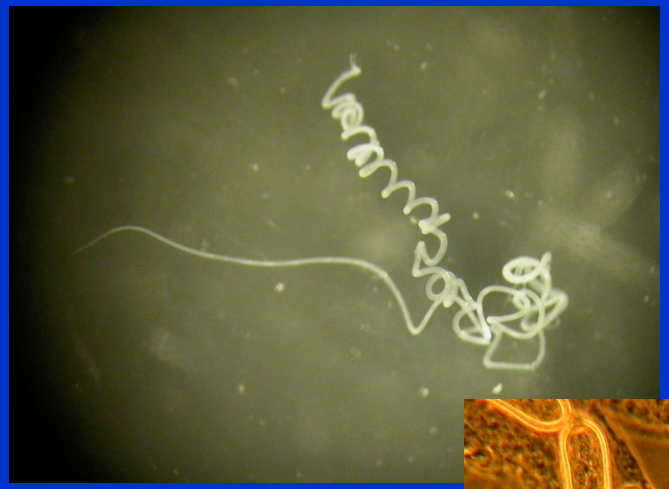
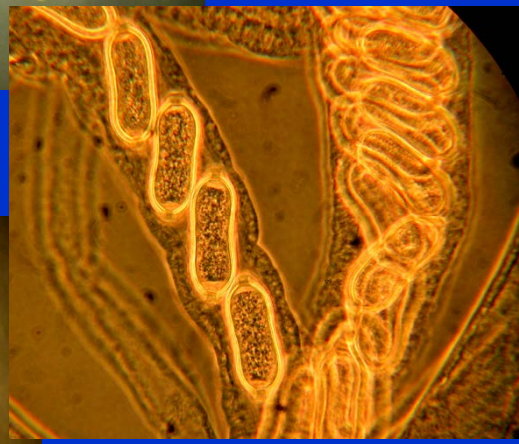
Parasite analysis

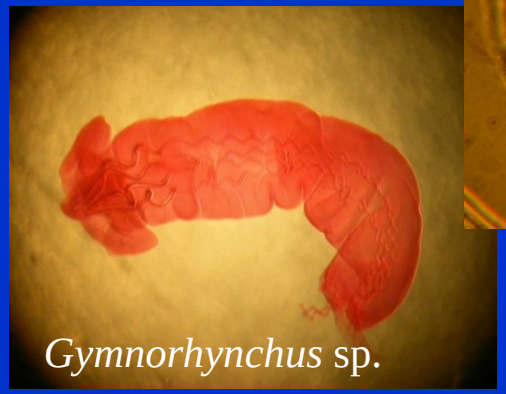
20 thresher/20 blue spiral valves - 2011/2012 -bio-tags-

Parasite species	Host	Host
Prosobothrium armigerum	**Blue**	
Anthobothrium laciniatum	**Blue**	
Paraorygmatobothrium prionacis	**Blue**	
Platybothrium auriculatum	**Blue**	
Unid. *Phyllobothriid*	**Blue**	
Gymnorhynchus sp.	**Blue**	**Thresher**
Acanthocelius sp.	**Blue**	
Cestode fragments	**Blue**	
Gymnorhynchus sp.	**Blue**	
Paraorygmatobothrium exiguum		**Thresher**
Lacistorhynchus tenuis		**Thresher**
Anisakis sp. larvae		**Thresher**
Hysterothylacium incurvum		**Thresher**
***Piscicapillaria* sp.**		**Thresher**
Rhadinorhynchus cololabis		**Thresher**
Pennella remains		**Thresher**

Piscicapillaria sp. could a new species of nematode in threshers. Awaiting confirmation from experts. (Ralph Appy, Cabrillo Aquarium San Pedro and UCSB parasite group)







Gymnorhynchus sp.

Fish can become infected with a parasite only when they come within the endemic area of that parasite. The endemic area is that geographical region in which conditions are suitable for the transmission of the parasite.

Da qui…dove andiamo?
(Where do we go from here?)

Ecosystem-Based Management

"I have a DREAM" … "that all these diets won't just be famous recipes on *fish-food Network TV* but they will be employed towards ecosystem-based management and to promote sustainable fisheries"

Foraging data can be incorporated into Ecosystem-Based models:

- **NOAA IEA (Integrated Ecosystem Assessment)**
- **NOAA Atlantis Ecosystem Model**
- **Multispecies Fisheries Models**
- **Ecopath/Ecosim, new modeling software/programs**
- **…**

Some random ideas

In order to have a more defined picture of the food chain:

JOIN/ADD diet data efforts:

- Add new predator species: marine mammals/sharks/billfish (in progress, A. Preti)
- Diet data and SIA for bluefin/albacore/yellowfin/ opah/yellowtail (2007 on) (Owyn Snodgrass)
- Diet data for sea lions (20 or 30+ years) (Mark Lowry)
- CPS/Ichthyoplankton – data on prey distribution/abundance

More/easier collaboration/communication between FRD_PRD_AERD

- maybe future job/positions that overlap w/ the divisions
- ’THINK ECOSYSTEM’ – NOT ‘my little species’

Add/expand lab techniques

- SIA apply to more species/samples
- Fatty Acids (QFASA)

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QUANTITATIVE FATTY ACID SIGNATURE ANALYSIS: A NEW METHOD OF ESTIMATING PREDATOR DIETS

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- NEW! Diet analysis via meta-barcoding. A shotgun sequencing approach to simultaneously identify every prey in a predator's stomach.

  -DNA analysis of predator stomach contents-

  (Andrew Thompson/Dovi Kacev)

Thank You!
Questions? Feedback?!

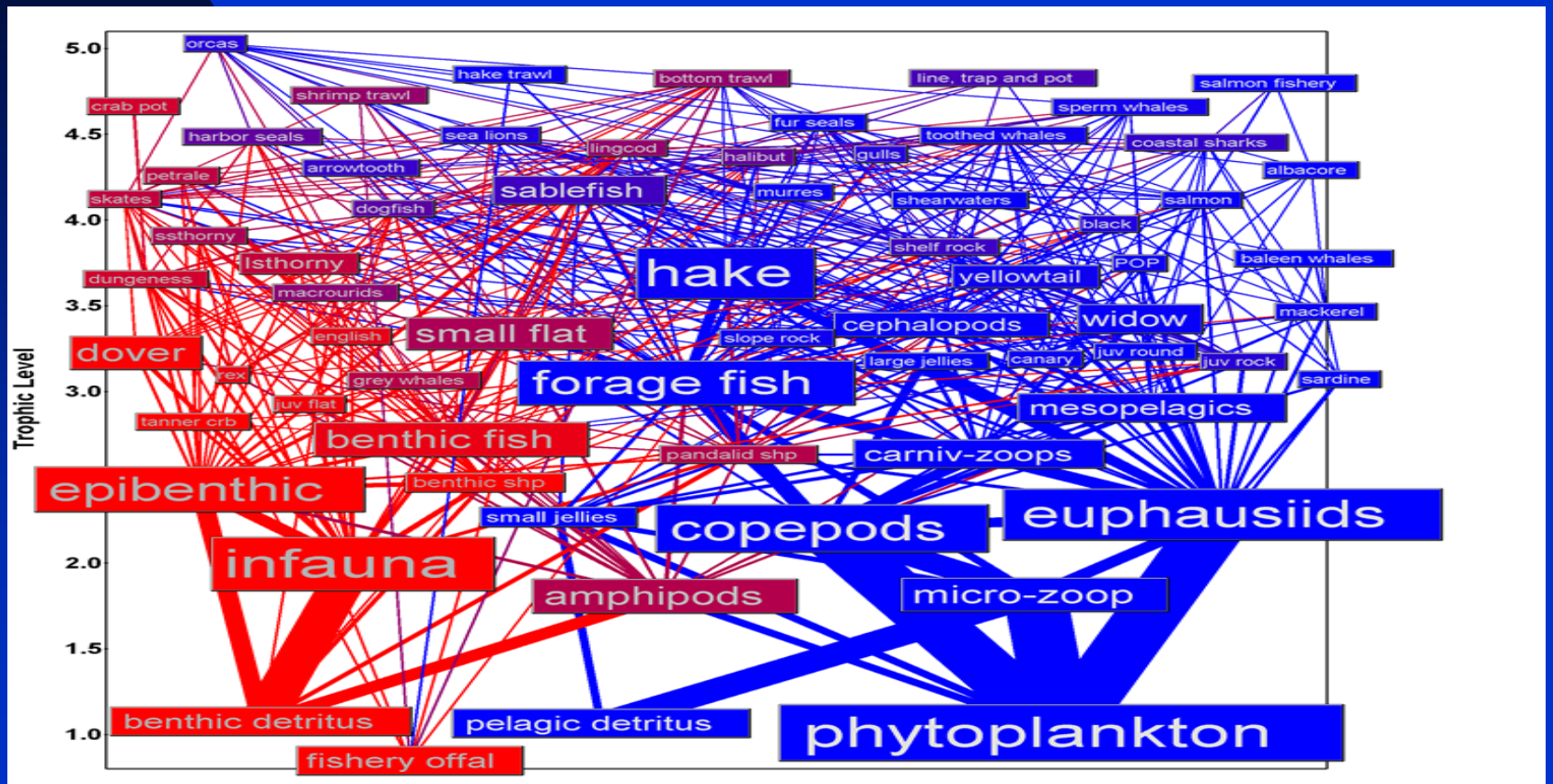


Image credits: John Field

THE END

Old slides follow

Mako	Blue	Thresher
Coastal and Oceanic		
Highly Migratory		
Migrate Vertically		
Few diet studies and anecdotal accounts--- mackerel, bonito, anchovy, tuna, other sharks, squid, marine mammals, and marlin	anchovy, jack mackerel, hake, flatfishes, dogfish, squids and pelagic crustaceans including euphausiids	northern anchovy, coastal pelagic fish, Pacific hake and market squid -- diet more diversified during 1998 El Niño

Background

Previous studies:

- **do not provide quantitative information on the diet compositions of these sharks concurrently and in a single eco-region**

- **suggest considerable diet variation but temporal and spatial patterns are unclear underscoring the need for a more comprehensive study**

Questions

How do the trophic niches of these 3 sharks compare?

