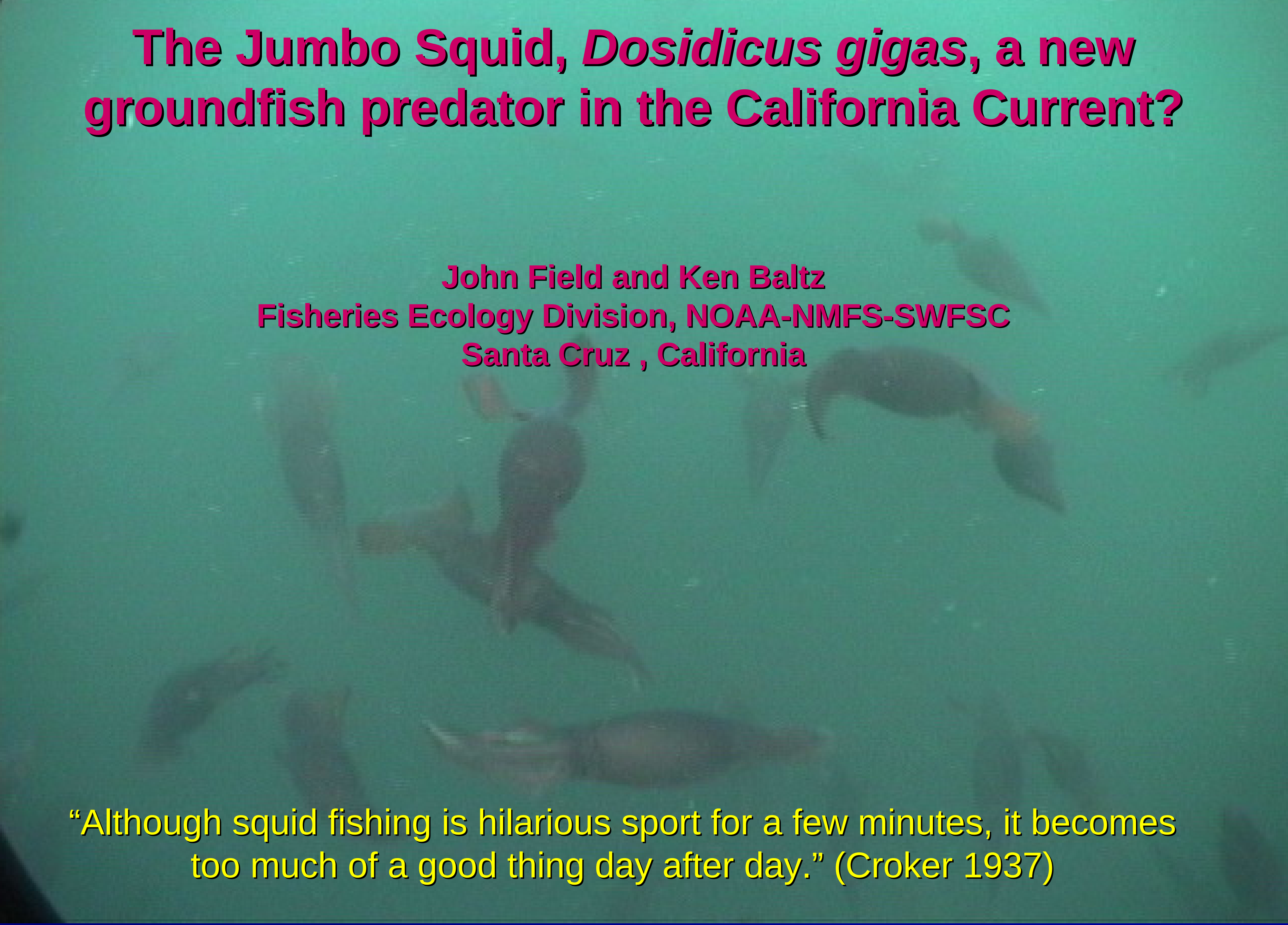
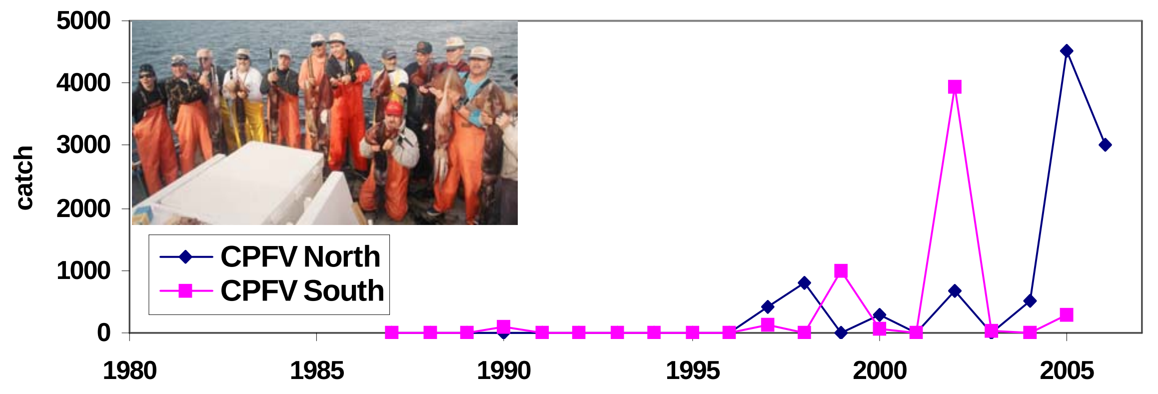
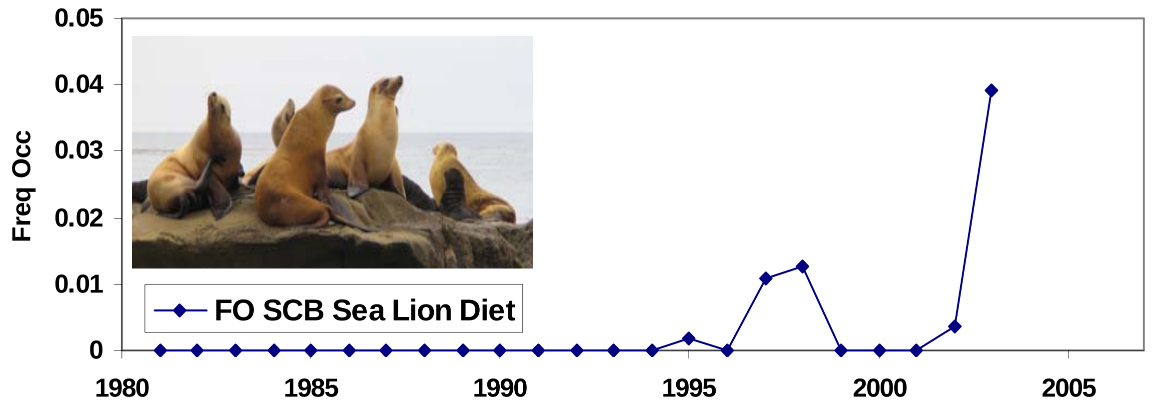
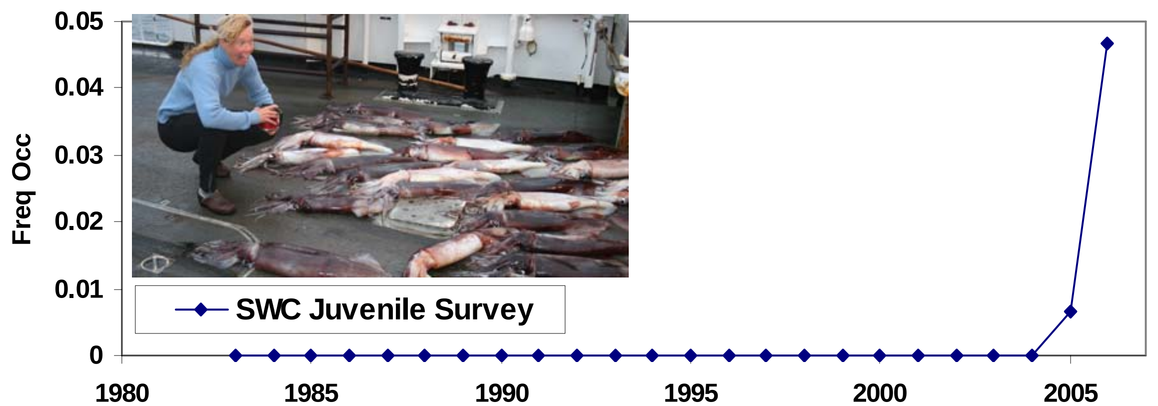


(Photo courtesy of Scot Anderson)

