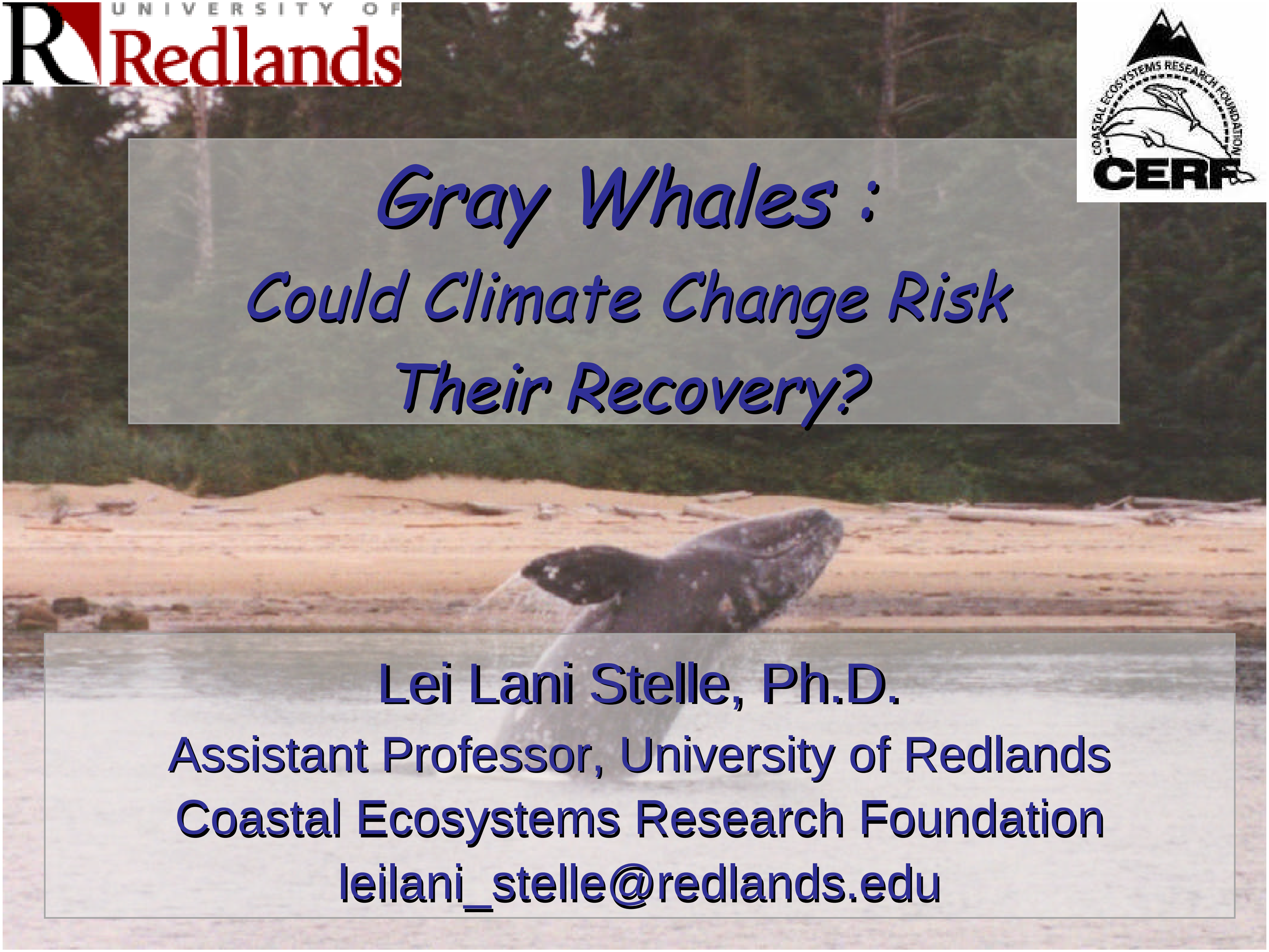

Gray Whales :
Could Climate Change Risk Their Recovery?

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Outline

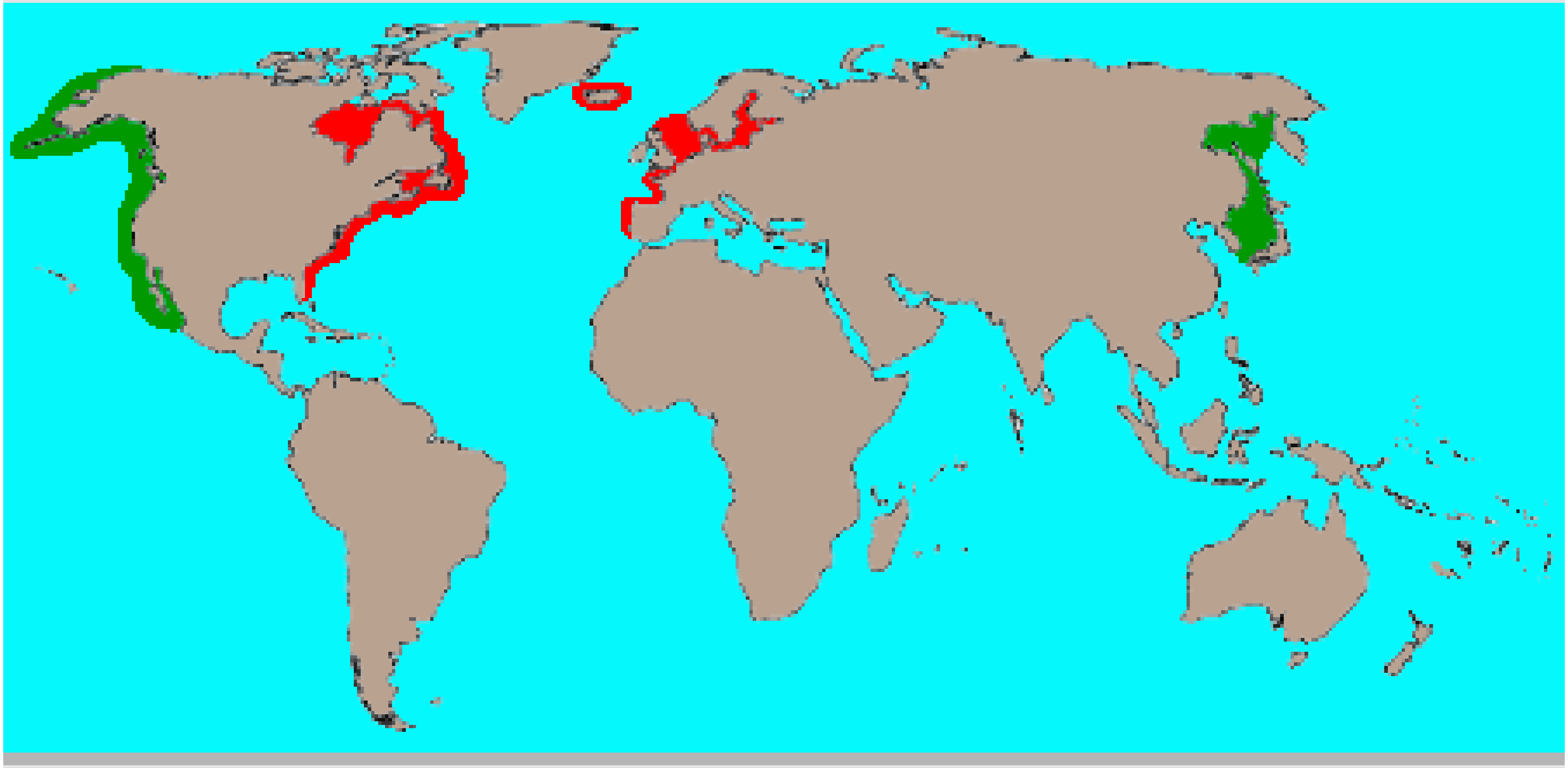
- Gray Whale Biology
- Population Status
- Sentinels of Climate Change (CC)
  - Cyclical CC
  - Directional CC
  - Impacts on grays
- My research
- Conclusions

Gray Whale Basics

Eschrichtius robustus

Mysticete	Baleen
Coloration	Gray
Size	36 - 50’
Weight	30 - 45 tons
Maturity	5 - 11 yrs
Lifespan	40 - 50 yrs

