Changing Food Habits of Harbor Seals (*Phoca vitulina richardii*) in San Francisco Bay, CA

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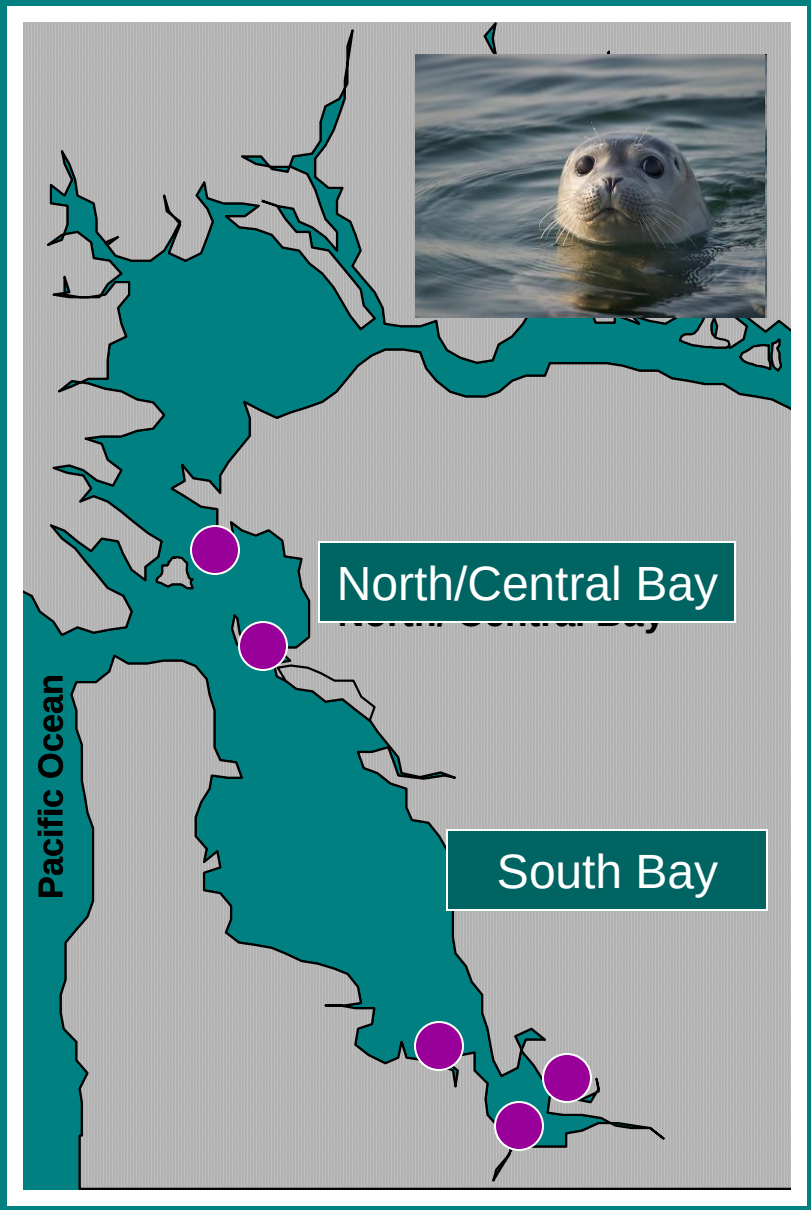
Introduction

- Harbor seals in San Francisco:
  - Area Use:
    - residents
      - foraging
      - breeding
      - resting
        - » five haul-outs
    - transients
      - breeding



Introduction

South SFB

- muddy salt ponds
- tidal marshes
- shallow water
- mild currents

North SFB

- rocky outcrops
- deep waters
- strong currents

- Different types of prey prefer different habitat types.

Introduction

- harbor seal status in California:
  - coastal California population increasing since the 1960s
  - no significant increase in SFB
- reasons that seal populations may not be increasing:
  - human disturbance
  - habitat modification
  - contaminant levels
  - local food depletion

Introduction

- harbor seals diet as an indicator of food depletions:
  - top predators in SFB
  - carnivorous generalists
  - benthic and pelagic fishes
  - high energetic needs
  - high consumption rates

Introduction

- San Francisco Bay Fish Populations:
  - native fish species
    - currently decreasing
  - seasonal fishes
  - transient fishes
  - intentionally introduced fish species
    - sport fishing
  - non-native invasive fish species
    - currently increasing

Introduction

- common traits of invasive species:
  - found more frequently in habitats modified by humans (TBIES 2003, 2005).
  - tolerate a wide range of environmental conditions
  - high dispersal capability
  - can be considered a measure of ecosystem health (Wang and Lyons, 2003)

Introduction

The Diet of Harbor Seals in San Francisco Bay

- last studied - Torok (1994)
- Feb 1991-Jan 1992
- South SFB
- 14 species of fish
- 1 species of cephalopod
- 0 Salmon
- 1 shrimp
- 5 species made up 86% of biomass

Species	Percent by Number
Yellowfin Goby	54.4
Northern Anchovy	5.4
Staghorn Sculpin	4.2
Plainfin Midshipman	4.1
White Croaker	2.0
Jacksmelt	0.8