Although jumbo squid were “not uncommon” in the early part of the century, and abundant in mid-1930s (Croker 1937), they have been very uncommon or absent off of Central CA from 1940s until late 1990s. Since the late 1990s, especially 2004-2006, they have been frequently encountered in large numbers in fisheries and surveys coastwide





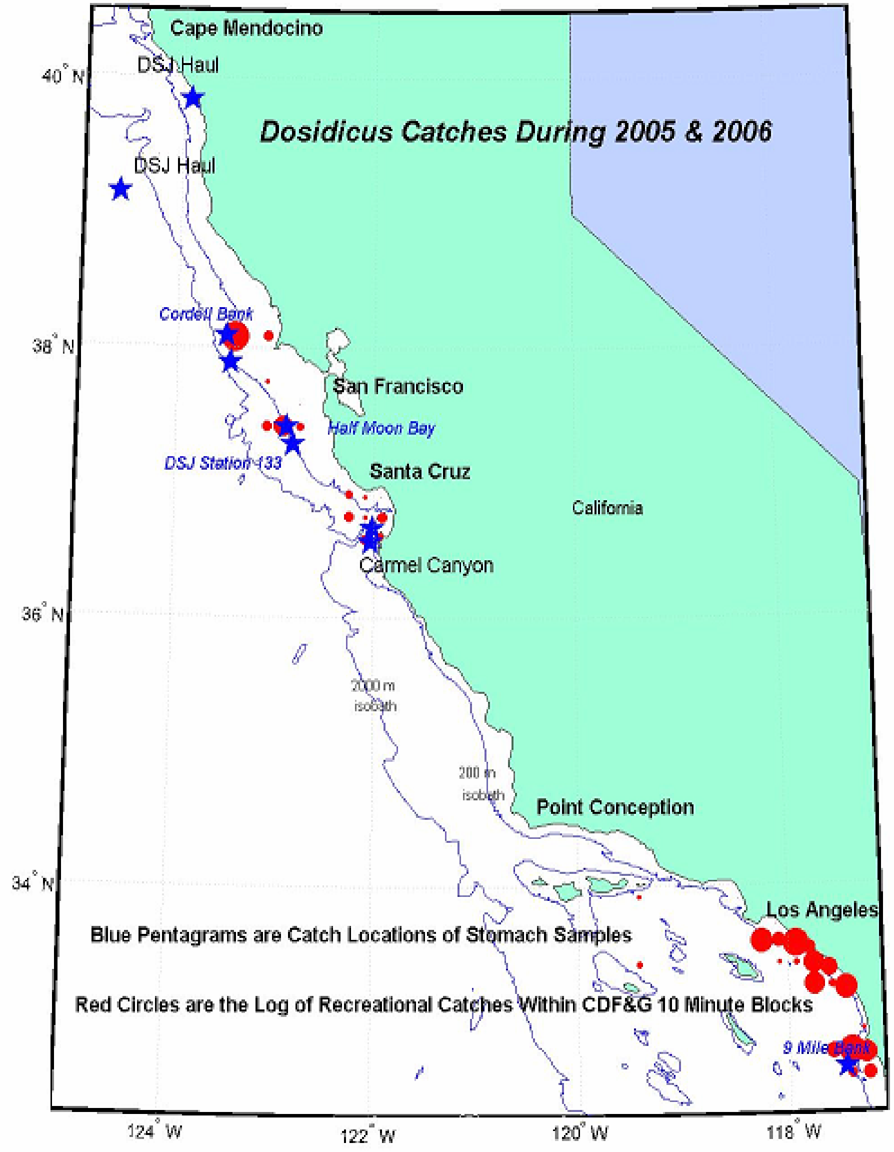


CPFV data courtesy Wendy Dunlap and CDF&G, sea lion data courtesy M. Lowry (PRD/SWFSC), SWC Juvenile Survey data from Baltz/Sakuma. Trawl survey data for NWFSC surveys 2002-2006 is pending from NWFSC, but ~ 10-15 positives per year for 2004-2006. Photos courtesy M. Lowry (sea lion, center), S. Webb (squid, bottom), T. Holland (CP vessel, left)

~500 Stomach Samples Collected During 2005-2006

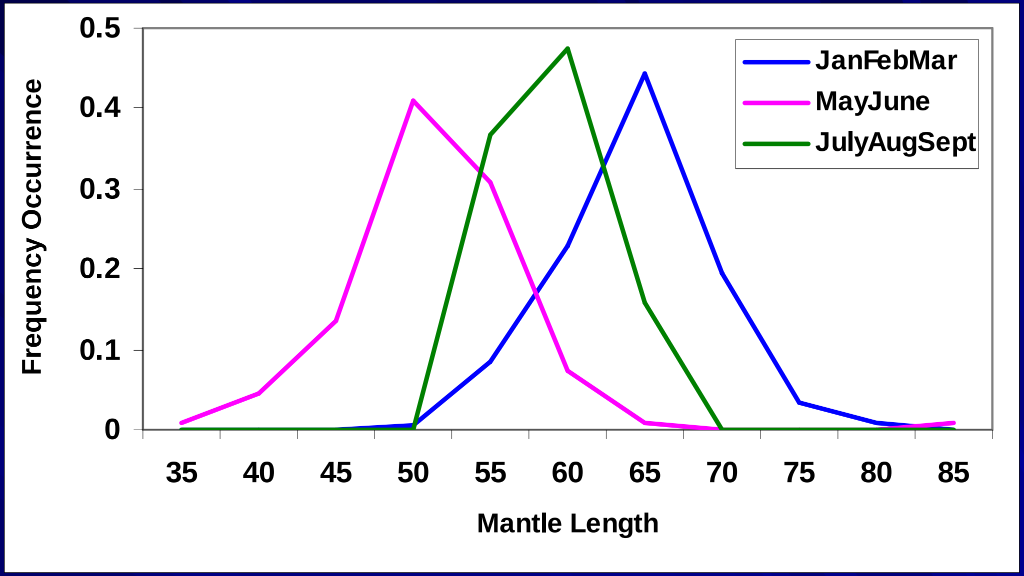
Squid sample locations ranged from San Diego to just south of Cape Mendocino, but most samples were collected off of Cordell Bank and Half Moon Bay on recreational charter vessels targeting squid during the winter months

Most animals caught in winter (Jan-Mar) recreational fishery (~300), with ~140 in the Spring NMFS SWFSC midwater trawl survey (May-June, ~ both trawl and line) and ~50 in NMFS NWFSC summer bottom trawl survey. ~60 samples have not been worked up yet (table below shows what has been worked up).

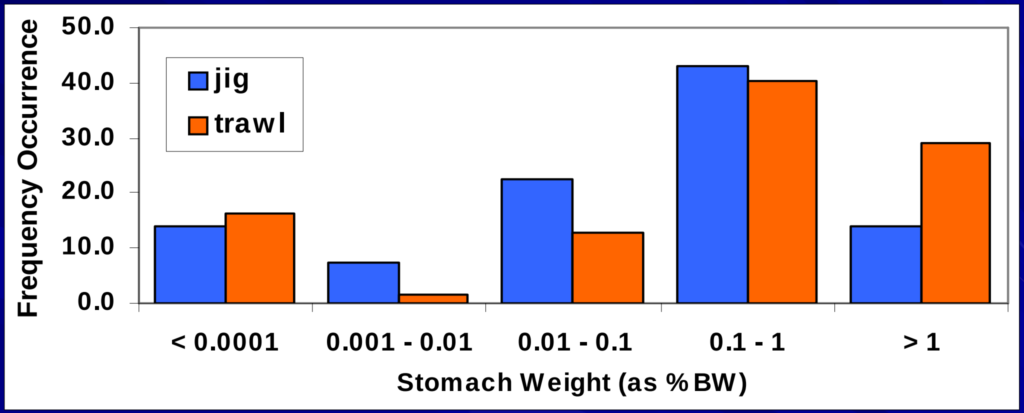


	Cordell Bank	Half Moon Bay	Monterey Bay	San Diego	NMFS bottom	NMFS midwater
Samples	81	116	21	25	20	104
# dates/trips	4	5	1	1	~10	10
seasons	Jan-March	Jan-March	Feb	Feb	July-Sept	May-June
Ave ML	67	65	69	60	58	59

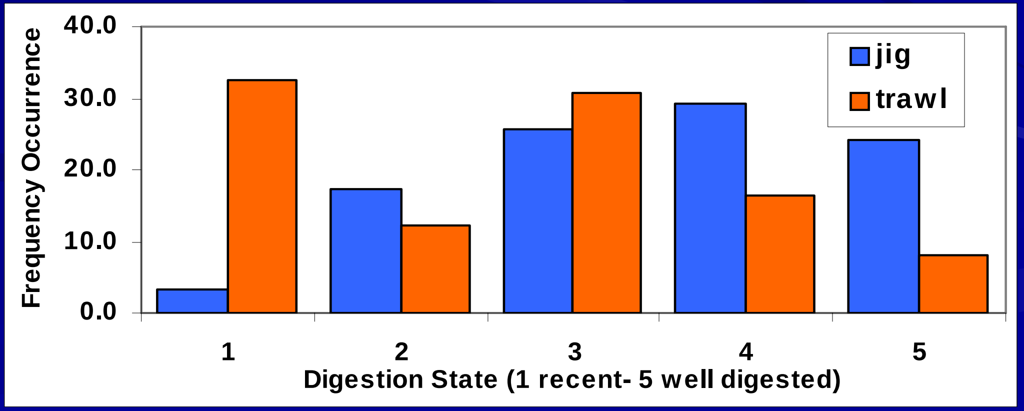
* Size structure based on mantle lengths suggests smaller animals in spring-summer, largest in winter (pre-spawning). Samples from summer months are rare with no samples from Oct-Dec. Quick disappearance from the central CA rec fishery starting in mid-March indicates post spawning die-off.



