Employing Genetics To Study Whales

An Informal Introduction

Of Course Not Because…

..Or ?

Lunch break in Samana Bay, the Dominican Republic 1990

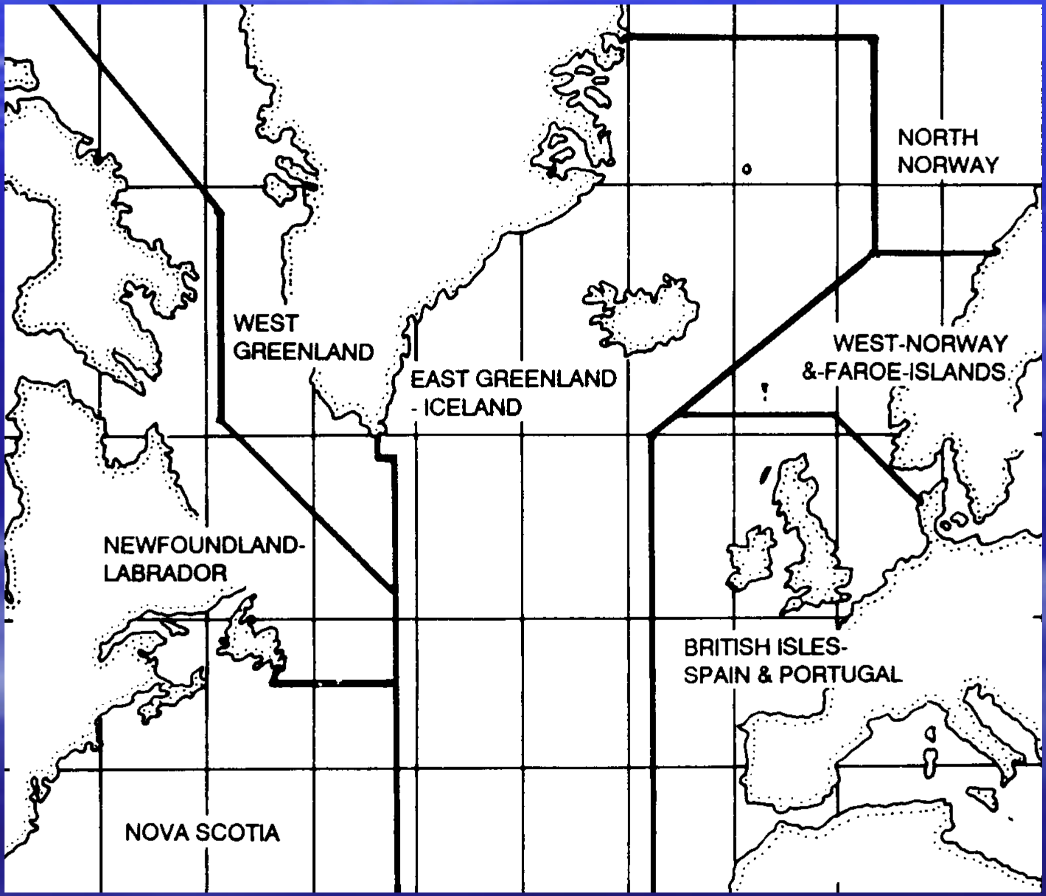
..Nor ?

Camp in Uummannaq District, Northwest Greenland 1991

Whales Are A Resource

- Many populations and species depleted due to past commercial whaling operations.
- Subsistence hunting still ongoing in many parts of the world, as well as scientific whaling, and some unknown degree of illegal whaling.
- Whale watching a source of income in many developed as well as underdeveloped countries.

…But Because…



NORTH
NORWAY
WEST
GREENLAND
EAST GREENLAND
- ICELAND
WEST-NORWAY
&-FAROE-ISLANDS
NEWFOUNDLAND-
LABRADOR
BRITISH ISLES-
SPAIN & PORTUGAL
NOVA SCOTIA

…And Because

- Very different system compared to “standard” terrestrial or fresh water models. Also different from many marine organisms
  - Active dispersal at all life stages
  - Wide ranges of movement in an environment with few barriers
  - Long life-span and presumably some degree of “culture” among individuals

Basic Aspects

- Advantages
  - Taxonomically closely related species-complex
  - Many truly cosmopolitan species, i.e., many different levels of evolutionary divergence
  - Mating and foraging tempo-spatially separated in many species

Basic Aspects

- Disadvantages
  - Difficult to observe and tag directly
  - Highly political due to very different cultural views on exploitation of whales
  - "Pop science"

Marine Mammals – Very Different Creatures Than Bugs and Plants

- Finite population sizes
- Overlapping generations
- Small litter size

  – For instance:
    - Humpback whales in the north Atlantic number some 10,000 individuals. Females mature at the age of six and give birth to one calf every second year. The life expectancy is supposedly 30 years, but not known.