Torok studied the South Bay exclusively

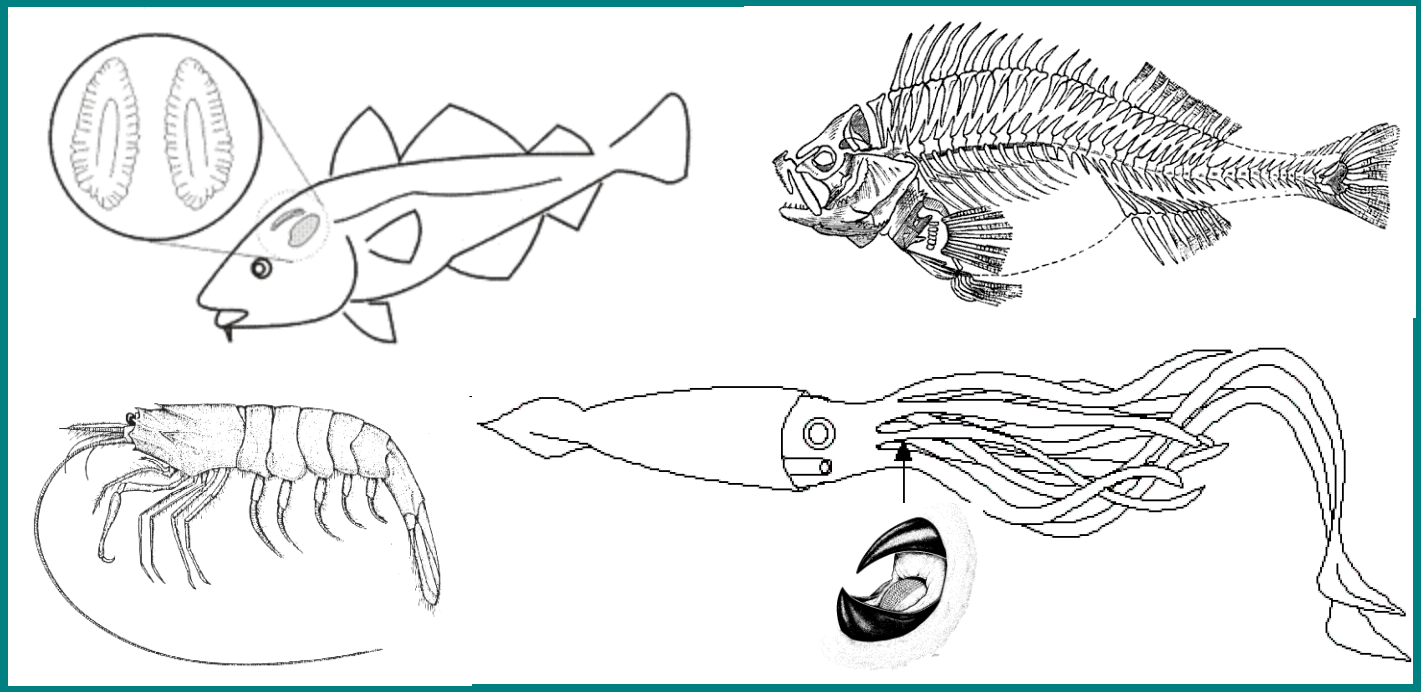
What did I expect?

1. The diet would vary by location (North SFB, South SFB).
2. Diet would change since last studied by Torok (1994).
3. There would be an increase of non-native invasive fish species.

Methods

- Scat Collection
  - Five Haul-out Locations
  - Sampled twice each month
  - Sampled from July 2007-July 2008

- otoliths
- bones
- beaks
- tails



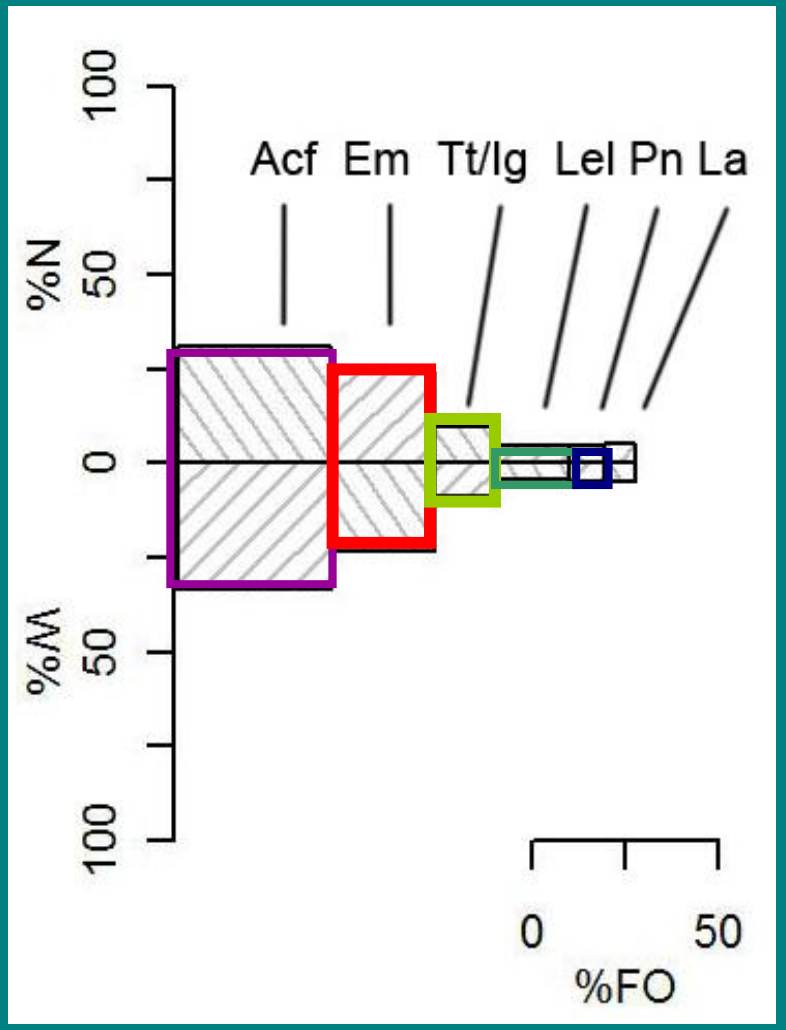
all-structures technique

Methods

- Statistical Means:
  - Index of Relative Importance:

(%N + %M) * %FO = IRI

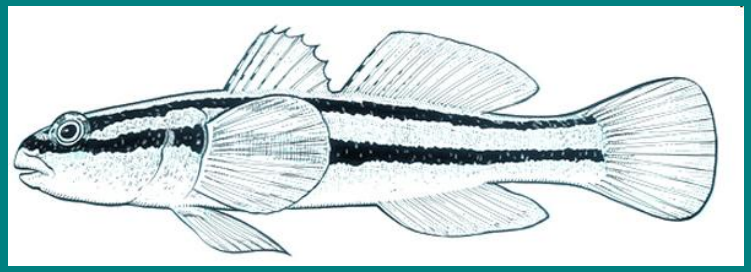
  - Spearman Rank Correlations
    - used to compare between two sets of data
  - CDFG trawl data

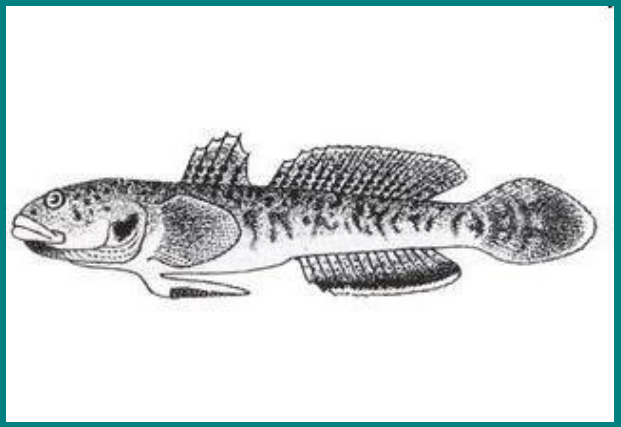


What did I find?

Results

- of 422 scats, 268 (63%) contained hard parts
  - 127 were from South SFB
  - 141 were from North SFB
- 22 species of fish & one species of crustacean
- Chameleon/Cheekspot Gobys found
  - grouped conservatively
- zero cephalopod beaks





Results - Most Important Species based upon IRI

Yellowfin Goby

Northern Anchovy

Bay Goby

Plainfin Midshipman

Staghorn Sculpin

Cheekspot/Chameleon Goby

Crangonid

White Croaker

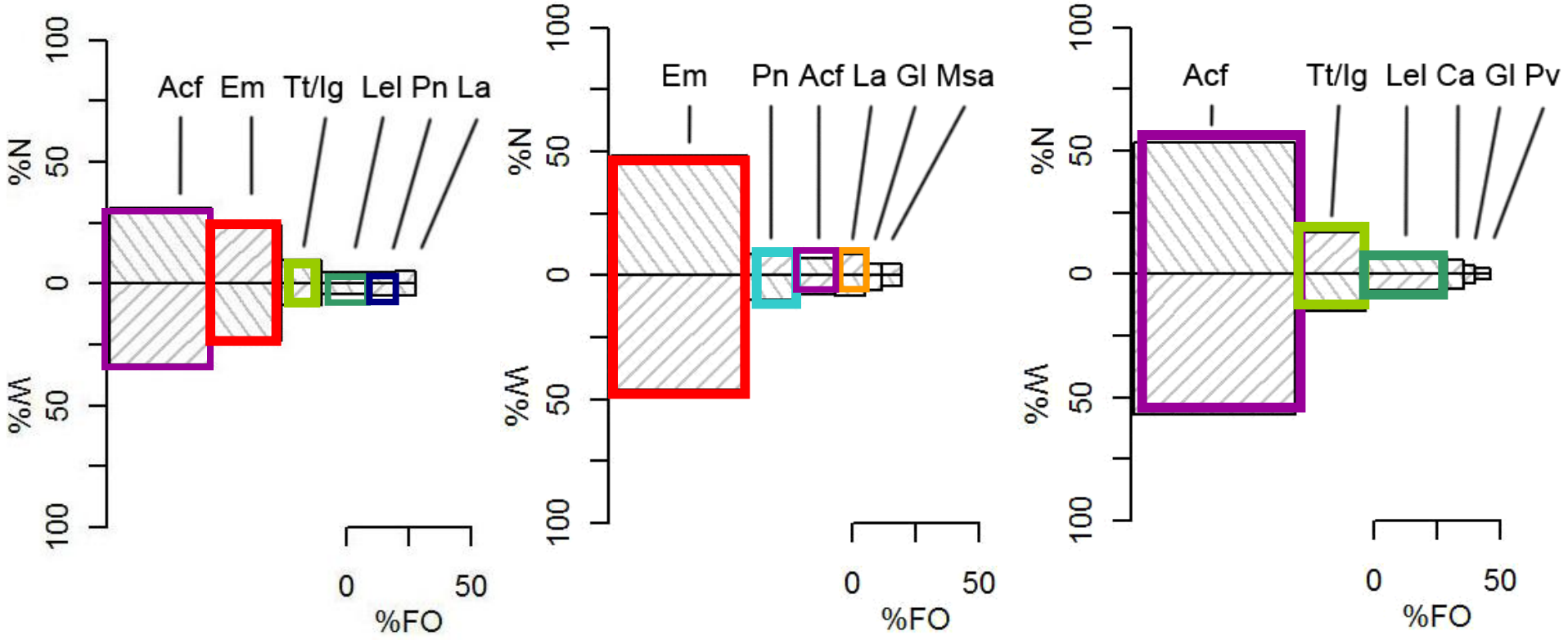
Shiner Surfperch

What did I expect?

