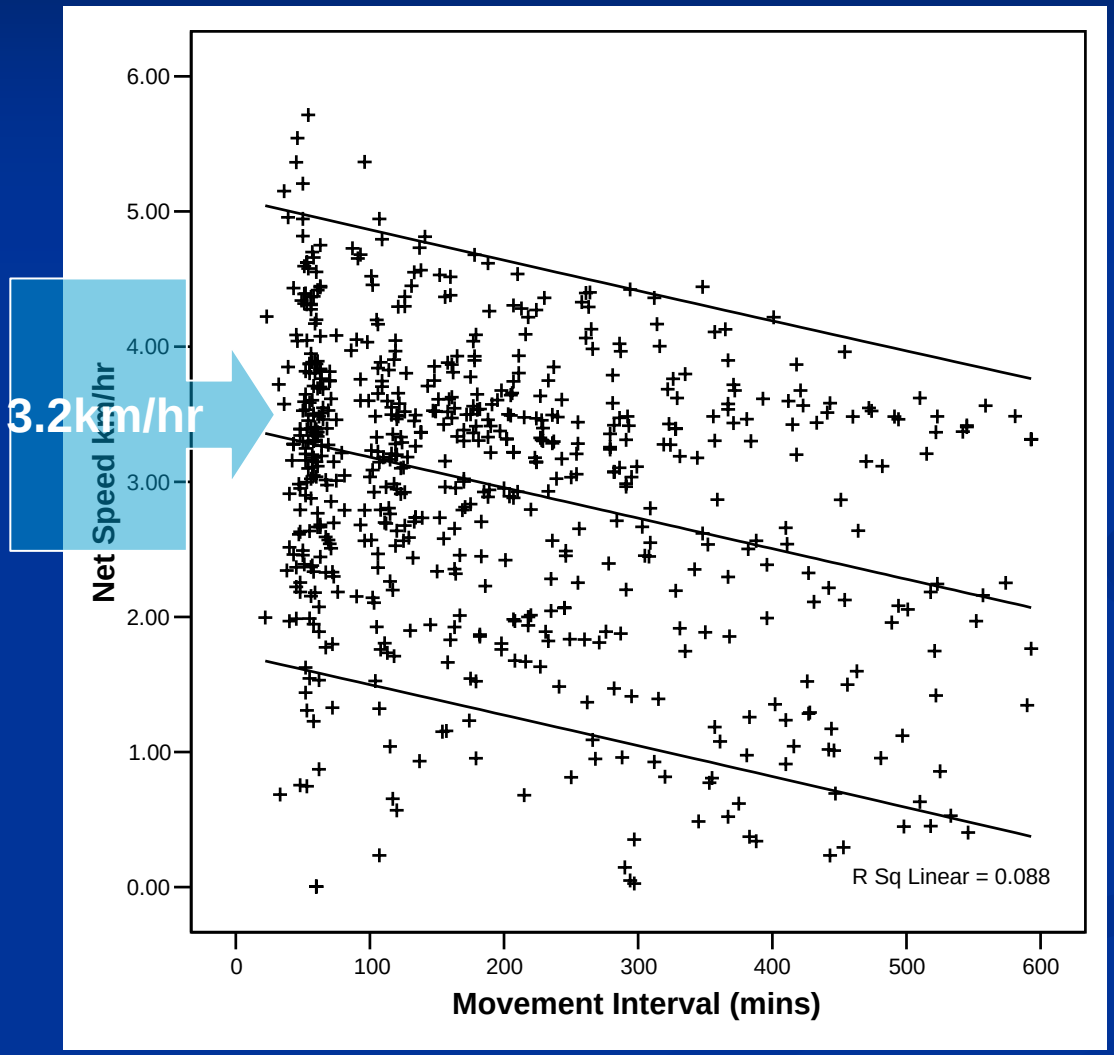

x 10^6
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
time (ms)
Sum of clicks (n = 169)
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
time (ms)
Sum of clicks auto-correlation
IPI estimate (= 5.1458)
Individual clicks IPI estimate histogram

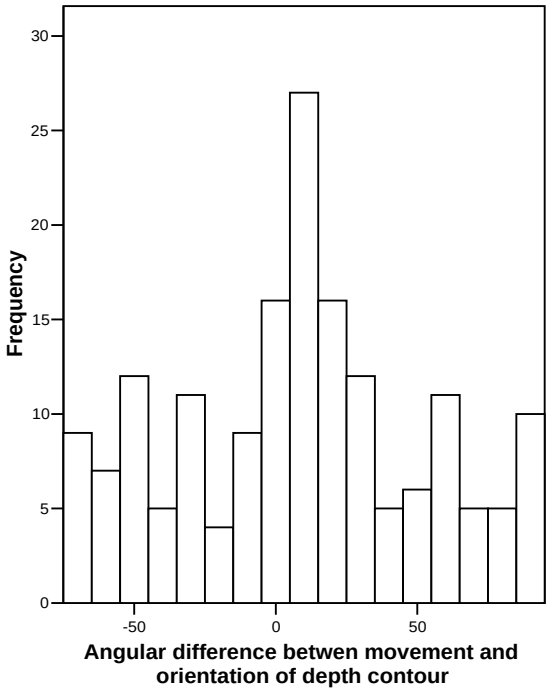
Time Intervals and Movements Between Resightings