Historical Distribution



Red – extinct

Green – extant populations

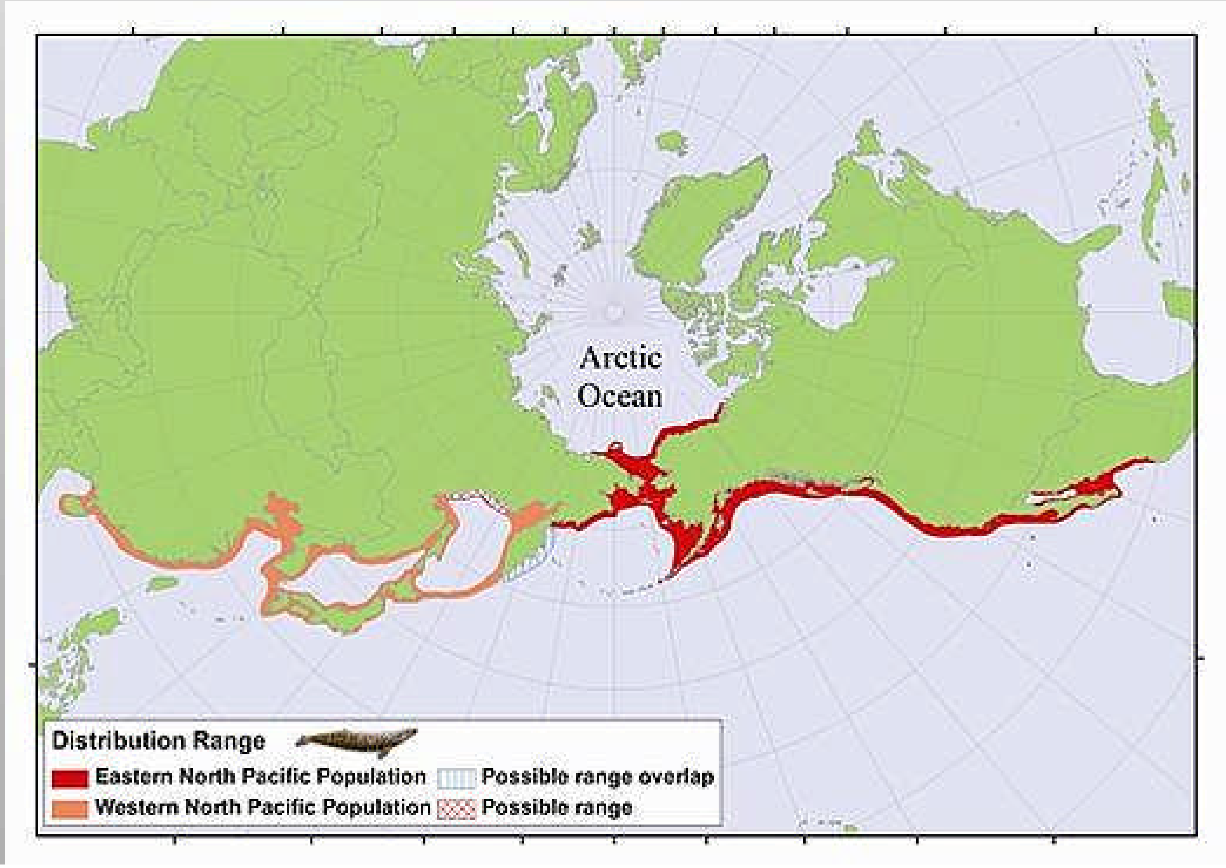
Extant Populations

Western Northern Pacific – critically endangered

- summer - Okhotsk Sea (Russia), winter location? – China Sea?

Eastern Northern Pacific – "recovered"

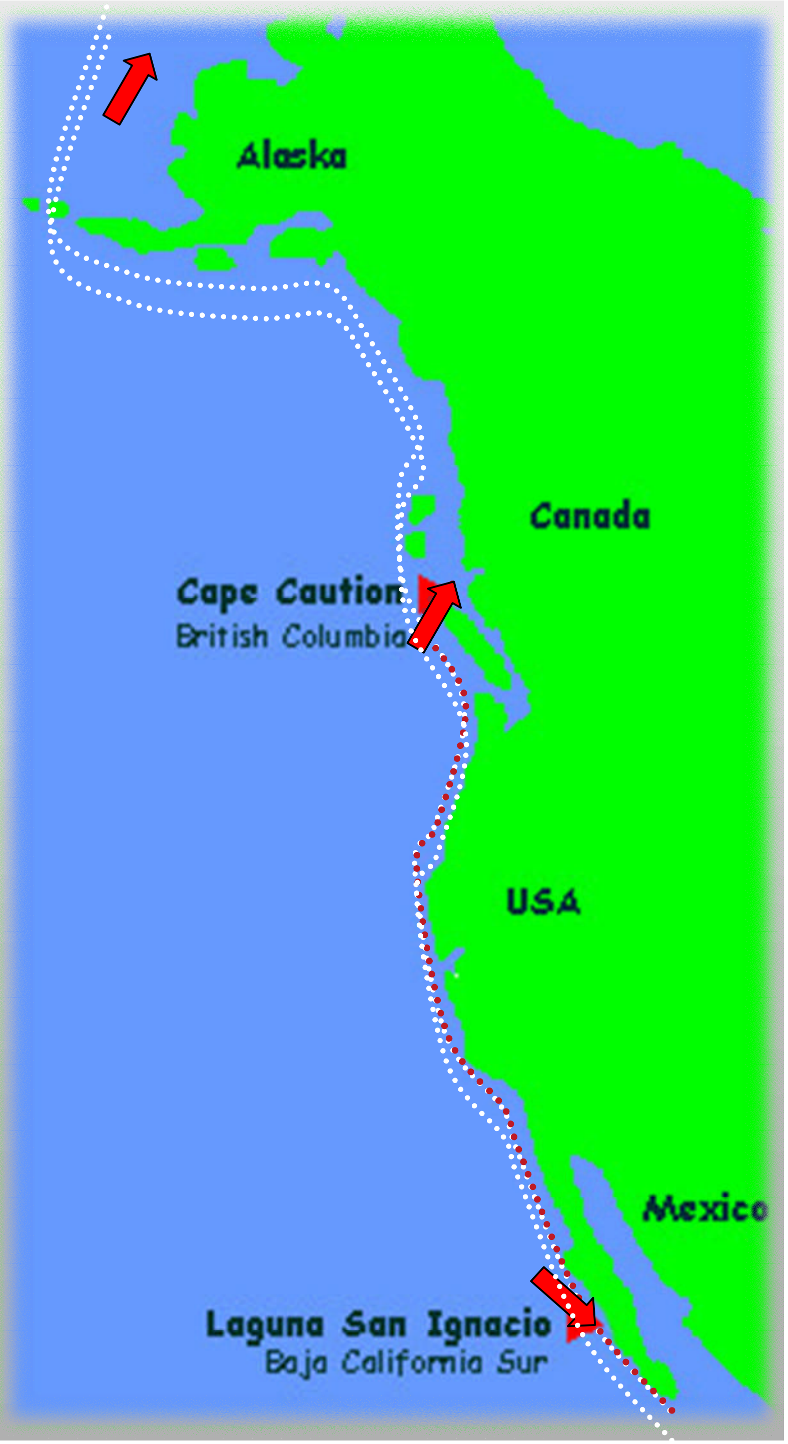
- summer in Arctic, winter in Baja



ENP Migratory Path

- ➢ Breed in Baja: Jan - April
  - Fast (?)
- ➢ Migrate North in spring
  - staggered by age & sex
- ➢ Feed in Bering/Chukchi Seas: June - Oct
  - some feed further south
- ➢ Migrate South in fall

❖ Migrate18,000 km rt annually



Why Migrate?

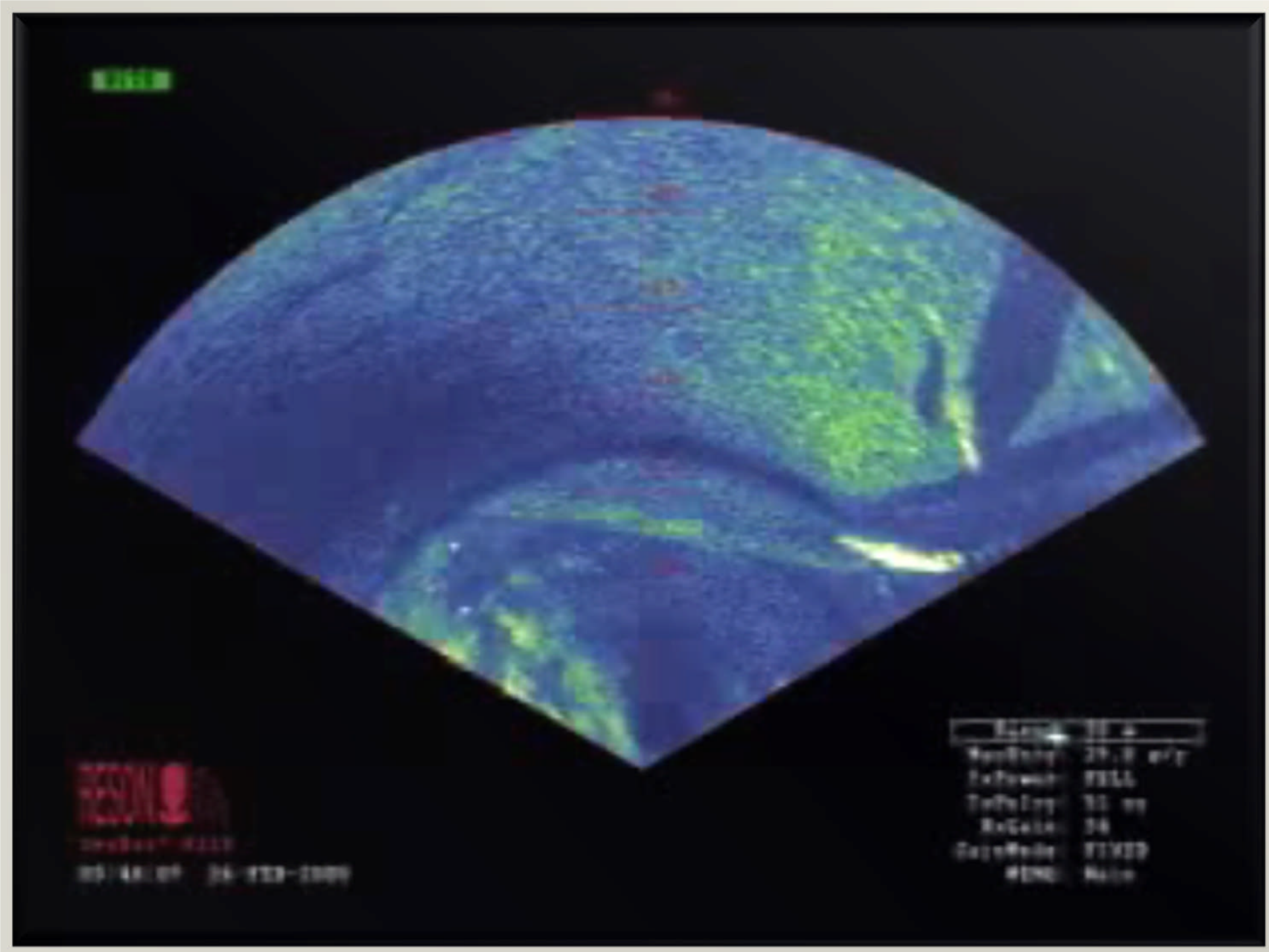
- No food in Northern waters in winter
- Thermoregulatory advantage in Baja, especially for calves
- Reduced risk of predation
- Migrate at speed of minimum COT so not a large cost