* Digestion state and stomach weight suggests that net feeding occurs in many trawl-caught animals (as do bite marks on other squid and fish in trawl!). However, it is also possible that jig-caught squid are hungrier.

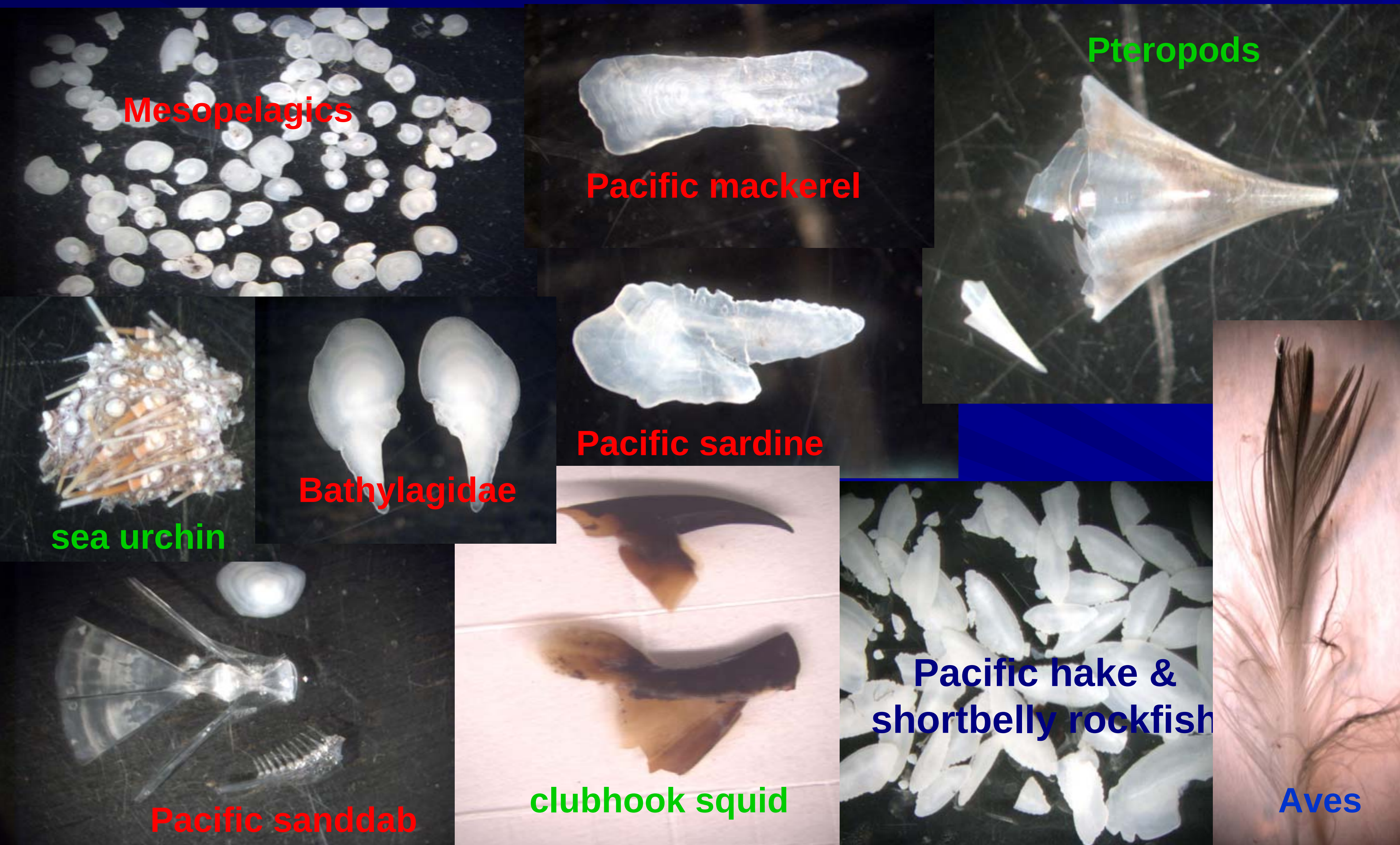


* Sex information was very spotty and some may be unreliable. Maturity information was not recorded (we could use some help on a key!), but anecdotal observations suggest that the large, mature females were the only squid seen in the winter months.



Animals were observed feeding on Pacific hake and sablefish from a submersible (Delta sub) near Cordell Bank in Sept. 2005 (video courtesy of Dan Howard, CBNMS, and Rick Starr, CA Sea Grant)

Prey items identified with hard parts (otoliths, scales, beaks, vertebrae, shell) using guides, reference collections, etc



About 50 otoliths & beaks could not be identified

(Recognize any of these? Let us know!)

Over 1100 prey items have been identified, representing ~45 taxonomic identities (most indentified to species or genus level)

Pacific hake, northern lampfish, northern anchovy, other *Dosidicus*, Pacific sardine, blue lanternfish and shortbelly rockfish were among the most frequently occurring prey items.

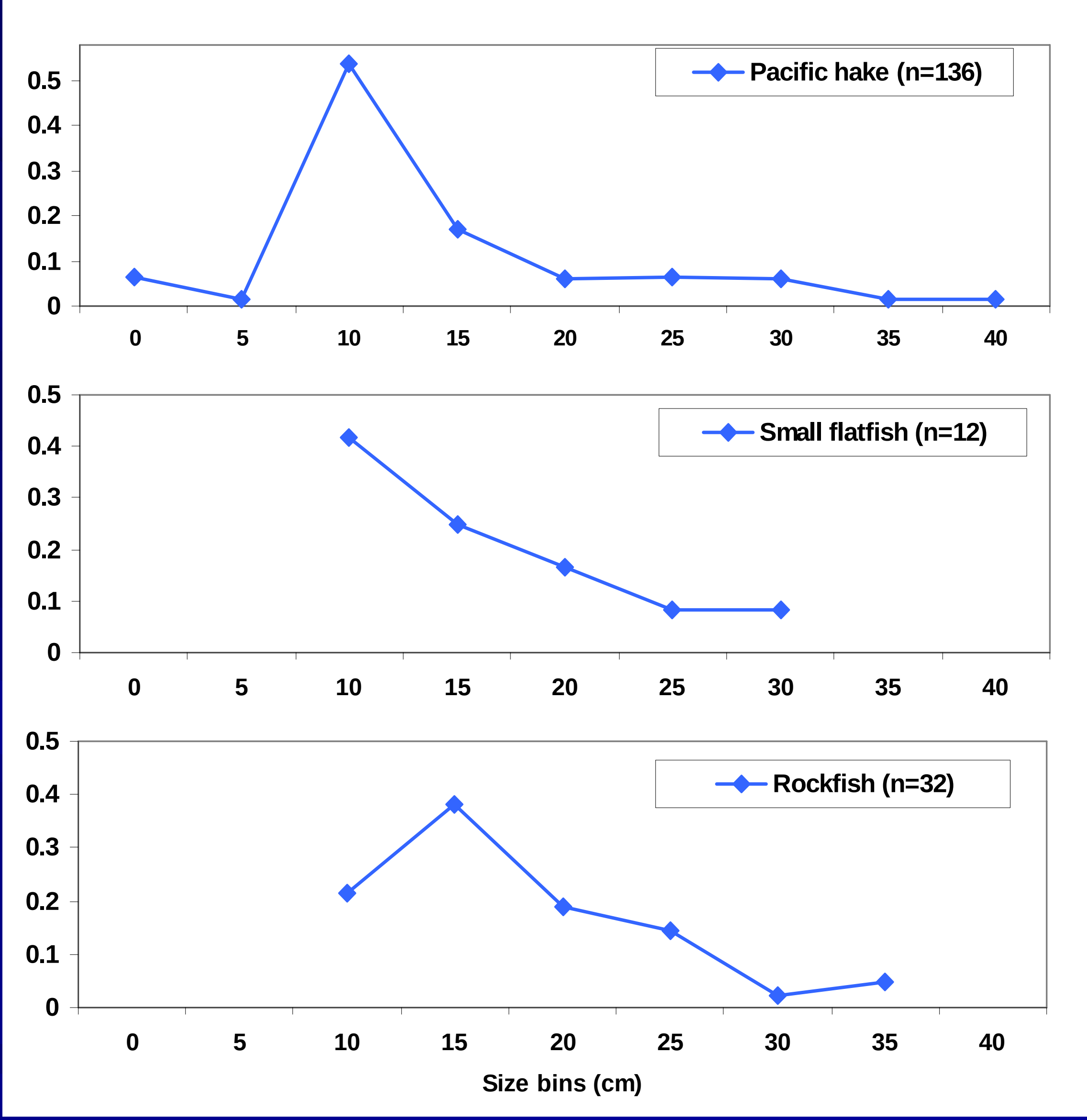
Only Euphausiid presence/absence was noted, as most were too well digested to enumerate. Many soft-bodied organisms (other gelatinous zooplankton?) could be underrepresented in diet studies due to the squids' high digestion rates.