- ***What are their main prey?***
- ***How much overlap is there between species?***

Where do they fall along the generalist / specialist continuum?

- ***How diverse is their diet?***
- ***How do they respond to novel prey?***

Study System

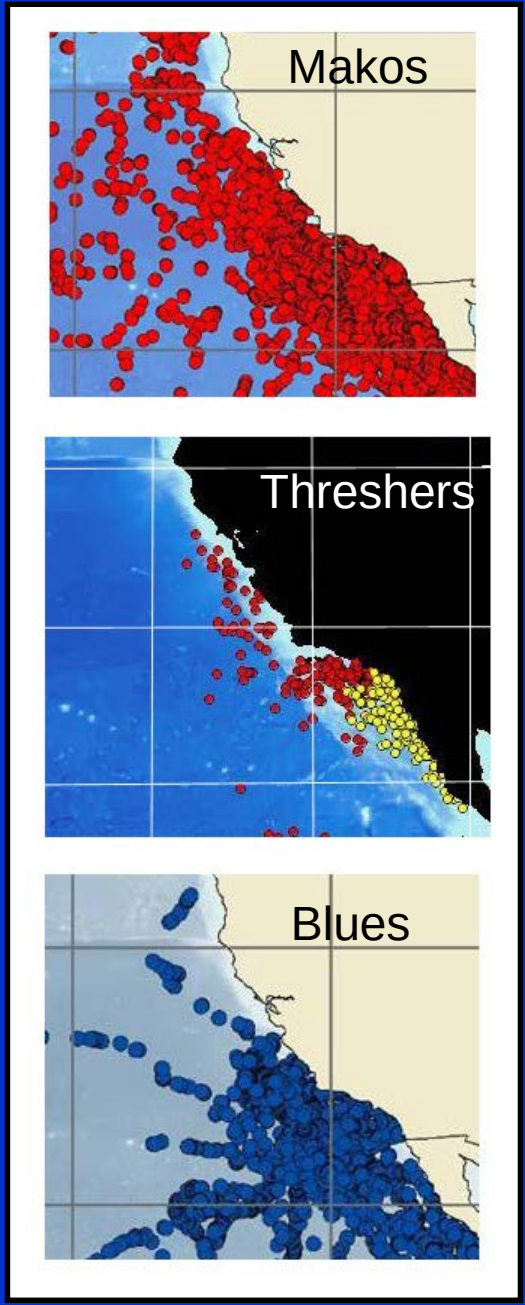
Distribution is overlapping off the U.S. West Coast

West coast drift gillnet fishery

- **Thresher and mako: incidental non-target species**
- **Blue: discarded bycatch species**

Important species in the food web

- **Ecosystem management**
- **Effects on other commercially important species**



SWFSC/TOPP/CICESE tracking data

Approach

Examine the foraging ecology of these sharks in the California Current where they overlap in time and space

Describe, analyze and compare:

- relative importance of prey types
- richness, diversity and evenness of diets
- dietary overlap
- diet variation by size, year, sex and subregion

Methods

Stomach samples were collected by federal fishery observers aboard commercial drift gillnet vessels

Sharks were caught during seven fishing seasons, August-January, 2002-08

Laboratory procedure

Analytical Methods

Relative Measures of Prey Quantity:

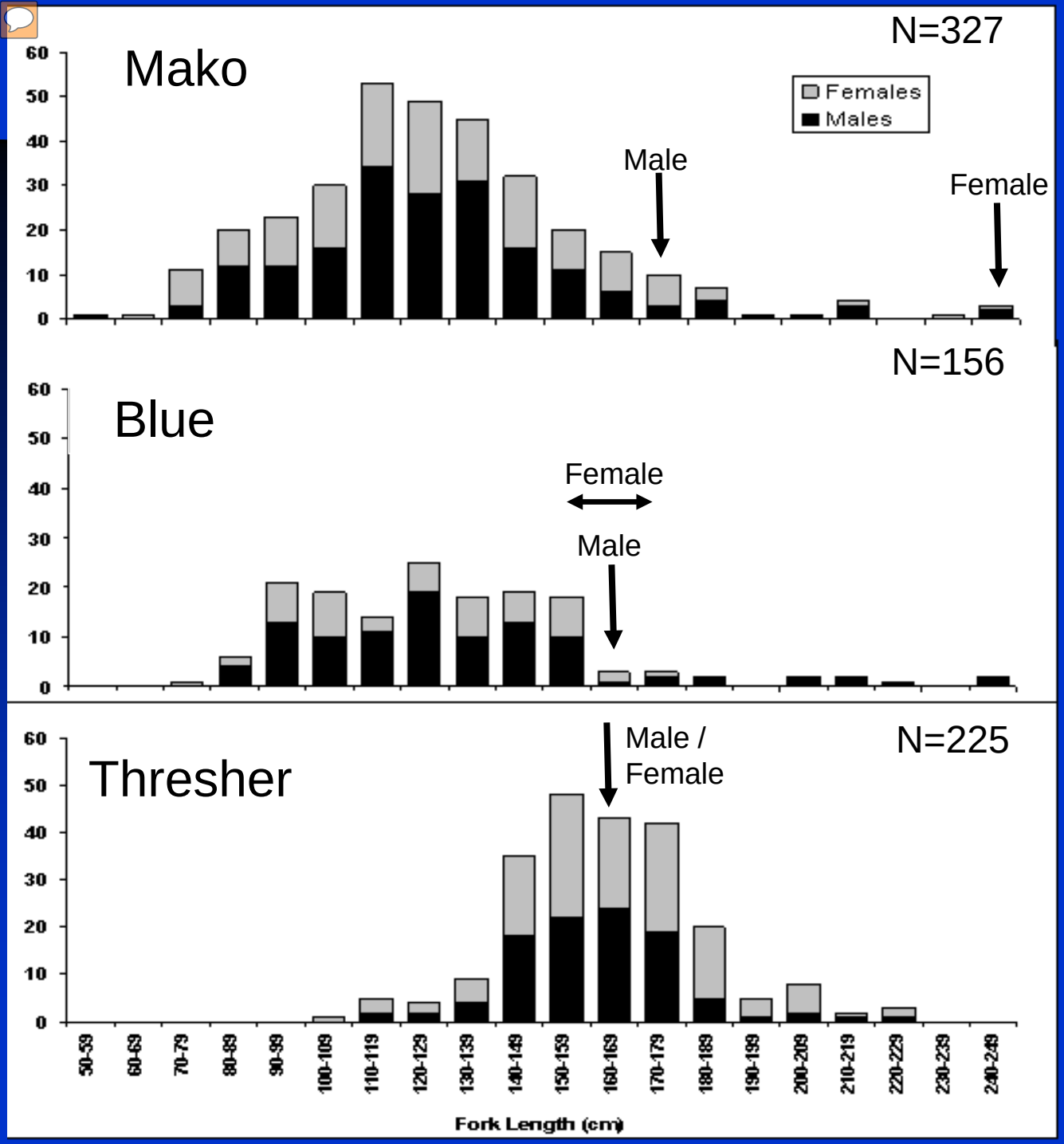
- Numeric Occurrence
- Weight
- Frequency of Occurrence

Univariate analysis methods:

- Importance of Prey: GII (Geometric Index of Importance)
- Rarefied Richness
- Diversity: Simpson (Evenness)
- Similarity: Sorensen

Multivariate analysis methods:

- ANOSIM (Analysis of Similarity)



Maturity:
M (174 cm FL)
F (249 cm FL)

Sample range:
53 to 248 cm FL

Maturity:
M (167 cm FL)
F (153-174 cm FL)