Interacting Levels and Processes

Molecular
Mode and rate of mutation

Ecosystem
Changes in abundance & structure

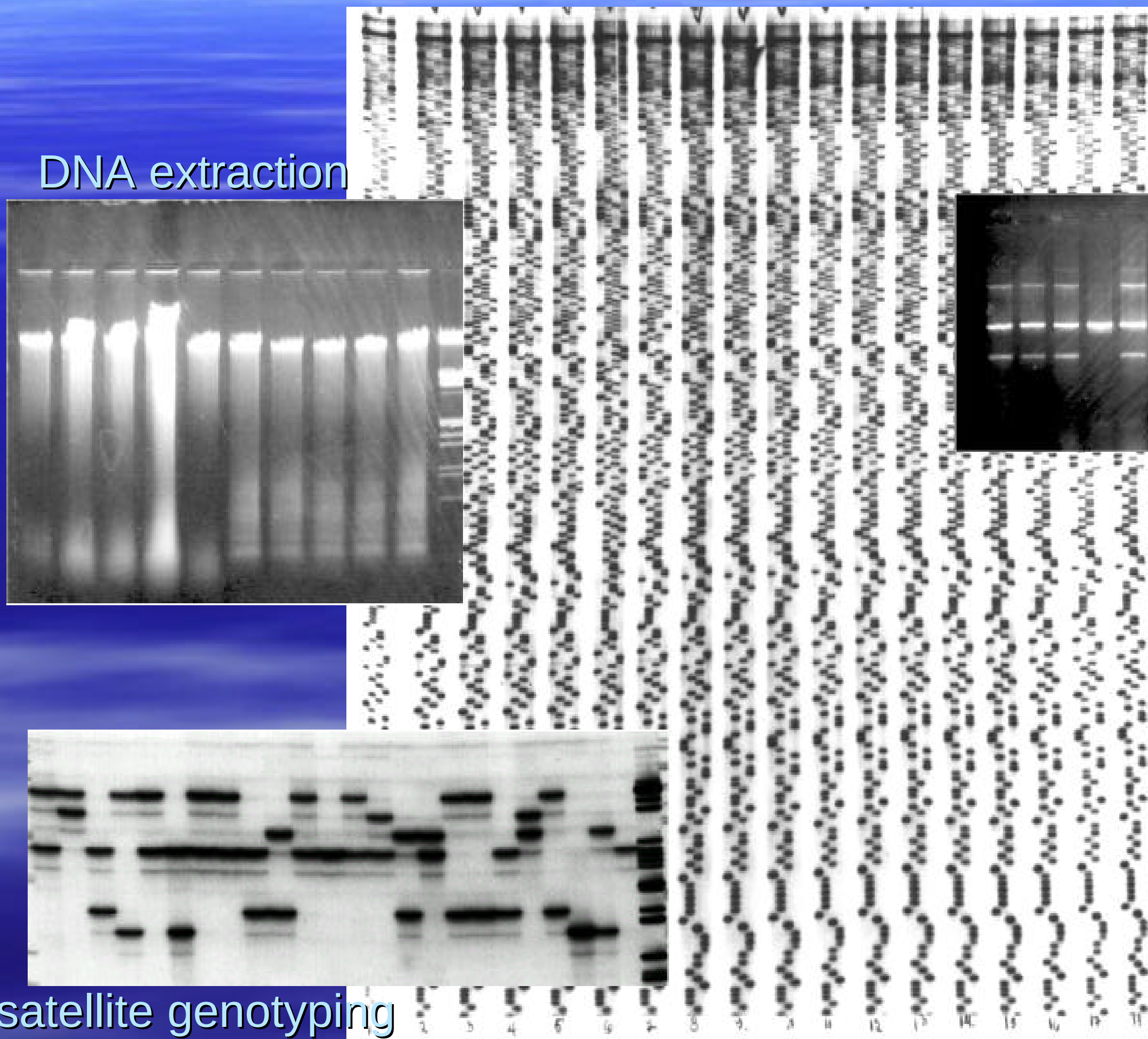
Organismal
Mode and rate of dispersal & gene flow