	F0	% FO	N	% N
Pacific hake (*Merluccius productus*)	78	21.3	185	17.5
N. lampfish (*Stenobrachius leucopsarus*)	71	19.3	134	12.6
Northern anchovy (*Engraulis mordax*)	61	16.6	171	16.1
Jumbo squid (*Dosidicus gigas*)	52	14.2	53	5.0
Pacific sardine (*Sardinops sagax*)	48	13.1	58	5.5
Blue lanternfish (*Tarletonbeania crenularis*)	33	9.0	49	4.6
Shortbelly rockfish (*S. jordani*)	32	8.7	44	4.2
Rockfish (*Sebastes spp.*)	27	7.4	27	2.5
Unidentified teuthoida	27	7.4	31	2.9
Euphausidae	24	6.5	*N/A*	*N/A*
Cal. headlightfish (*Diaphus theta*)	14	3.8	40	3.8
Barracudinas (*Paralepididae*)	14	3.8	17	1.6
Pteropoda (*Clio spp*.)	14	3.8	15	1.4
Blacksmelt (*Bathylagus spp.*)	13	3.5	13	1.2
Market squid (*Loligo opalescens*)	13	3.5	17	1.6
Gonatid squid (*Gonatus spp*.)	12	3.3	53	5.0
Unidentified Decapoda	12	3.3	20	1.9
Pacific sanddab (*Citharichthys sordidus*)	6	1.6	13	1.2
Boreal clubhook (*Onychoteuthis borealijaponicus*)	5	1.4	5	0.5
Slender sole (*Eopsetta exilis*)	4	1.1	5	0.5
Plainfin midshipman (*Porichthys notatus*)	4	1.1	6	0.6
Abraliopsis felis	4	1.1	5	0.5
Aurora rockfish (*S. aurora*)	3	0.8	3	0.3
Dogtooth lampfish (*Ceratoscopelus townsendi*)	3	0.8	4	0.4
osmeridae	3	0.8	3	0.3
Octopus spp.	3	0.8	3	0.3
Histioteuthis spp.	3	0.8	3	0.3
Pacific herring (*Clupea pallasii*)	2	0.5	2	0.2
Pacific mackerel (*Scomber japonicus*)	2	0.5	2	0.2
Rex sole (*Glyptocephauls zachirus*)	2	0.5	2	0.2
California lanternfish (*Symbolophorus californiensis*)	2	0.5	2	0.2
Jack mackerel (*Trachurus symetricus*)	1	0.3	1	0.1
Bank rockfish (*S. rufus*)	1	0.3	2	0.2
Bocaccio rockfish (*S. paucispinis*)	1	0.3	1	0.1
Splitnose rockfish (*S. diploproa*)	1	0.3	1	0.1
English sole (*Pleuronectes vetulus*)	1	0.3	1	0.1
Spotted ratfish (*Hydrolagus colliei*)	1	0.3	1	0.1
Bigfin eelpout (*Lycodes cortezianus*)	1	0.3	2	0.2
Mastigoteuthis dentata	1	0.3	1	0.1
Asteroidea	1	0.3	1	0.1
Echinoidea (likely *Strongylocentrotus spp.*)	1	0.3	1	0.1
Teleost unidentified	55	15.0	63	5.9

Size Structure of Consumed Groundfish

Most hake (74%) and flatfish (100%) could be associated with a otolith-based length, while barely half (54%) of rockfish could be. Most of those that could not, had no otoliths, as their rock-like heads were likely not consumed, but the vertebrae suggested sizes >30 cm).

We are exploring the potential for genetic methods (Pearse et al., in press) to identify many of the rockfish to species, but no size information would be possible.



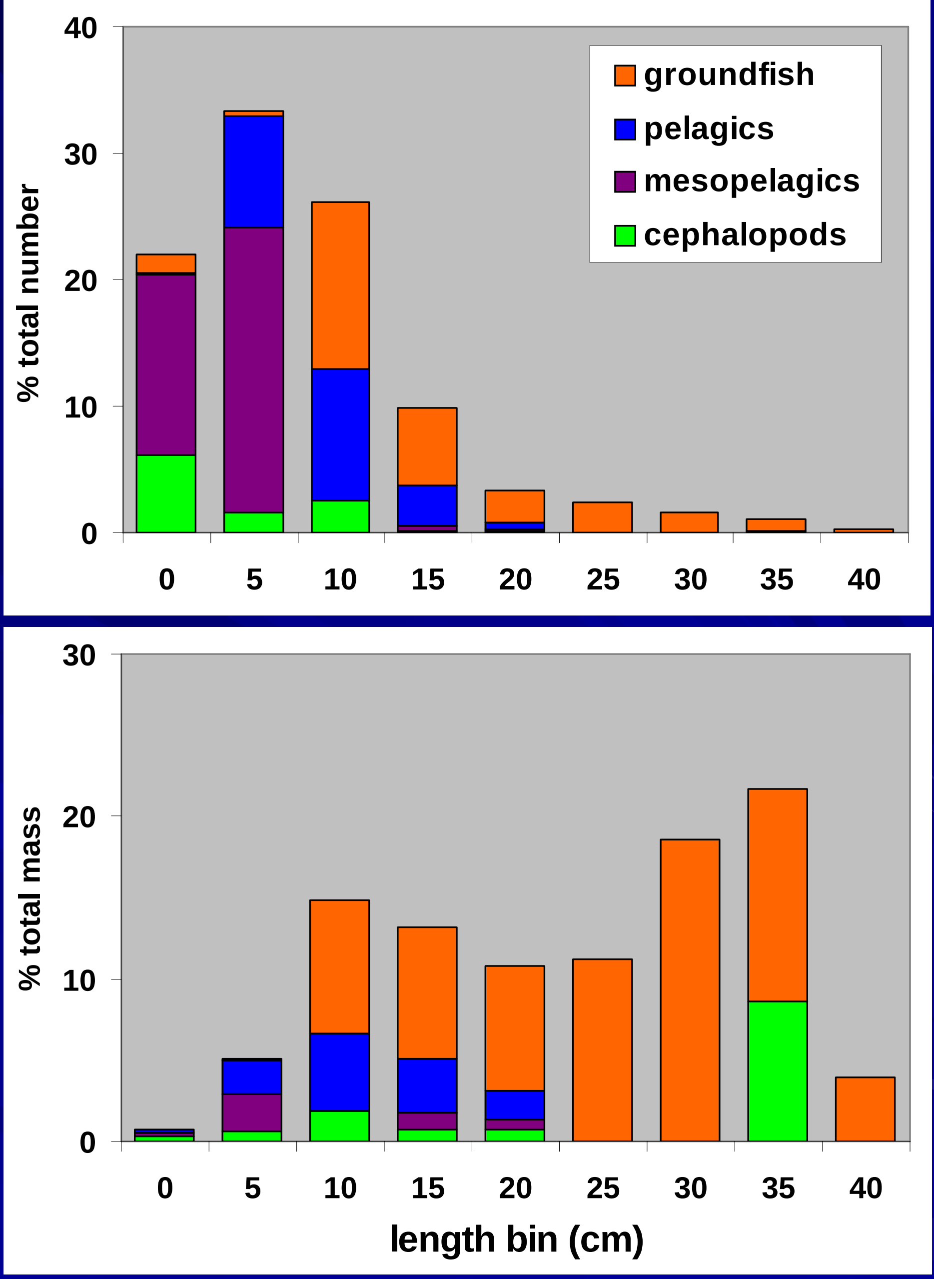
X-axis is the length of consumed species (cm)

Y-axis is the relative frequency of occurrence in stomachs

We used length data and weight/length relationships to infer more about the relative importance of different prey items.