1. The diet would vary by location (North SFB, South SFB)

Results - Difference in Diet by Location

Combined Locations **North Bay Locations** **South Bay Locations**



- Ca – Shiner Perch
- Acf – Yellowfin Goby
- Pn – Plainfin Midshipman
- La – Staghorn Sculpin
- Pn – Plainfin Midshipman
- Tt/Ig – Chameleon/Cheekspot Goby
- Lel – Bay Goby
- Em – Northern Anchovy

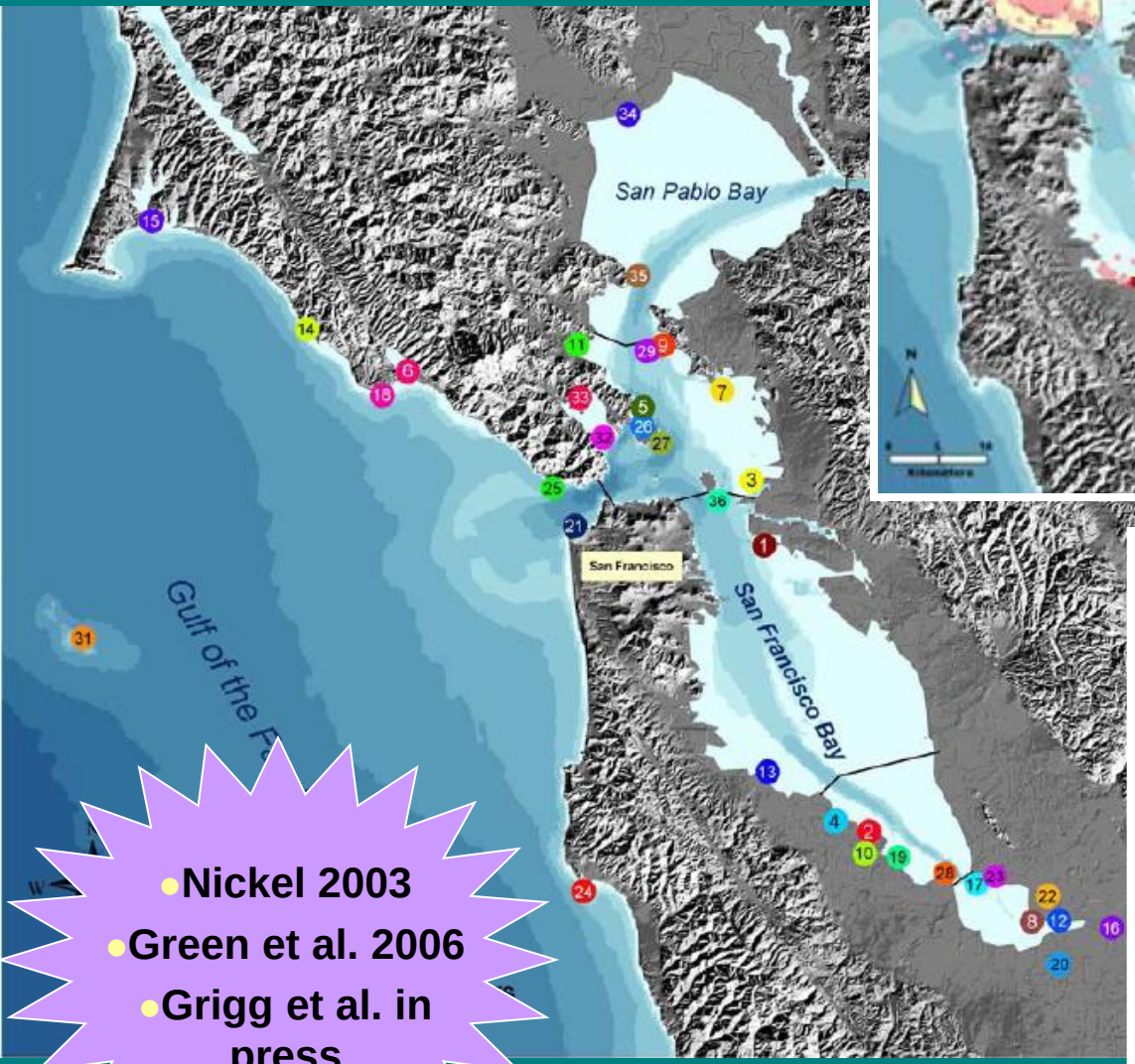
Difference in Diet by Location

- Spearman Rank correlations confirmed the diet between locations was not correlated ($P > 0.05$).
- IRIs indicated a change in diet between locations.

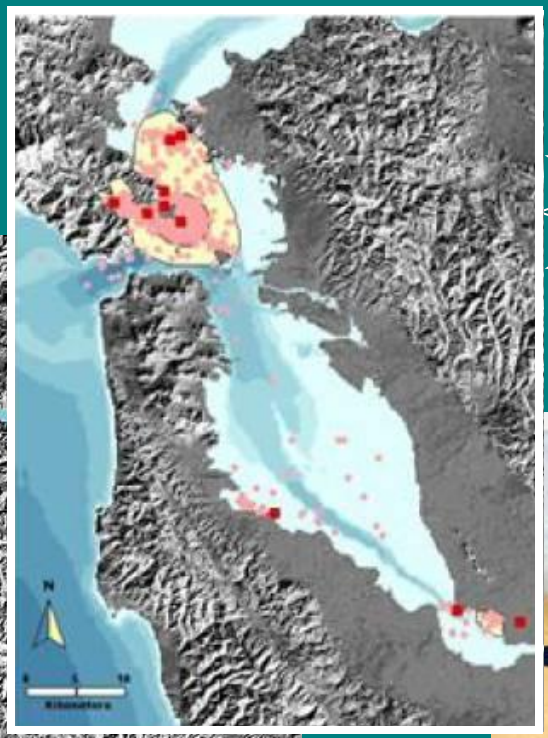
Difference in Diet By Location

- harbor seals exhibit:
  - regional foraging
    - with extended trips to other parts of the bay
    - with extended trips to the outer coast
  - foraging plasticity
  - prey following
- Because there is a change in diet between different bay locations:
    - all major haul-out areas should be examined
    - combining locations misleads interpretation