Sample range:
76 to 248 cm FL

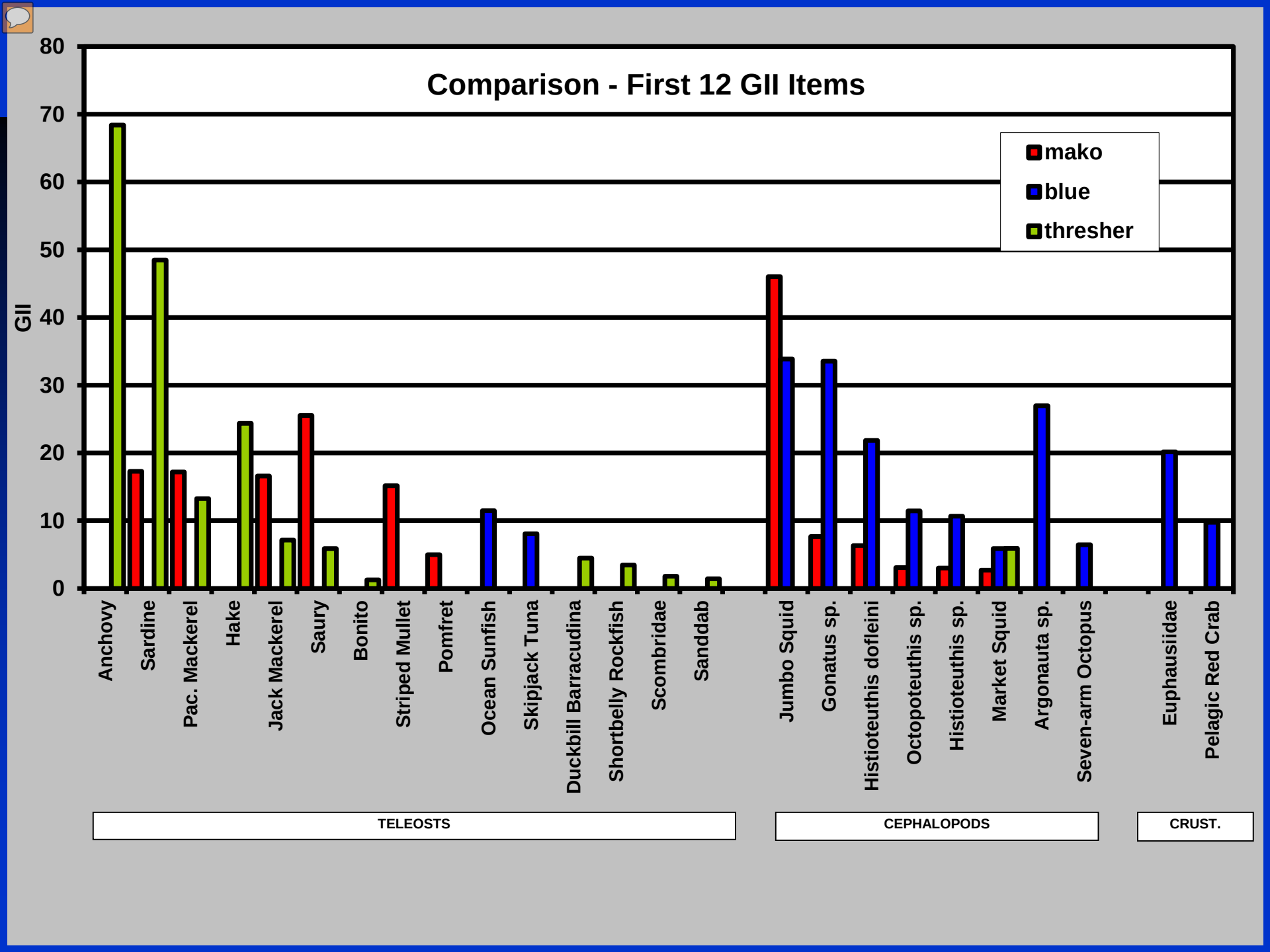
Maturity:
M & F (160 cm FL)

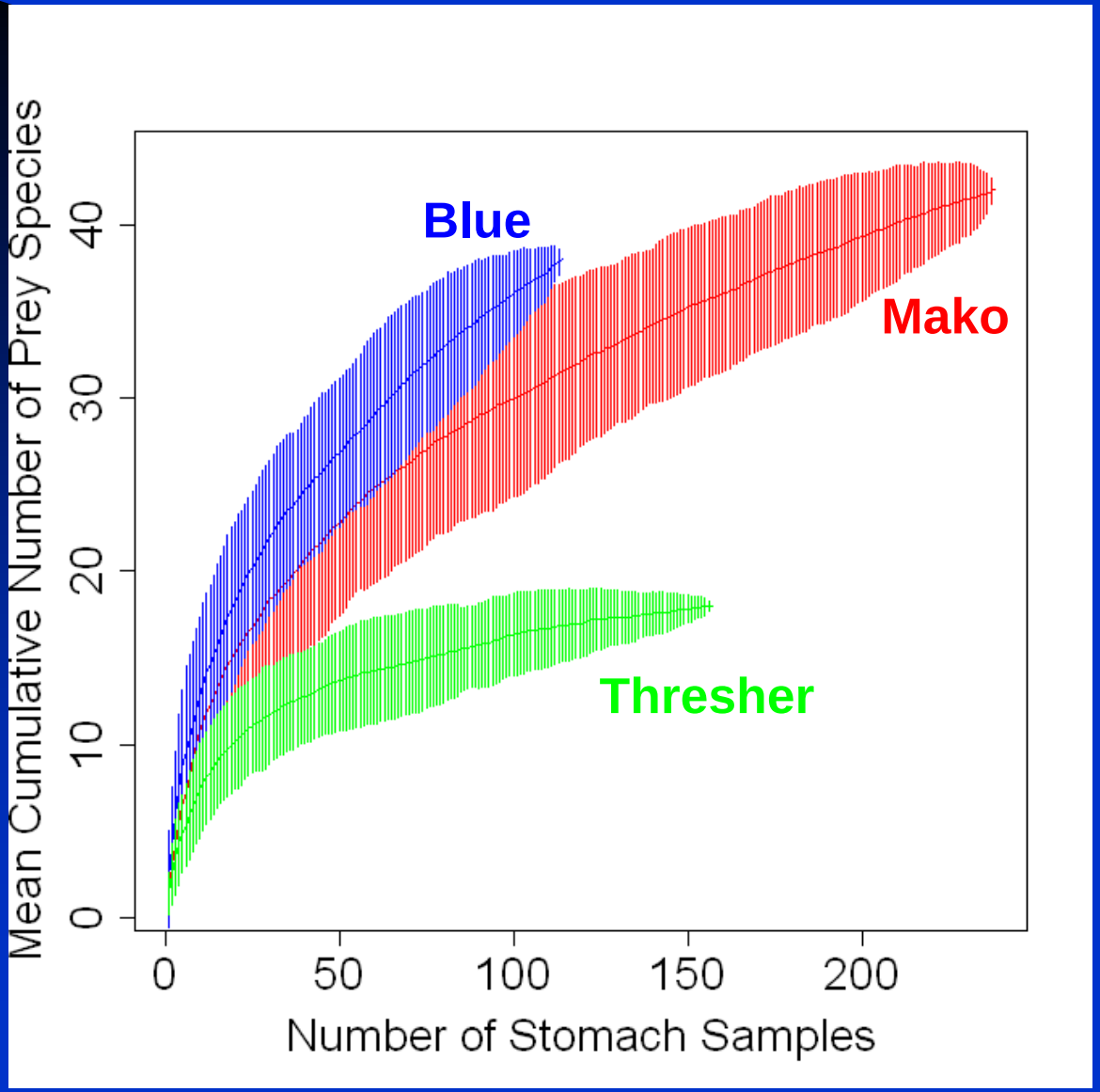
Sample range:
108 to 228 cm FL

Results: GII

	Mako	Blue	Thresher
stomachs	330 stomachs 238 w / food (72%)	158 stomachs 114 w / food (72%)	225 stomachs 157 w / food (70%)
prey taxa	43	38	18
rank 1	Jumbo squid (GII=46.03)	Jumbo squid (GII=33.86)	N. anchovy (GII=68.40)
rank 2	Pacific saury (GII=25.54)	*Gonatus* spp. (GII=33.56)	Pacific sardine (GII=48.49)
rank 3	Pacific sardine (GII=17.28)	*Argonauta* sp. (GII=26.97)	Pacific hake (GII=24.38)
rank 4	Pac. mackerel (GII=17.20)	*Histioteuthis dofl.* (GII=21.86)	Pac. mackerel (GII=13.27)
rank 5	Jack mackerel (GII=16.60)	Euphausiidae (GII=20.16)	Jack mackerel (GII=7.14)
rank 6	Striped mullet (GII=15.18)	Ocean sunfish (GII=11.49)	Market squid (GII=5.93)

Almost all the prey found was identifiable to the species level with the exception of a few that were identified to the family level.

