Predation on jellyfish by pelagic and demersal fishes in the Northeast Pacific

Sea Nettles
Monterey Bay, CA

Richard D. Brodeur[1], Troy W. Buckley[2], Geoffrey M Lang[2], John C. Buchanan[1], Douglas A. Draper[1] and Richard E. Hibpshman[3]

[1]NOAA Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR,
[2]NOAA Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA
[3]JISOA, University of Washington, 7600 Sand Point Way NE, Seattle, WA

Jellyfish Workshop, Yokohama Japan, November 2018

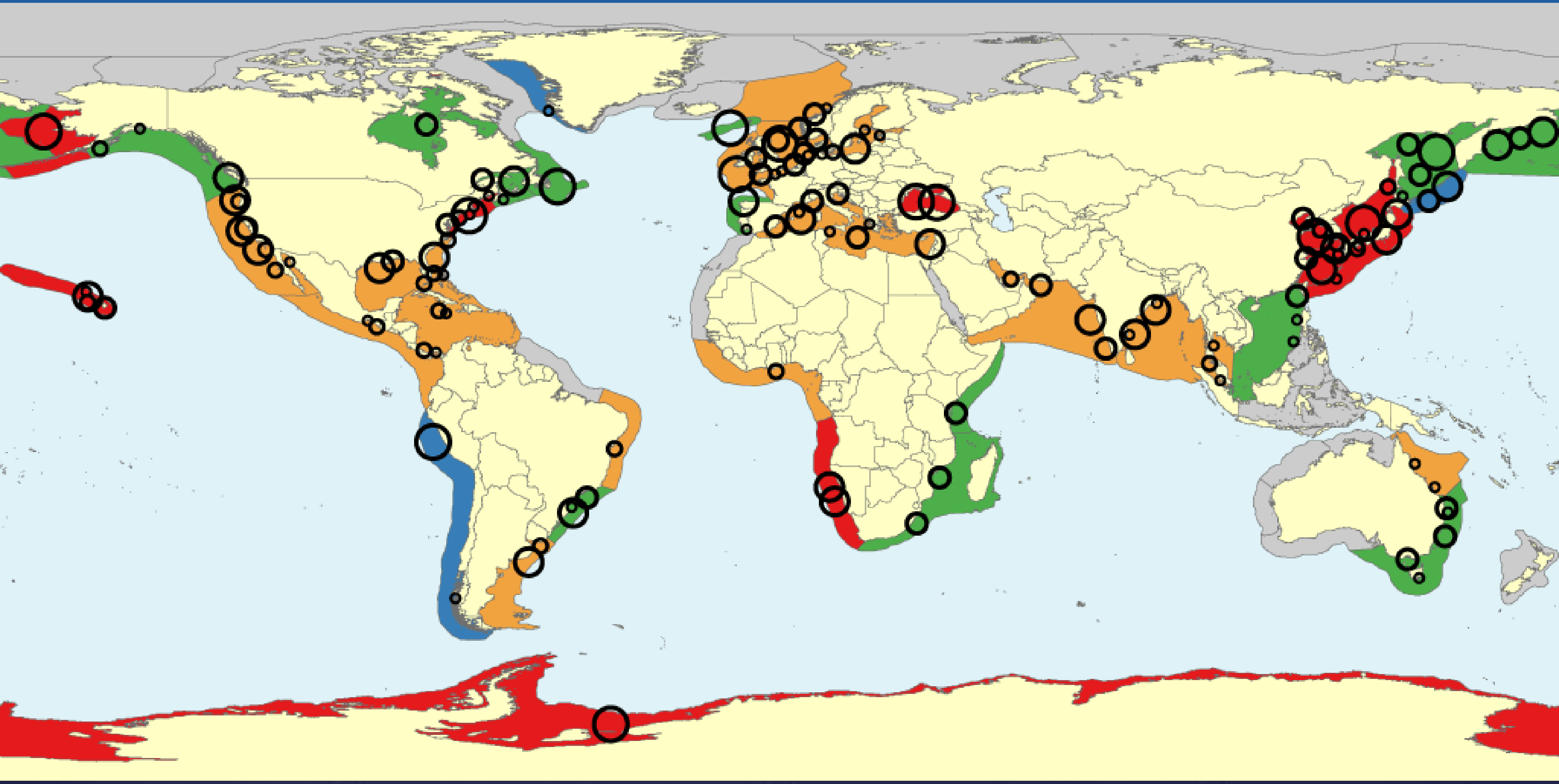
Why the Interest in Jellyfish?