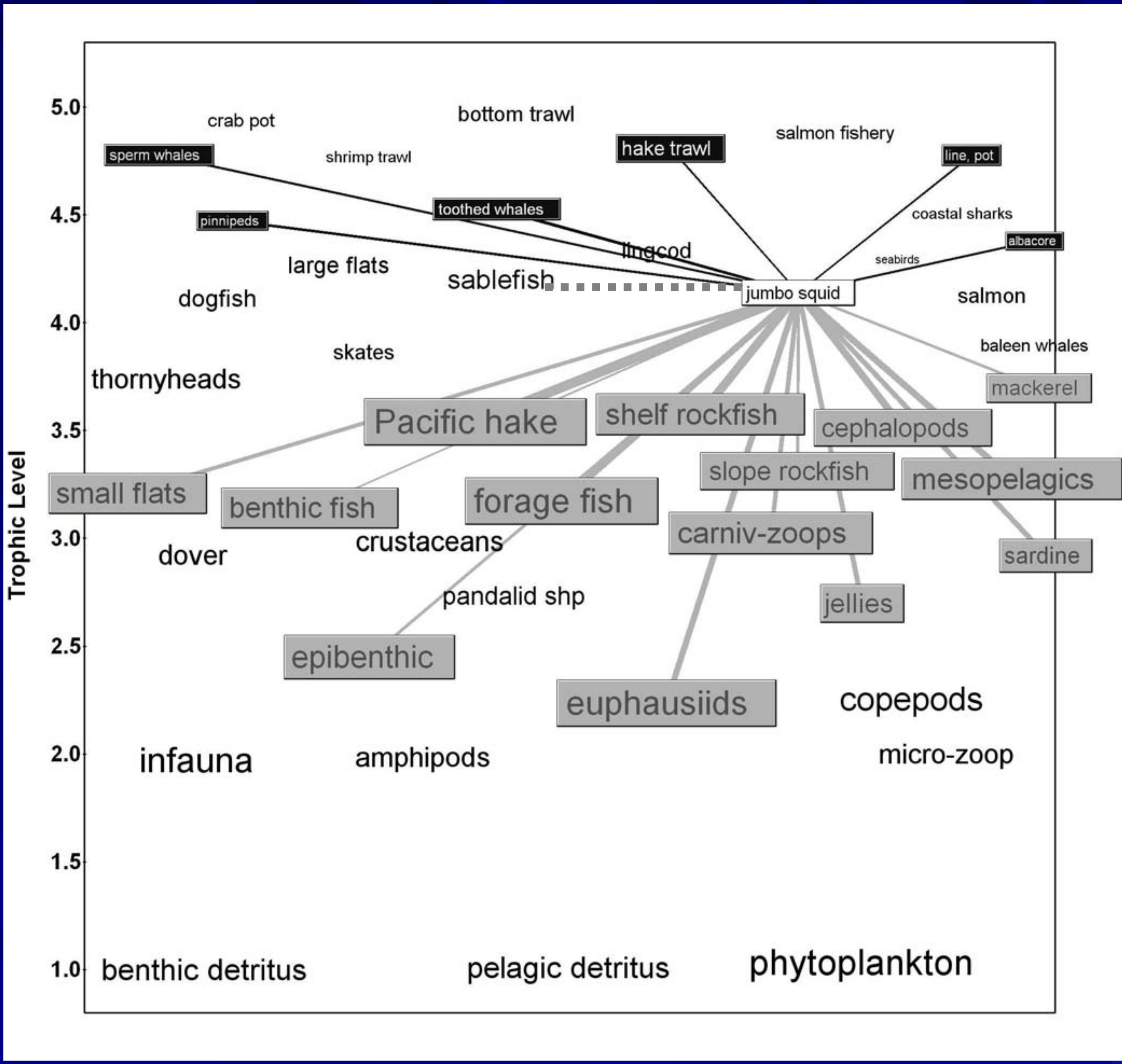
	% FO	% N	av wt	% Mass
Pacific hake	21	17	57	24
Non *D. gigas* squid	19	11	45	12
Northern anchovy	17	16	14	5
Mesopelagics	43	25	4	3
Pacific sardine	14	6	44	6
Shortbelly rockfish	9	4	109	11
other rockfish	8	3	506	35
small flatfish	4	2	69	3

The inferred sizes of prey suggest that Pacific hake and rockfish (*Sebastes*) were relatively more important than suggested by %FO and %N, with mesopelagics being relatively less important, pelagics and squid other than *Dosidicus* were about the same in importance.

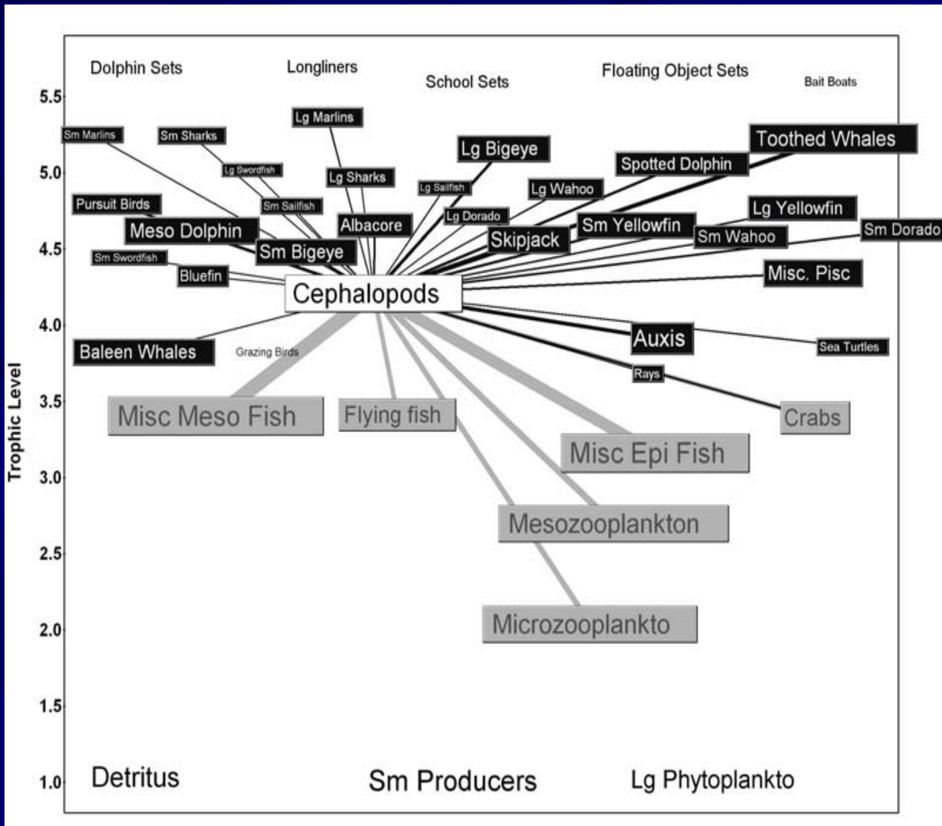


Considering the Role of Jumbo Squid in the Ecosystem

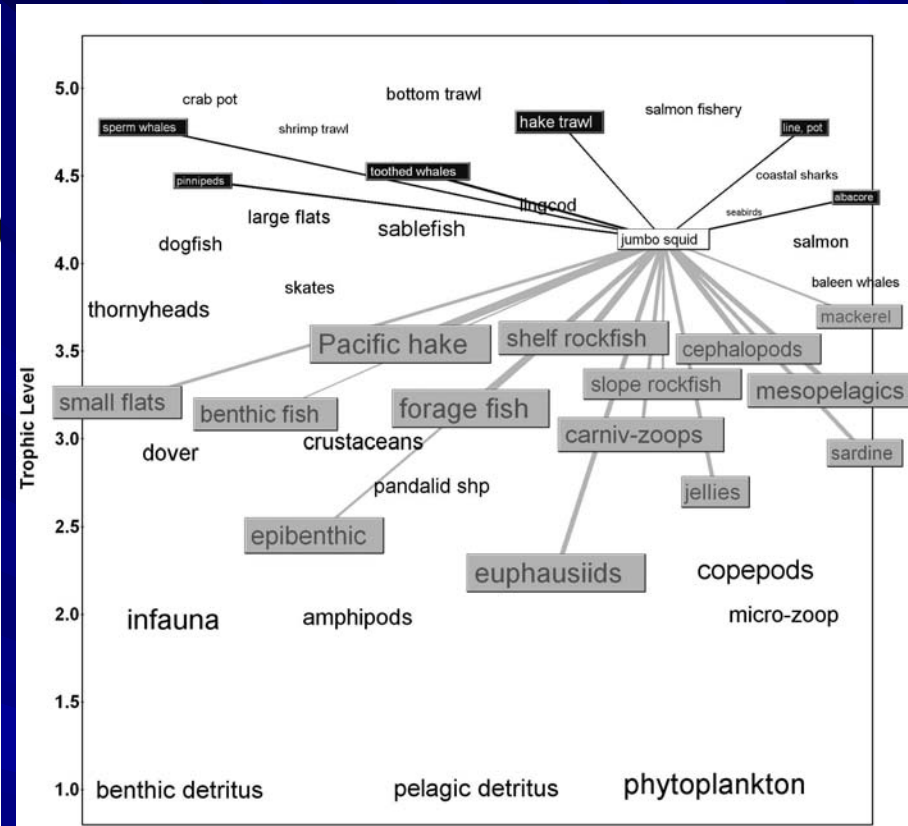
Based on adding *Dosidicus* to a “simplified” food web Ecopath model of the Northern California Current (Field et al. 2006), we see that they fall out as a very high trophic level predator (predation on sablefish inferred from submersible, not from stomach contents).