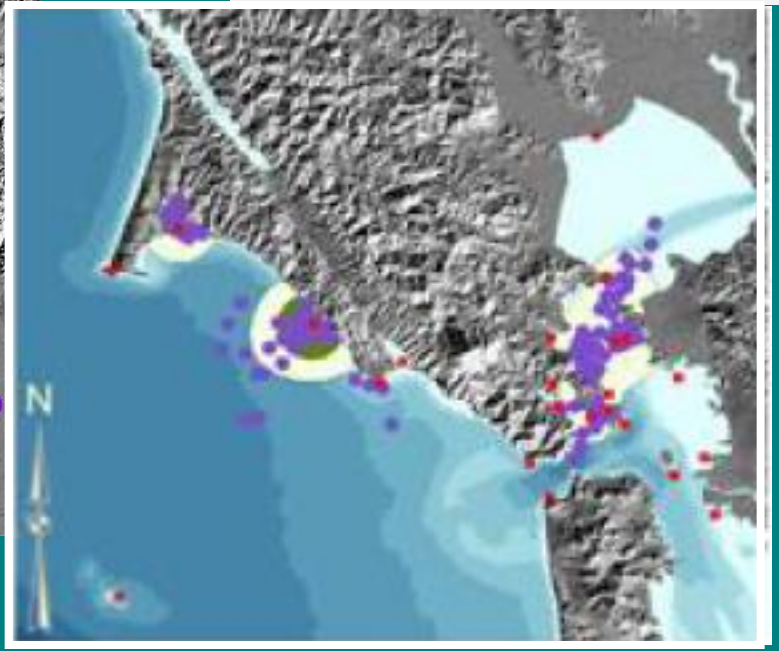
Discussion - Location Differences



- Nickel 2003
- Green et al. 2006
- Grigg et al. in press



Harbor seal movements highlighted by radio tagging studies



What did I expect?

1. The diet would vary by location (North SFB, South SFB)
2. Diet would change since last studied by Torok (1994).
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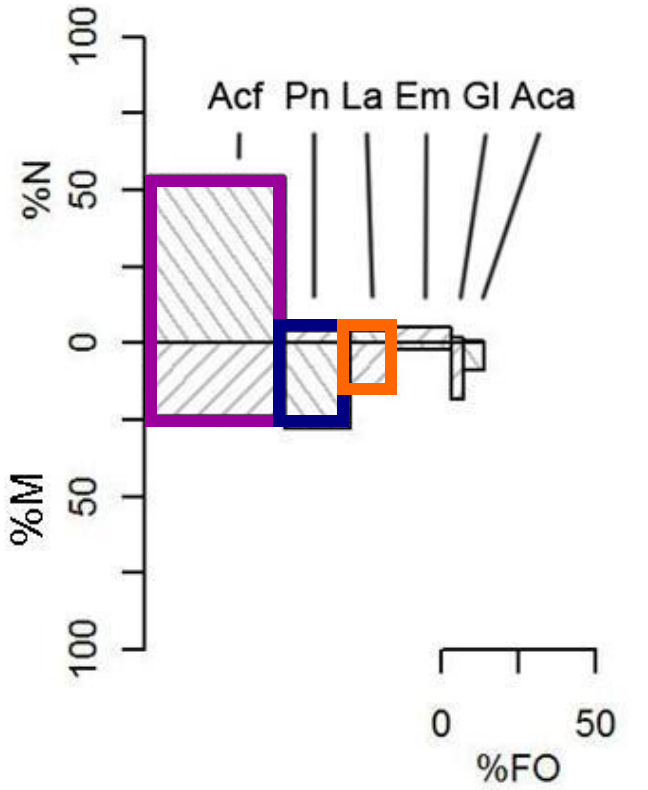
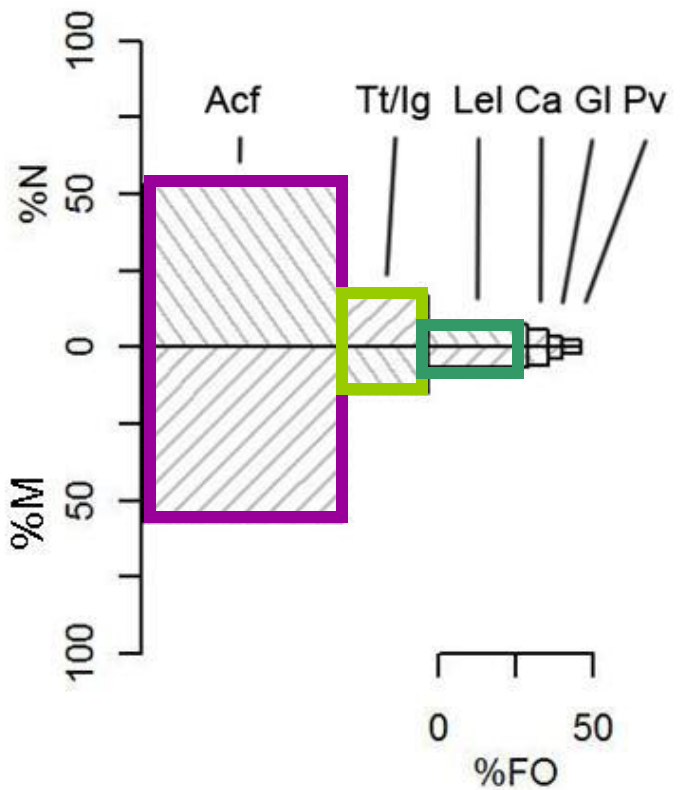
Diet Differences, Invasive Increases