Biopsy Collection

……And Into Pickle Juice

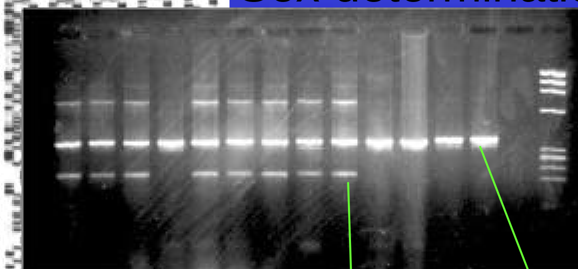
Genetic Analyses Conducted

DNA extraction



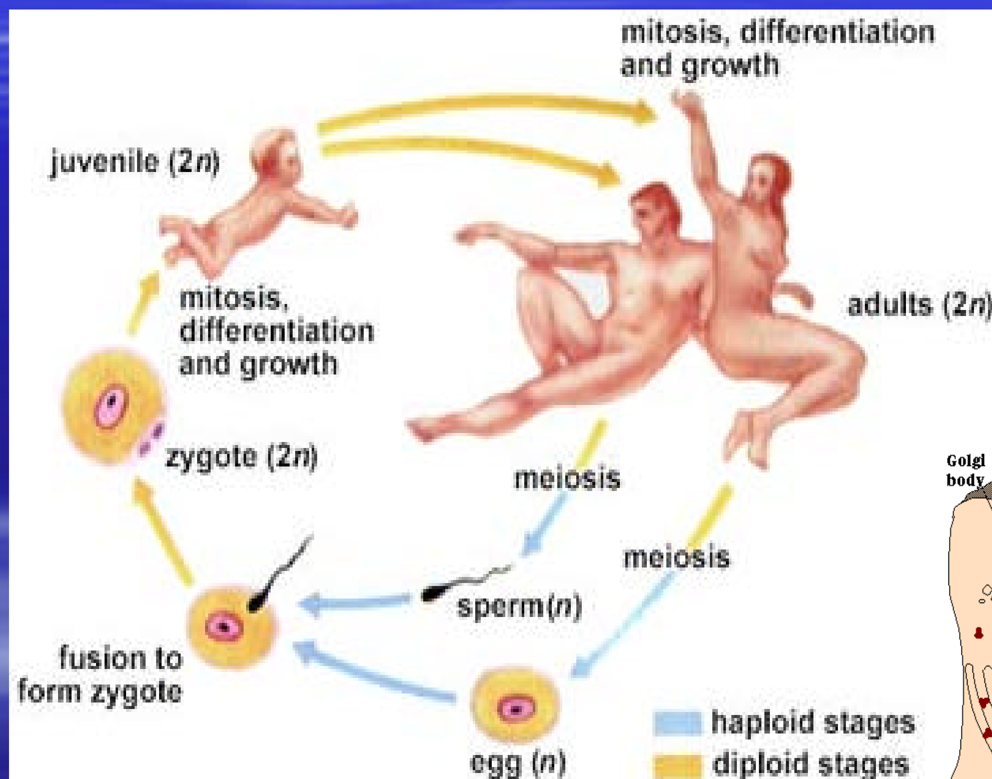
Sequencing mtDNA

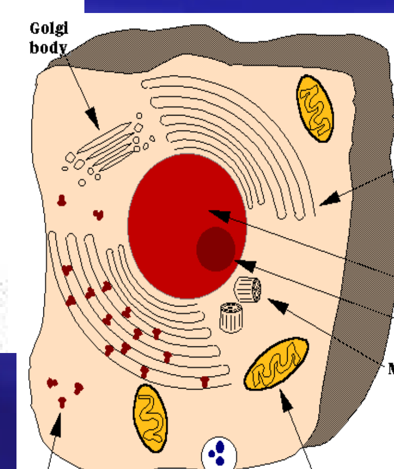
Sex determination



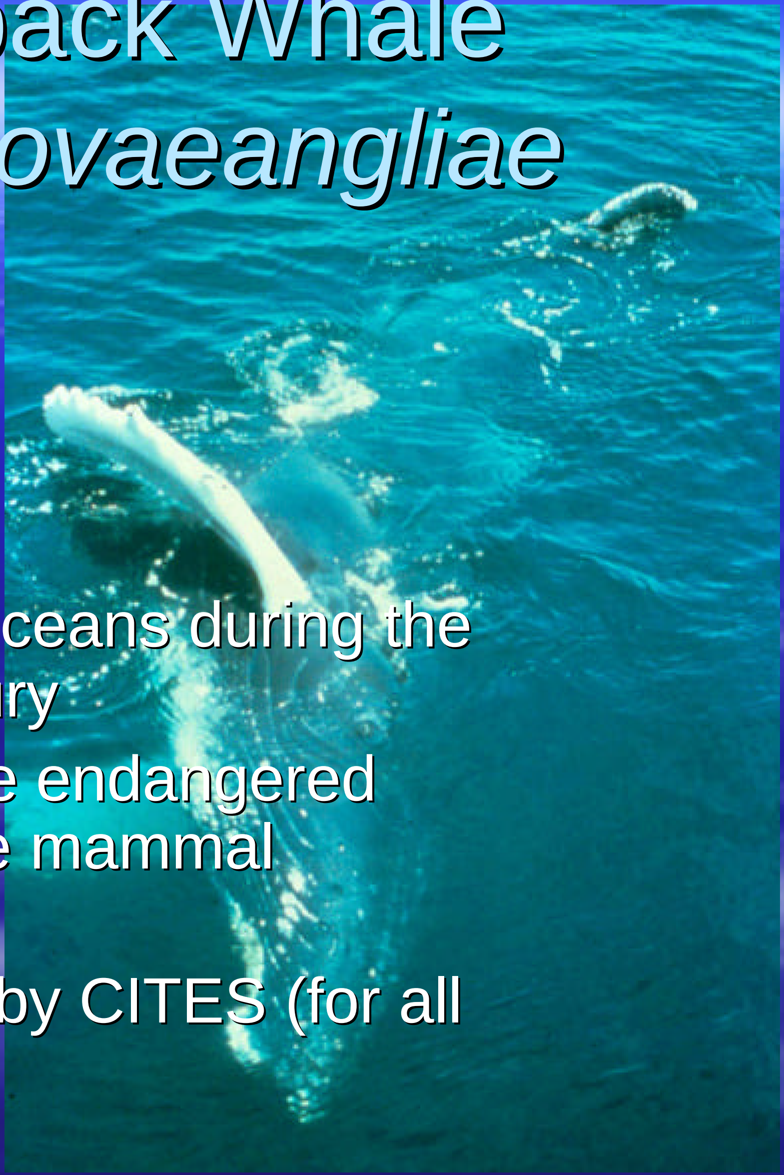
Microsatellite genotyping

Analysis of Maternally and Bi-parentally Inherited Genetic Markers



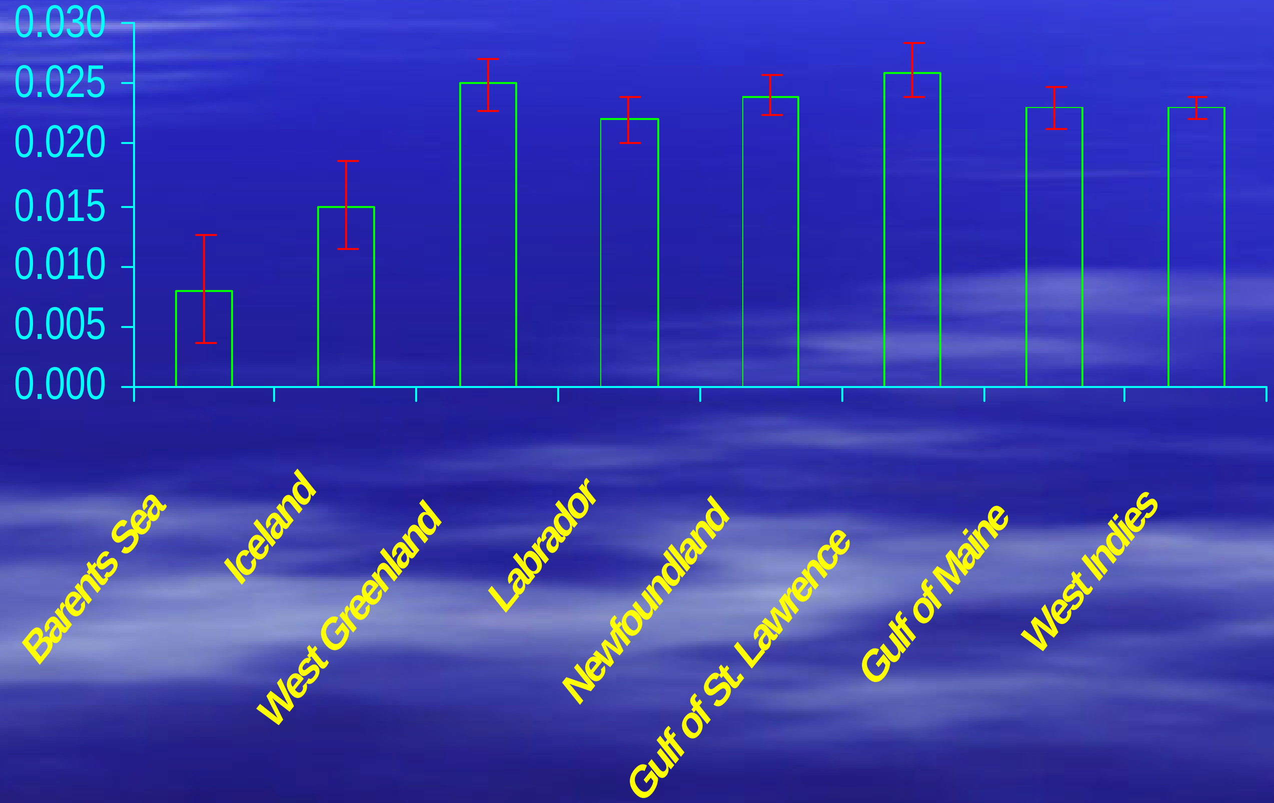


The Humpback Whale *Megaptera novaeangliae*



- Cosmopolitan species
- Weight: ~40 tonnes
- Length ~45' or 15 meters
- Age at maturity: 6-7