Kissing Whales in Baja

Reproduction

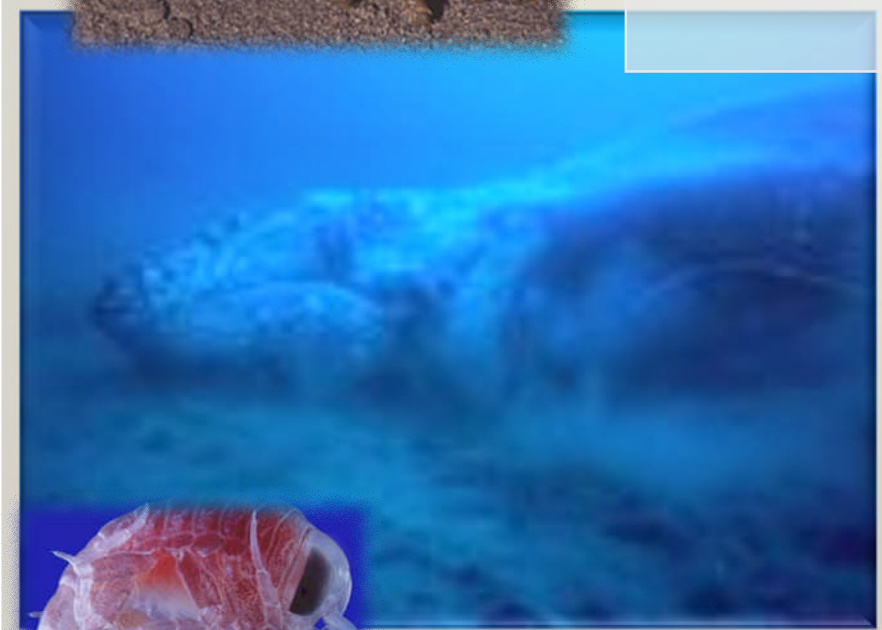
- Mating System
  - Sperm competition
  - Dance?

- Gestation
  - 14 months
  - 15’ at birth
- Lactation
  - 8 months
  - 50% fat



Feeding & Diet

Benthic prey - amphipods & ghost shrimp



Pelagic prey - mysids, amphipods, crab larvae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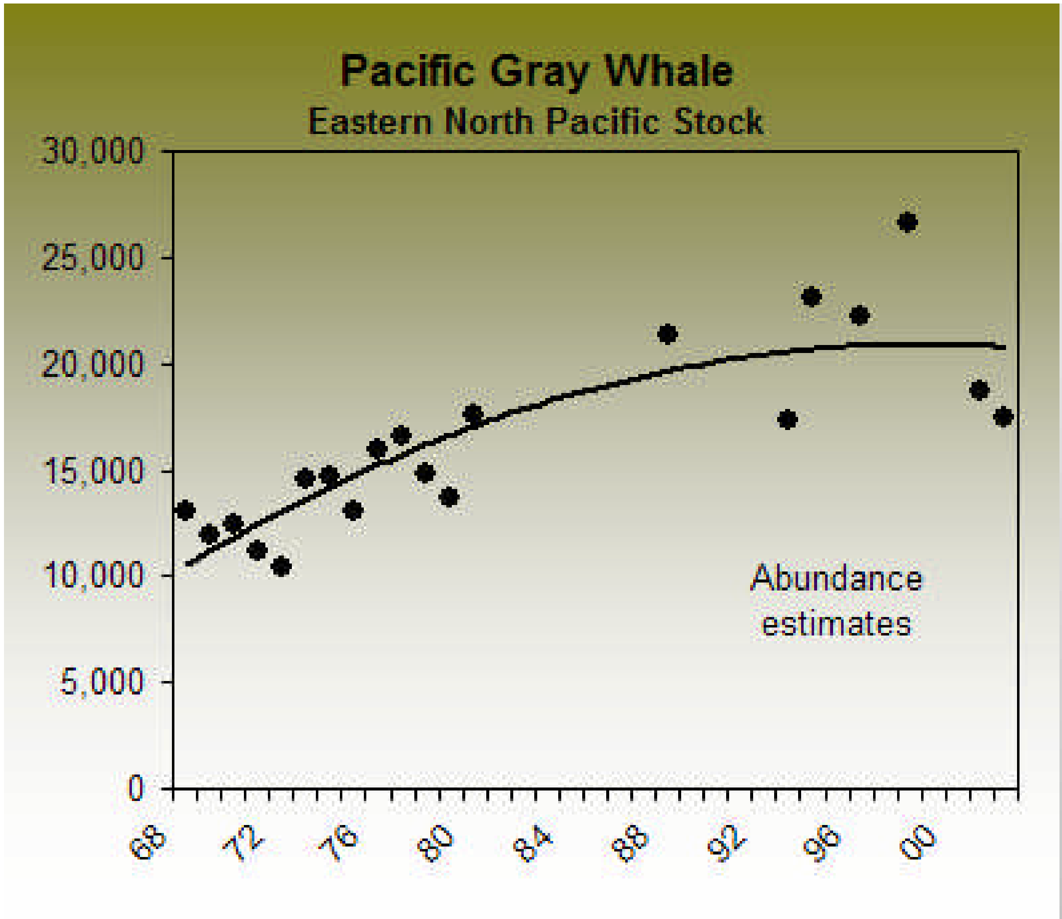


Recovery

1994 - Removed from Endangered Species List

- Census counts match pre-whaling estimates
- BUT Genetic diversity estimates population <50% of historical abundance (Alter et al. 2007)

Threats

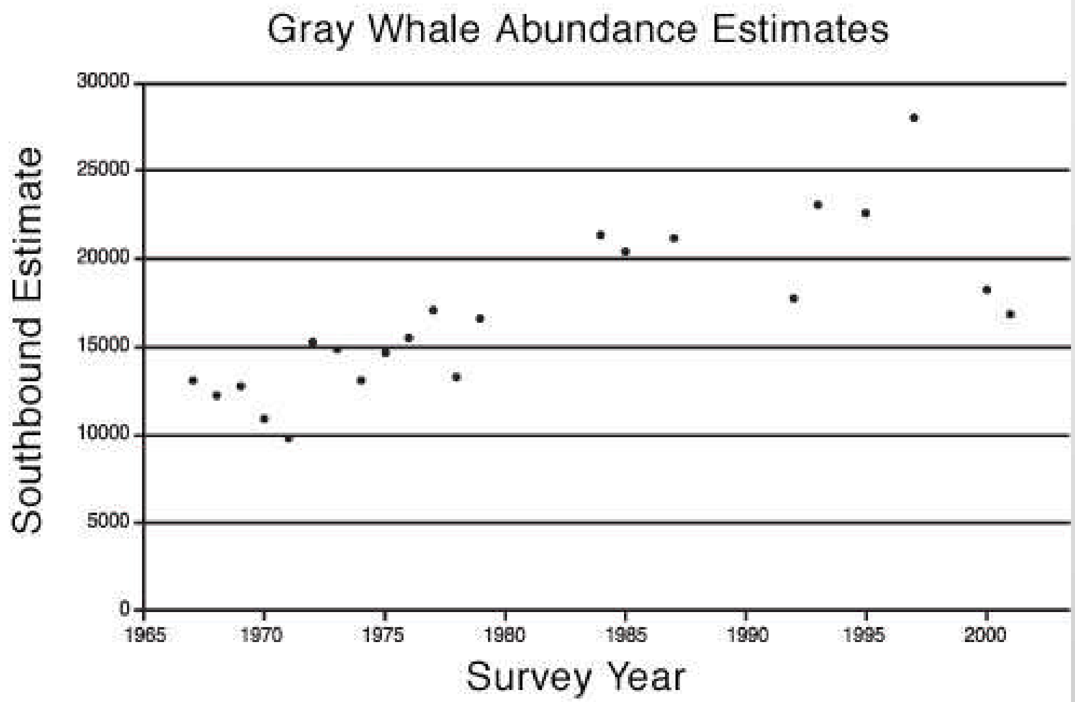
Makahs in Washington

• renew 1855 treaty rights to hunt grays

Orcas (Killer Whales)

- main predator
- target calves; up to 30% mortality

Climate Change



Population Status

- ➢ Decline in ’99-’00
  - High mortality
  - Low calf production

➢ Did they hit K?