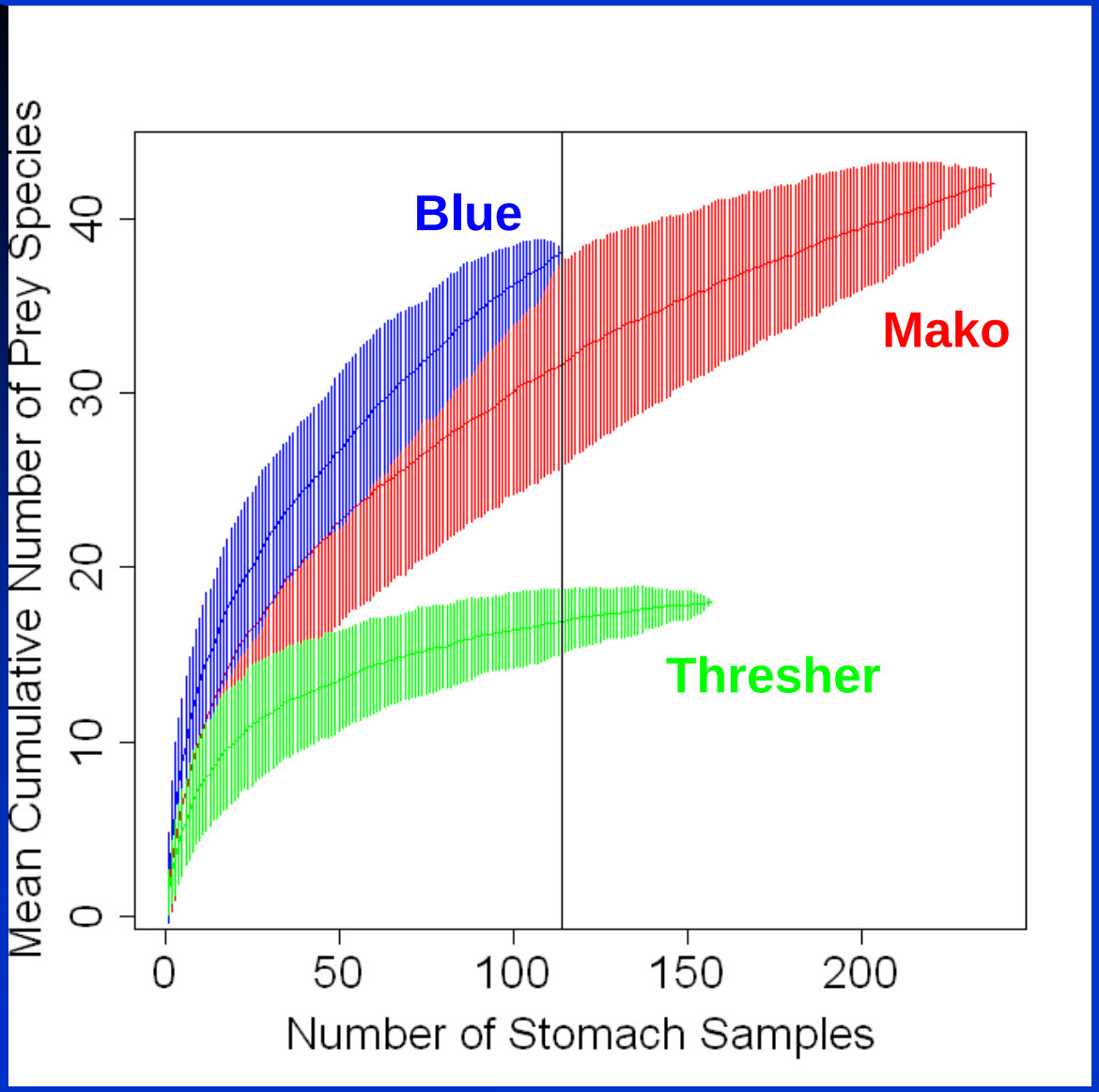

Comparison - First 12 GII Items
GII
0
10
20
30
40
50
60
70
80
mako
blue
thresher
Anchovy
Sardine
Pac. Mackerel
Hake
Jack Mackerel
Saury
Bonito
Striped Mullet
Pomfret
Ocean Sunfish
Skipjack Tuna
Duckbill Barracudina
Shortbelly Rockfish
Scombridae
Sanddab
Jumbo Squid
Gonatus sp.
Histioteuthis dofleini
Octopoteuthis sp.
Histioteuthis sp.
Market Squid
Argonauta sp.
Seven-arm Octopus
Euphausiidae
Pelagic Red Crab
TELEOSTS
CEPHALOPODS
CRUST.



Cumulative Prey Curve

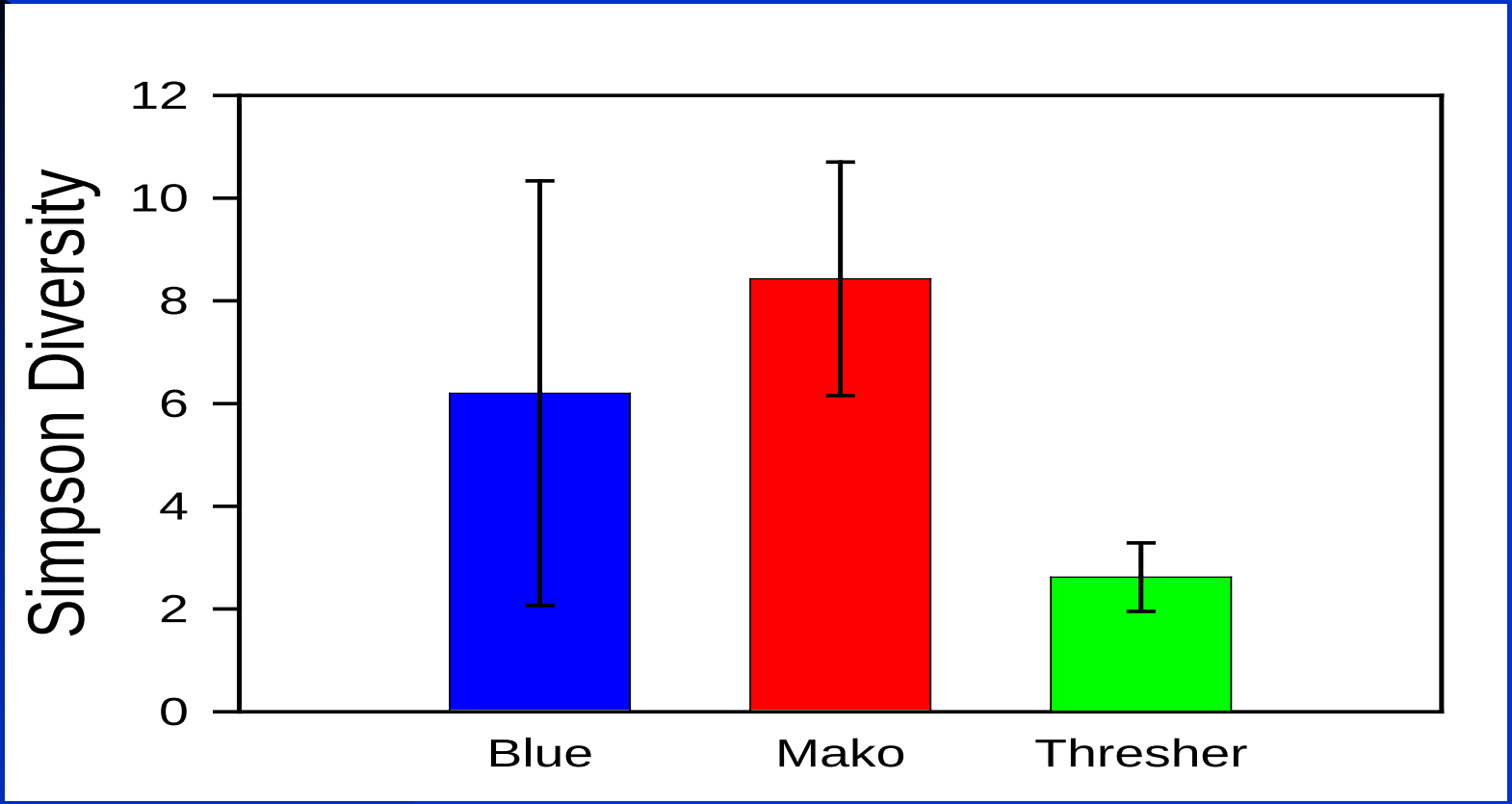
based on individual prey species

Is sample size adequate to fully describe the diet?



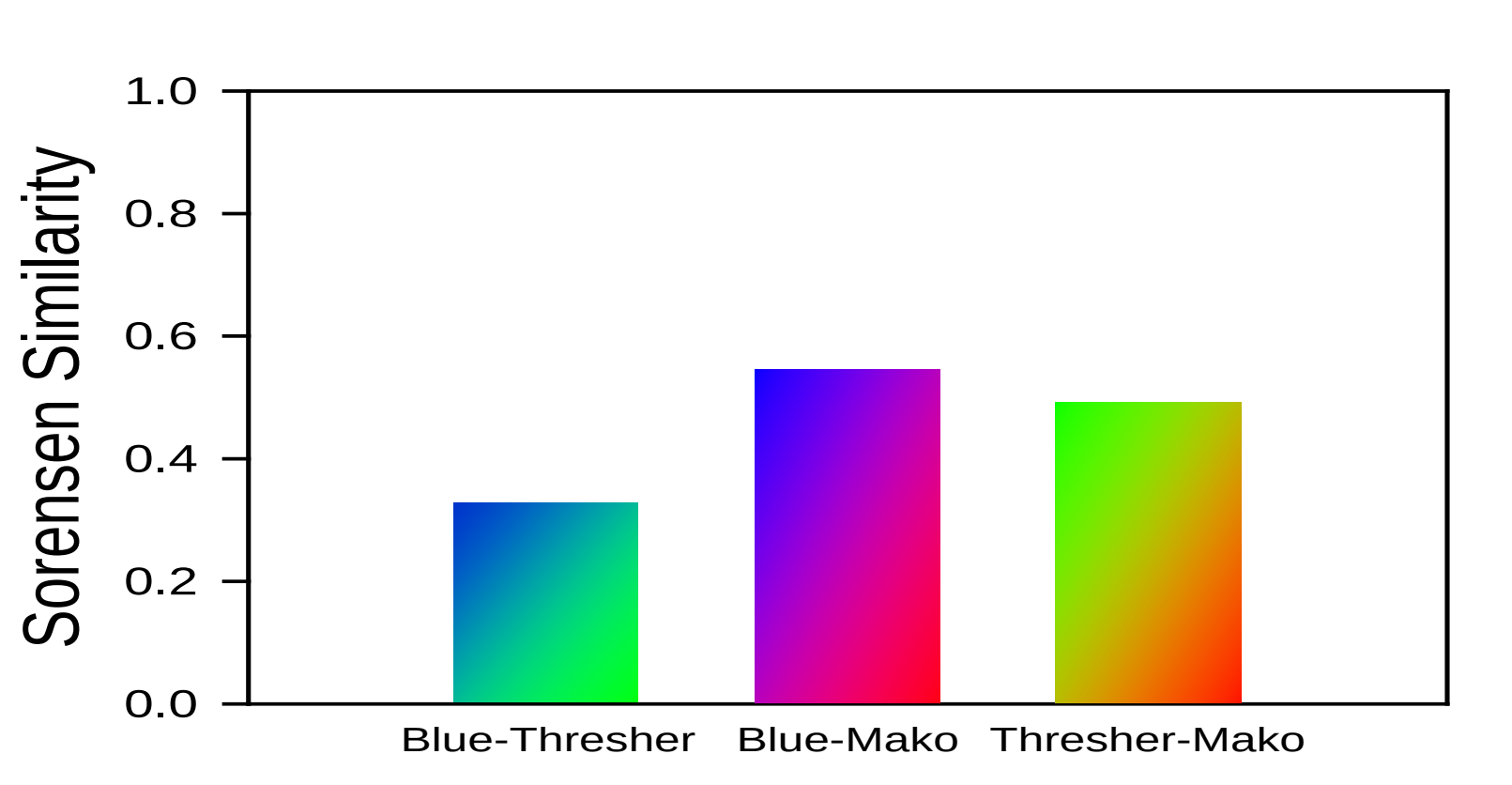
Rarefied Diet Richness

Results: Simpson diversity



Simpson diversity is influenced by the relative number of each prey taxa

Results: Sorensen similarity



Index range: 0-1

Sorensen similarity is based on presence and absence (in 2 predator species) of the same food type