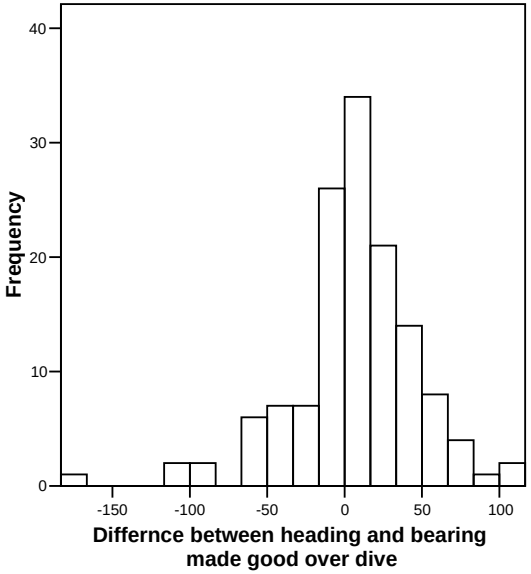


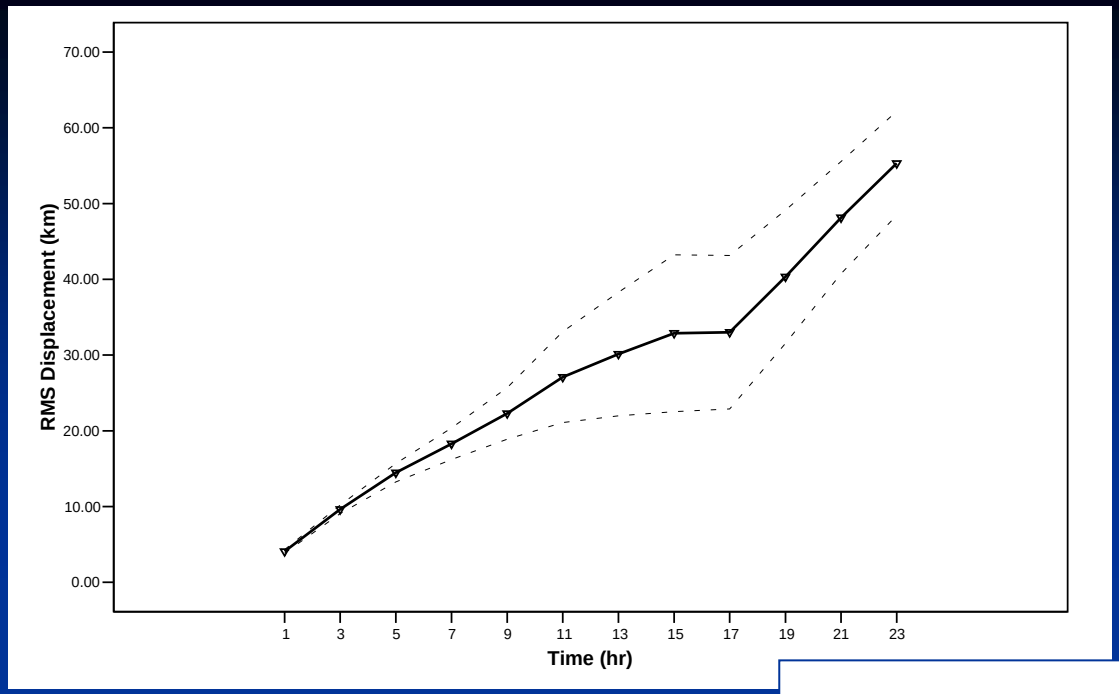
SWSS Movement Data: Temporal Scales

Speeds, Headings Movements

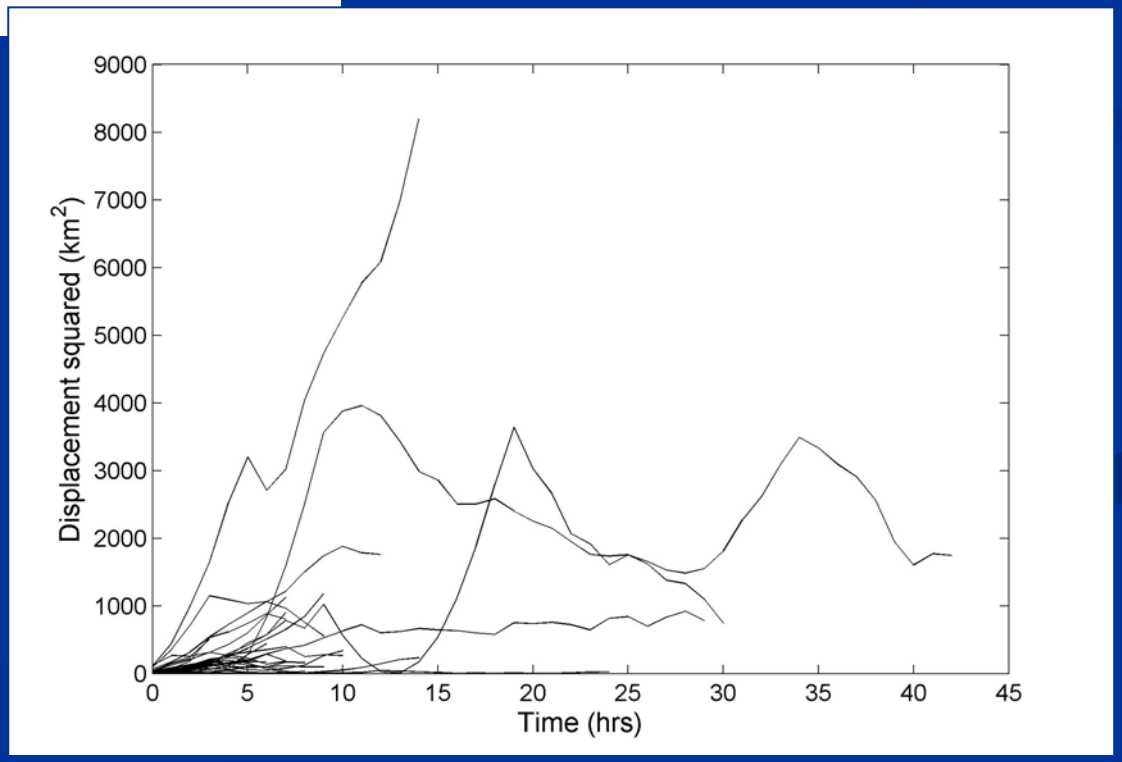






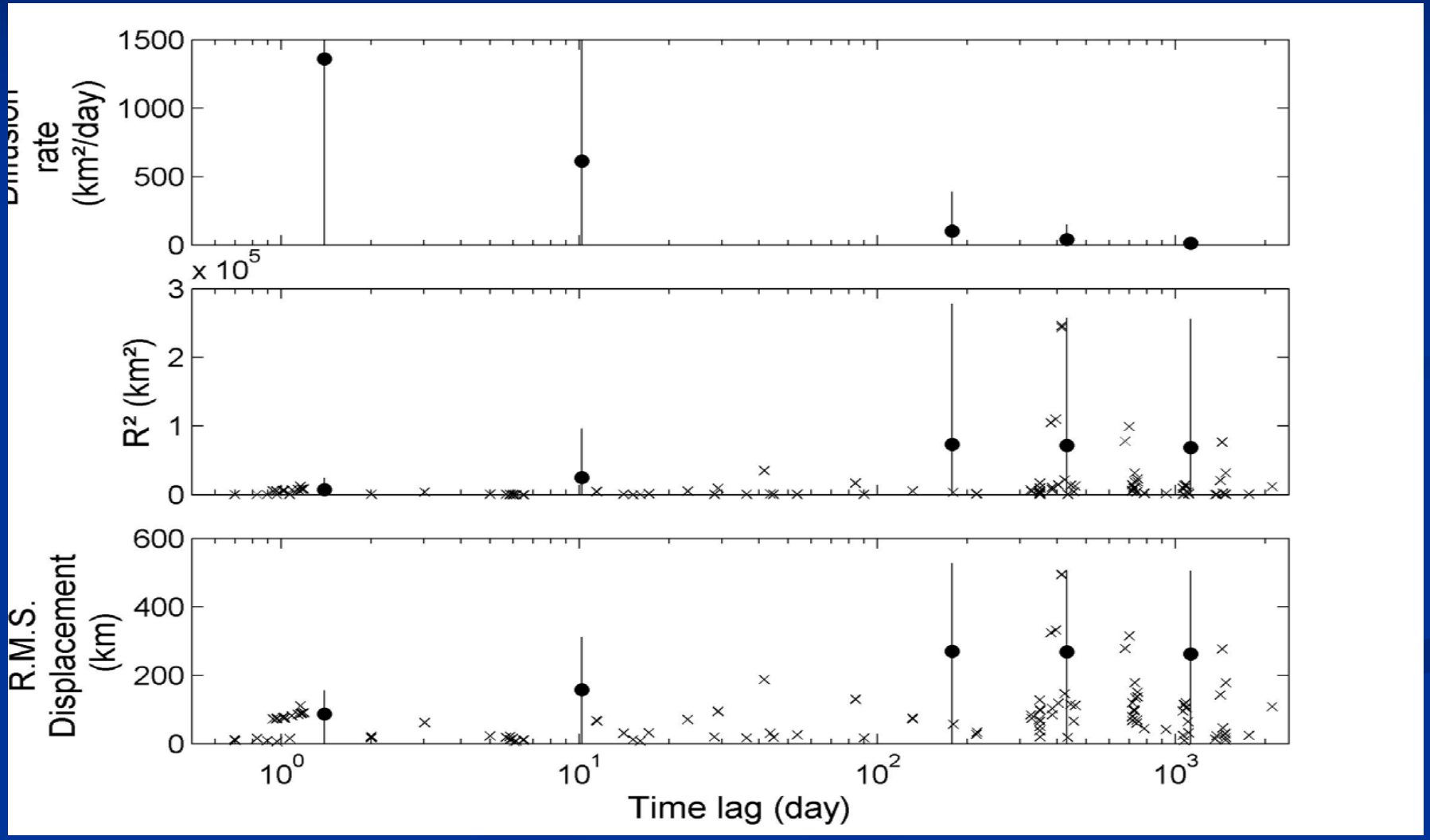


RMS Displacement Between IDs

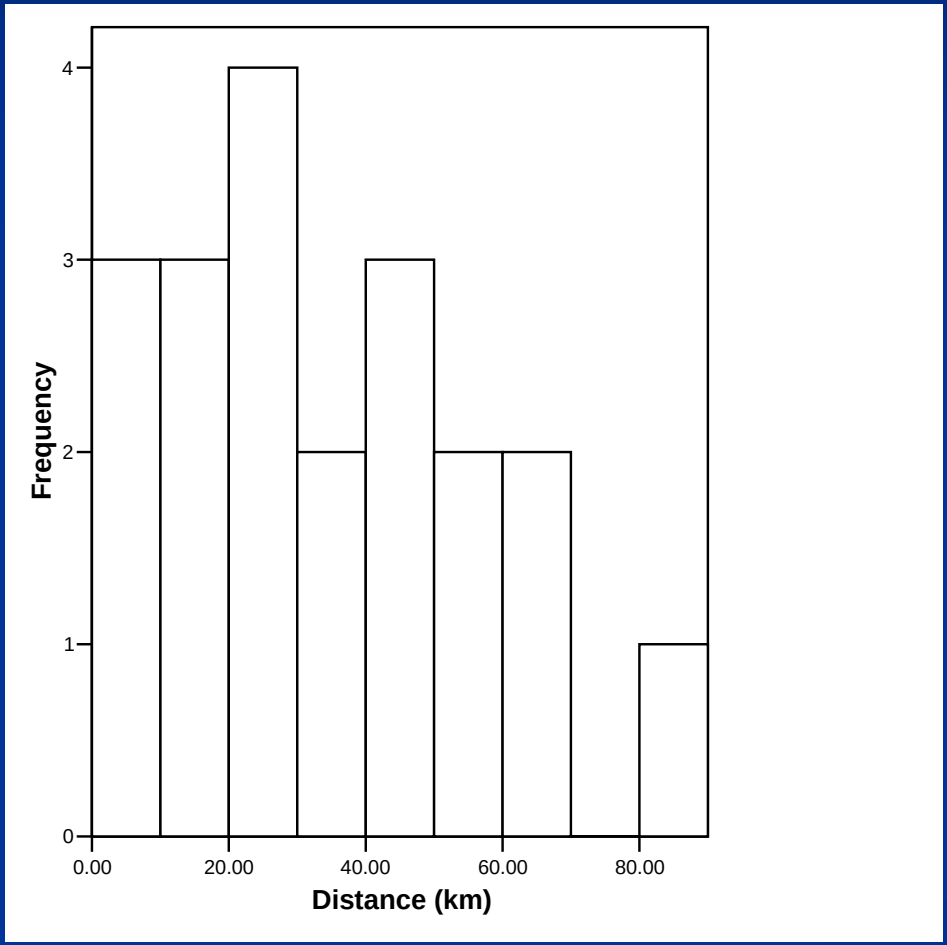


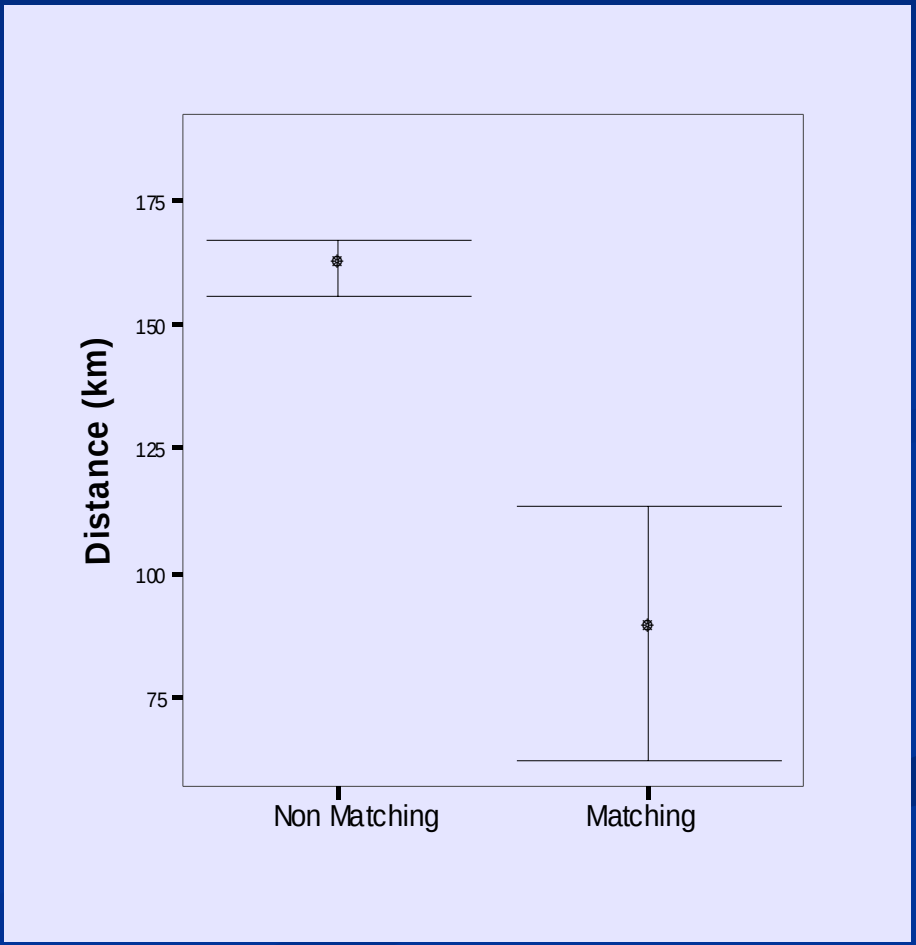
Displacement of Groups Being Tracked

Maximum Likelihood Estimates of Movement Parameters (SocProg)



Movements Between Years: Evidence of Individual Preferred Areas





Sperm Whale Movements and Foraging

Indirect Signs of Behavior at Depth

- Defecation at surface, usually before beginning of dive (fluke-up)
- Movement patterns
  - Frequent direction change: good feeding
  - Little direction change: searching for good feeding conditions

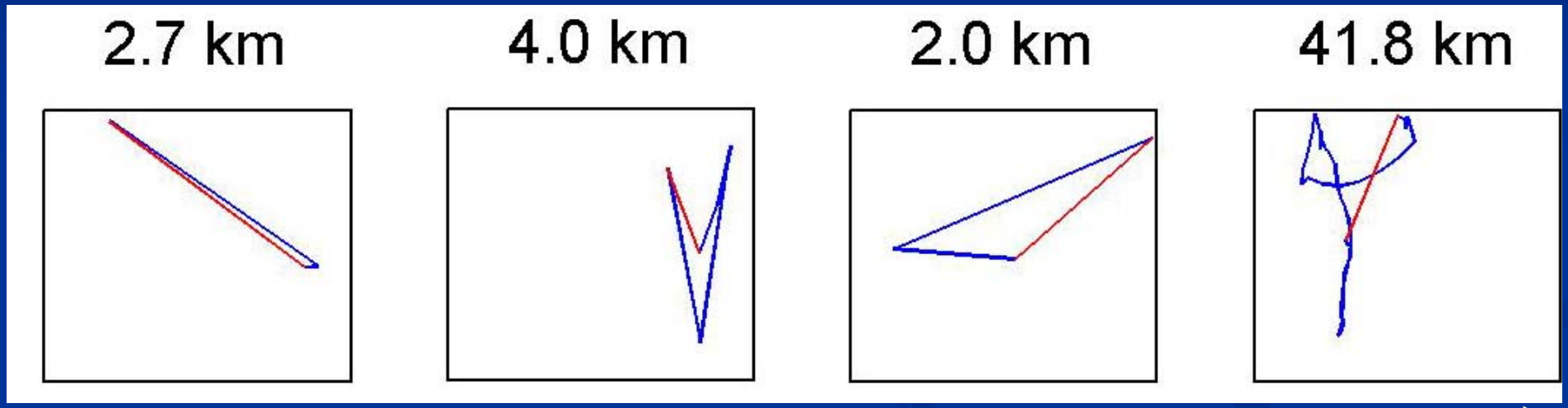
Measuring Defecation Rate

- Only from 2004 and 2005