Considering the Role of Jumbo Squid in the Ecosystem



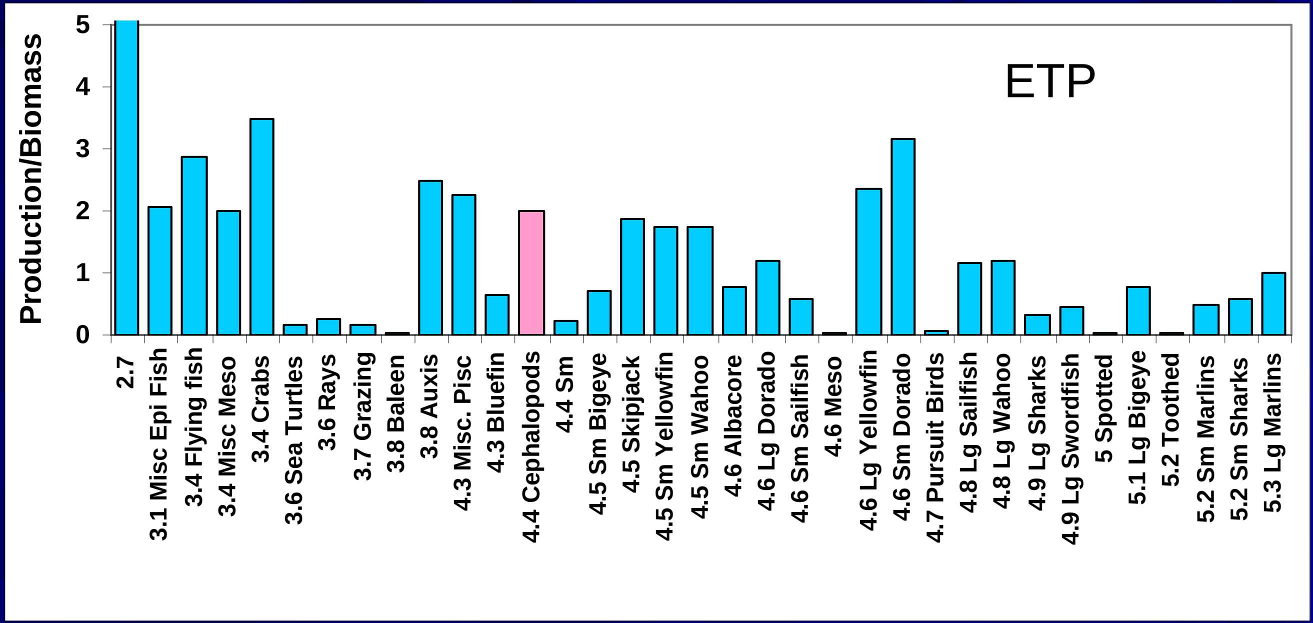
Eastern Tropical Pacific
(Olson and Watters 2003)

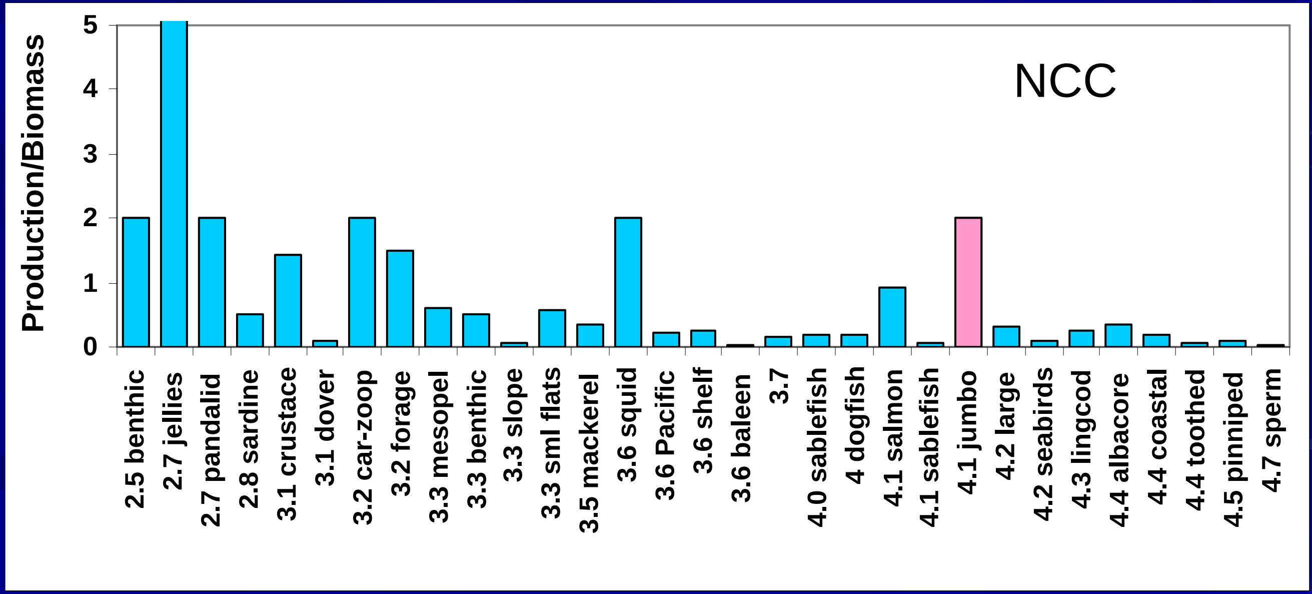


Northern California Current
(Field, Francis and Aydin 2006)

Comparing the “*Dosidified*” California Current model to the ETP model, we see that squid are primarily forage for commercially important species in the ETP, but are predators of many commercially important species in the CCS

Considering the Role of Jumbo Squid in the Ecosystem



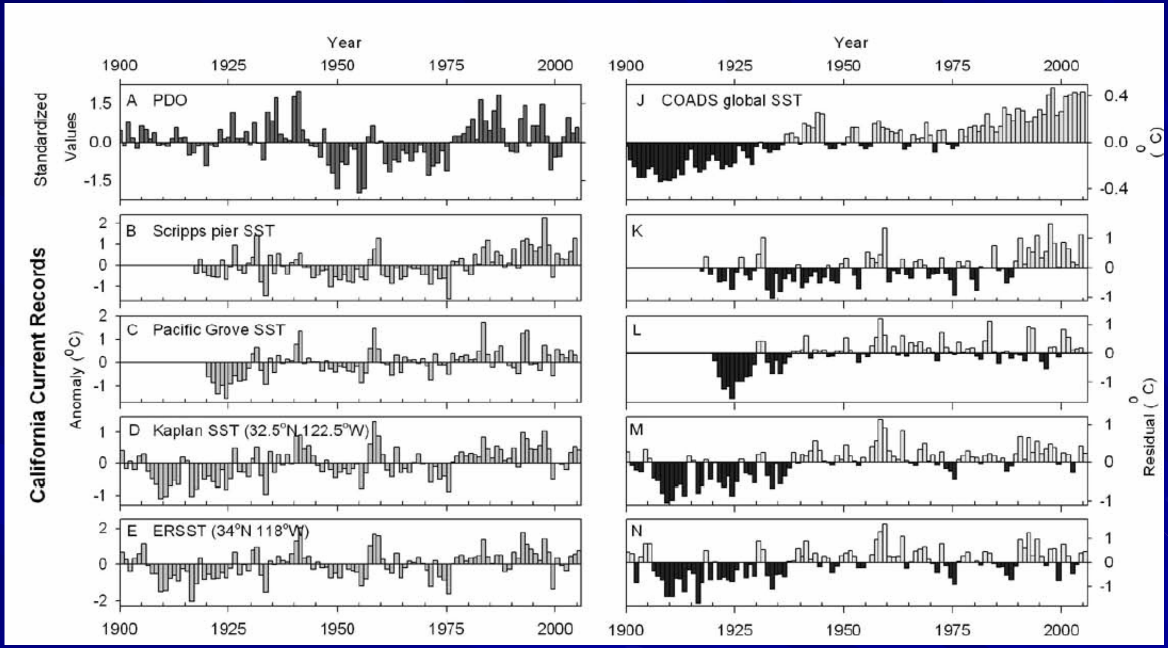


The high production to biomass ratio of *Dosidicus* is consistent with the distribution of PB values for higher trophic levels in the ETP, but considerably less so in the California Current – What might be the consequence of range expansions or incursions of fast-metabolism tropical species into temperate ecosystems dominated by "slower" life histories?