Torok 1991/1992 All Seasons



Gibble 2007/2008 South SFB
All Seasons



- **Acf – Yellowfin Goby**
- **Pn – Plainfin Midshipman**
- **La – Staghorn Sculpin**
- **Tt/lg – Chameleon/Cheekspot Goby**
- **Lel – Bay Goby**

Diet Differences, Invasive Increases

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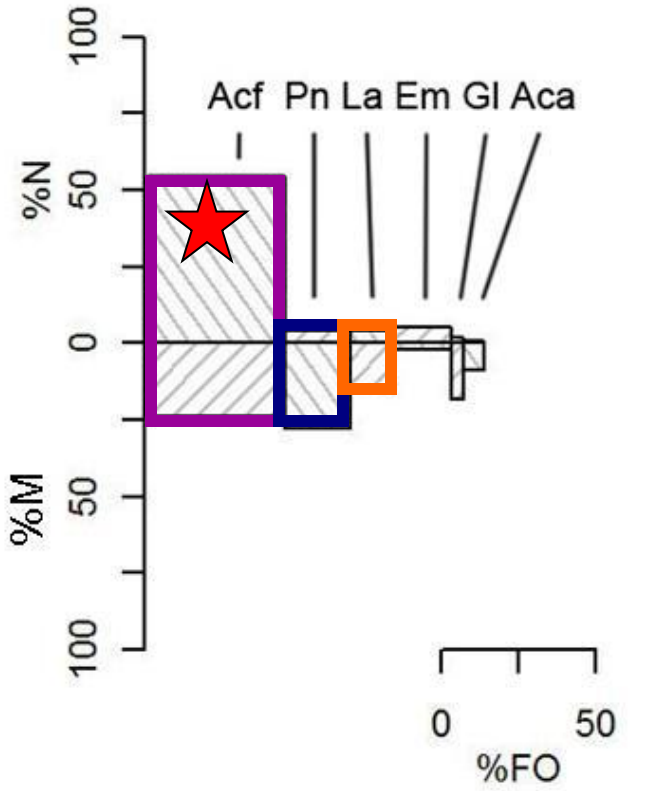

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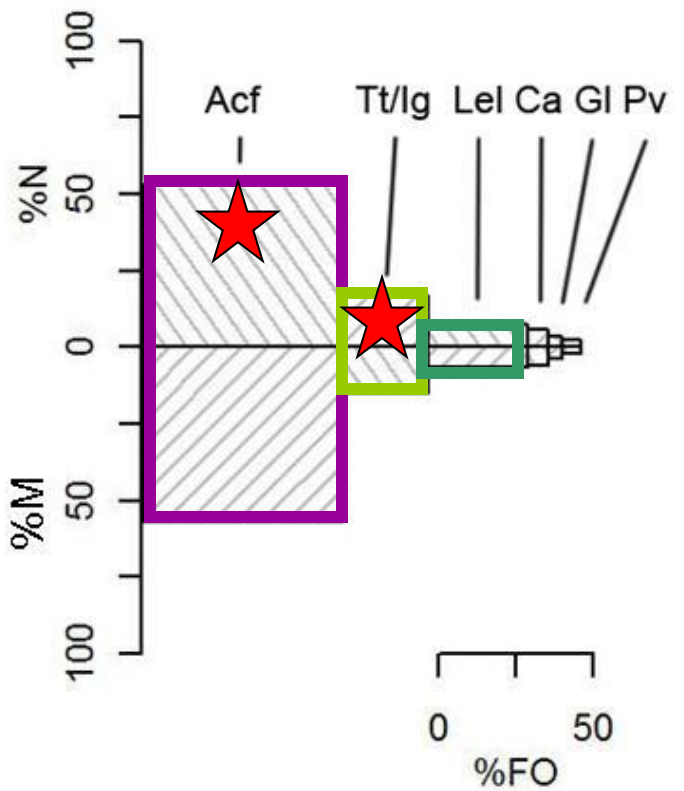

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Diet Changes, Invasive Increases

- IRIs indicated a difference in diet between Torok's study and my study.
- Spearman Rank Correlation indicated no correlation ($P > 0.05$).
- IRIs indicated an increase in non-native invasive species in the diet.
- Trawl data confirmed an increase of non-native invasive species in San Francisco Bay.

Diet Changes, Invasive Increases

- The number of scats containing identifiable prey hard parts decreased:
  - Torok - 71.2% (215 collected 153 w/hard parts)
  - Gibble South Bay – 55% (230 collected 127 w/hard parts)
- A decrease in prey contained in each scat may be suggestive of:
  - decrease in available prey
  - decrease in prey per meal
  - increase in species without hard parts

Diet Changes, Invasive Increases

- Non-native invasive species became more important in the diet of seals.
- Two new species of Asiatic gobies in CDFG Trawls
  - Shimofuri Goby (*Tridentiger bifasciatus*)
  - Shokihaze Goby (*Tridentiger barbatus*)
  - These species have not yet been found in the diet of harbor seals within the bay.
- The increase in gobies may be indicative of ecosystem degradation.

Increase in Non-native Invasive Species

- The reliance of harbor seals on invasive species may result in a decrease in nutritional health for harbor seals.
- Gobies generally are nutritionally less rich than some native species in SFB.
  - Round Goby (*Neogobius melanos*) 1.5 kcal/g
- Many native species in SFB have a greater energy content.
  - Pacific Herring - 6.6kcal/g (Perez 1994),
  - Northern Anchovy - 4.8 kcal/g (Petza et al. 2006)
  - Starry Flounder - 4.1 kcal/g (Ball et al. 2007).