- After fluke-up, "foot print" was inspected for presence of feces
- Every tracking period with ≥ 5 fluke-ups, individual fluke-up was scored as:
  - Feces present
  - No feces present
  - Not inspected

Defecation Rates in the GOM

- 280 fluke-ups were used in analysis
- Mean defecation rate = 0.21 (0.045)
- No differences
  - Between years
  - Between age classes
- Defecation rates in other areas:
  - South Pacific = 0.084 (Jaquet and Whithead 1999)
  - Galápagos = 0.032 (Whitehead 2003)

Measuring Changes in Direction

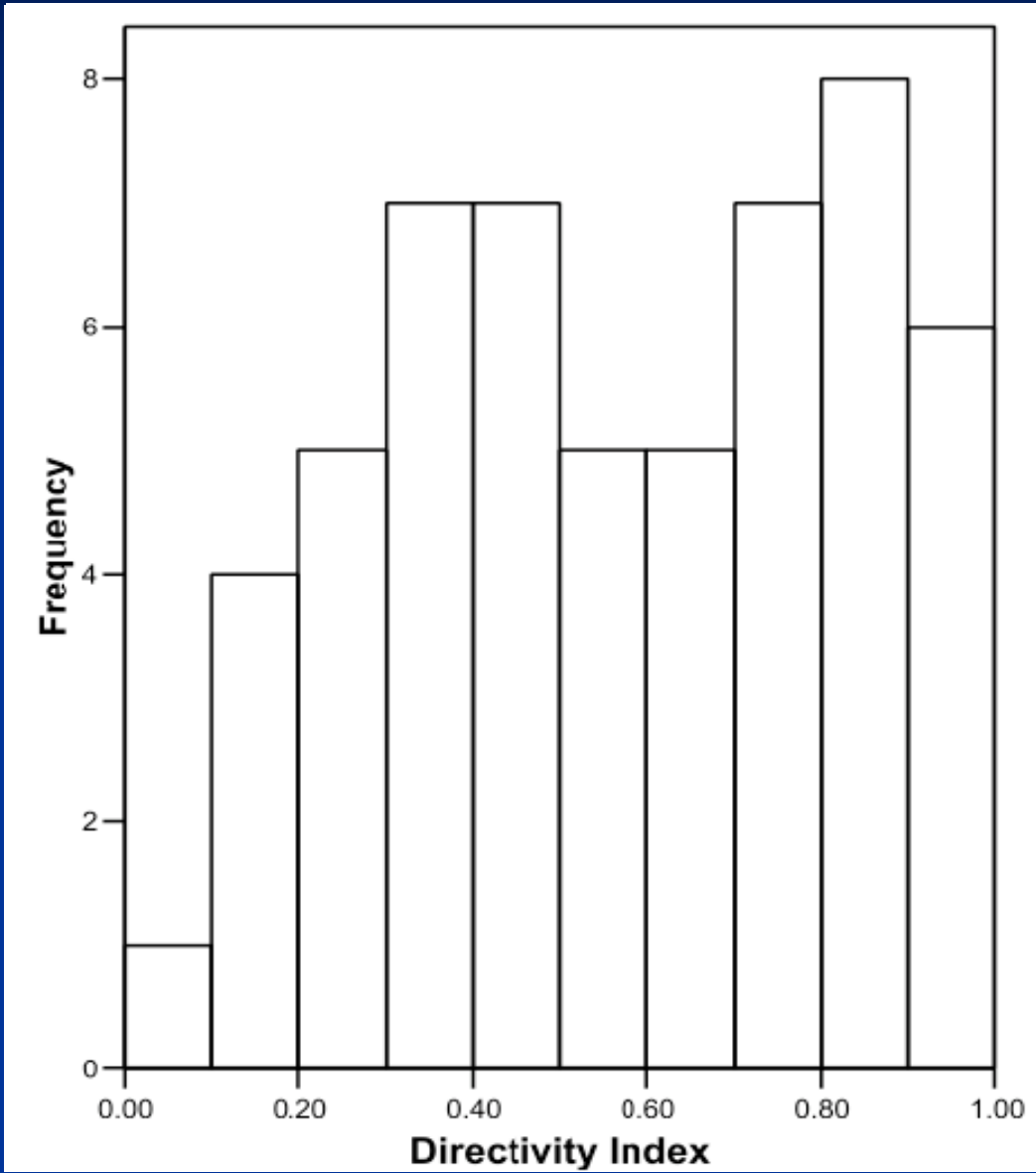


Large DI (appr. 1)
Searching

Small DI
Foraging

Directivity index (DI) = Net displacement / Distance traveled

DIs Did Show Bimodal Pattern



There Is No Correlation Between DI and Defecation Rate

- High defecation rate, but no correlation with movement
- Short tracking periods in the GOM compared to other areas
- Prey distribution does not require changes in movement