In recent years, there have been some major increases in jellyfish blooms throughout the world's oceans which has led to a lot of scientific interest as to the causes of these outbreaks.

Some of these 'blooms' may be natural occurrences but most probably are the result of human activity such as overfishing, eutrophication, species introductions, and pollution.

Jellyfish Index in Large Marine Ecosystems

Brotz et al. (2012) Hydrobiologia

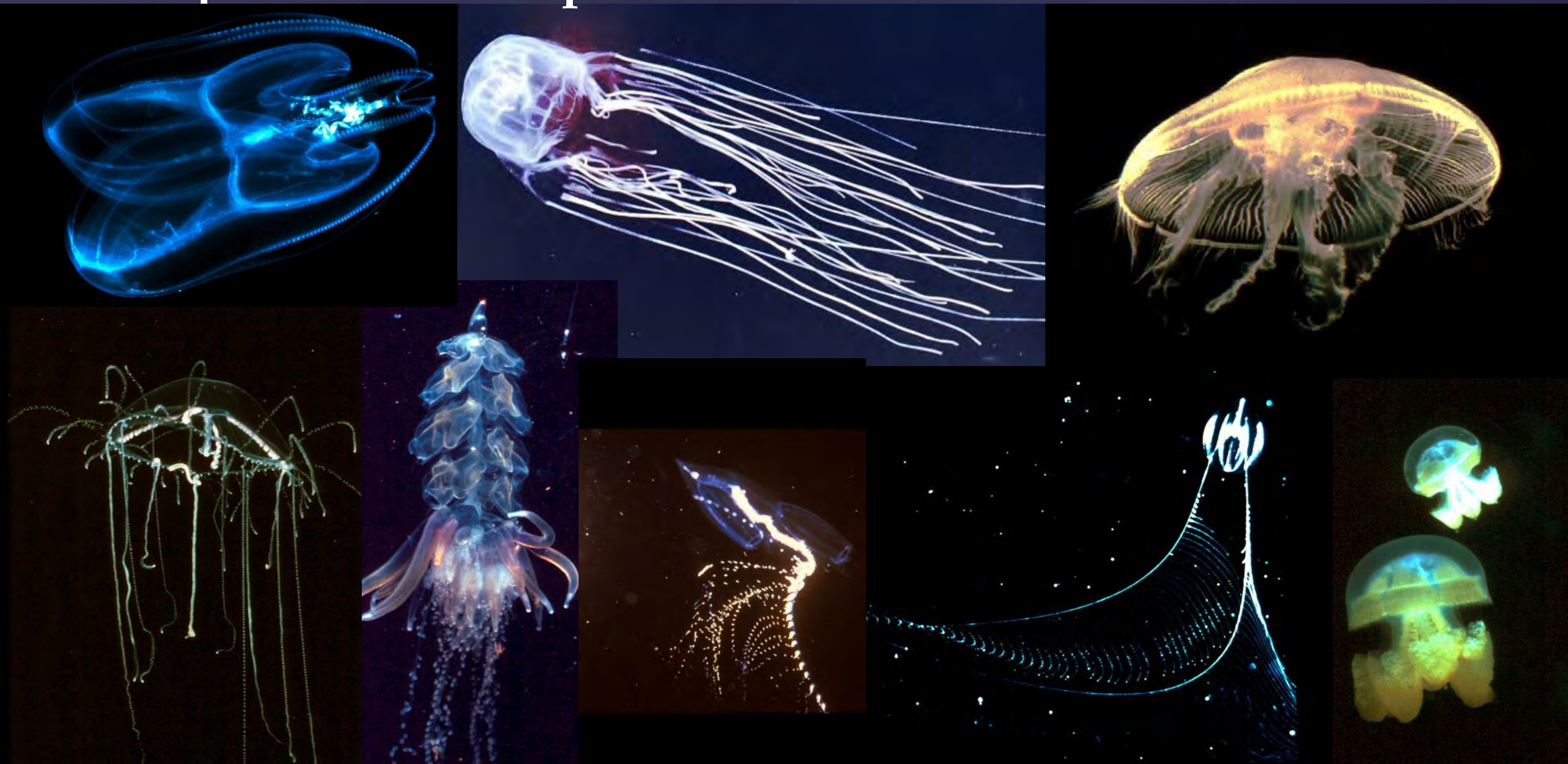


- Increase (high certainty) – 10 (22%)
- Increase (low certainty) – 18 (40%)
- Stable/Variable – 14 (31%)
- Decrease – 3 (7%)

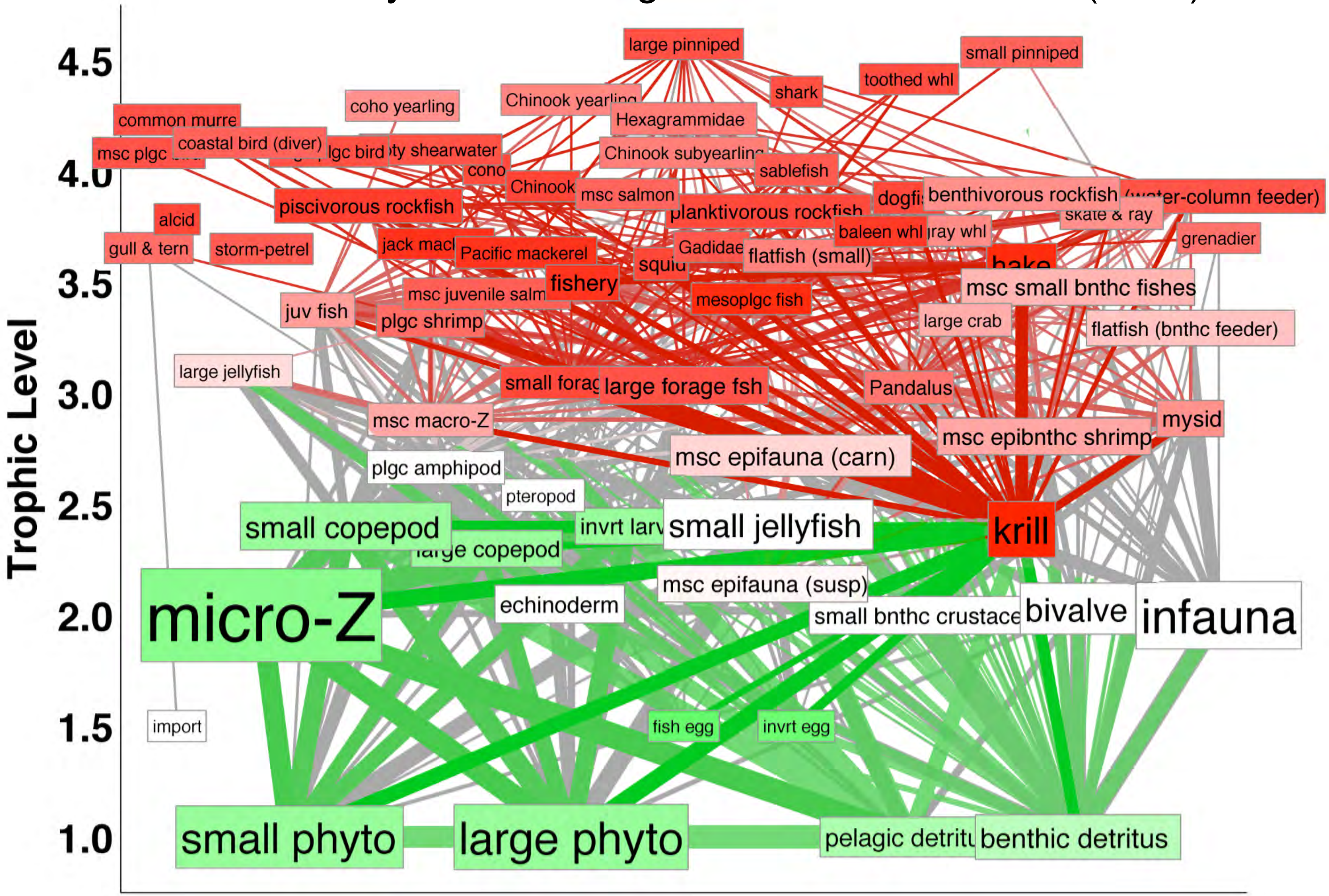
What do we mean by jellyfish?