- Extensively harvested in all oceans during the 19th and early-mid 20th century
- Protected in the US under the endangered species as well as the marine mammal protection act
- International trade regulated by CITES (for all cetacean species)

East-west Cline in Estimates of Genetic Diversity in the Maternally Inherited Mitochondrial Genome



Genealogy Of Mitochondrial "Alleles"

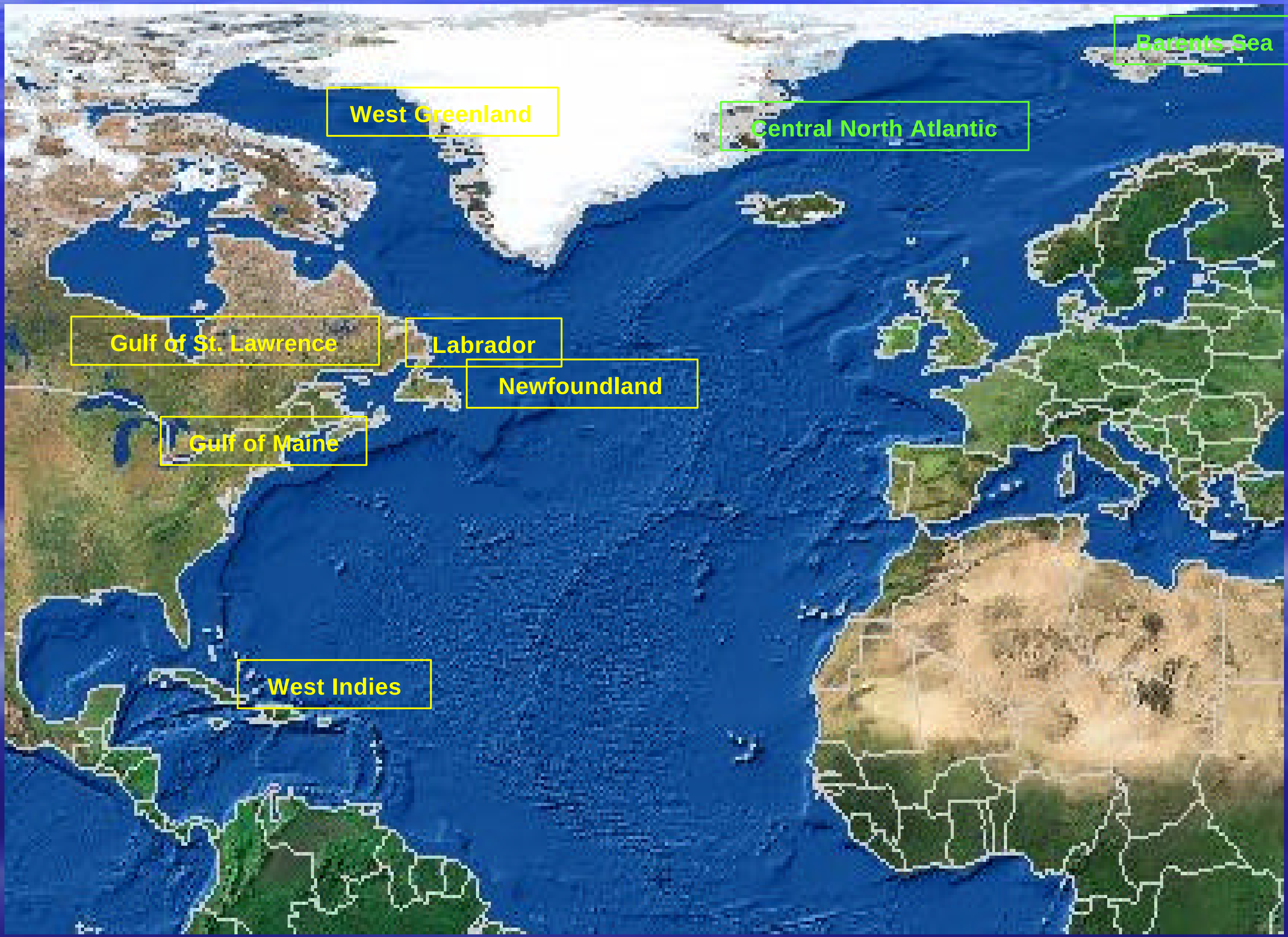
Area	% of each clade Common	western
Barents Sea	97	3
Iceland	86	14
West Greenland	70	30
Labrador	74	26
Newfoundland	68	32
Gulf of St. Lawrence	62	38
Gulf of Maine	67	33