The Social Structure of Sperm Whales in the GOM

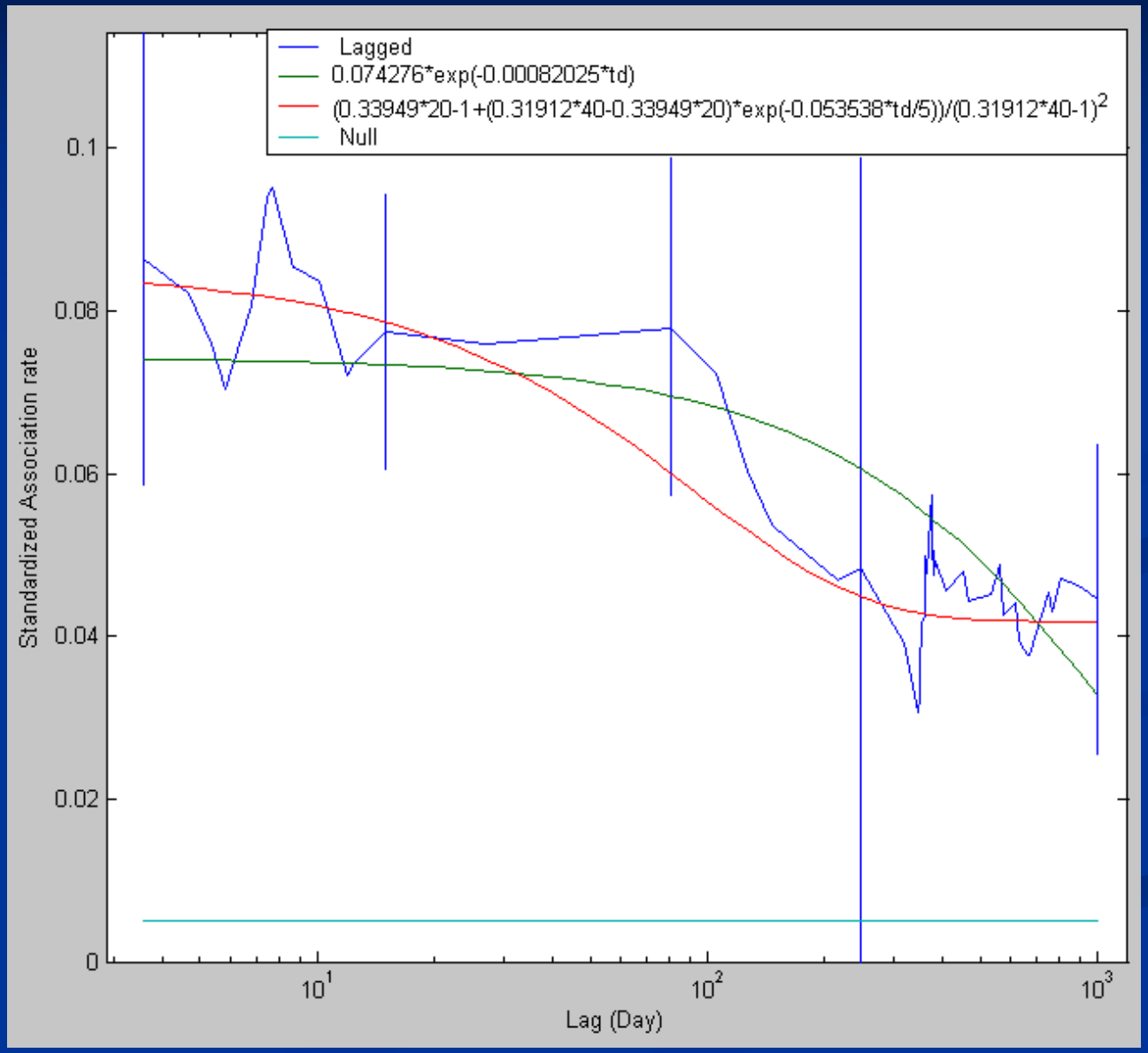
Males Become Increasingly Solitary with Age

Females Live in Social Units

What We See and What We Interpret

- Groups:
  - Females and immature whales
  - Stay together for days
  - Between 20 and 30 individuals
- Social unit:
  - Long-term companions, staying together for years or decades
  - On average 10 individuals from several matrilines
  - Two or more units form groups

Estimating Social Behavior



GOM Whales in Comparison

	Chile	Galapagos	GOM
Group size	31.1 (18.7)	27.7 (8.1)	12.8 (4.29)
Unit size	11.0 (18.0)	11.5 (6.3)	6.8 (3.83)
Disassociation rate	0.134 (0.185)	0.053 (0.065)	0.011 (0.692)

Coda Usage in the GOM

Sperm Whales Are Vocal

- Regular clicks
- Creaks
- Clangs
- **Codas**

Codas Are "Rhythmic" Clicks

- Bursts of 3–20 clicks in a repeated stereotyped pattern
- Typically heard from groups resting/socializing at the surface
- Thought to be adapted for communication. Rhythm-based communication very unusual in mammals

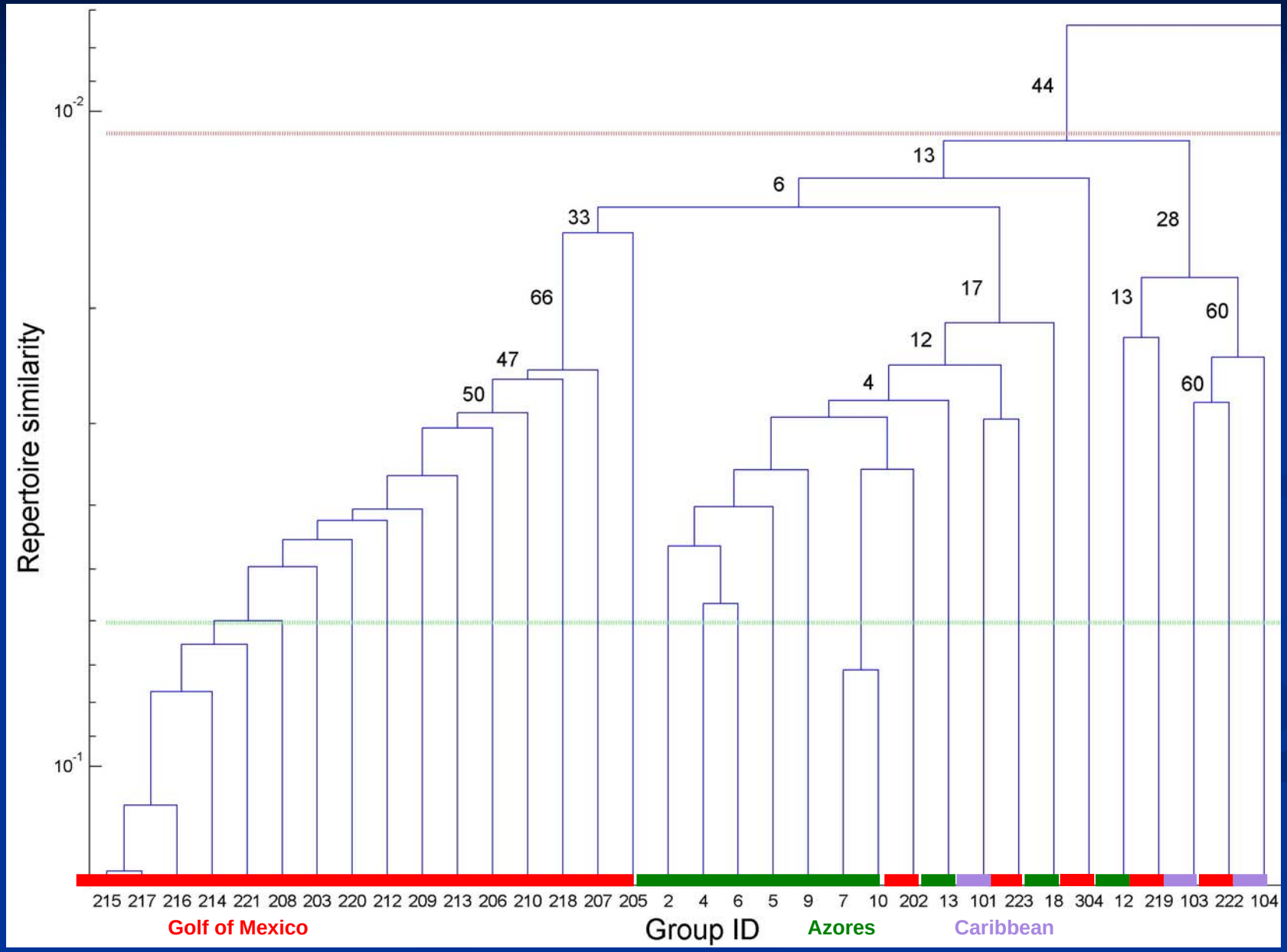
Codas Are Clan-Specific

- Repertoires of codas vary between mixed groups
- Coda repertoires define a higher level of social organization – the **Clan**
- Members of different clans may be sympatric but units only associate with other units from the same clan
- Evidence of culture

Coda Data and Analysis

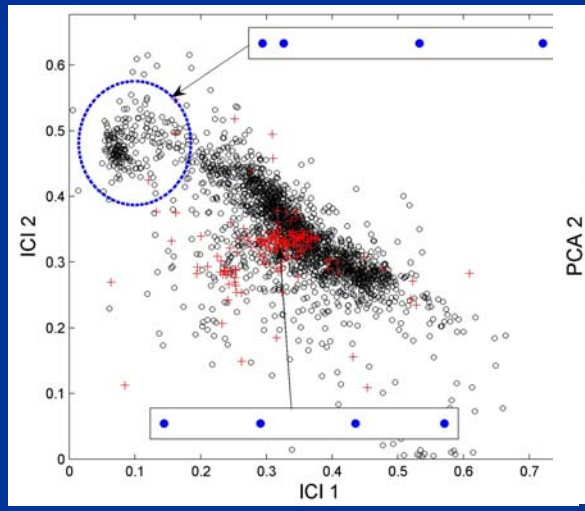
- 3129 codas from Gulf of Mexico (SWAMP and SWSS)
- 5092 from Azores, 121 Caribbean, 543 from Mediterranean
- Click intervals measured using Rainbow Click and standardized.
- Coda repertories compared by calculating a similarity index for each pair
- Coda analysis in collaboration with Luke Rendell, SMRU, St. Andrews

GOM Sperm Whales Have a "Dialect"

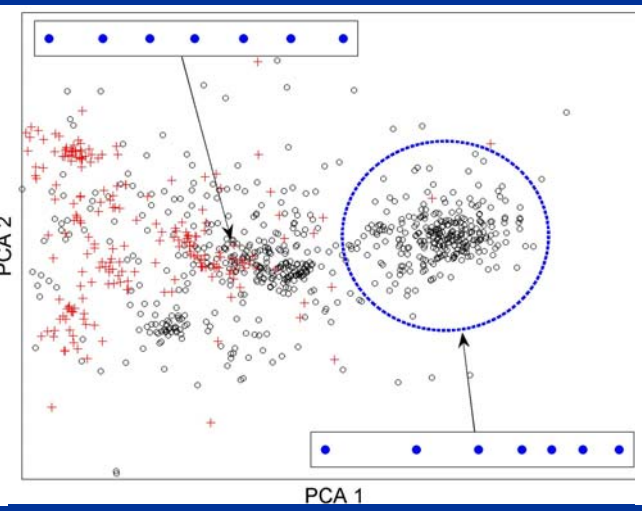


What Does the GOM "Dialect" Sound Like?