190 species of Scyphomedusae
20 species of Cubomedusae
840 species of Hydromedusae
200 species of Siphonophores
150 species of Ctenophores

>30,000 species of fish



Model of NCC Ecosystem Showing Flow to and From **Krill** (2006)

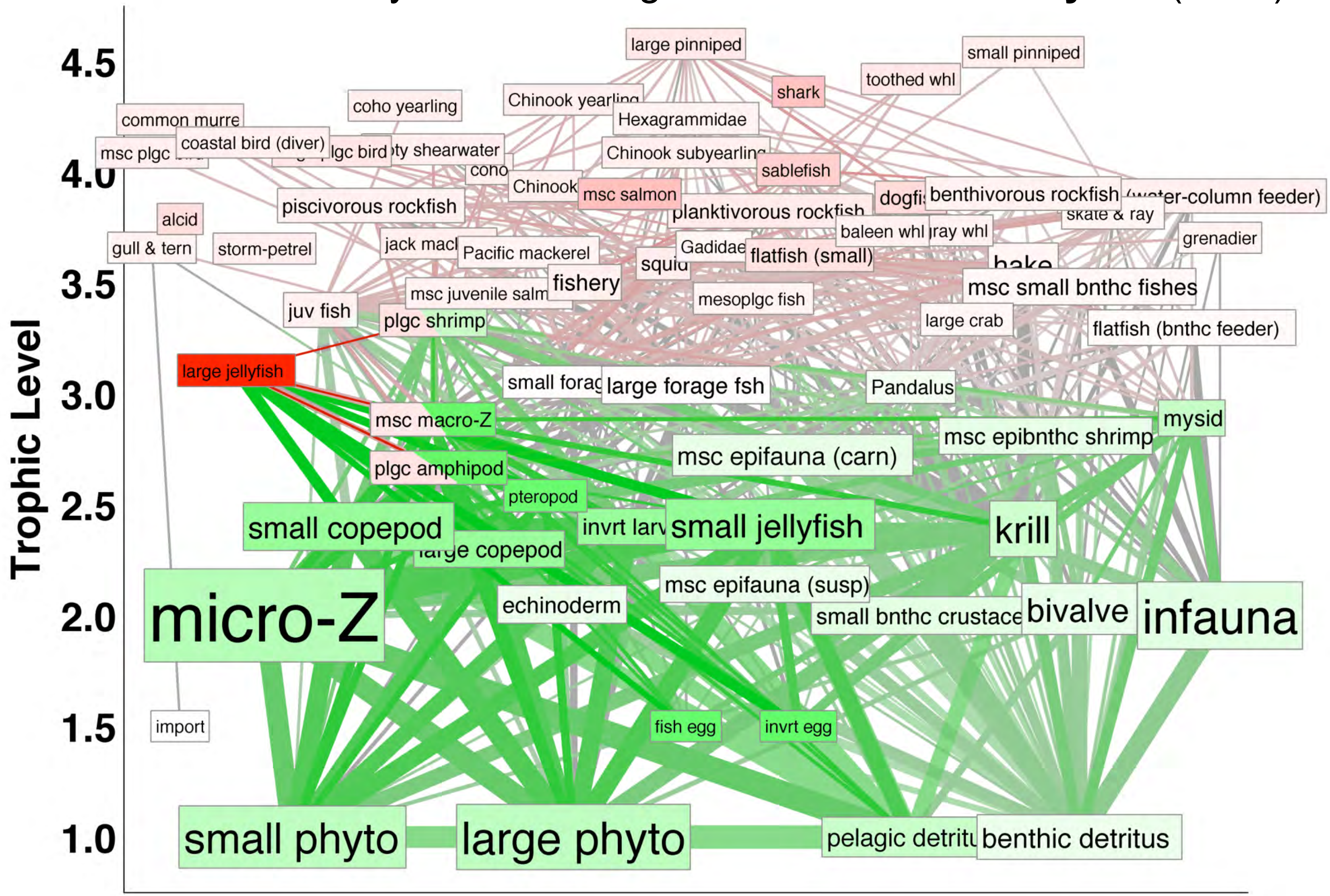


Footprint = 0.0299

Reach = 0.0079

Ruzicka et al. (2012) *Prog. Ocean*.

Model of NCC Ecosystem Showing Flow to and From **Jellyfish** (2006)



Footprint = 0.0641

Reach = 0.00015

Ruzicka et al. (2012) *Prog. Ocean.*

Jellyfish are important in the diets of marine animals

- Several sea turtle species
- Many fishes, notably molas, chum and pink salmon, butterfish, mackerels, dogfish sharks
- Birds, such as parakeet auklets and albatrosses

Research Questions

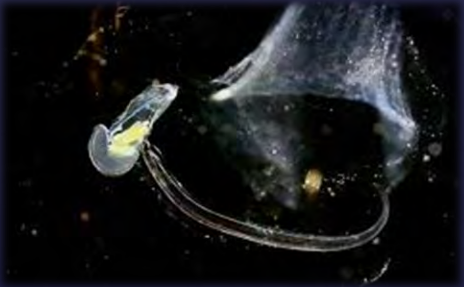
- What species of fish consume jellyfish?
- What are the interannual and spatial patterns of jellyfish consumption?
- What are the biases associated with alternative methods for detecting jellyfish in the diets?

“Sea Jellies”, “Jellyfish”

Collective terms for:

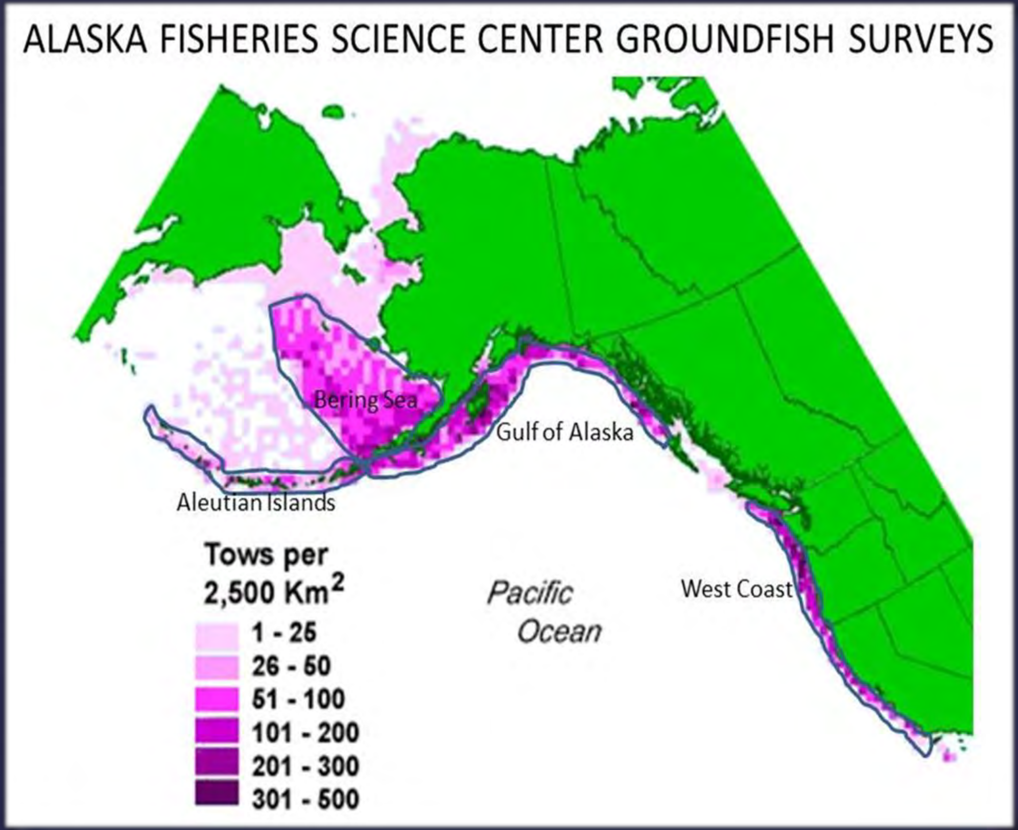
- typical jellyfish
- comb jellies

- salps
- larvaceans



Demersal Fish Surveys

- 1981 – 2017 AFSC Bering Sea Annual Trawl Surveys
- 1981 – 2016 AFSC Aleutian Island Biennial Trawl Surveys
- 1981 – 2017 AFSC Gulf of Alaska Biennial Trawl Surveys
- 1980 – 1992 AFSC West Coast Annual Trawl Surveys
- 2005 – 2017 NWFSC West Coast Annual Trawl Surveys



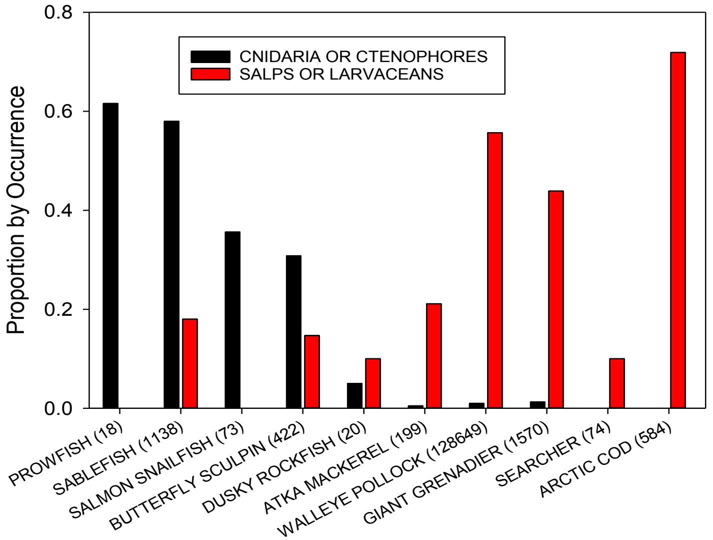
Summary of Groundfish Utilization of Gelatinous Material

Region	Years	# Species	# Stomachs	Containing Jellyfish		Containing Salps	
		Examined	Examined	Number	Percent	Number	Percent
Bering Sea	1981-2017	92	312805	28	30.4	23	25.0
Aleutian Islands	1981-2012	34	37088	14	41.2	18	52.9
Gulf of Alaska	1981-2017	72	84588	24	33.3	32	44.4
West Coast	1980-1992	14	16368	4	28.6	2	14.3
West Coast	2005-2017	22	4955	6	27.3	6	27.3