(LeBoeuf et al. 2000)

➢ Disease or Toxins?

(Moore et al. 2001)

➢ ENSO?

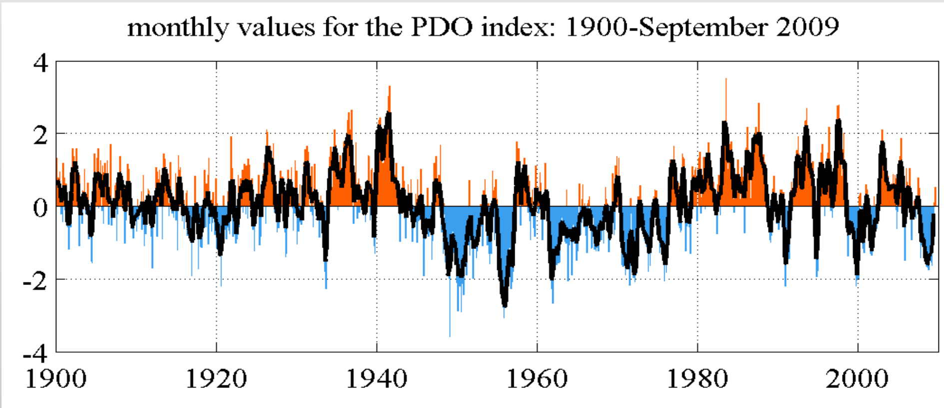
Ecosystem Sentinels

"Marine mammals integrate and reflect ecological variation across large spatial and temporal scales"
(Moore 2008)

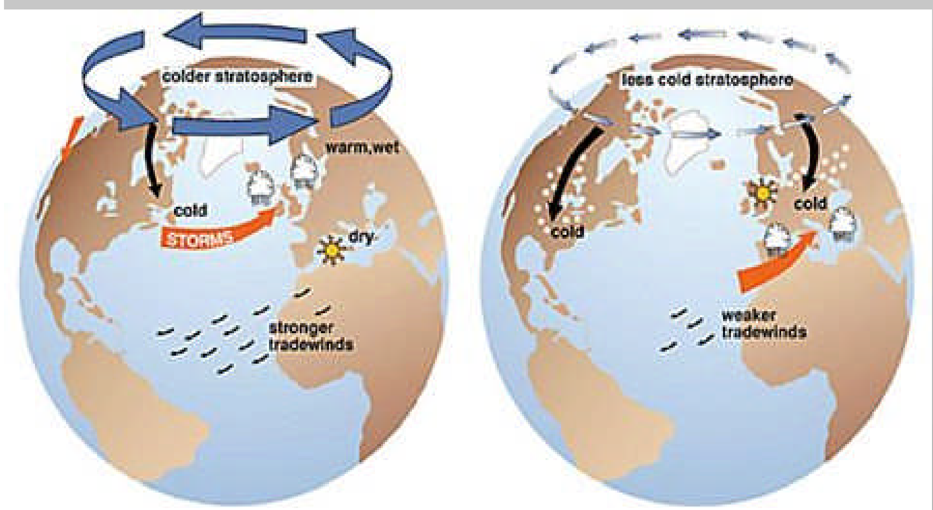
- Most studies use chlorophyll a to describe ocean productivity and relate to abiotic conditions
- Rarely include predators
- Polar cetaceans reflect rapid changes while migratory mysticetes are useful for broadscale shifts
- Evidence grays responding to ecosystem changes, so ideal sentinels

Cyclical Climate Change

Pacific Decadal Oscillation (PDO)



- long-term cycling sea surface temp (SST)
- “regime shift” in late ’70’s
- correlates w/ productivity & declining marine mammals



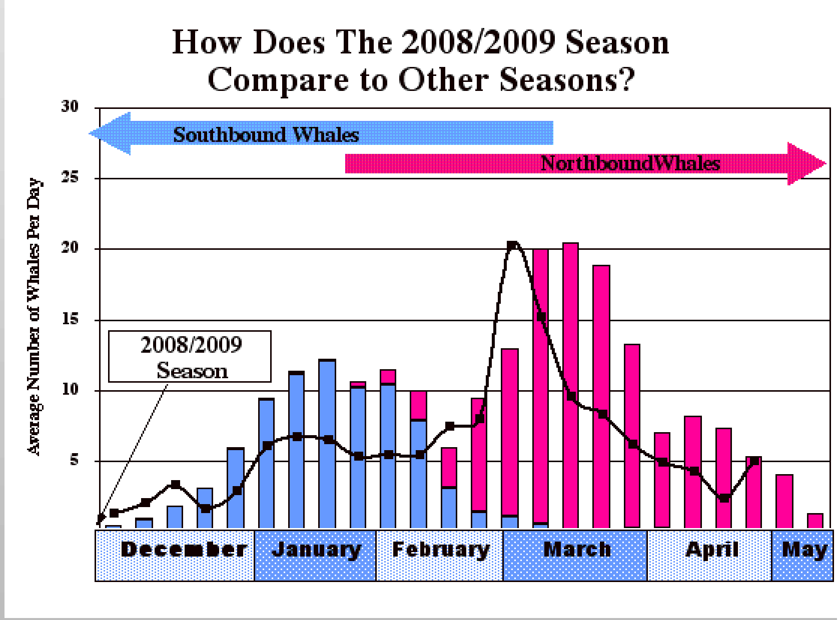
Effects of the Positive Phase of the Arctic Oscillation | Effects of the Negative Phase of the Arctic Oscillation

Arctic Oscillation (AO)

- alternating pressure
- positive phase – low pressure in Arctic, decline zooplankton & salmon

Evidence: Migratory Timing

- Delay (1 week later) in southbound migration after 1980 (Rugh et al. 2001)
  - Coincides with North Pacific “regime shift” (PDO)

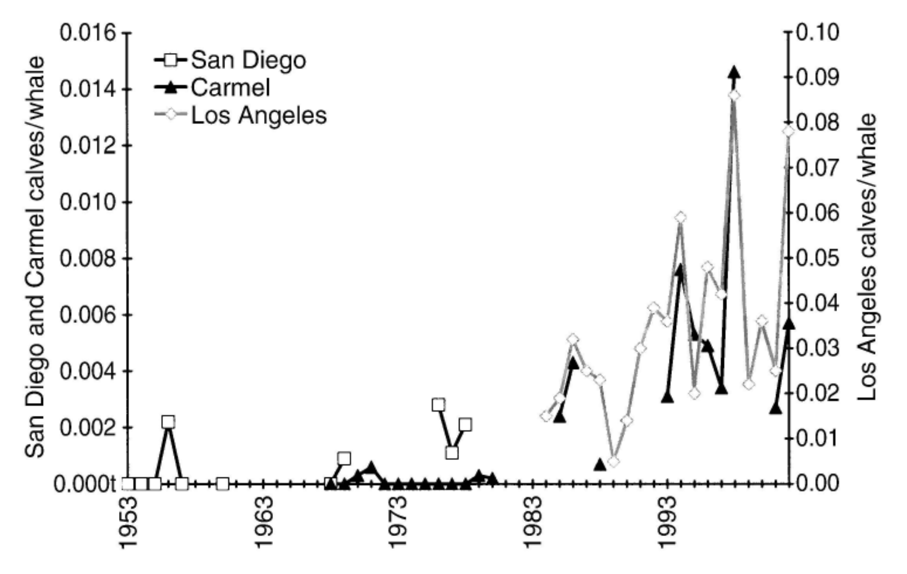


Why?

- Starting from further north so takes longer to migrate
- Decline in prey, need more feeding time to store reserves?