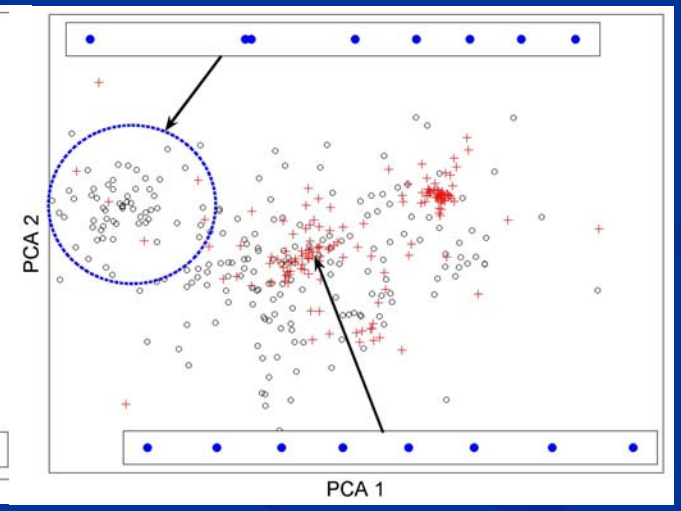
4-click coda



7-click coda



8-click coda



Codas Separate GOM Whales

- Discrete clan in N. GOM (and only one) which is not encountered in other areas
- Members of this clan may have been distinct for periods of year to decades
- Supports results from genetic analysis: mixed groups in Northern GOM are a discrete sub-population
- Possible "Western" sub-population

Why Do Differences in Coda Usage Matter for Management?

- Differences in coda usage reflect population structure at medium temporal scales
  - Clans may be an appropriate unit for management
- Cultural information may also include experiences with anthropogenic impacts
  - Clans may respond similarly to human activities
  - In other areas clans have different behavioral strategies

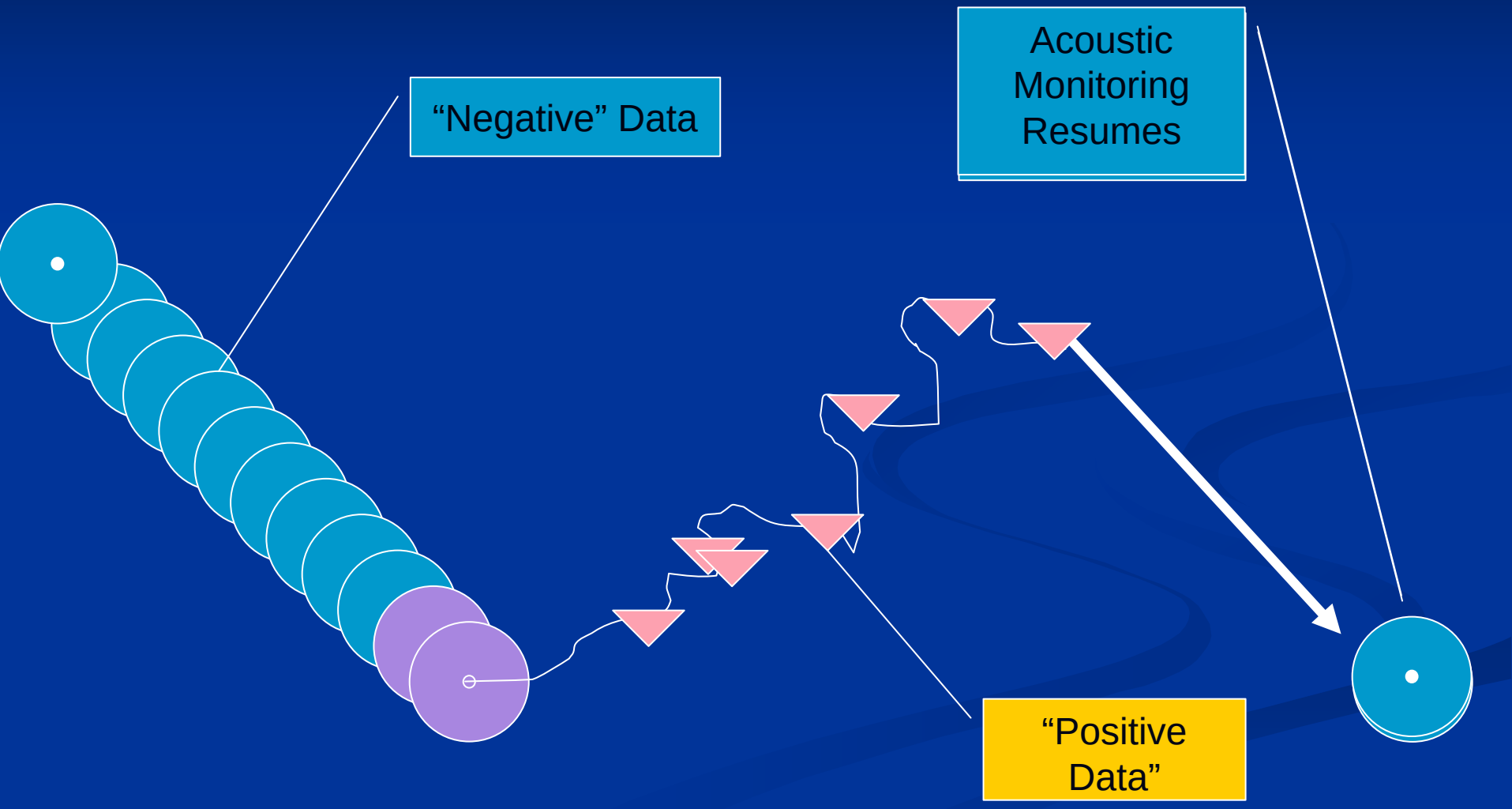
Adult and Calf
Calves discriminated on basis of size and behavior

Proportion of Calves: Index of Reproduction

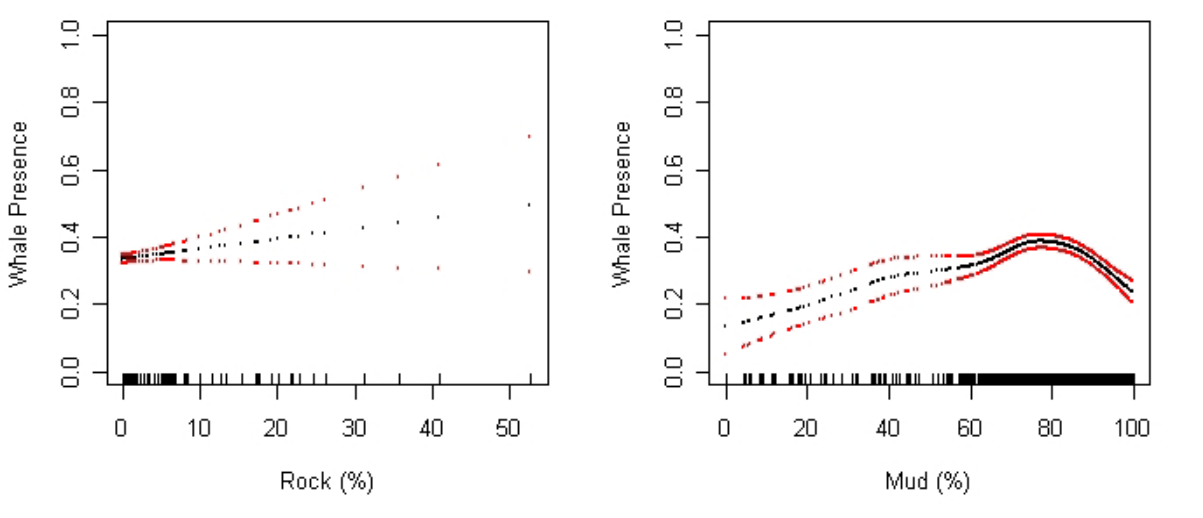
		2002	2003	2004	2005
Tracking periods	Total number	14	17	30	18
	With calves (% of total)	4 (29)	7* (41)	14* (47)	3 (17)
	Overall % of tracking periods with calves	**37%**			
Number of whales	Total number of adult whales	41	36	118	76
	Number of calves (% of total)	**4 (9.8)**	**7 (19.4)**	**15 (12.7)**	**4 (5.3)**
	Number of adults with calluses (% calves to adults with calluses)	-	-	18 (83.3)	26 (15.3)
	Overall ratio adults/calves	**11.07%**			