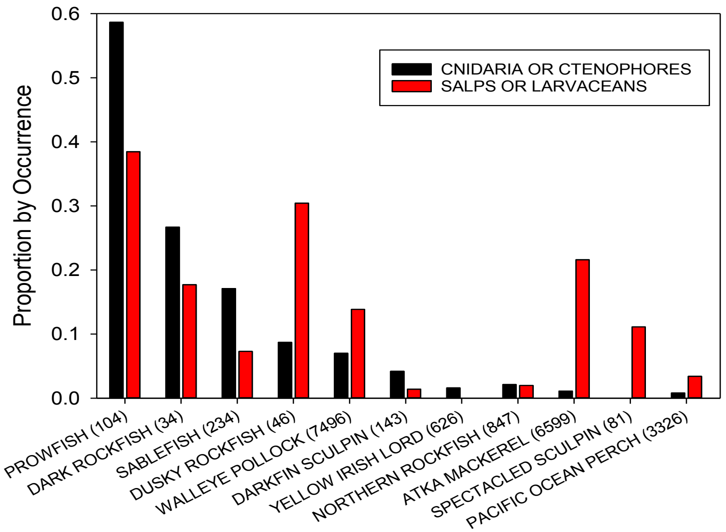
Total # of Stomachs Examined = 455,804 !