Antarctic alleles

Common North Atlantic alleles

western North Atlantic alleles

Western and eastern North Atlantic areas

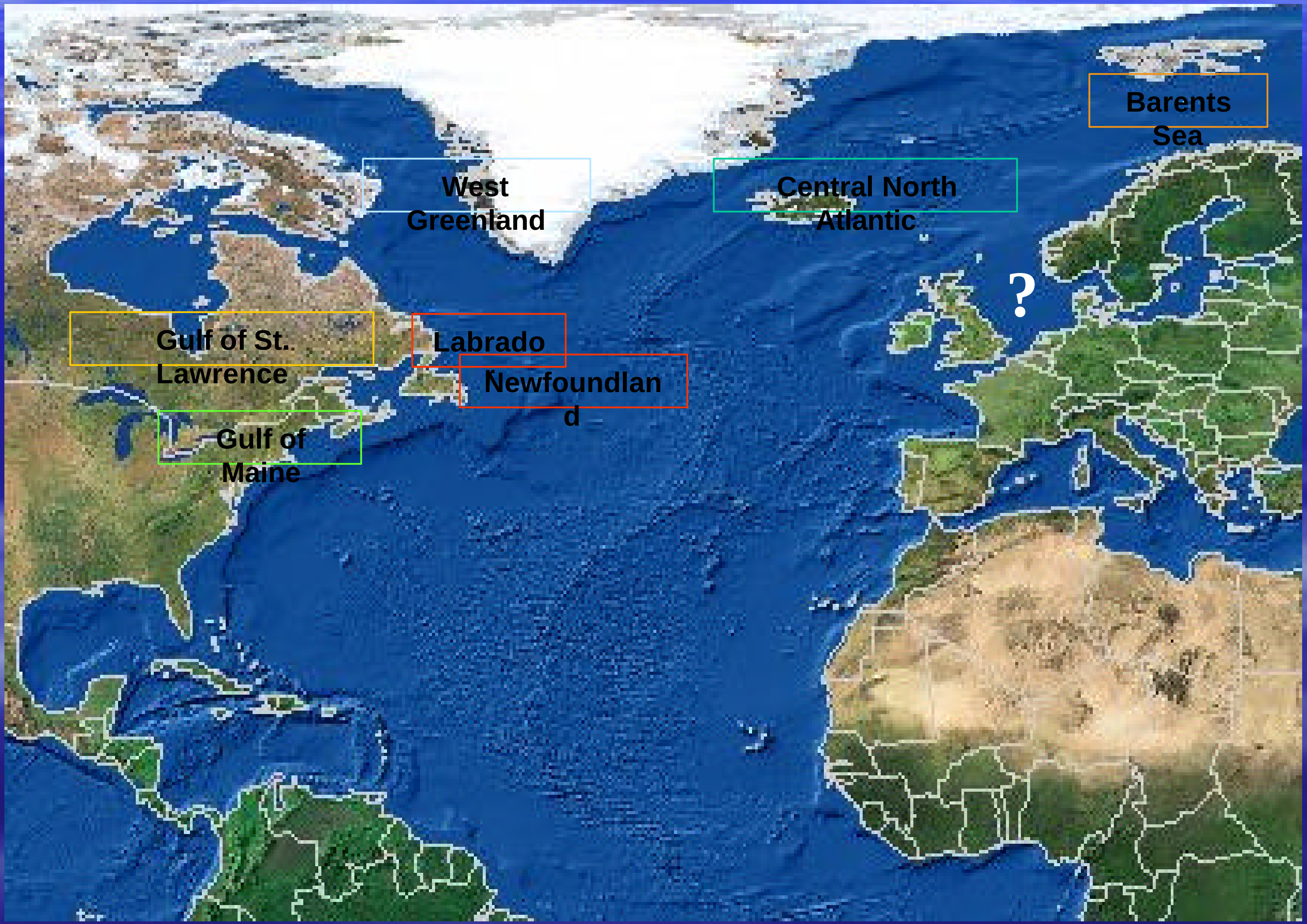


Divergence Estimates

	Nuclear DNA		mtDNA	
Area	**F_{ST} (mean)**	**Range**	**H_{ST} (mean)**	**Range**
eastern NAtl.	.0022	-	.009	-
western NAtl.	.0002	.0001 - .0005	.009	.000 - .026
Barents Sea - wNAtl.	.0038	.0009 - .0078	.040	.015 - .085
Iceland - wNAtl.	.0014	.0003 - .0027	.025	.010 - .042