Increase in Non-native Invasive Species

- A “junk-food” diet may cause:
  - decrease in size
  - muscle impairment
  - vital organ failure
  - extended foraging trips
  - pup abandonment
    - (Rosen and Trites 2000)

- Harbor seal pup abandonment an issue in SFB

Conclusions

- Knowledge of harbor seal diet provides a better understanding prey species diversity and abundance in SFB.
- Invasive species may be increasing in the bay and this may represent depressed ecosystem health.
- Harbor seal health may be compromised if there is decreased local prey availability and low food quality.
- Parental care and reproduction may decline if more time is spent acquiring food resources.
- If harbor seal populations in the bay decline, their positive impacts may correspondingly decrease.

Acknowledgements

- CDFG's San Francisco Bay Study and the Interagency Ecological Program for the San Francisco Estuary & Kathy Hieb.
- Jim Harvey, MLML Mammal Lab and Sampling Volunteers
- Funding:
  - SJSU Harvey Ecology Scholarship
  - SJSU Archimedes Scholarship
  - Meyers Trust Grant
  - Packard Foundation Grant

Questions?

Photo: Aric Crab

Index of Relative Importance

(%N + %M) * %FO = IRI

$$\%N_i = 100 \bullet \frac{N_i}{\sum_{i}^{j} N}$$

where the number of prey in a sample (Ni) was divided by the sum of all prey, *i* to *j*, and then multiplied by 100 to yield a percentage

$$\%M_i = 100 \bullet \frac{M_i}{\sum_{i}^{j} M}$$

where the mass of prey in a sample (Mi) was divided by the sum of all prey, *i* to *j*, and then multiplied by 100 to yield a percentage

$$FO_i = \frac{\sum_{k-1}^{s} O_{ik}}{s}$$

Where *Oi* = 0 if taxon *i* is absent in fecal *k*
1 if taxon *i* is present in fecal *k*
s = total number of fecal samples that contained prey

Spearman Rank Correlation

- data is ranked by %IRI
- used to compare between two sets of data
- the following equation is applied to the rank:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n^3 - n}$$

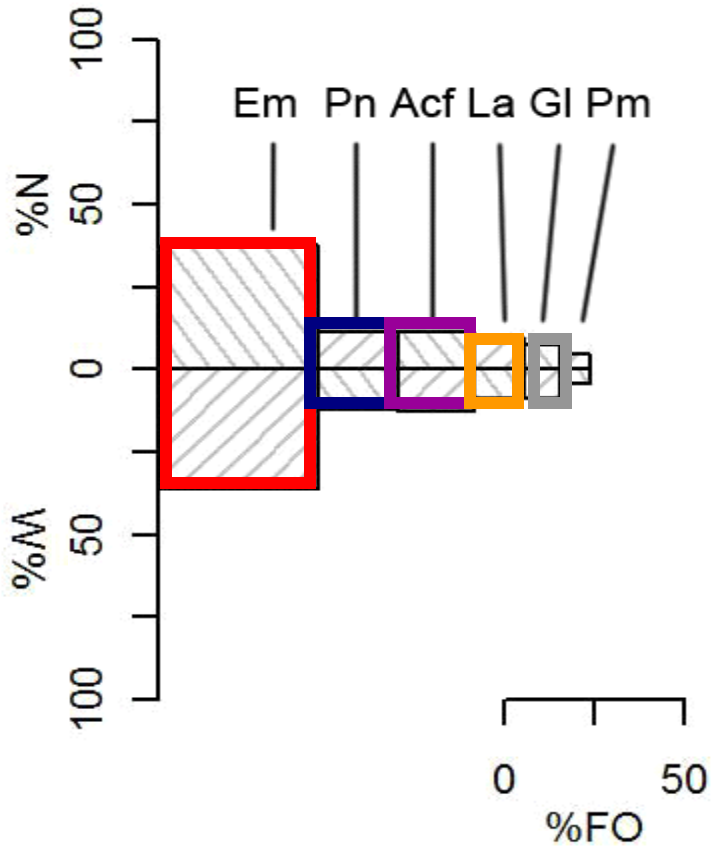
where:

d_i = a difference between X and Y ranks

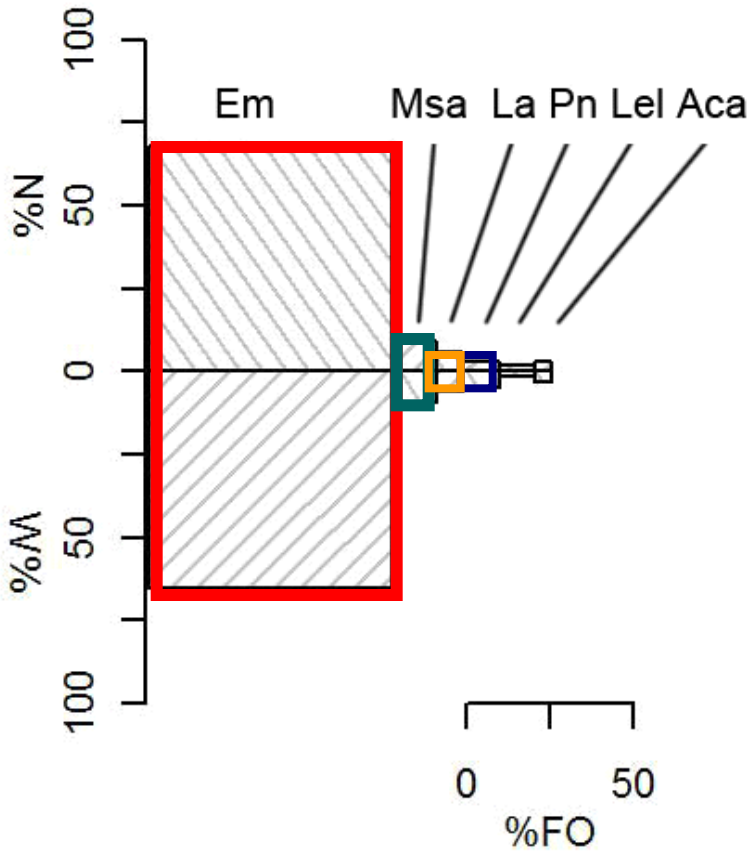
- The significance of r_s is assessed by printed statistical tables of critical values.