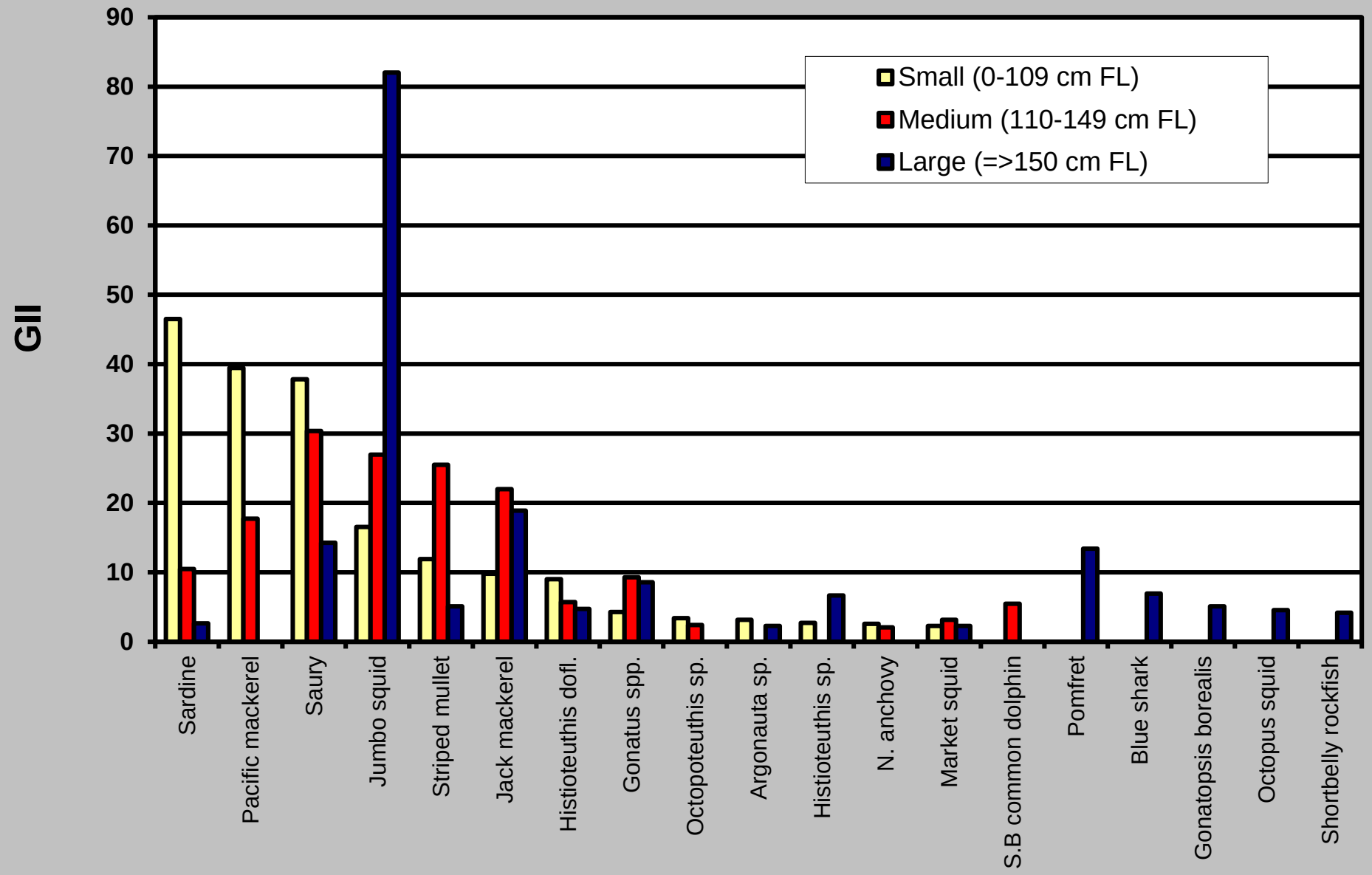
ANOSIM Results

Average among the 3 shark species

Comparison	Global R	p-value
Among Size Classes	0.03	< 0.001
Among Years	0.086	0.001
Between Regions	0.07	< 0.001
Between Sexes	0.006	0.131

Significant differences in diet, among size classes, among years, between regions, but not between sexes

Mako GII comparisons by size



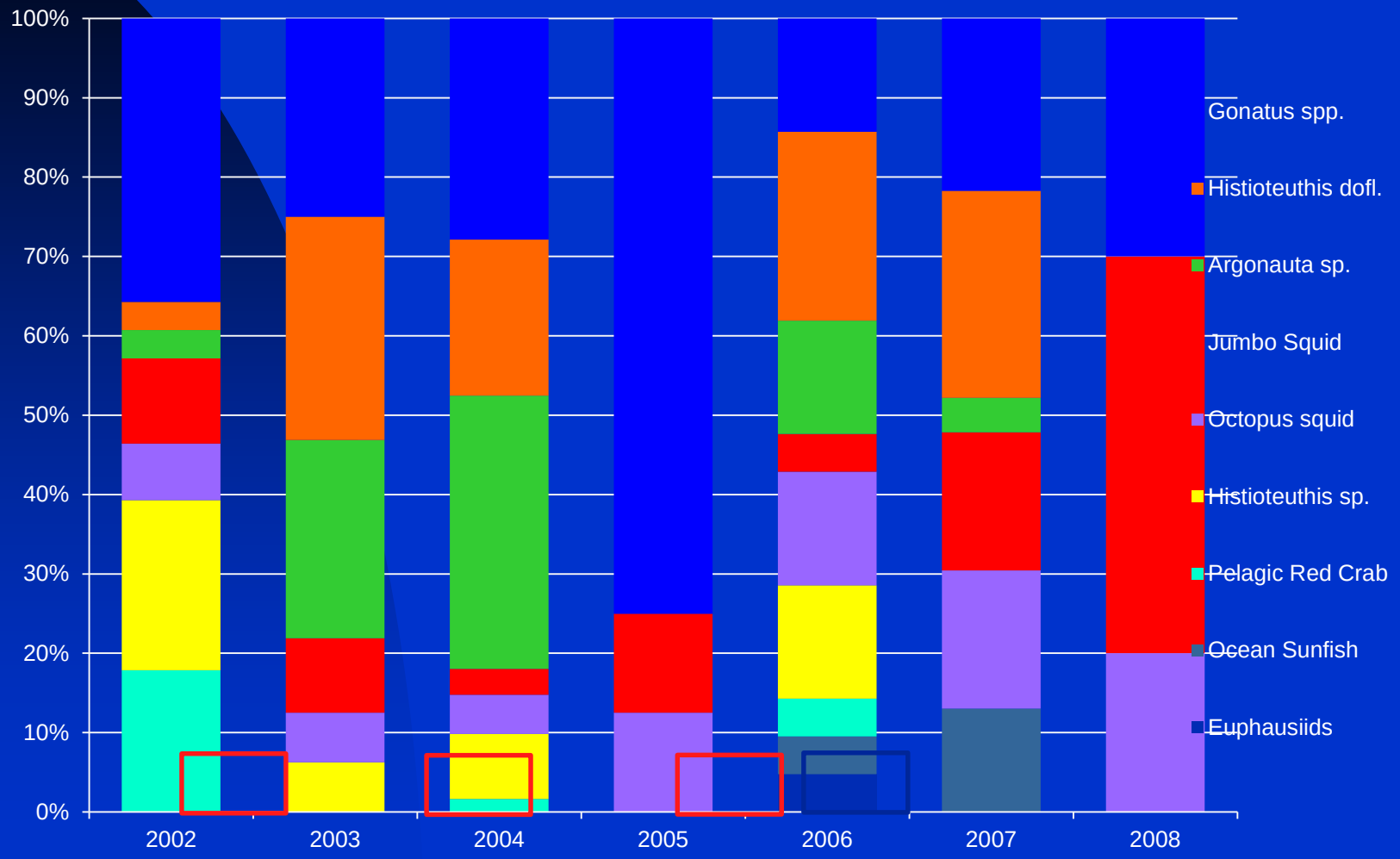
Jumbo squid occurrence off California

Jumbo squid frequency was low or non-existent in previous studies

Our study reveals that jumbo squid is now very important for mako and blue sharks

This may be related to the recent expansion of jumbo squid and points to a potential shift in diet in these top predators

Interannual variation in blue shark diet - relative %FO - top 9 prey by GII



(Prey availability ~ Oceanographic conditions)

Conclusions

Trophic niche separation occurs among the 3 sharks species

Makos and blues show a more diverse and generalized diet than the threshers

Thresher sharks prefer small schooling pelagic fish while blue sharks feed heavily on cephalopods

Conclusions

Jumbo squid is important for mako and blue but top-down control remains to be determined

Diet analyses suggest that management of coastal pelagic fish, Pacific hake and market squid should consider predation by these sharks

Ecosystem management should include bottom-up effects on shark population dynamics focusing on key prey items

Acknowledgements

NMFS Fisheries Observers
Susan Smith
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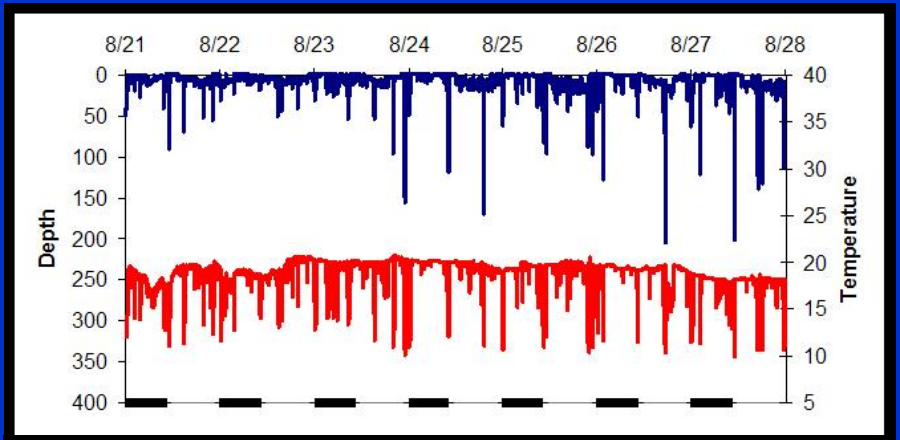
Eric Hochberg
John Hyde
Iliana Ruiz-Cooley
Russ Vetter
Nancy Lo
Steve Teo
James Wraith
Owyn Snodgrass
Scott Aalbers
Phil Zerofski
Richard Herrmann
Mark Conlin
Amy Bergen
Charles Villifana
Dave Wells
Natalie Spear

Does diving behavior help explain diet differences?....