North Pacific Demersal Fishes

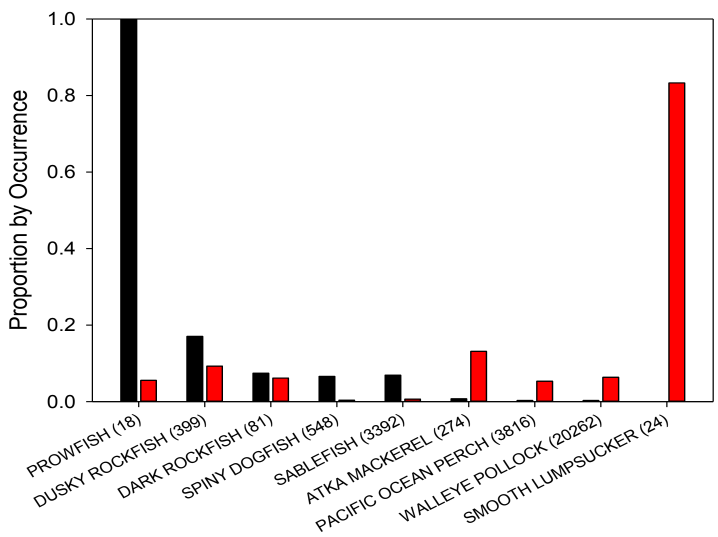
Bering Sea 1981-2017



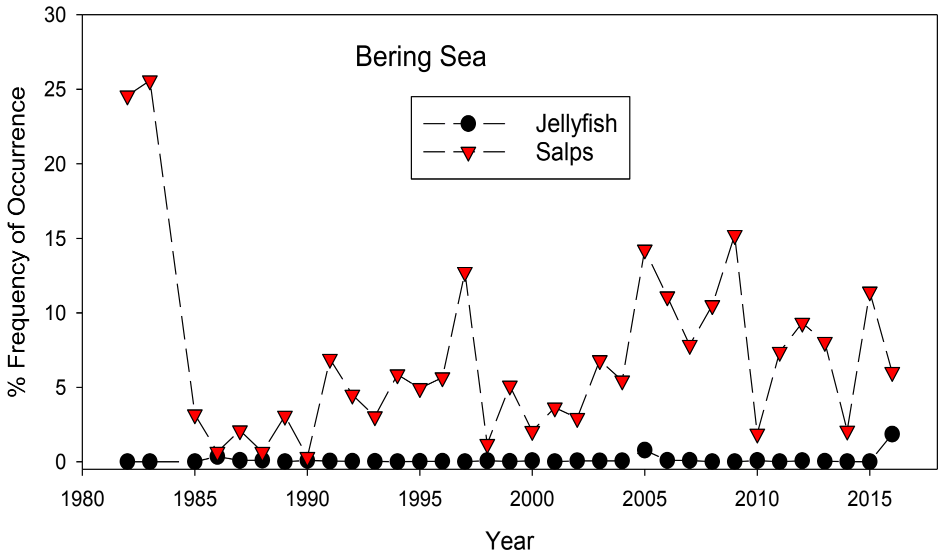