Calves Born During Migration

- Increase in # of Calves born during S. bound migration
  (Shelden et al. 2004)



- With 1 week delay, births should occur 1000 km N

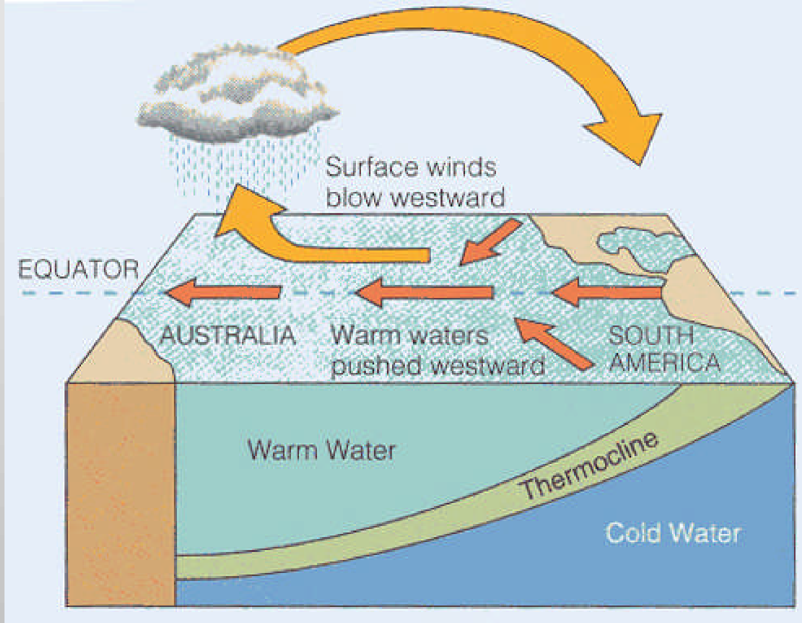
- Warmer water may help calves survive outside of lagoons

Cyclical Climate Change: El Nino-Southern Oscillation (ENSO)

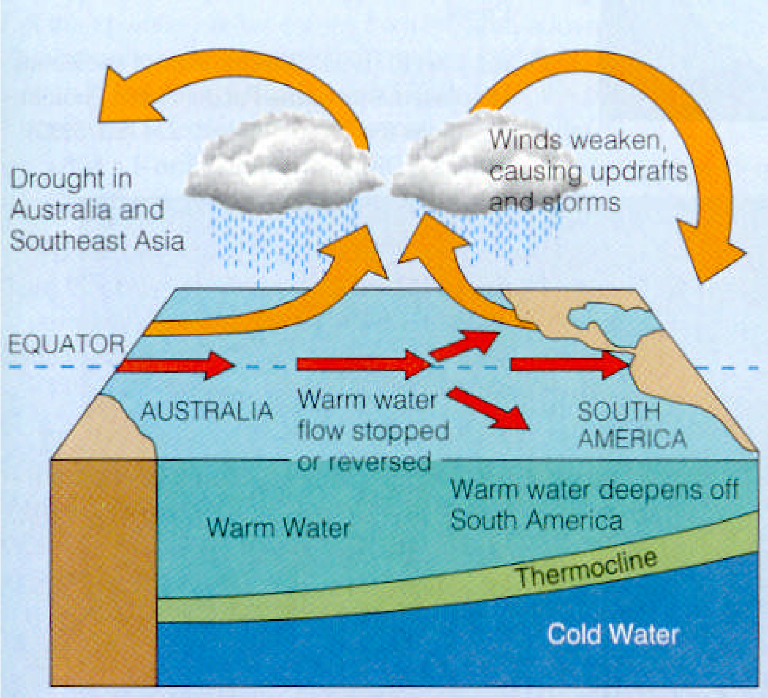
Normal year:

• Trade winds cause upwelling of nutrients

• High productivity



a Normal Conditions



c El Niño Conditions

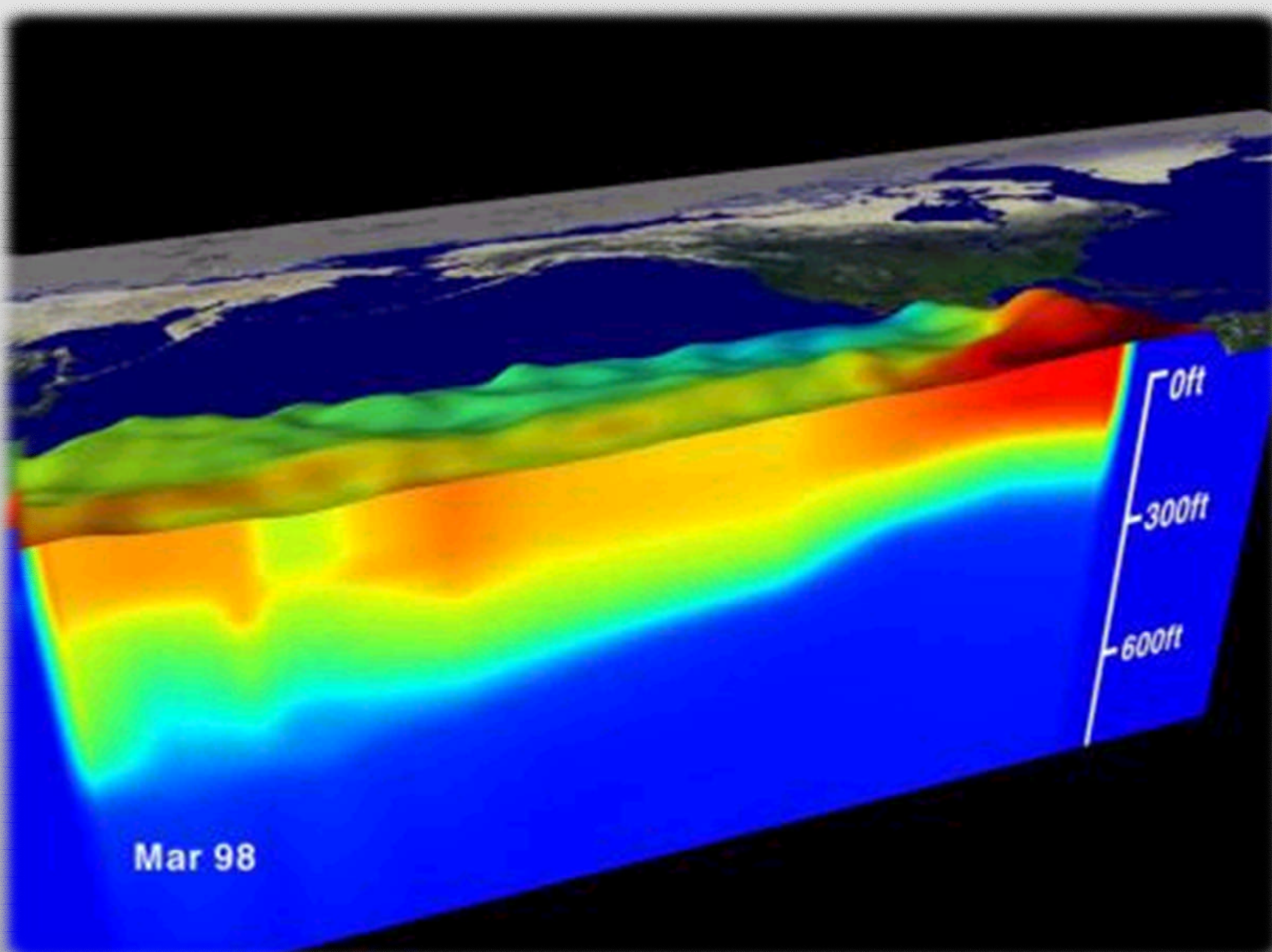
ENSO year:

• Weak trade winds, no upwelling

• High SST

• Low productivity

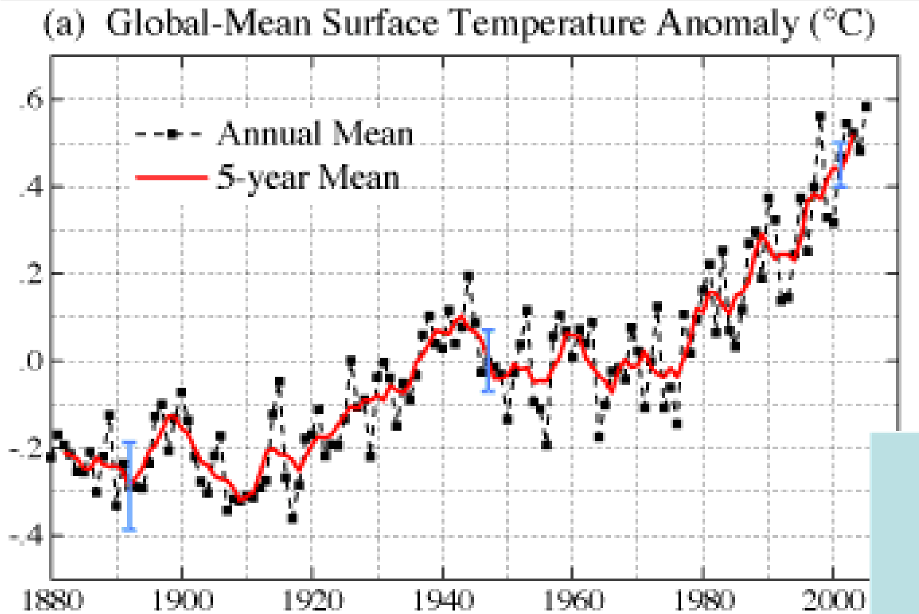
El Nino (ENSO) 97-98



Evidence: Trends in Lagoons

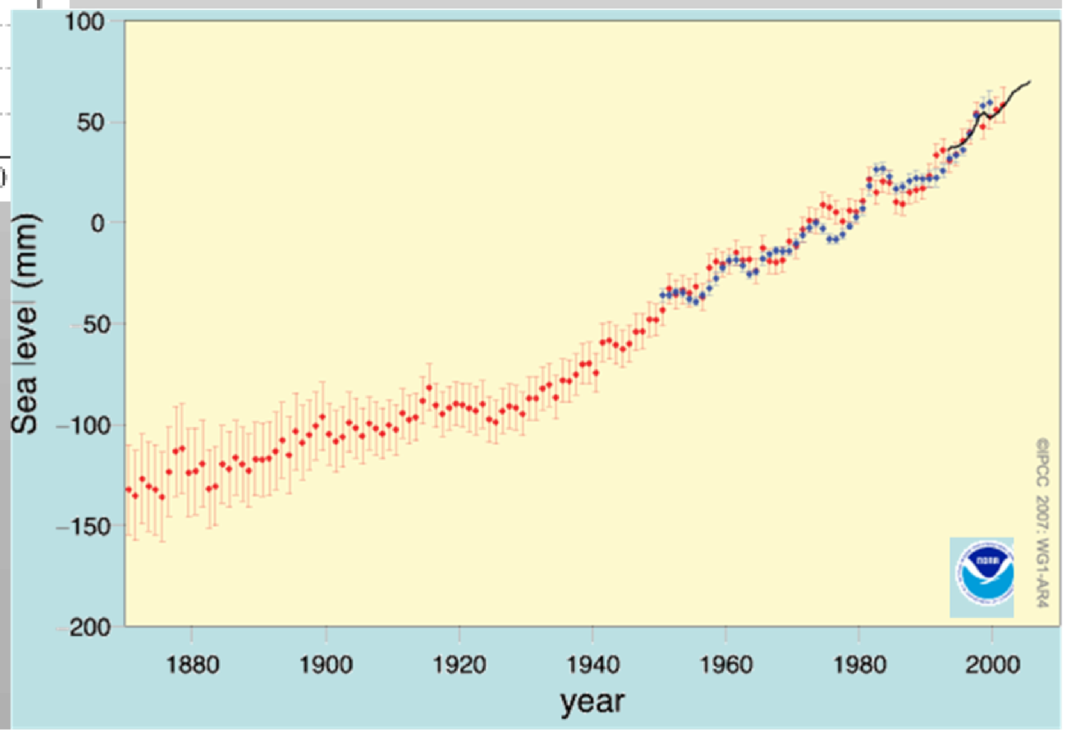
- 1997-98 El Nino effected sightings in Laguna San Ignacio (Urban et al. 2003)
  - El Nino - distribution shifted North; La Nina - shifted South and into Gulf of CA
  - cow-calf pairs: decline #s, delay in peak occupancy
  - Normally 1/3 of pairs use areas outside of lagoons, but >50% in 1998
  - Longer calving interval measured ’96-00 vs ’77-82: density dependent response b/c pop near K or related to ENSO?

Directional Climate Change: Global Warming



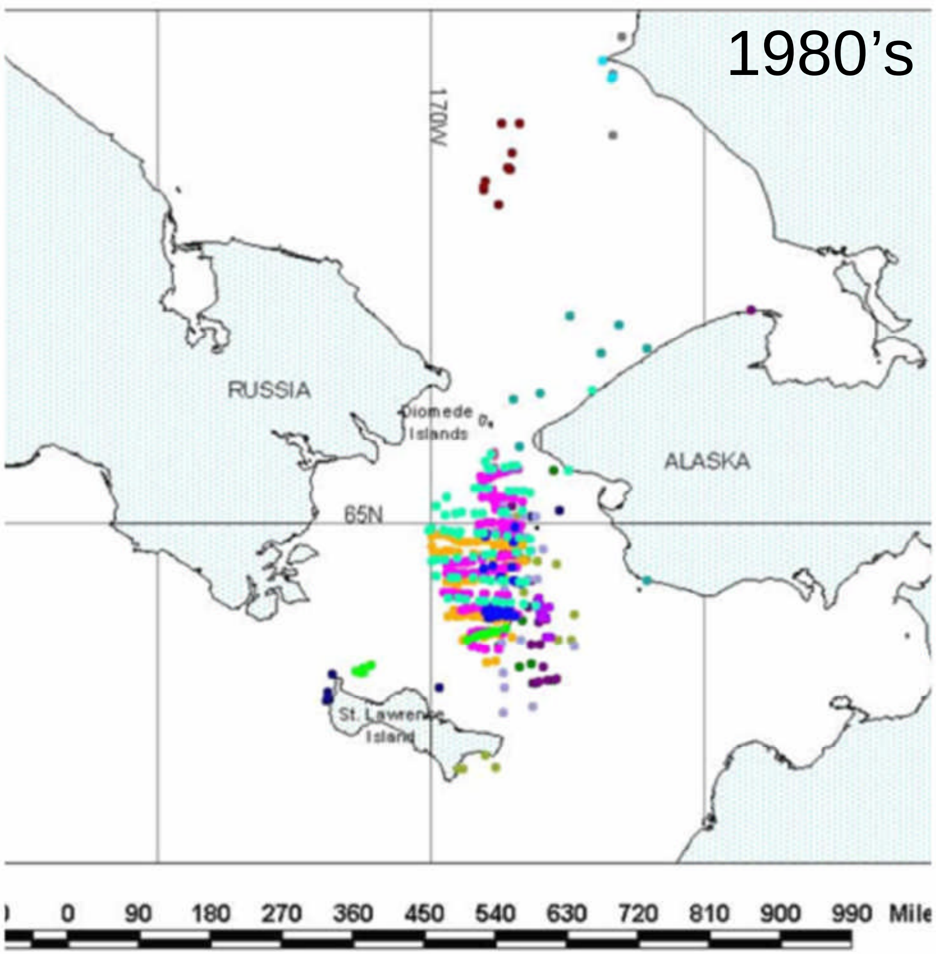
- Ocean Warming

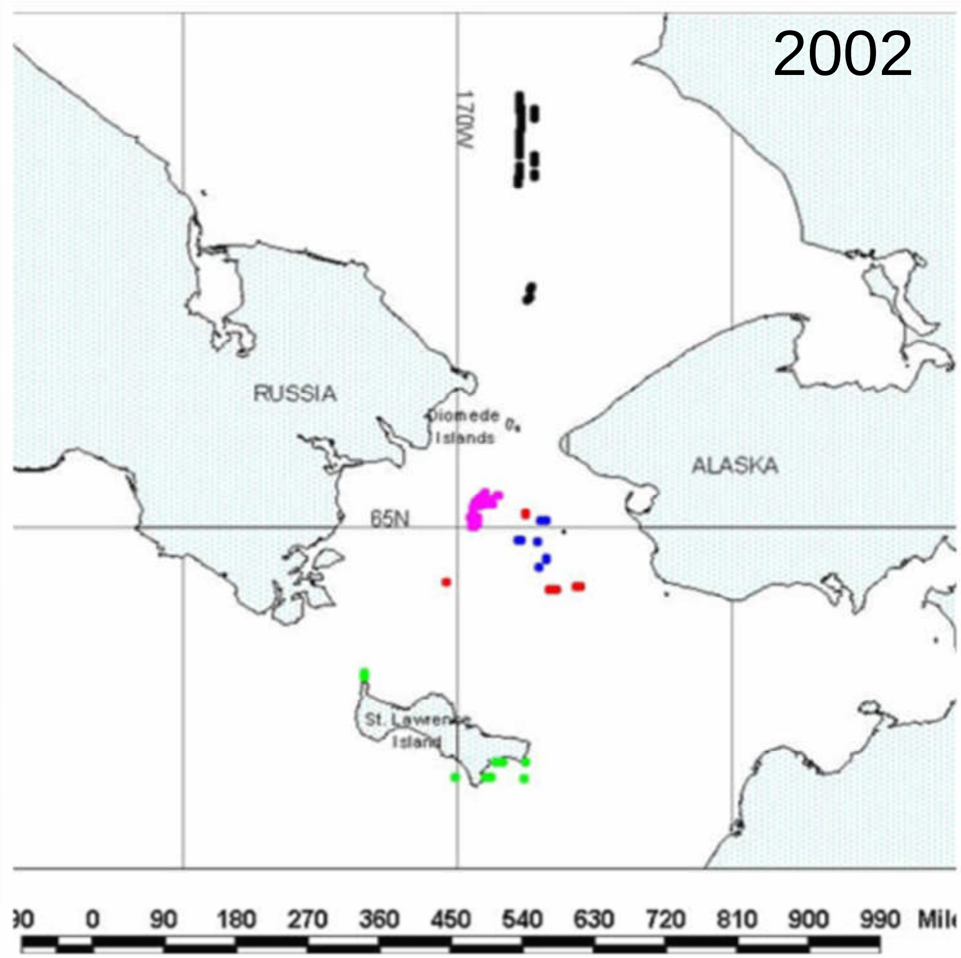
- Rise in Sea Level



Evidence: Chirikov Basin

- "Hole" in Chirikov Basin; grays still feeding in traditional area North (Moore et al. 2003)