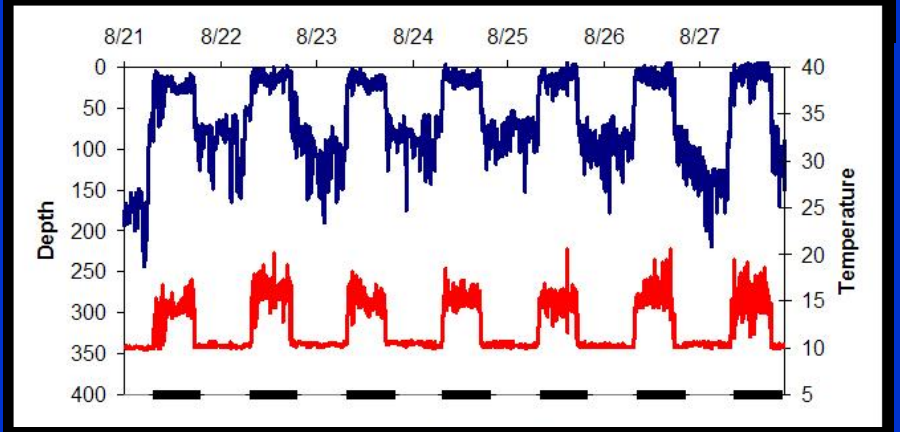
Maybe!

Chicken and EGG??

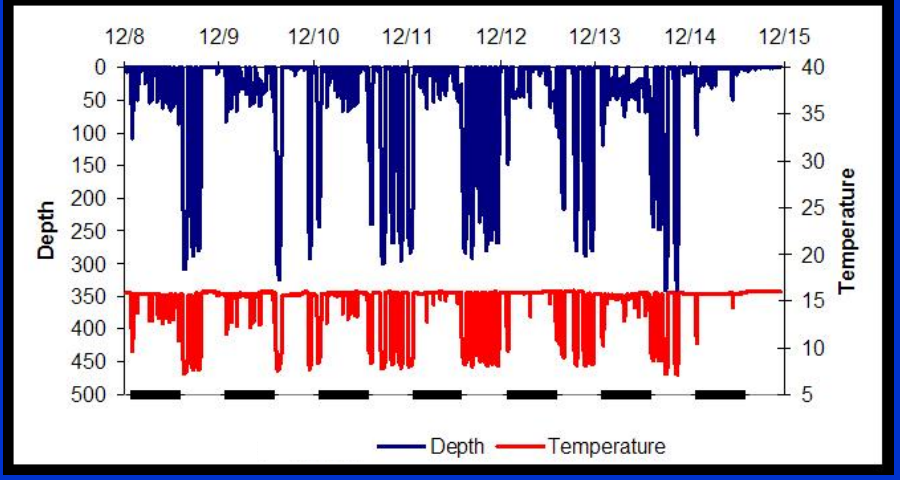
Mako

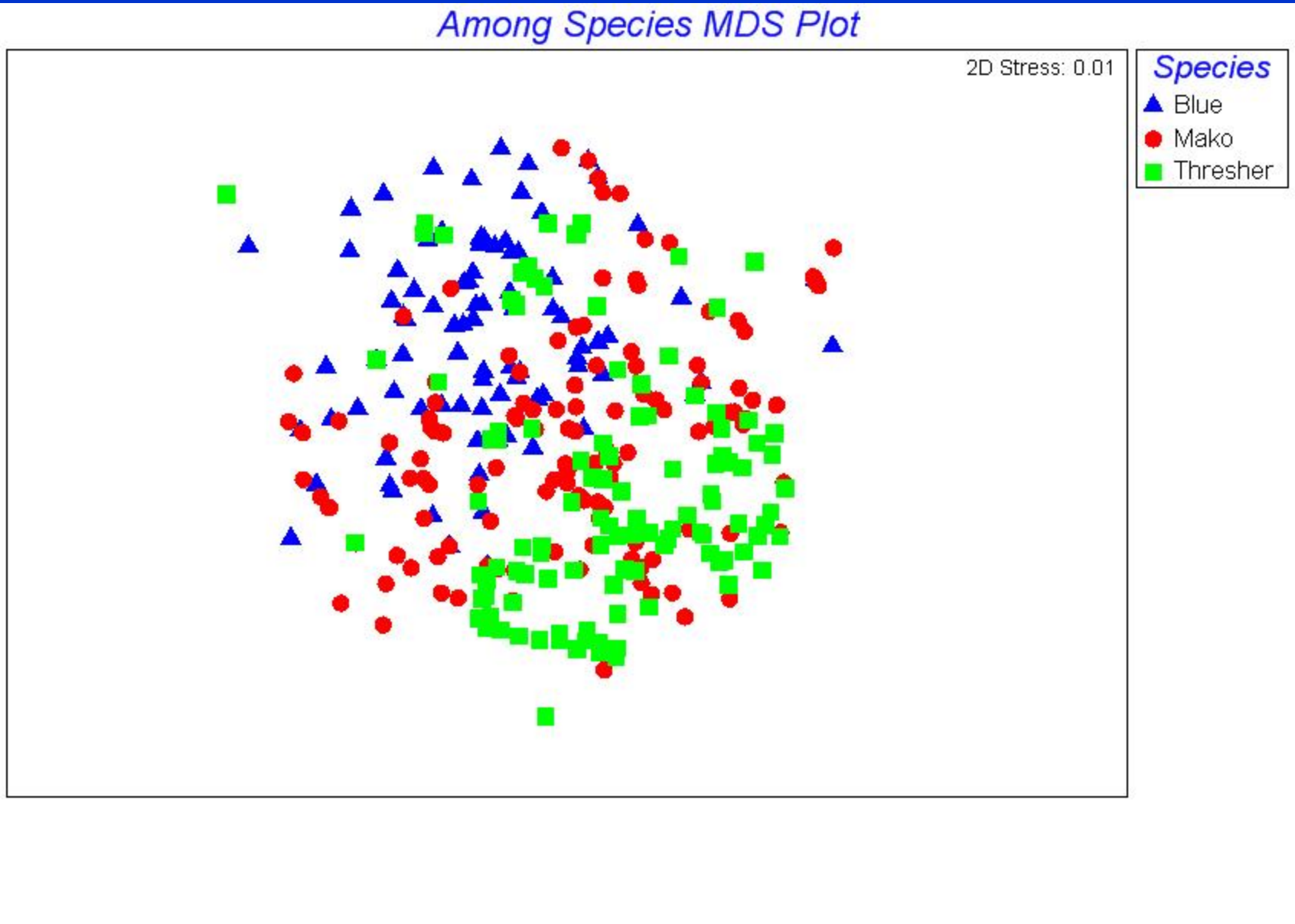


Thresher



Blue




Among Species MDS Plot
2D Stress: 0.01
Species
Blue
Mako
Thresher

Shortfin mako shark

Coastal and oceanic - to depths of 500 m

Highly migratory - very active - warm bodied

Diet not well described off the U.S. West Coast (anecdotal / partial / unpublished observations)

- Smaller makos - mackerel, bonito, anchovy, tuna, other sharks and squid
- Larger makos - some encounters with harbor seal, sea lion, small cetaceans and marlin

Blue shark

Oceanic and pelagic - to depths of CHECK W JAMES m (deeper in warmer waters)

Highly migratory - seasonal movements likely related to feeding and reproduction

Diet described in previous studies off the U.S. West Coast:

- anchovy, jack mackerel, hake, flatfishes, dogfish, squids and pelagic crustaceans including euphausiids

Common thresher shark

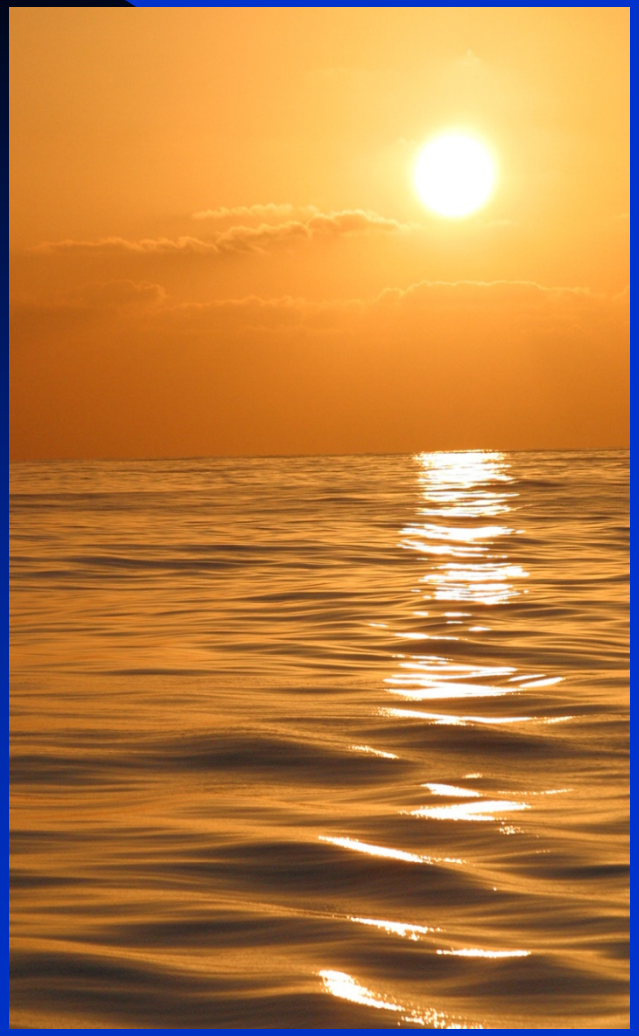
Coastal and oceanic - to depths exceeding 350 m
Most abundant near land (pups use inshore nurseries)