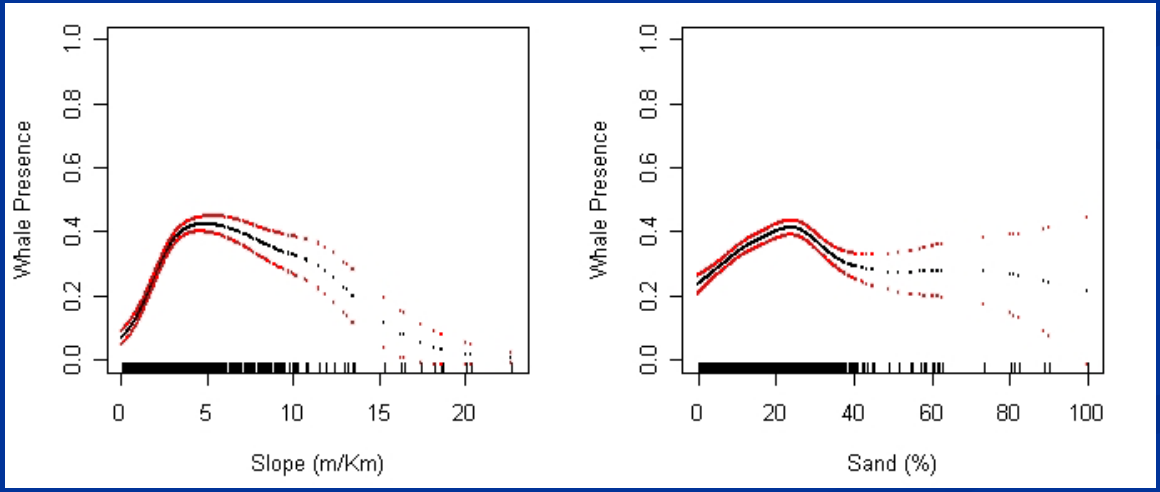
Summary of calf sightings by year. * indicates that two calves were sighted in one of the tracking periods

Predictive Models of Densities and Distribution

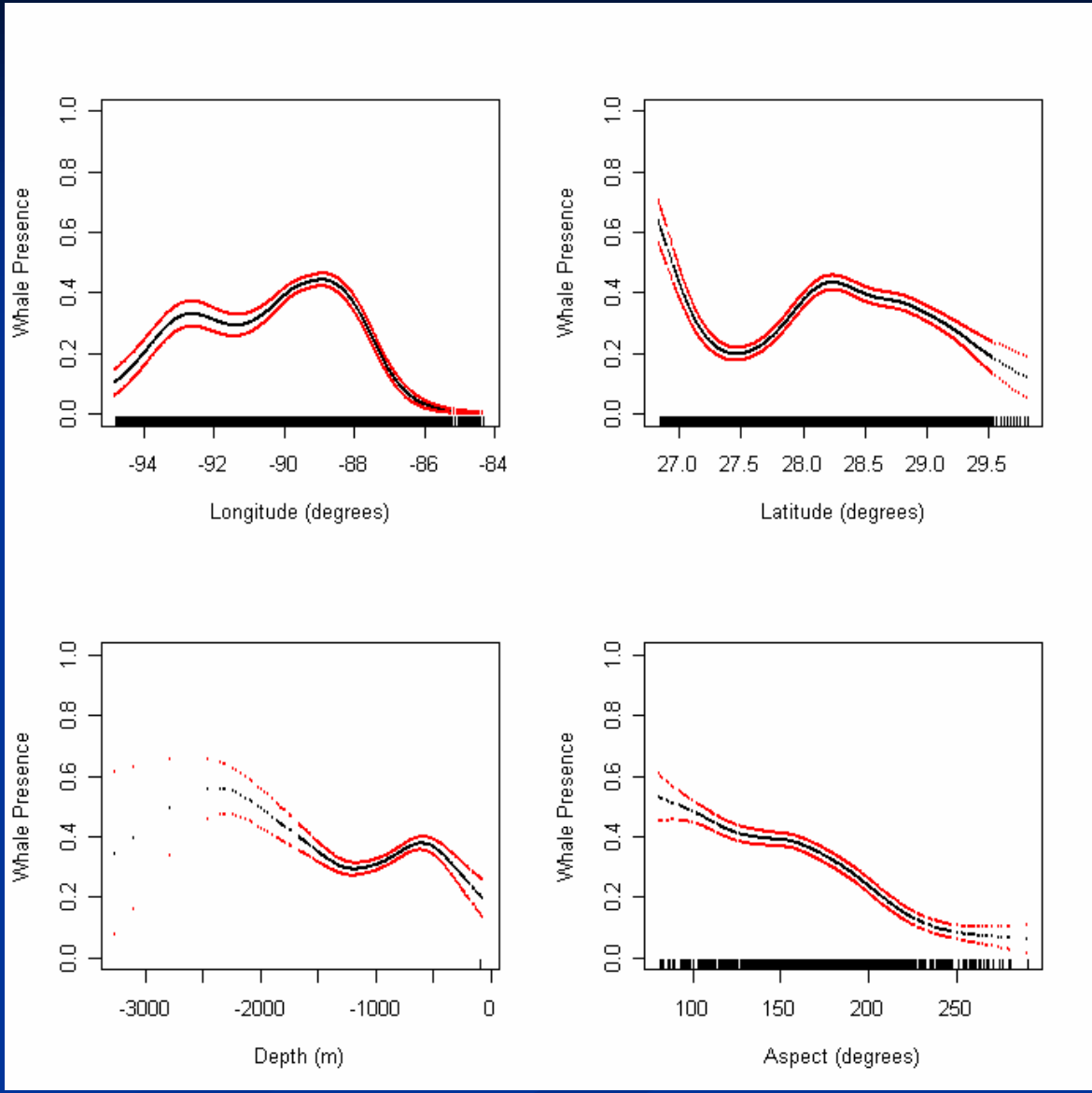


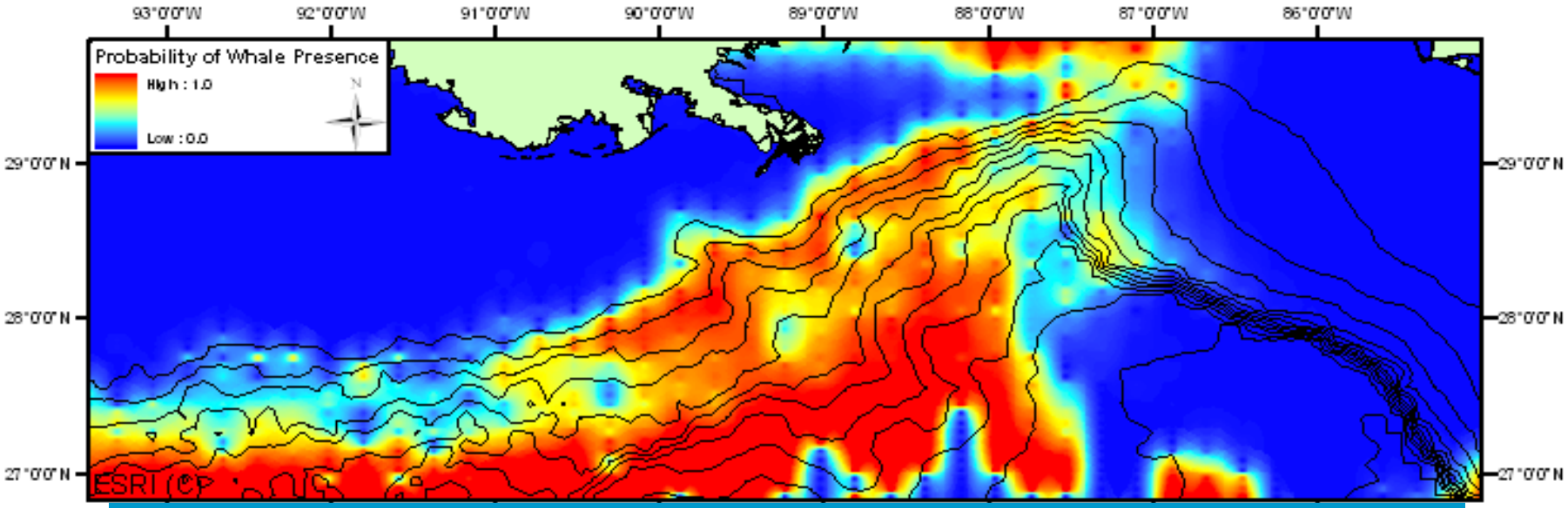
GAMS Modeling of Predictor Variables – Static and Dynamic



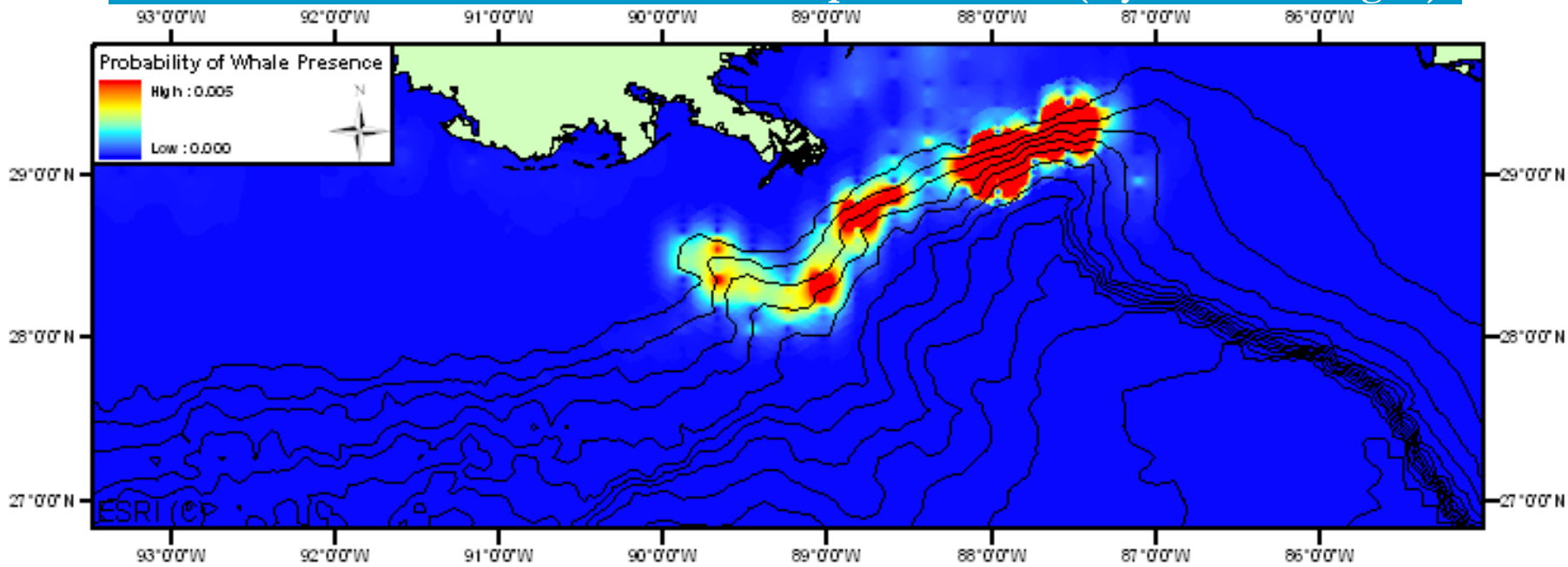


GAMS Modeling of Predictor Variables – Static and Dynamic (cont.)