Nuclear DNA estimates based on six loci

MtDNA divergence among feeding grounds



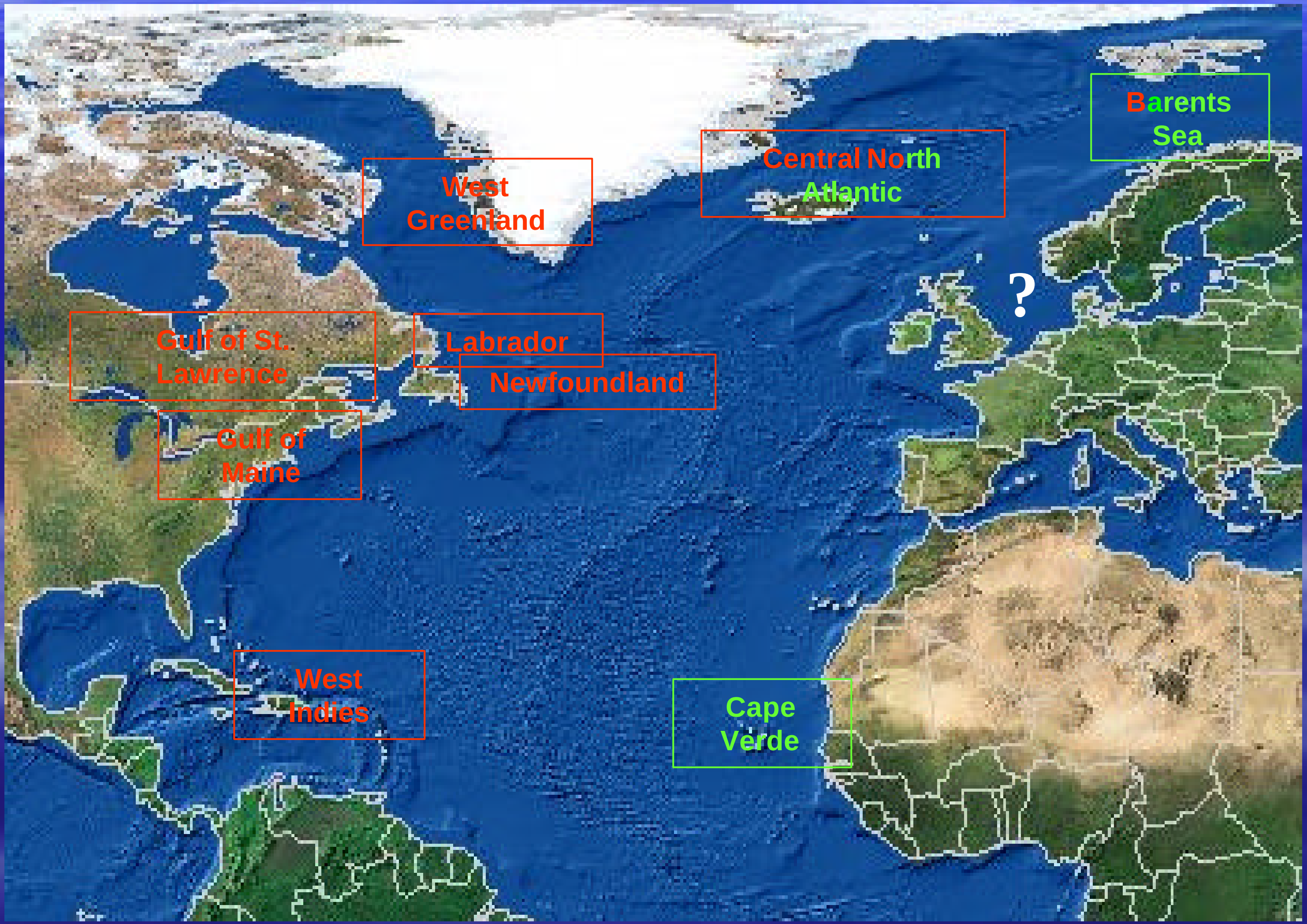
Calves Stay With Their Mother the 1st Year

Identification Of Mother & Calf Relations

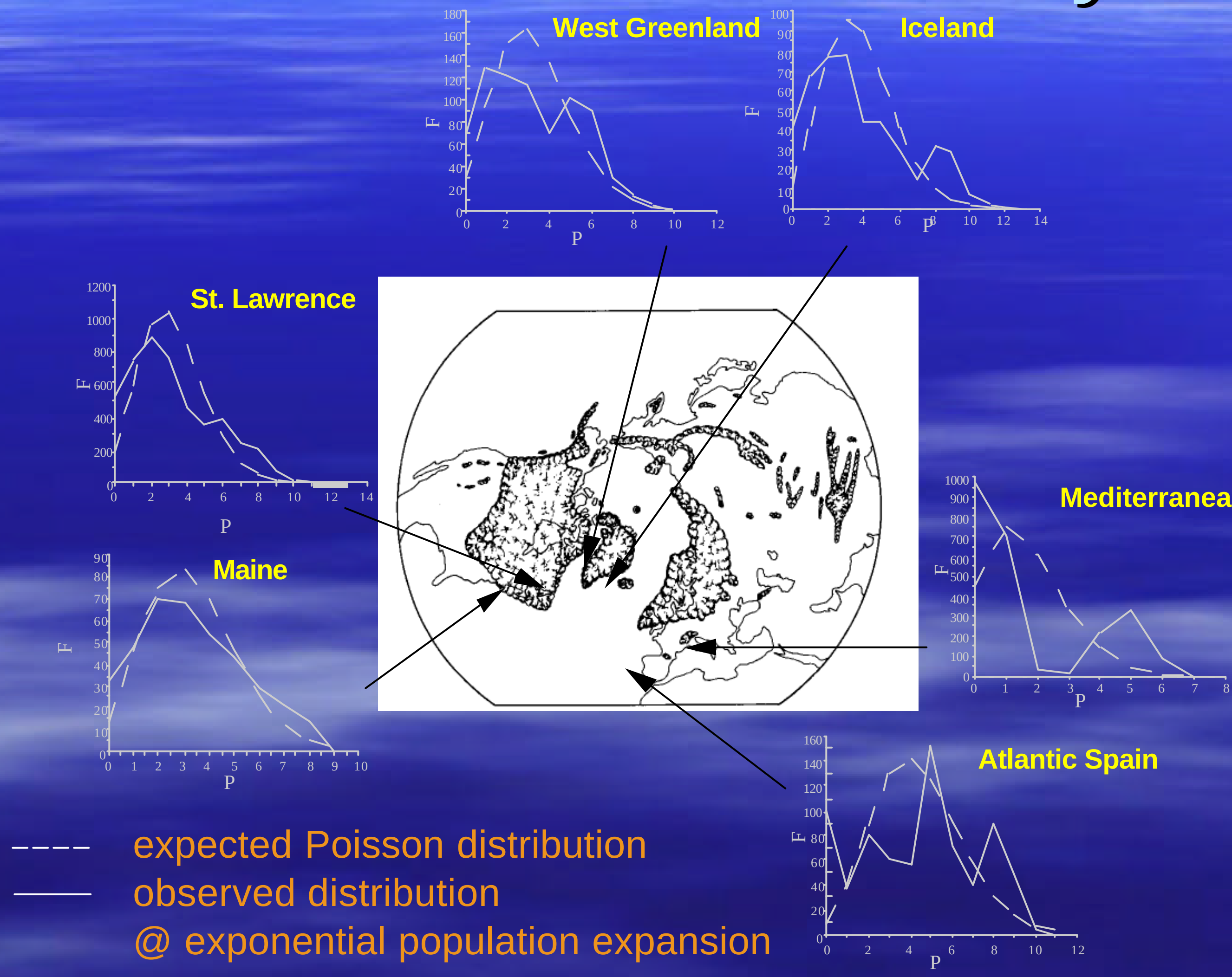
Maternally-directed Site-fidelity to Summer Feeding Grounds