Seasonal migrations along the coast

Herds and stuns small fishes with tail, sometimes cooperatively

Diet described (California and Oregon)
by Preti et al. (2001, 2004):

- northern anchovy, coastal pelagic fish, Pacific hake and market squid
- diet more diversified during the 1998 El Niño year

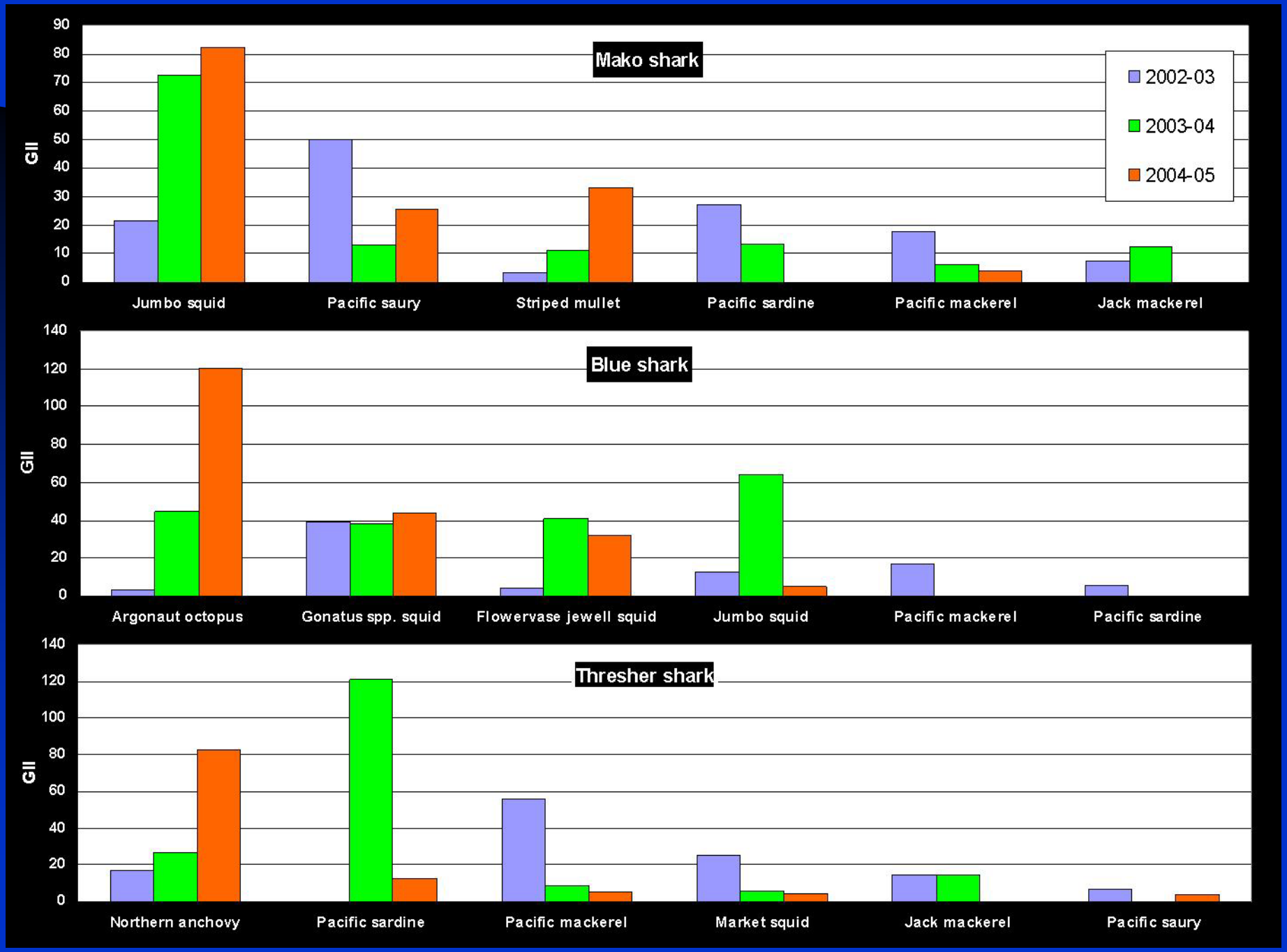


Striped mullet (*Mugil cephalus*)

- Ranked 4th in GII value in the mako.
  Found also in one blue and one thresher stomach.
- Catadromous - coastal bays, lakes, marshes, fresh water in spring / summer
- Fall through winter adults migrate up to 50 miles offshore to spawn.
- Sharks with mullet were taken in late October to early November (2 week span).
- The occurrence in the shark diet coincided with the peak spawning period.
- We suggest that this prey item will be important in the diet of mako sharks only during the fall months when the fish are available in offshore marine waters.

Net Feeding

- 1 mako and 27 blue shark stomachs contained fresh chunks of large prey.
- Contents included:
  - tuna and swordfish chunks
  - skipjack head with net in the mouth
  - small blue shark stomach and kidneys
- Drift net catches almost always include damaged tunas and swordfish.
- Net scavenging appears to be widely occurring in this fishery.
- Sharks may become entangled as a consequence of this behavior.


Mako shark
GII
90
80
70
60
50
40
30
20
10
0
2002-03
2003-04
2004-05
Jumbo squid
Pacific saury
Striped mullet
Pacific sardine
Pacific mackerel
Jack mackerel
Blue shark
GII
140
120
100
80
60
40
20
0
Argonaut octopus
Gonatus spp. squid
Flowervase jewell squid
Jumbo squid
Pacific mackerel
Pacific sardine
Thresher shark
GII
140
120
100
80
60
40
20
0
Northern anchovy
Pacific sardine
Pacific mackerel
Market squid
Jack mackerel
Pacific saury

Jumbo squid occurrence off California COMBINE THE 2 SLIDES

In 2002 thousands of squid washed ashore at La Jolla Cove north of San Diego, California. In January 2005 at least 1500 of the squid ended up on beaches between San Diego and Los Angeles.

Scientists speculate that the squid have remained in the area, since the 2002 event, moving farther north.

????Index Used to Analyze Relative Importance of Diet Items

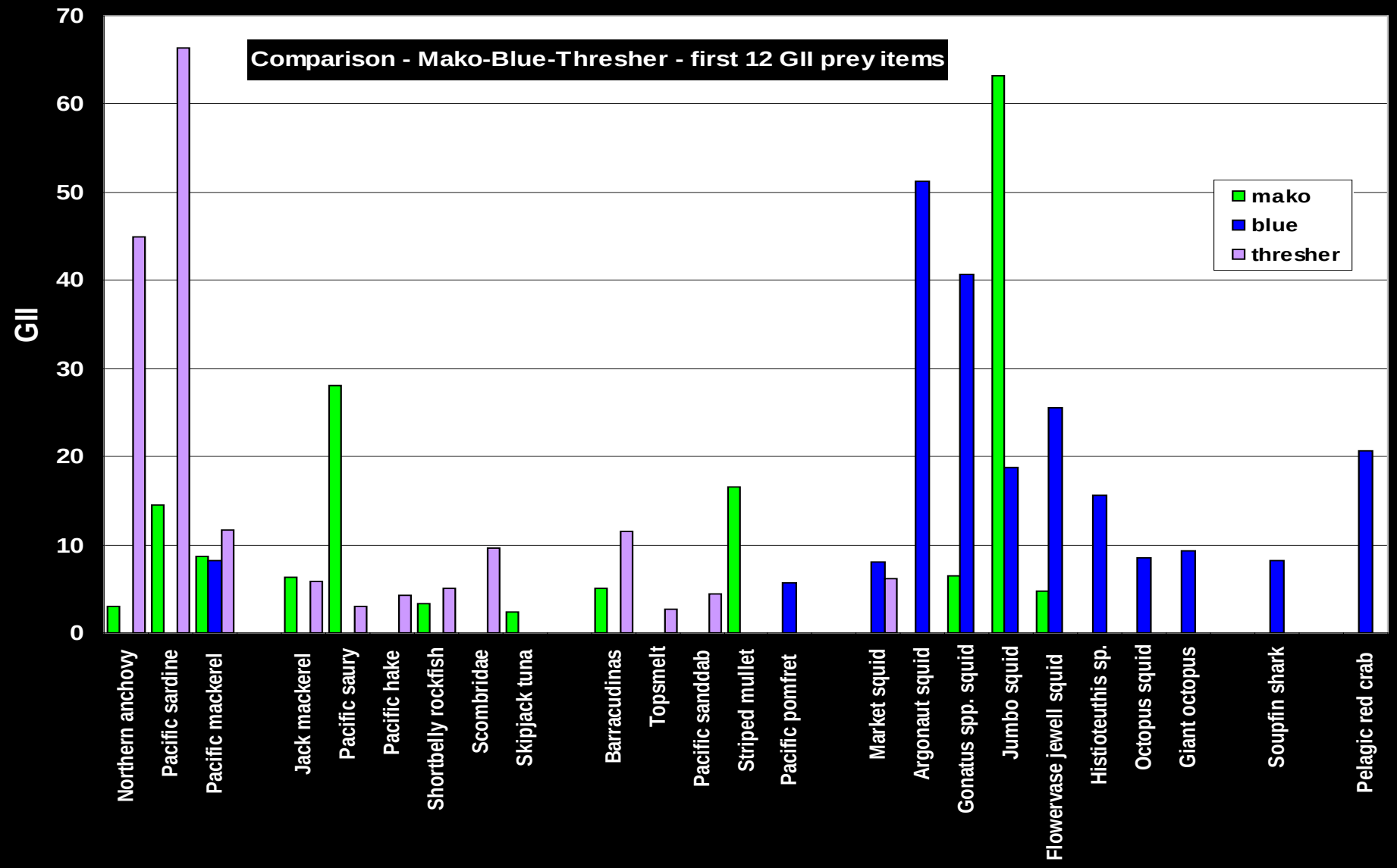
Assis' (1996) Geometric Index of Importance (GII) (vector-based):