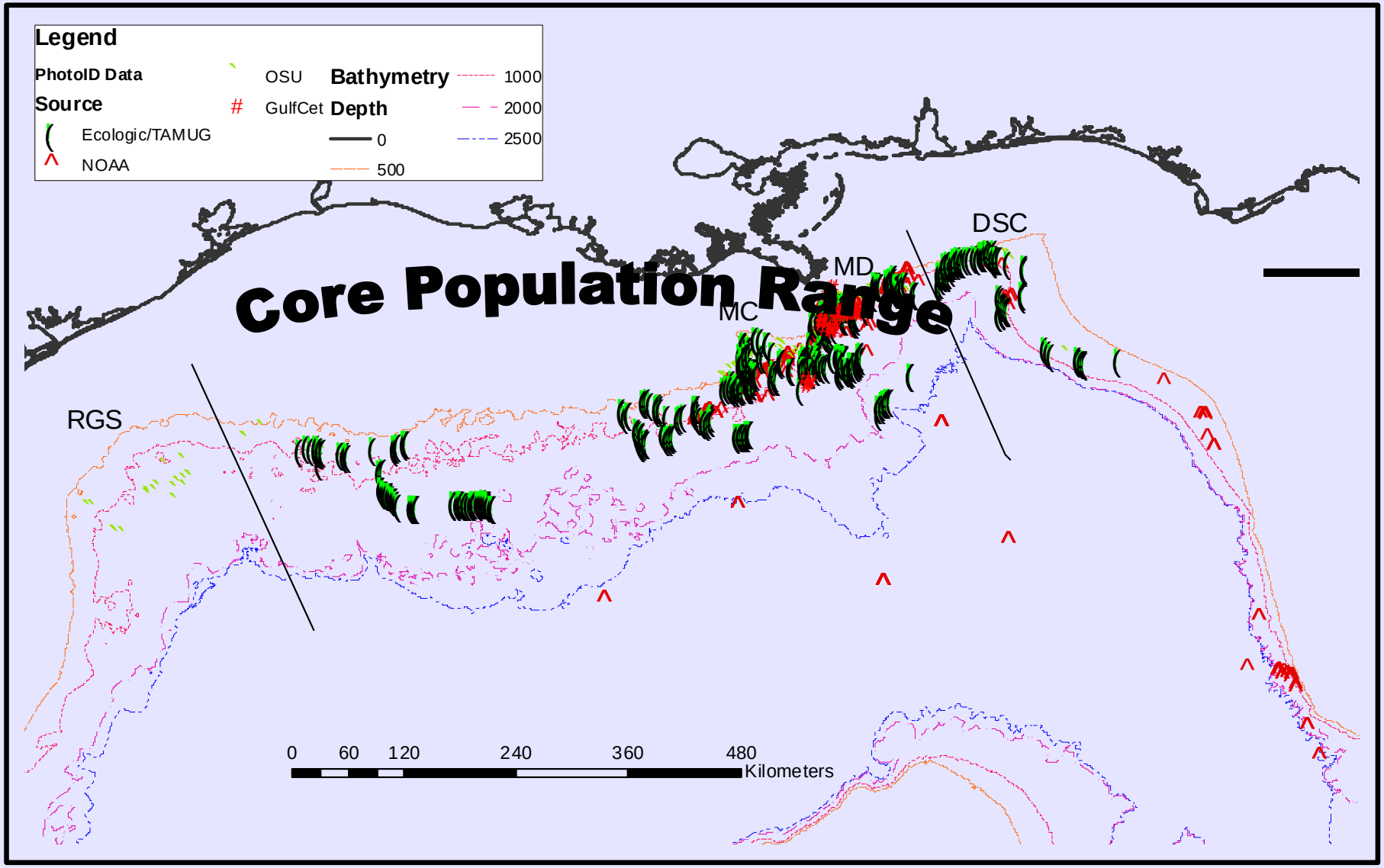




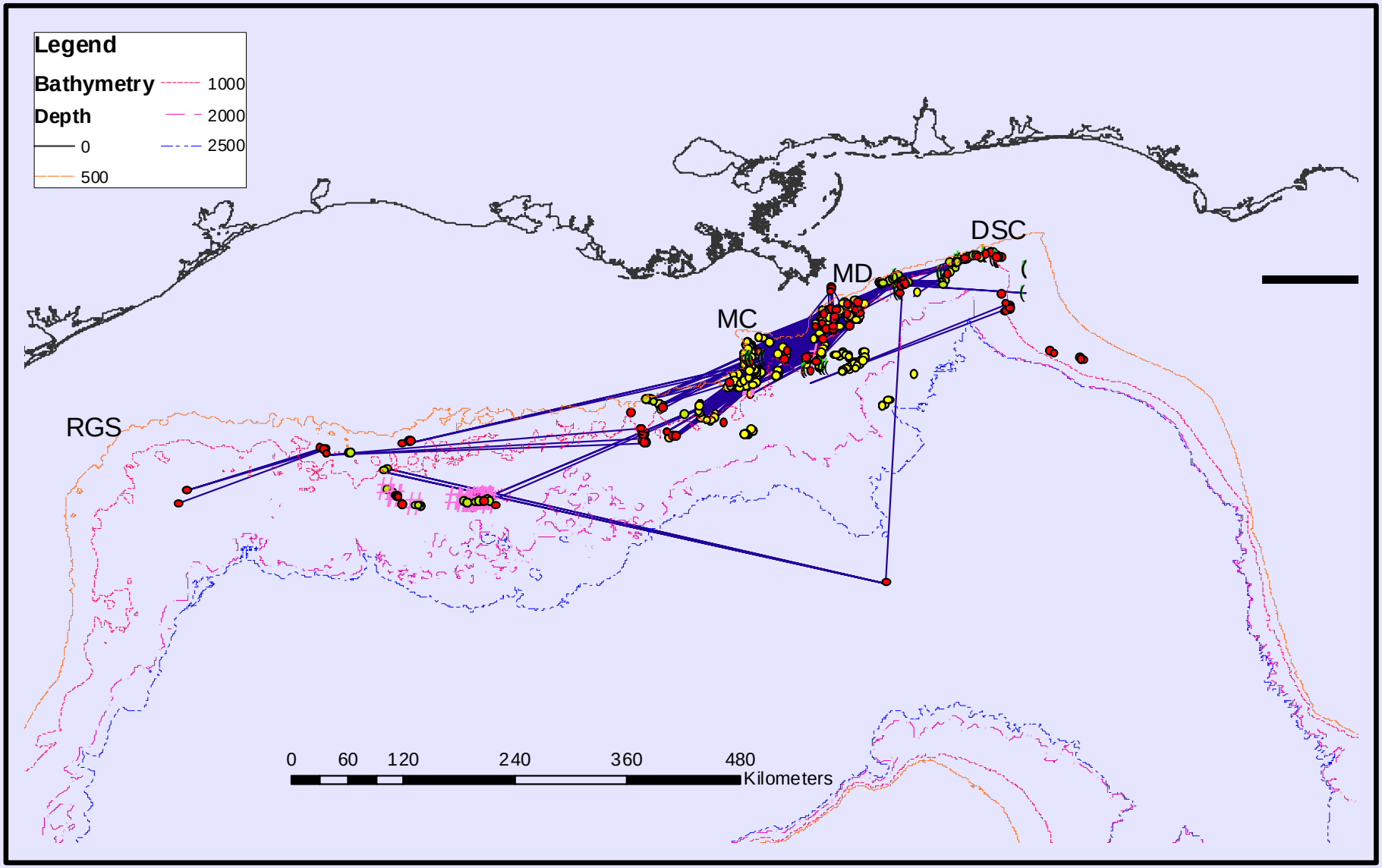
Predicted Distributions for Mixed Groups and Males (Dynamic Averaged)



Mark Recapture Photo Identification Effort



Movements Between Years



Mark Recapture Population Estimate

- "Core" and "extended" populations estimated separately
- Excludes calves (whales that don't fluke up)
- Analysis restricted to well marked whales and high-quality images
- <1997 and 2005 data excluded

“Extended Population” Mark Recapture Population Estimate

DATASET	Model	Population Size	Mortality	Trend	Emigration/ Reimmigartion	AIC
Total\\ Population 2000--2004	Closed	379 (307-478)				334.06
	Mortality	242 (159-339)	0.259 (0.813-0.574)			330.02
	Mortality and Trend	**217 (164-331)**	**0.179 (0.000-0.354)**	**0.356 (0.129-0.531)**		**324.06**
	Reimmigration	242			0.227 0.00	328.89
	Reimmigration and Mortality	243	0.136 (0.00- .317)		0.106(0.0-0.227) 3.83 e-014 (0-0.119	334.02