- **Individual humpback whales appear to return to the same high-latitude feeding ground every spring throughout its life**
- **The feeding ground of choice is that to which the calf migrated to with its mother**
- **Cultural transmission**

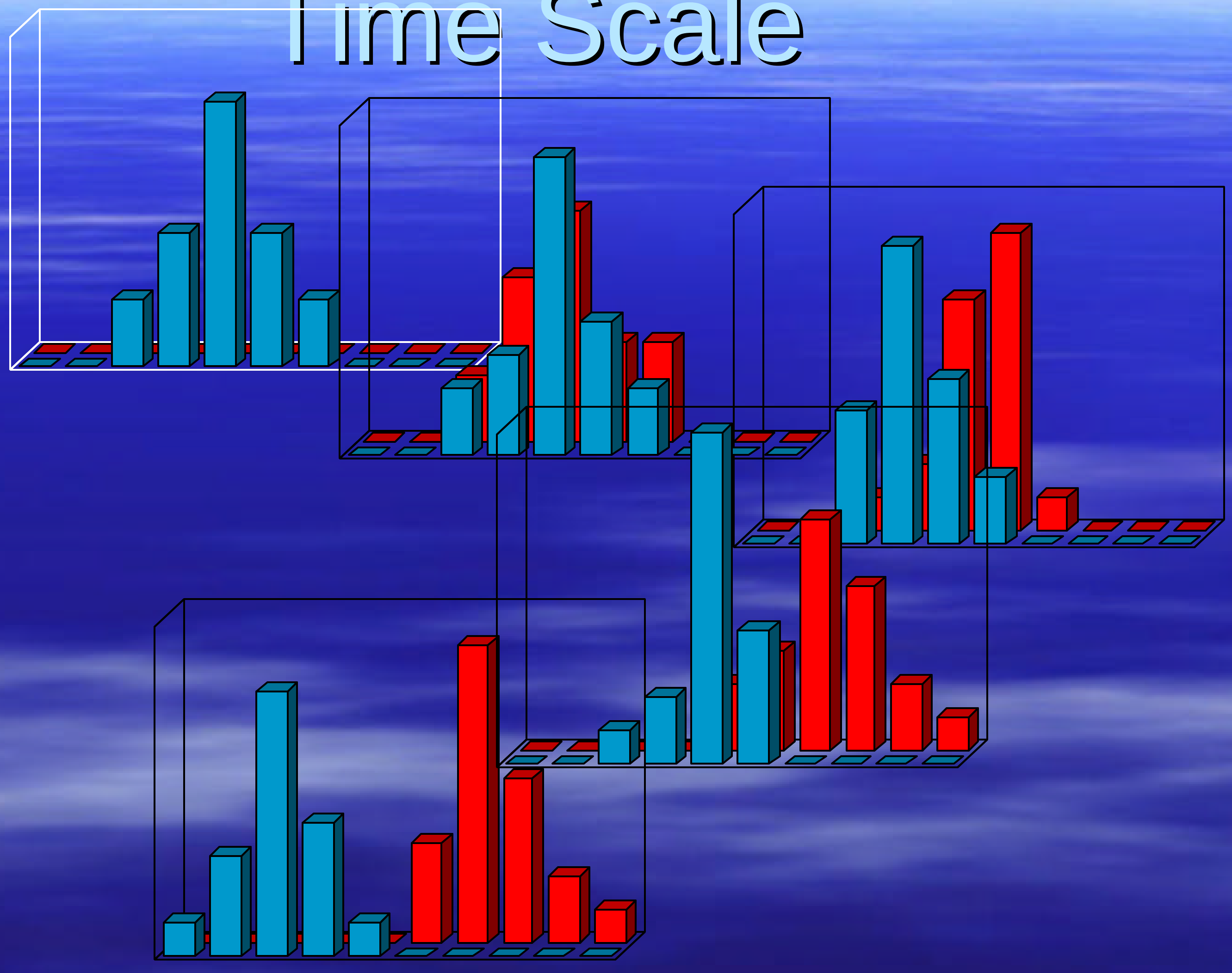
Two Breeding Populations



Effects of Pleistocene Glaciations On Genetic Diversity



Divergence On An Evolutionary Time Scale



Individual-based Analyses

- Insights on an ecological time scale
  - Individual identification
    - 6-15 microsatellite loci
    - Estimation of abundance and individual ranges of movement
  - Identification of close relatives
    - 20+ microsatellite loci for parent-offspring detection
    - Estimation of abundance
    - Reproductive success -> selection
    - Population structure
    - Estimation of demographic parameters