Results – Seasonal Differences

North SFB Non-Pupping Season



North SFB Pupping Season



Acf – Yellowfin Goby

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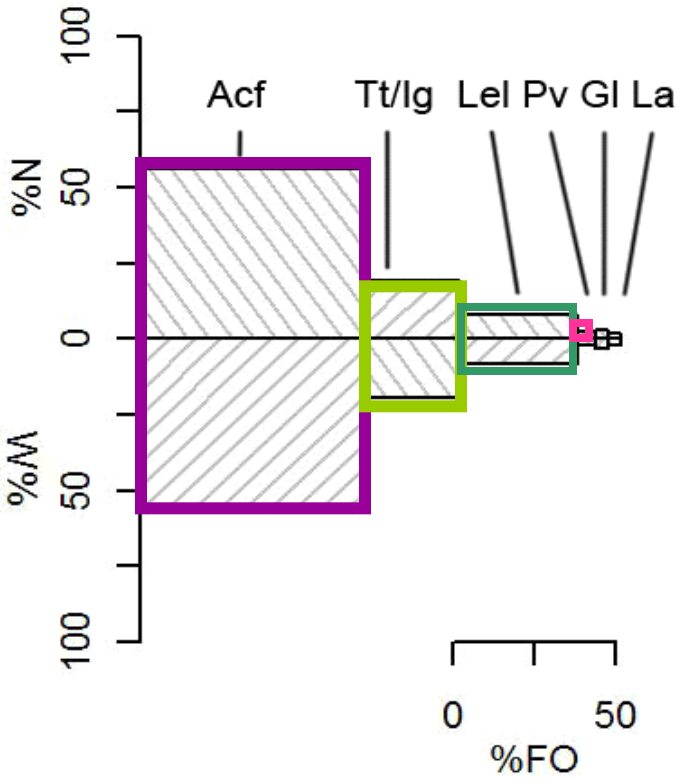
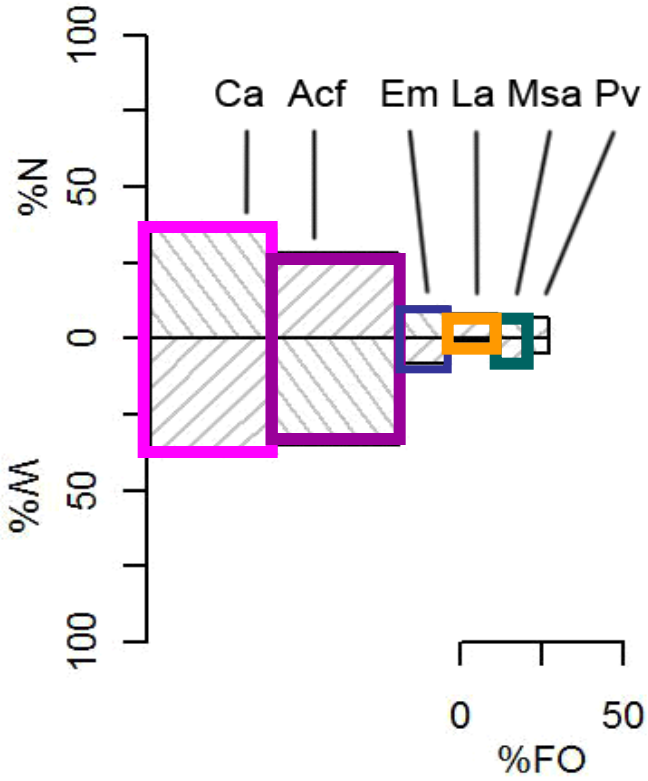
Gl – White Croaker

Results – Seasonal Differences

South SFB Non-Pupping Season



South SFB Pupping Season



- La – Staghorn Sculpin
- Ca – Shiner Surfperch
- Acf – Yellowfin Goby
- Tt/lg – Chameleon/Cheekspot Goby
- Pn – Plainfin Midshipman
- Lel – Bay Goby
- Pv – English Sole
- Em – Northern Anchovy
- Msa – Striped Bass
- Gl – White Croaker

Results - Hypothesis 2

- Spearman Rank Correlations found no correlation between season ($P > 0.05$).
- IRIs indicated a change in diet between the pupping and the non-pupping season.

Discussion – Seasonal Differences

Torok (1994) also found a dietary difference between seasons

- Females:
  - indicate strong homing behavior during pupping (Thompson 1993, Nickel 2003, Green et al. 2000).
  - nurse pups for ~ four weeks (Reeves et al. 2002)
  - restrict their movements in the early portion of lactation.
  - later in the lactation period they make occasional foraging trips with pups. (Van Parijs et al. 1997, Bowen et al. 2001, Boness et al. 2006).

Discussion - Seasonal Differences

- Prey species that were most important during the pupping season were also most available based on comparison with CDFG trawl data.
- North SFB
  - diet of non-pupping season more varied
- South SFB
  - increase in Shiner Surfperch during pupping season
    - timing correlates with spawning activity
    - spawn in shallow environments like South SFB