Why now?

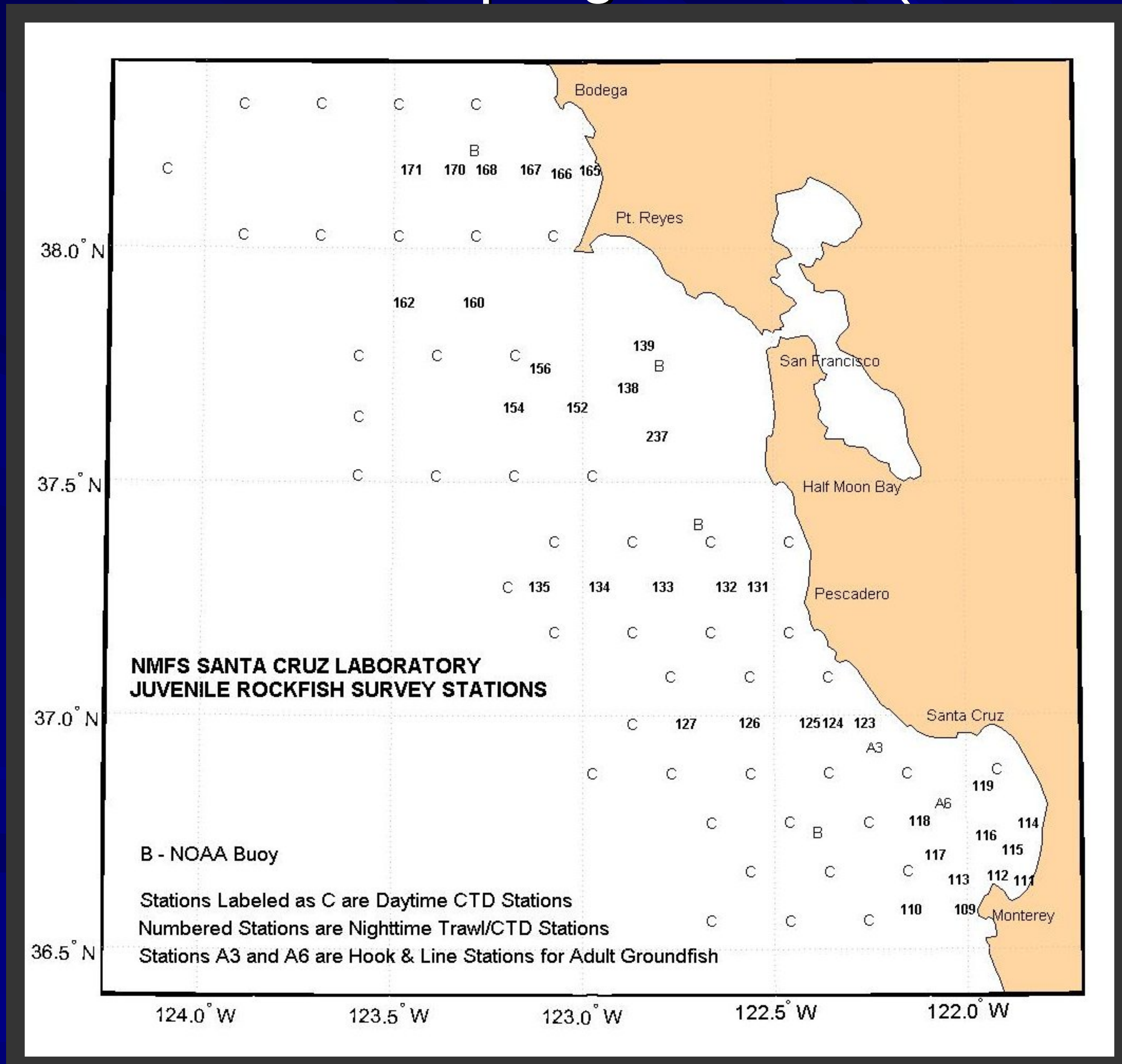
California Current has a well established history of variable climate on a decadal scale, and previous incursions of squid in the mid-1930s were during the middle of a warm period. There is also increasing evidence of monotonic increases in sea temperature associated with Global Climate Change.

In the continental shelf and slope ecosystem, there is also some evidence of shifts in community structure, from long-lived slow growing species to high turnover species (Levin et al. 2006). However, this would be a pretty extreme example of a fishing-induced change in community structure……

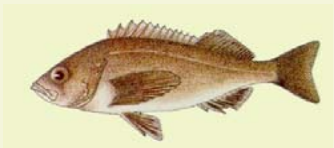


Secular warming in the California Current and North Pacific. D. Field et al., in press, CalCOFI Reports

NOAA NMFS SWFSC Midwater Trawl Survey Core Area and Sampling Stations (1983-2006)

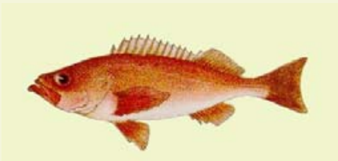


10 Rockfish Species Sampled by SWFSC Trawl



widow rockfish
Sebastes entomelas
60 yr, 59 cm max
schooling
commercial

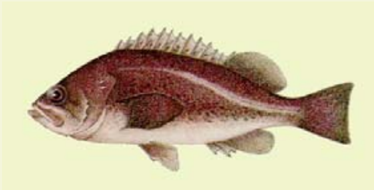
yellowtail rockfish
Sebastes flavidus
64 yr, 66 cm max
schooling
commercial



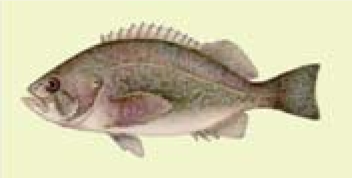
chilipepper
Sebastes goodei
35 yr, 59 cm max
schooling
commecial

squarespot rockfish
Sebastes hopkinsi
29 yr, 29 cm max
aggregate around outcrops
commercial bycatch

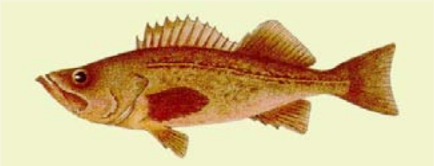
shortbelly rockfish
Sebastes jordani
32 yr, 35 cm max
schooling
unexploited



black rockfish
Sebastes melanops
50 yr, 69 cm max
schooling, outcrops
primarily sport