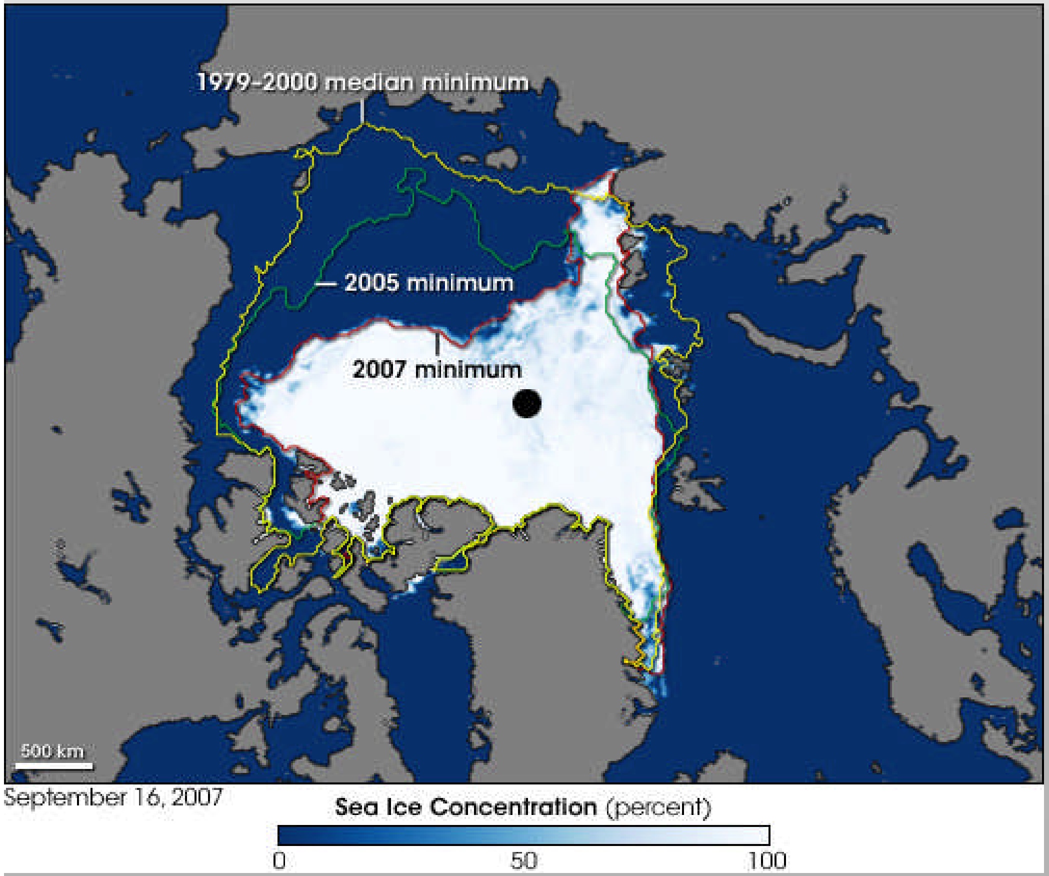


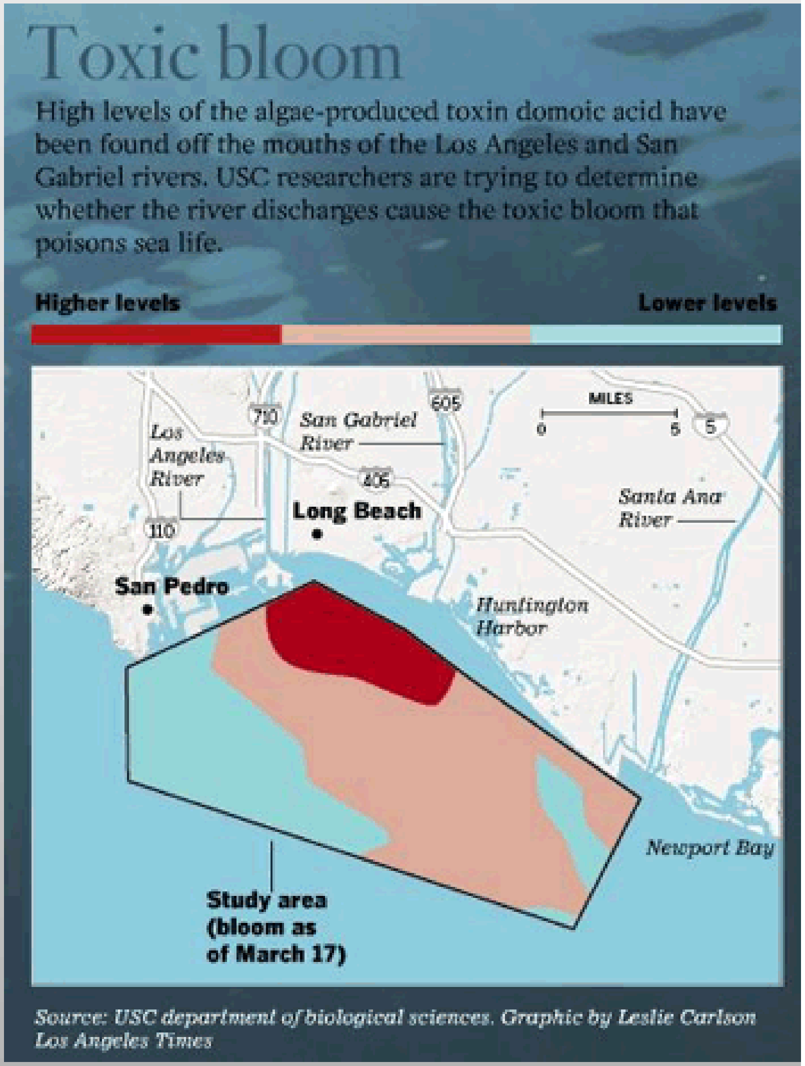
Evidence: Chirikov Basin

- Concurrent decline in amphipods because:
  - Reduced carbon & nutrient transfer linked to PDO
  - Coarser sediments, problem for tube-dwelling amphipods
  - Warmer water slows amphipod growth, reduces brood size & lifespan (Highsmith & Coyle, 1991)
  - Competition between invertebrates
  - Gray whale over-predation
- Carrying capacity of Bering-Chukchi ecosystem declined by 30% in last 30 yrs (Springer 2000)

Global Warming (cont.)

- Loss of sea ice





- Coastal algal blooms

Ice Impacts

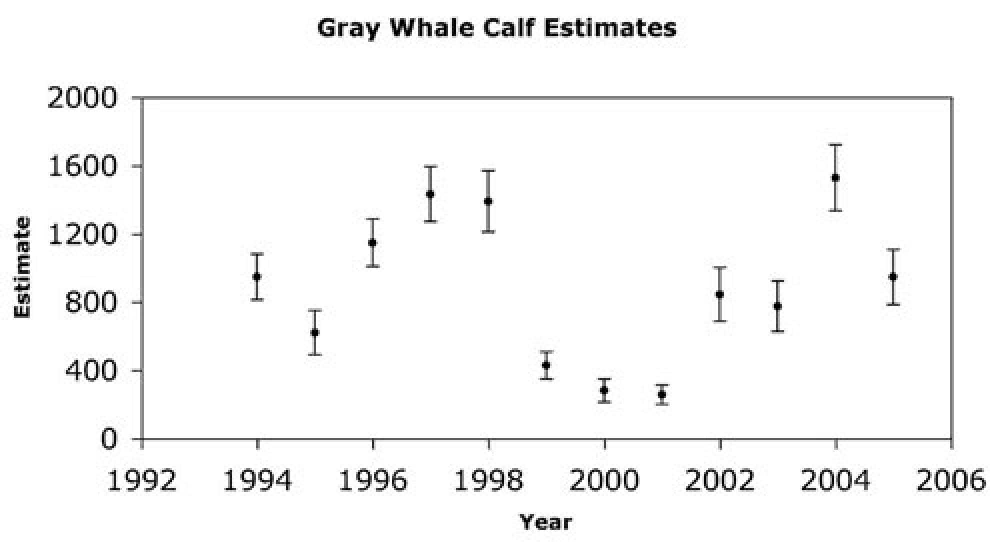
- Arctic productivity is light-limited
- Chukchi sea has become cloudier since 1984 (Bond 2008)
- Ice Cover advances during El Nino
- 8% decrease/decade since 1970’s (Fiedler 2008)
- 2007 max open water area, increased primary productivity (Fiedler 2008)
- But potential negatives: freshwater inflow and increased risk of predation

Evidence: Calf Production

- Fluctuating # of calves migrating North (Perryman et al. 2002)
  - Highest calf counts associated with length of time the Chirikov Basin was ice-free
  - Ice blocks access to feeding grounds
  - Correlation only during pregnancy not ovulation

- Major anomalies in ice coverage in early '80's but no effect on calves

What changed?