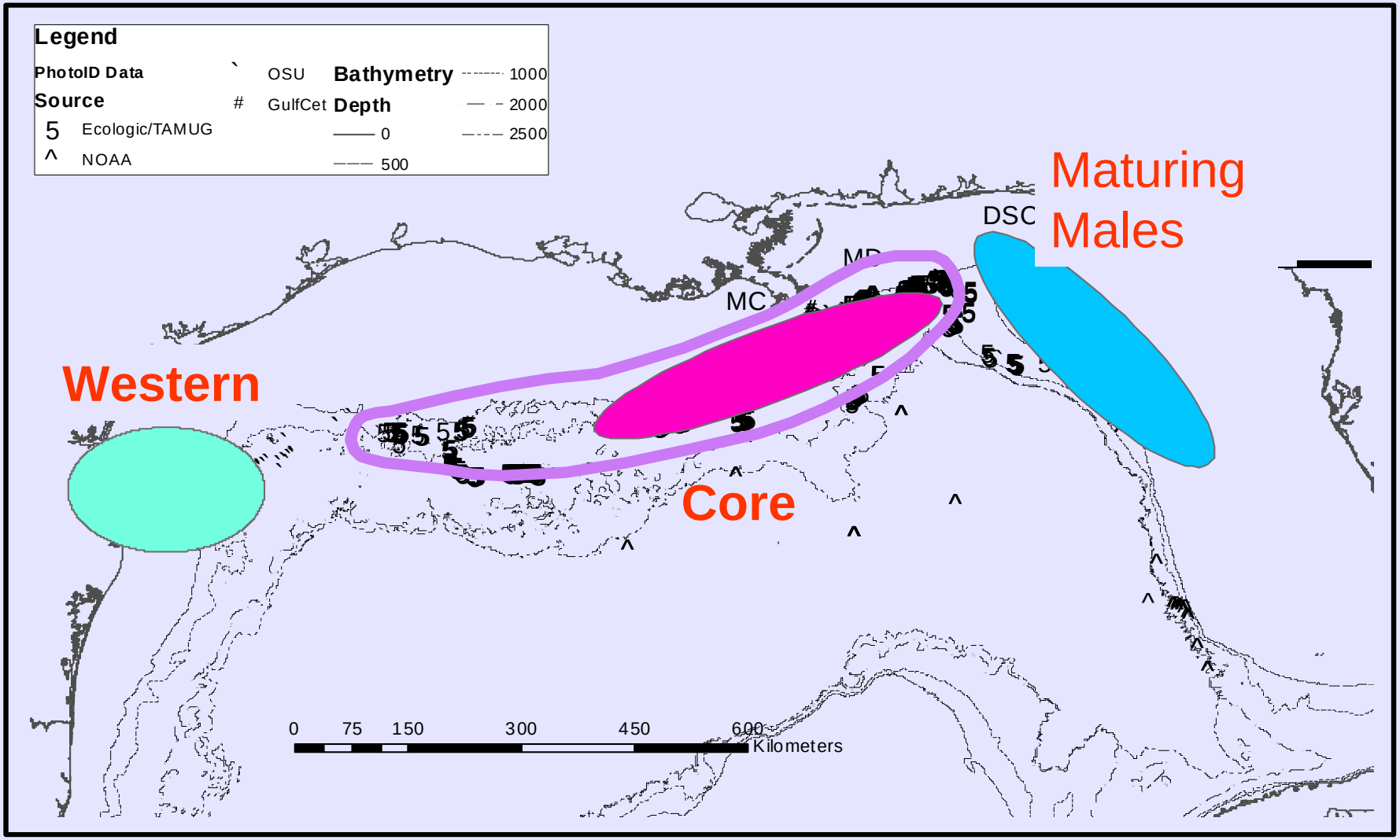
"Core Population" Mark Recapture Population Estimate

DATASET	Model	Population Size	Mortality	Trend	Emigration/ Reimmigartion	AIC
Core Population 2000--2004	Closed	207 (179-264)				256.46
	Mortality	128 (96-184)	0.273 (0.104-0.477)			250.03
	Mortality and Trend	**108 (84-152)**	**0.223 (0.030-0.400**	**0.352 (0.123-0.576)**		**244.68**
	Reemmitgation	128 (93-163)			0.240 (0.117-0.387) 5.5 e-012 (0.0- 0.0062)	252
	Reimmigation and Mortality	129 (96-183)	0.131 (0.065 – 0.254)		7.68 e-10 (0.0-0.226) 0.006 (0.0-0.0173)	254

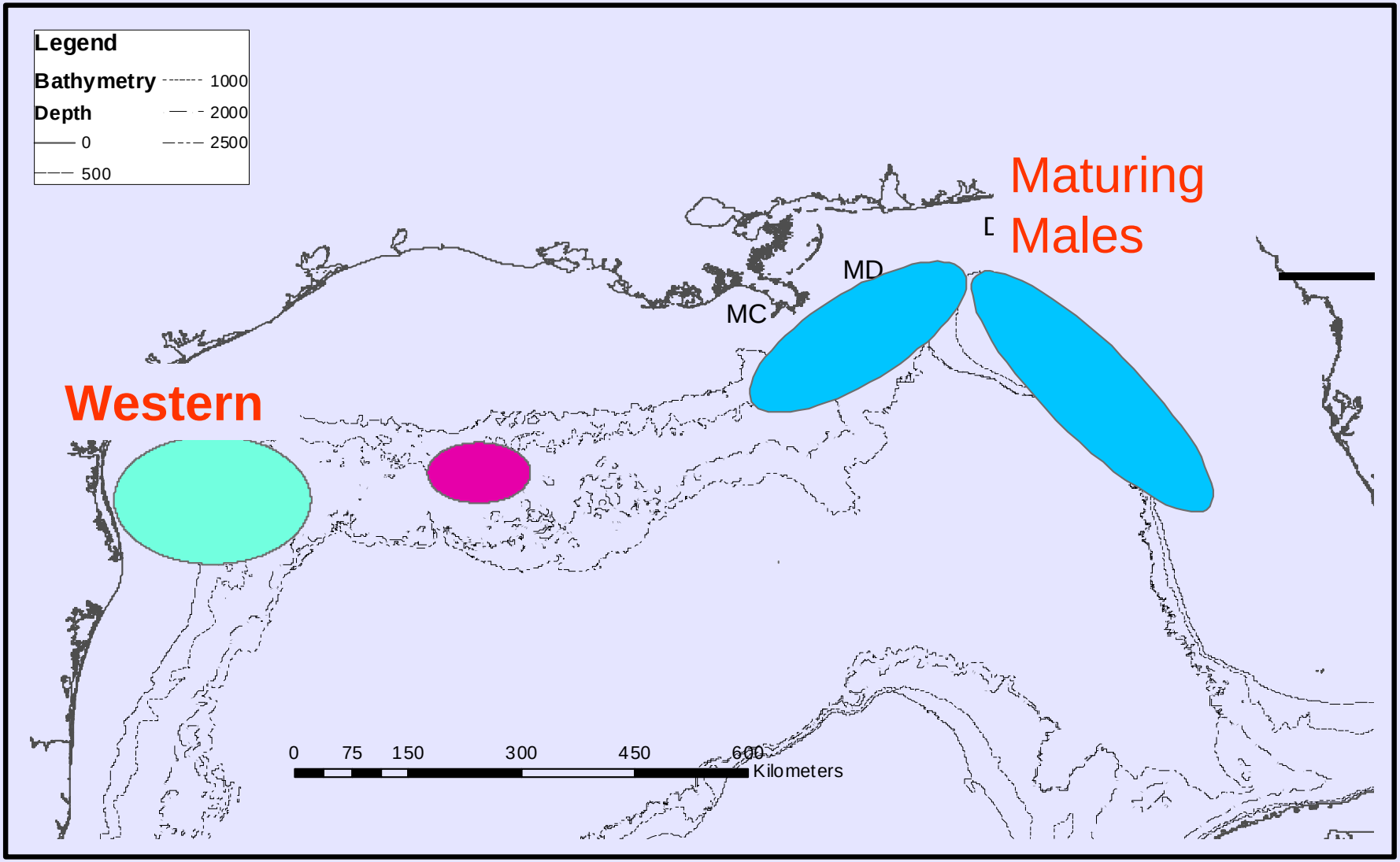
Core Population Mark Recapture Population Estimate

- 108 well-marked whales
- 140 (200–103) whales in total
- 88 mature females (assuming mixed groups)
- 15–20 calves per year

1996–2004


Legend
PhotoID Data
Source
5 Ecologic/TAMUG
^ NOAA
` OSU
GulfCet
Bathymetry
Depth
0
500
1000
2000
2500
Maturing Males
DSC
MC
Western
Core
0 75 150 300 450 600
Kilometers

2005: Core Population Missing



2005 Anomaly Poses a Series of Questions

- Where did they go? Are they alive?
- Why?
  - Biggs and Jochens oceanographic explanation
  - Can anthropogenic causes be ruled out?
- What's happening now?
  - Can we still apply what we've learned through SWSS or is a new "regime" in place

Broad Conclusions

- Have been able to measure some important biological parameters
- Some are generally in line with findings from other populations
- Some are different
  - Small discrete population
  - Small body size
  - Smaller social units
- Should be treated as very preliminary
  - Haven't even studied the population over one average calving interval
  - High inter-annual variability indicated
- This approach could provide reliable measures and form the basis of an effective long-term monitoring project

Potentially a Baseline for an Affordable Long-Term Monitoring Project

- Oil industry and sperm whales are going to live together in the Gulf of Mexico for decades
- So far, no indications of serious acute problems, but need to monitor what's happening to the population
- Important to understand natural variability and dramatic incidents

Acknowledgments

MMS

IAGC
RFC
NFWF

Field teams

Visual and acoustic observers

References

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