blue rockfish
Sebastes mystinus
44 yr, 53 cm max
Schooling, nearshore
sport



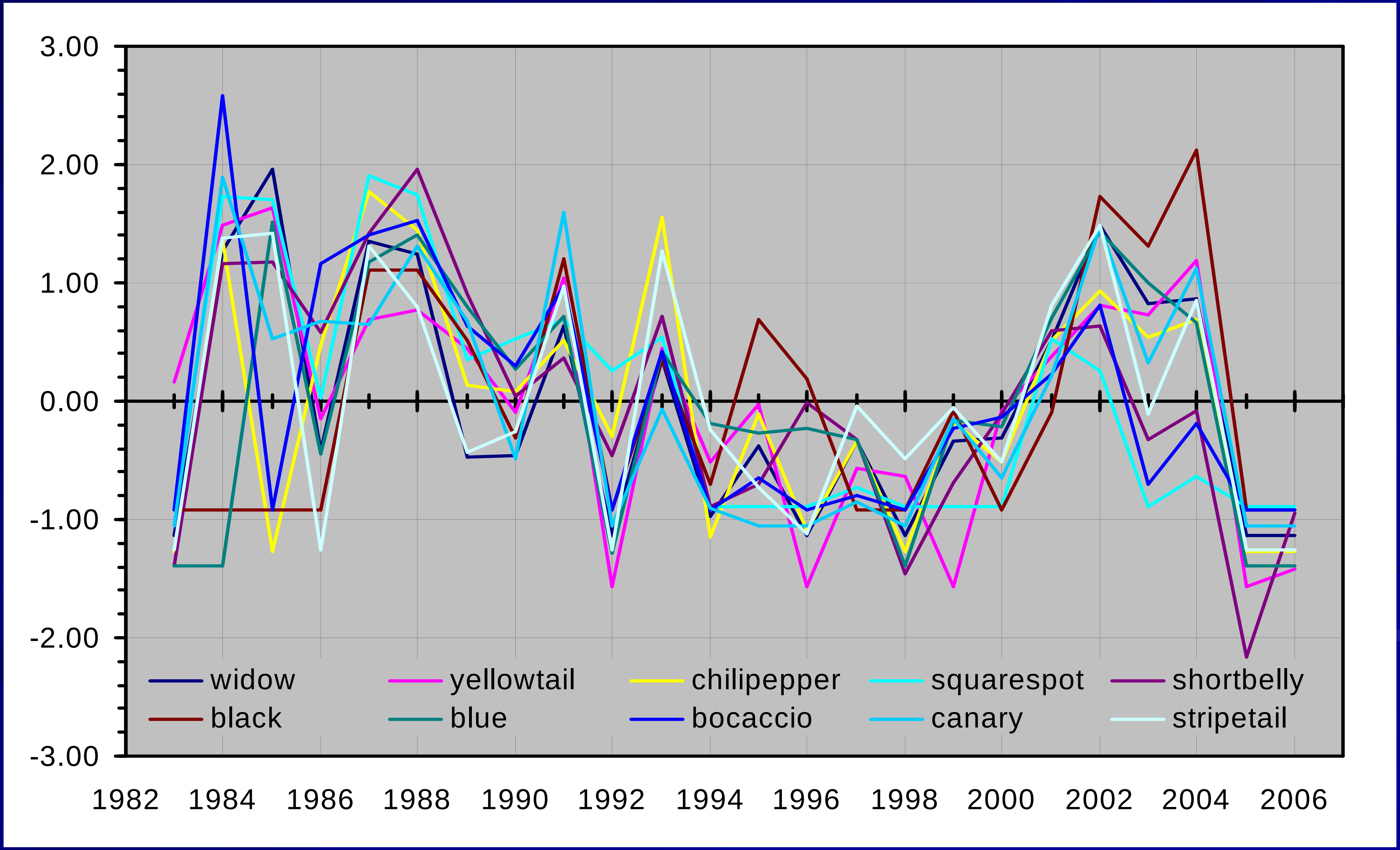
bocaccio
Sebastes paucispinis
45 yr, 91 cm max
schooling (various),
commercial, depleted

canary rockfish
Sebastes pinniger
84 yr, 76 cm max
aggregate around outcrops
commercial, depleted

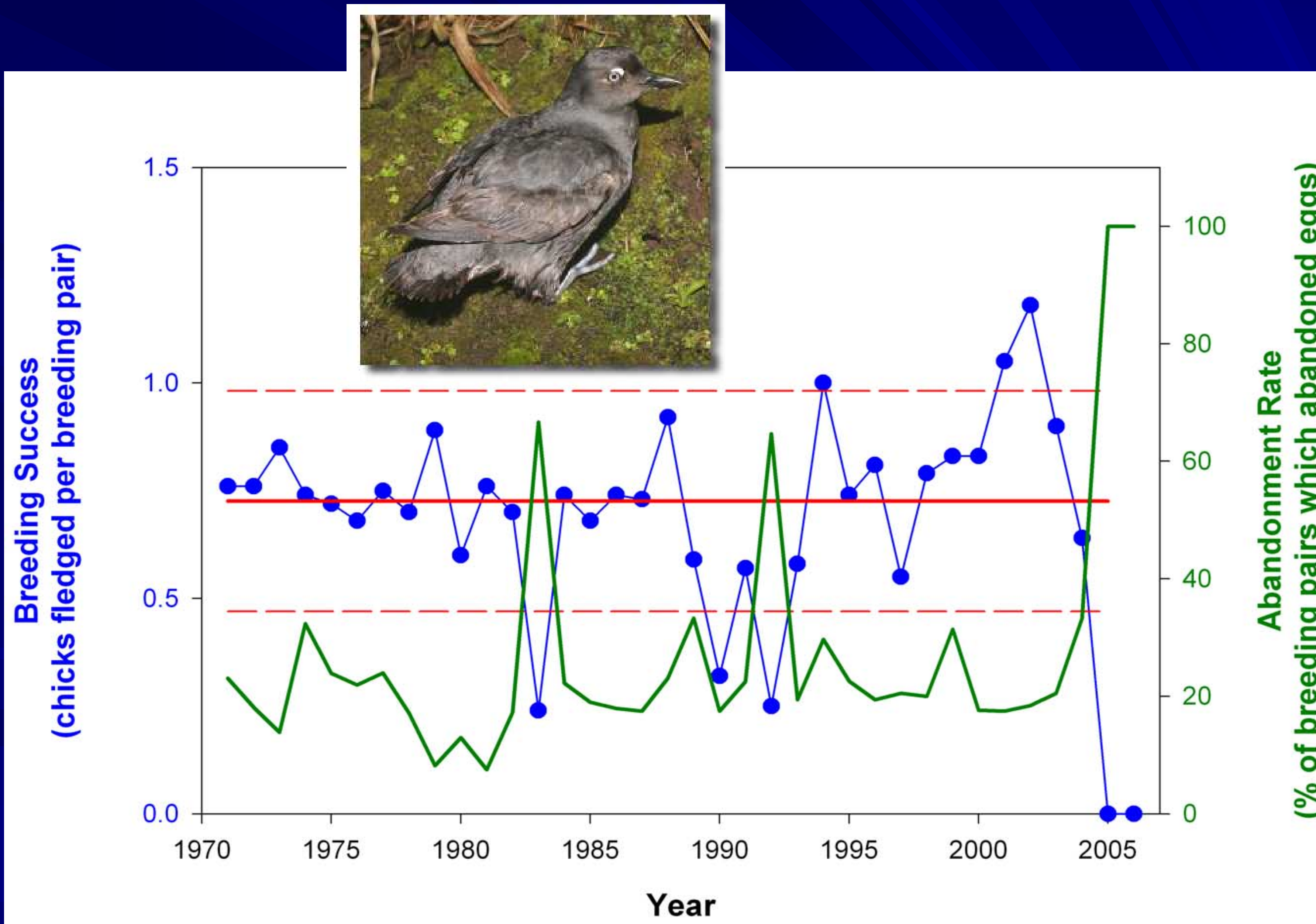
stripetail rockfish
Sebastes saxicola
38 yr, 41 cm max
solitary around mud
commercial bycatch

Illustrations from Eschmeyer *et al*. 1983, other information from Love *et al*. 2002

Trends in Abundance of YOY Rockfish in the Core Area of the NOAA NMFS SWFSC Midwater Trawl Surveys (2005 & 2006 are Lowest Years on Record)



Complete Reproductive Failure of Cassin's Auklets on SE Farallon Island in 2005 & 2006 (*slide provided by Bill Sydemen of PRBO*)



General Conclusions

- *Dosidicus* were rare in the CA Current System prior to the late 1990s, but have been encountered with increasing frequency since then.

- *Dosidicus* will eat just about anything they can capture. When encountered in temperate coastal waters, groundfish (especially semi-pelagic), coastal pelagics, and mesopelagics are important prey.

- The impact on the ecosystem is hard to infer given the lack of abundance data, but the potential impact could be substantial, particularly due to the mis-match of tropical v. temperate life histories.

- Stomach analysis and preliminary food web modeling indicate that *Dosidicus* are significant *higher trophic level predators in the northern CA Current eco*system, vs. being a significant forage species in semi-tropical and tropical waters of the Pacific.

- In Chile, the hake stock assessment suggested that *Dosidicus* had a major impact when the frequency of occurrence in trawl surveys increased from 1-2% to 40-50%. Based on California Current resource surveys we're probably not there yet, but we could be someday…

- More research, monitoring, modeling will be key!

Acknowledgements

This could not have been done without the tremendous help and assistance in collecting samples by a large number of people, particularly recreational and commercial fishing vessel operators! Special thanks to Tom Mattusch and the crew of the Huli Cat, Frank Bertroni, Rick Powers and the crew of the New Sea Angler, John Ymate and crew of the New Seaforth, the Captain and crew of the Sir Randy, the NWFSC FRAM division and the FVs that participated in the 2005 and 2006 bottom trawl surveys, and the Officers and crew of the NOAA Ship David Starr Jordan in 2005 and 2006. We also thank Steve Berkeley, David Field, John Hyde, David Stafford, for their help in collecting samples; Scot Anderson Wendy Dunlap, Mark Lowry, Dan Howard and Rick Starr for sharing their data, photos and videos; and William Gilly, Eric Hochberg, Mark Lowry Don Pearson, Keith Sakuma, Eric Bjorkstedt, Mike Weiss, and Lou Zeidberg for their help with specimens.