North Atlantic Humpback Whale

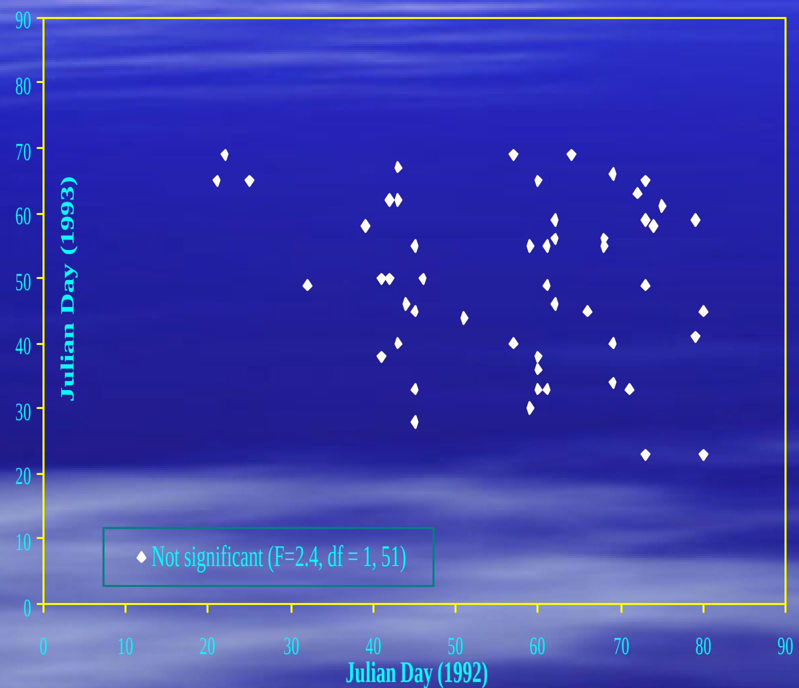
Area	Period	Samples	$I^{\#}$ (x 10^{-7})	95% CI limits§ (x 10^{-7})	Genotypes	Males	Females
Barents Sea	1992-1993	36	8.46	4.9 - 38	35	13	22
Gulf of St. Lawrence	1990-1995	65	1.94	1.26 - 5.52	56	28	28
Gulf of Maine	1990-1995	292	1.38	1.02 - 2.11	256	118	138
Iceland/Jan Mayen	1991-1993	112	1.42	0.88 - 3.28	100	50	50
Newfoundland/Labrador	1991-1995	572	1.34	1.07 - 1.86	464	237	227
West Greenland	1988-1994	189	1.23	0.89 - 2.10	148	75&	72&
West Indies	1989-1995	1,794	1.81	1.57 - 2.15	1,432	884&	545&
Minus inter-area recaptures		2,491	1.51	1.34 - 1.75	2,368		
Unique genotypes only		2,368	1.51	1.32 - 1.72		1,331&	1,033&

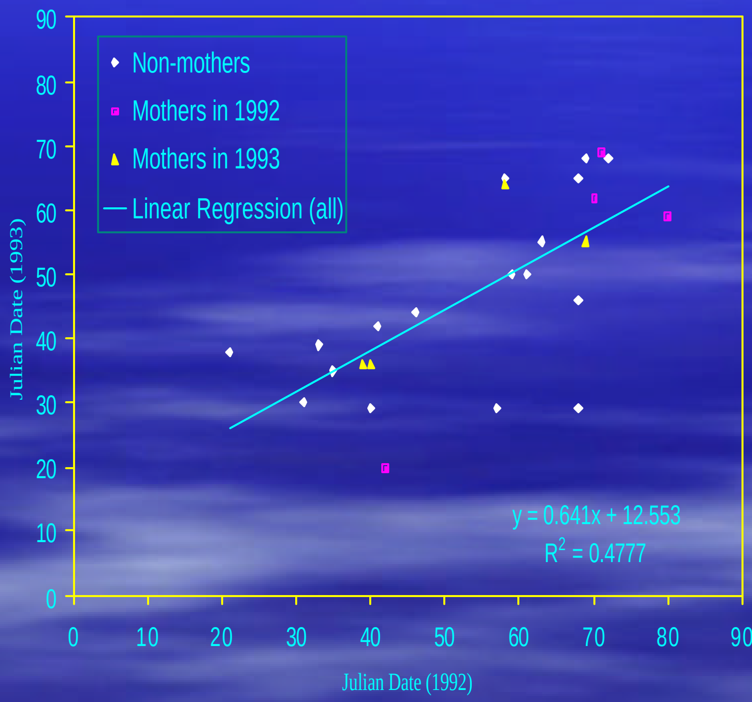
#Probability of identical genotype[26] across all loci calculated from all samples (including recaptures). §Estimated from 1,000 bootstrap samples. &No gender was obtained for a total of four samples

Different Number of Males and Females on the Breeding Grounds

- Abundance estimates of each sex were estimated from with the samples collected on the breeding ground during 1992 and 1993
  - 4,804 males (95% CI: 3,374 - 7,123)
  - 2,804 females (95% CI: 1,776 - 4,463)
- Even sex ration in calves and among feeding ground samples
- Difference in male and female abundance probably due to "temporal fidelity" in migration timing among females

Temporal Fidelity





Thank You