Evidence: Year-round Whales

- Grays observed feeding year-round in Alaska (Moore et al. 2007)
  - Commonly feeding in former migratory areas
  - Feeding on cumaceans, atypical prey, and amphipods absent
- Calls detected on autonomous recorders in W. Beaufort sea in winter (Stafford et al. 2007)
  - Cracks in sea ice observed on satellite images, allowed them to breathe

Skinny Whales

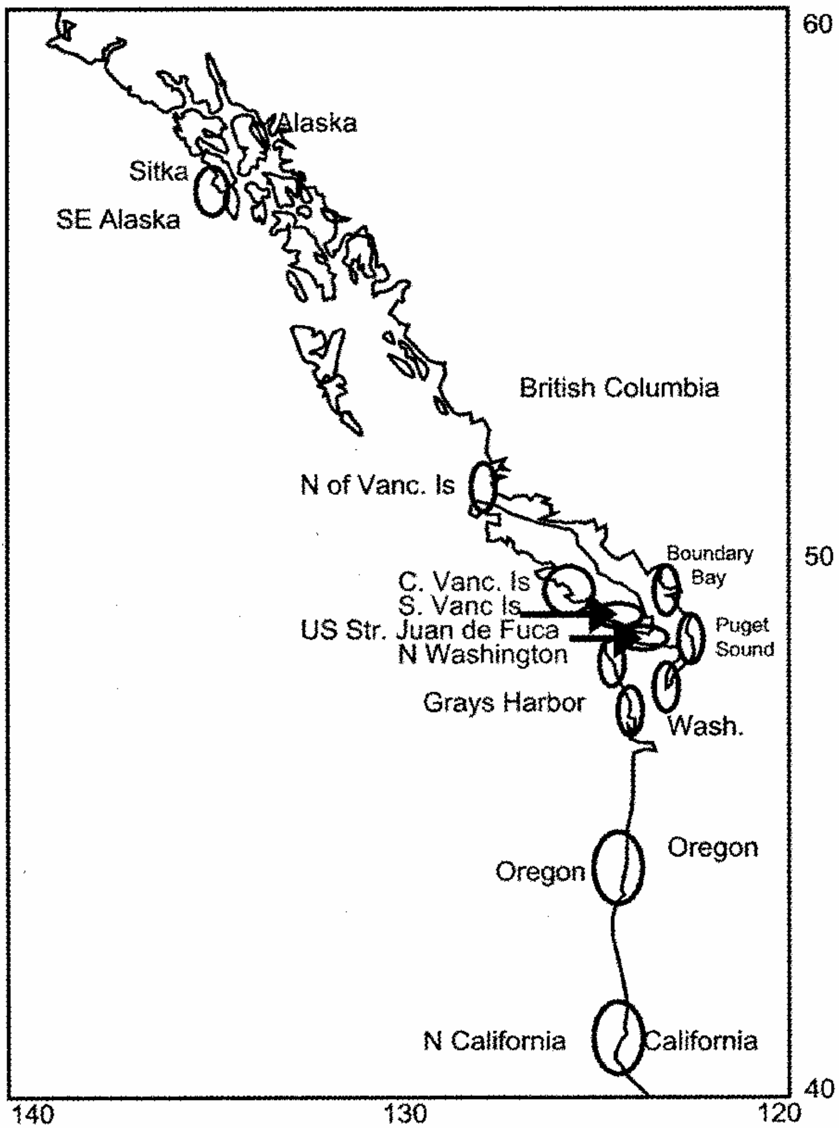
- 10% of grays in Baja emaciated in 2007

Decline in prey biomass (Coyle et al. 2007) due to:

- over-consumption by grays?
- ecosystem shift? (Grebmeier et al. 2006)
- climate change?

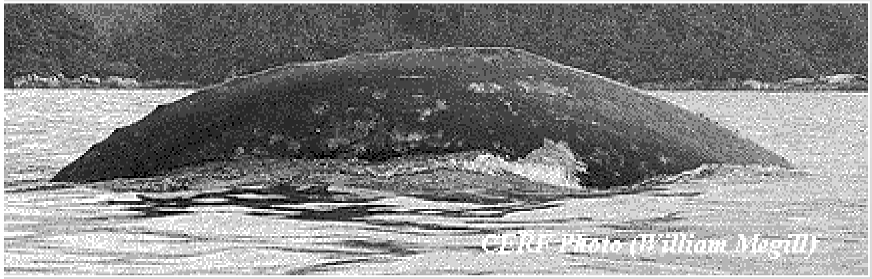
Southern Feeding Grounds

- Seasonal residents from S. Alaska to N. CA
- Population ~200-250, stable since 1998 (Calambokidis 2008)
- Cyclic abundance of grays in BC, appears linked to prey crashes (Feyrer et al 2008, Maud et al 2008)



Current Research

❖ Photo- ID in Baja & BC

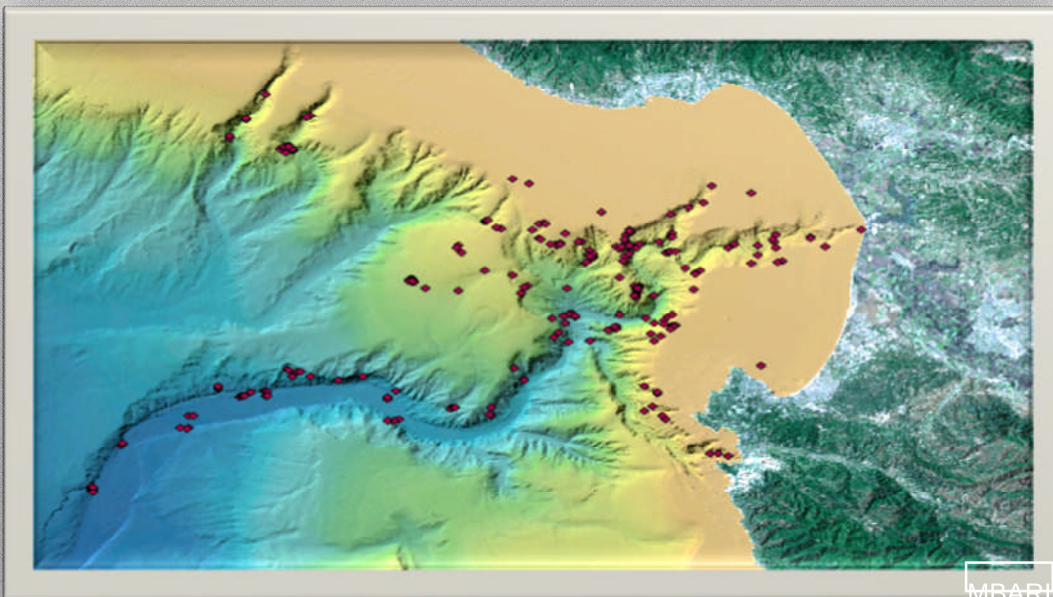


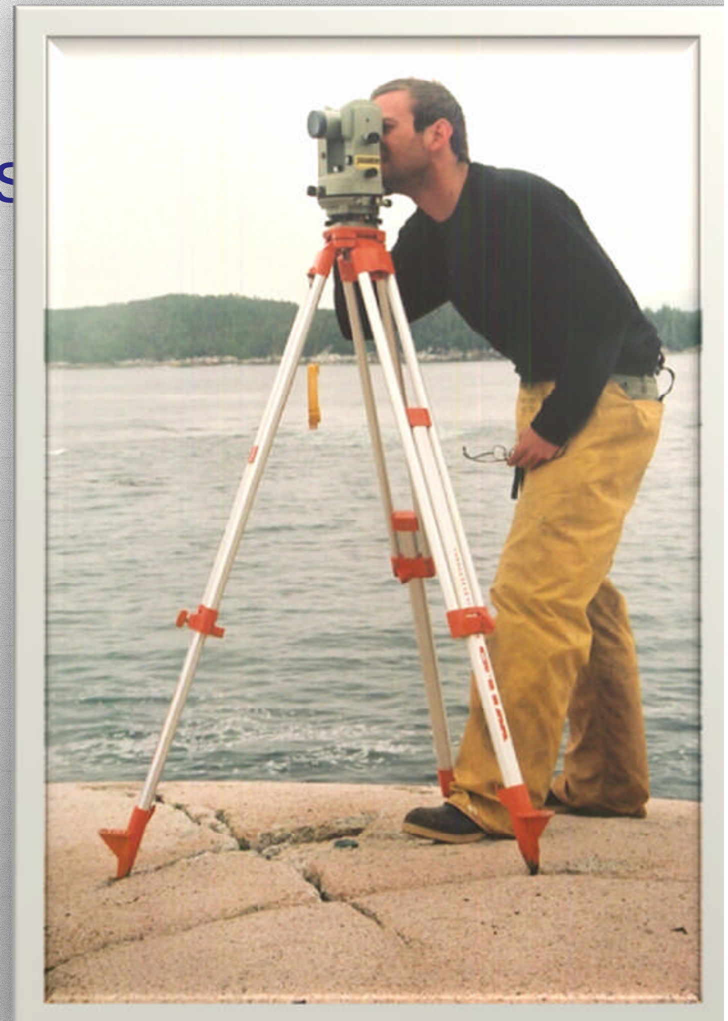
❖ Feeding in Baja?

Current Research:
Migratory Physiology

Shore-based observations:

- Swim speeds & respiration rates





GIS maps

- integrate oceanography, prey and whale data

Conclusions

Gray whales can act as Sentinels of Climate Change because:

- flexible
- already responding
- long-term dataset
- (relatively) easy to study
- charismatic megafuana

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"Whales of British Columbia"

7 day trips July – Sept

- Adult
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- Teen

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Abstracts from ACS 11th International Conference, Monterey Bay, CA Nov. 14-16, 2008

- Bond “North Pacific – Arctic ocean climate oscillations
- Calambokidis et al. “Seasonal resident gray whales in the Pacific Northwest: results from collaborative research between 1999 to 2007”
- Fiedler “ENSO and longer-term variability of productivity in the North Pacific”
- Feyrer et al. “The beggar’s banquet: gray whale predator-prey dynamics on the outskirts”
- Maud et al. “Switching predator in a changing ocean: is predator-prey cycling in grey whales feeding near Cape Caution, VC, sustainable?”

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