$$GII_j = \left(\sum V_i\right)_j / \sqrt{n}$$

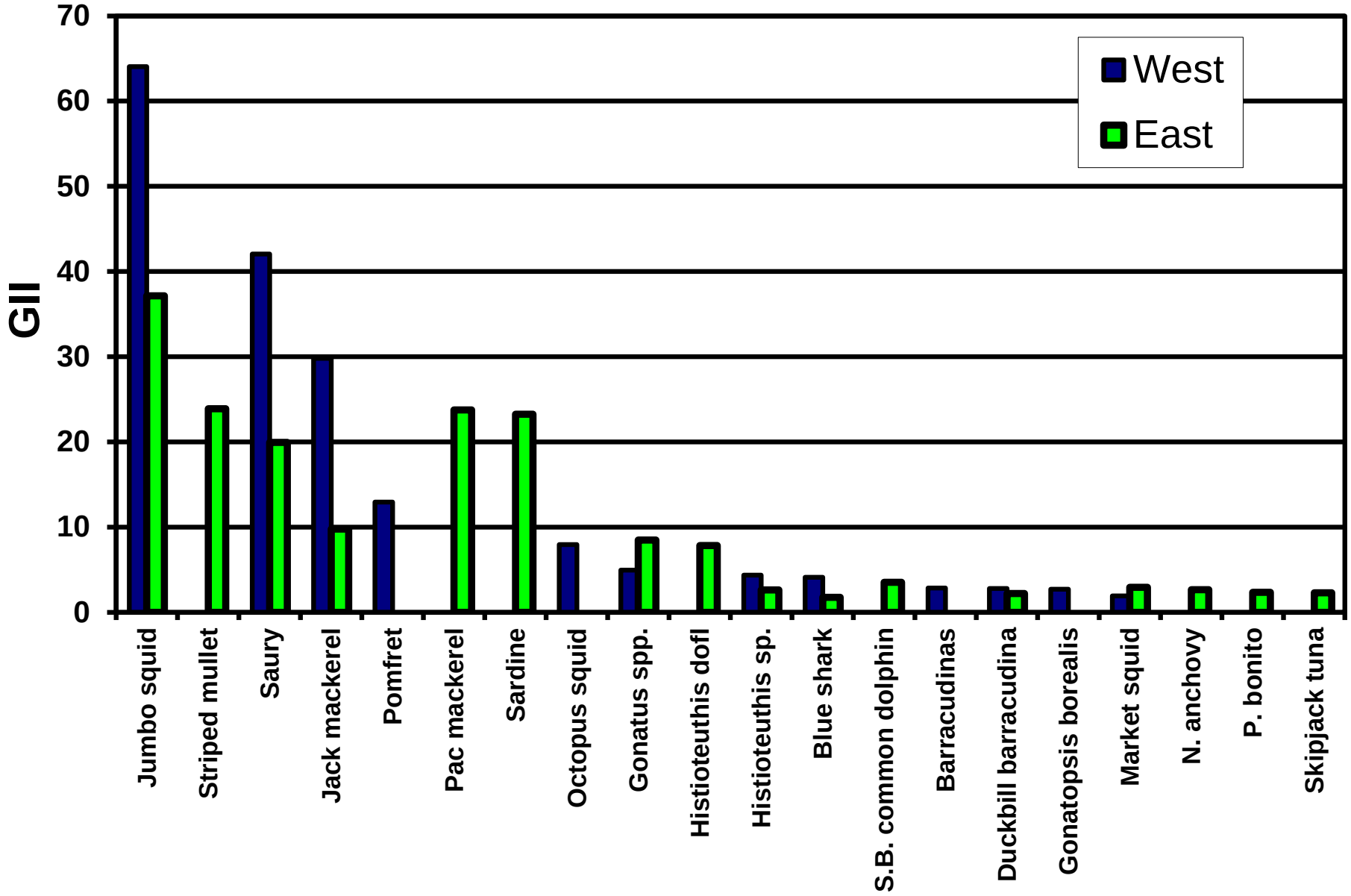
GII = index value for the jth prey category;
Vi = vector for the ith RMPQ (Relative Measures of Prey Quantity) in the jth category;
n = number of RMPQs used in the analysis.

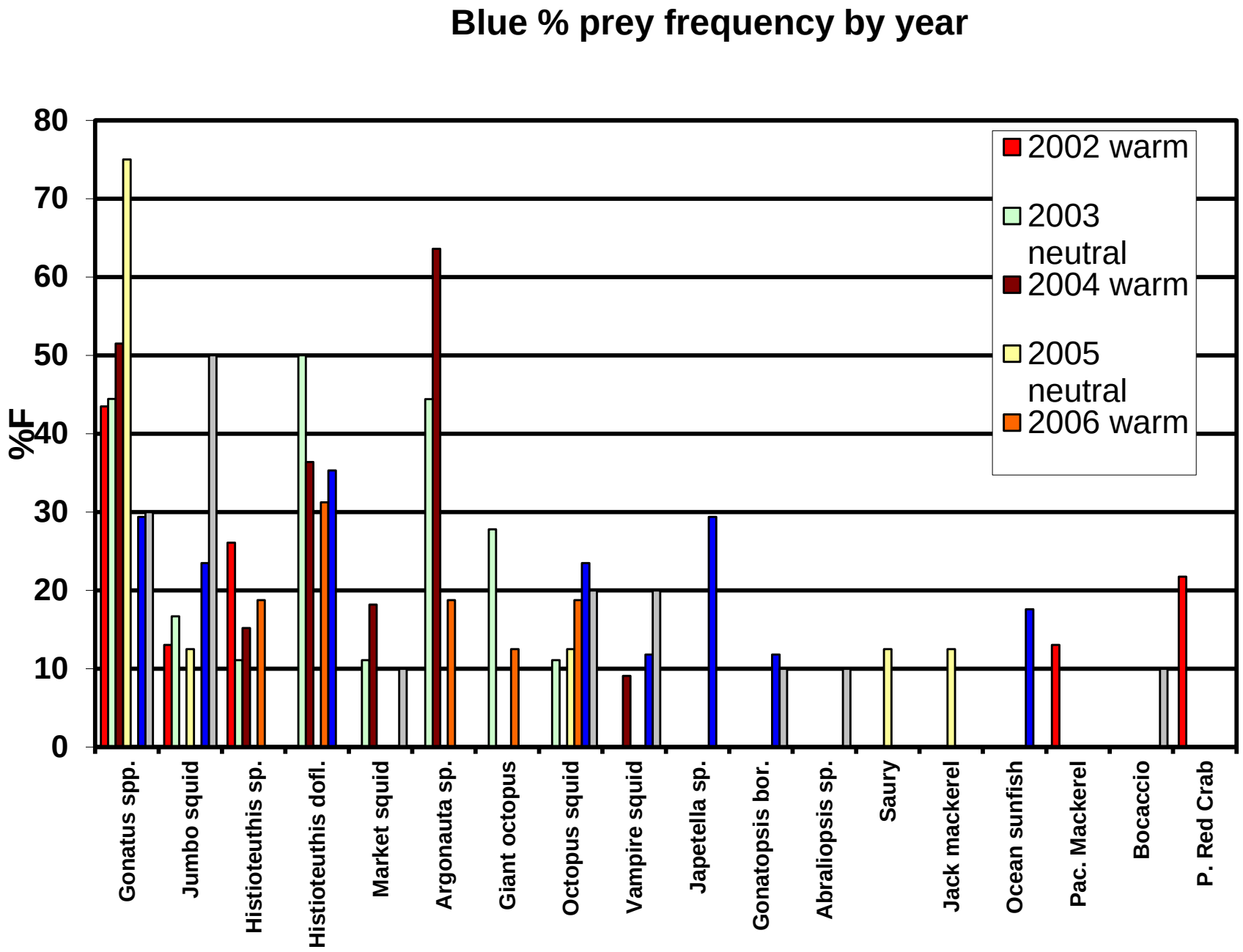
For this analysis:

$$GII_j = (\%N_j + \%W_j + \%F_j) / \sqrt{3}$$


Comparison - Mako-Blue-Thresher - first 12 GII prey items
GII
70
60
50
40
30
20
10
0
mako
blue
thresher
Northern anchovy
Pacific sardine
Pacific mackerel
Jack mackerel
Pacific saury
Pacific hake
Shortbelly rockfish
Scombridae
Skipjack tuna
Barracudinas
Topsmelt
Pacific sanddab
Striped mullet
Pacific pomfret
Market squid
Argonaut squid
Gonatus spp. squid
Jumbo squid
Flowervase jewell squid
Histioteuthis sp.
Octopus squid
Giant octopus
Soupfin shark
Pelagic red crab

Mako GII comparison by region (East / West of 120º30')




Blue % prey frequency by year
%F
80
70
60
50
40
30
20
10
0
2002 warm
2003 neutral
2004 warm
2005 neutral
2006 warm
Gonatus spp.
Jumbo squid
Histioteuthis sp.
Histioteuthis dofl.
Market squid
Argonauta sp.
Giant octopus
Octopus squid
Vampire squid
Japetella sp.
Gonatopsis bor.
Abraliopsis sp.
Saury
Jack mackerel
Ocean sunfish
Pac. Mackerel
Bocaccio
P. Red Crab