Aleutian Islands 1981-2016

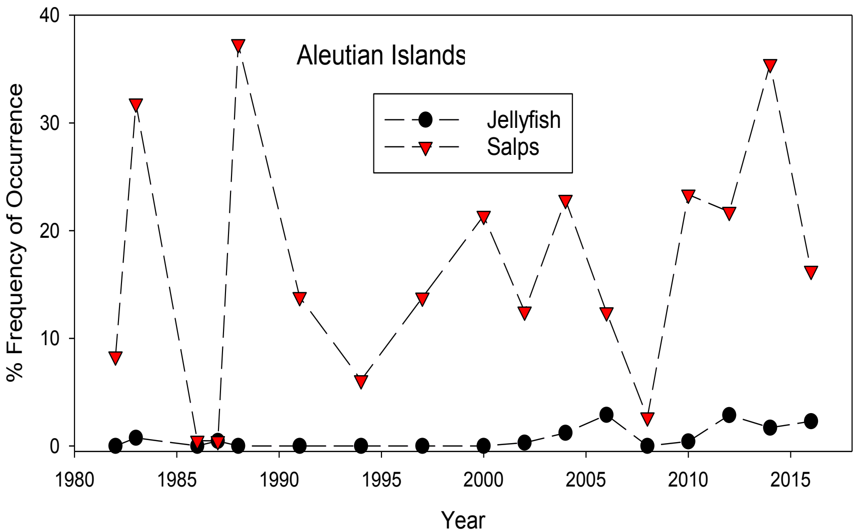


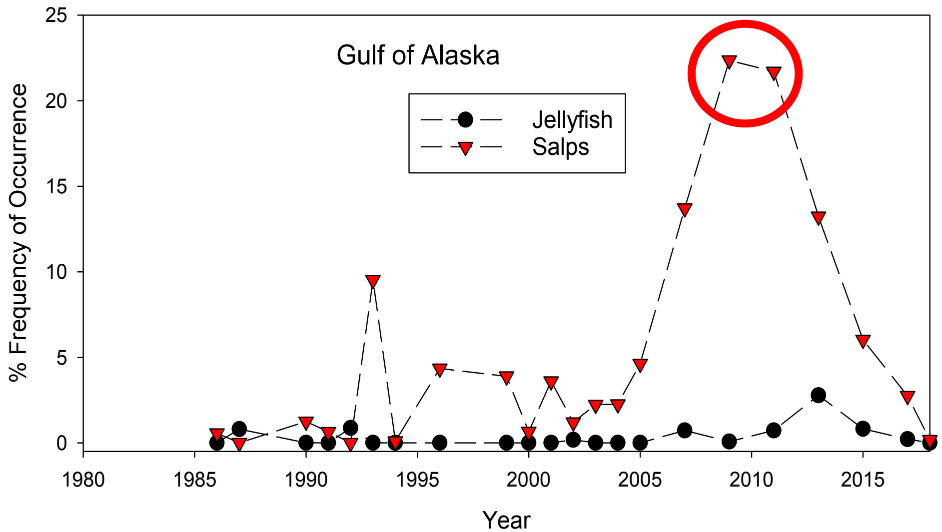
Gulf of Alaska1981-2018



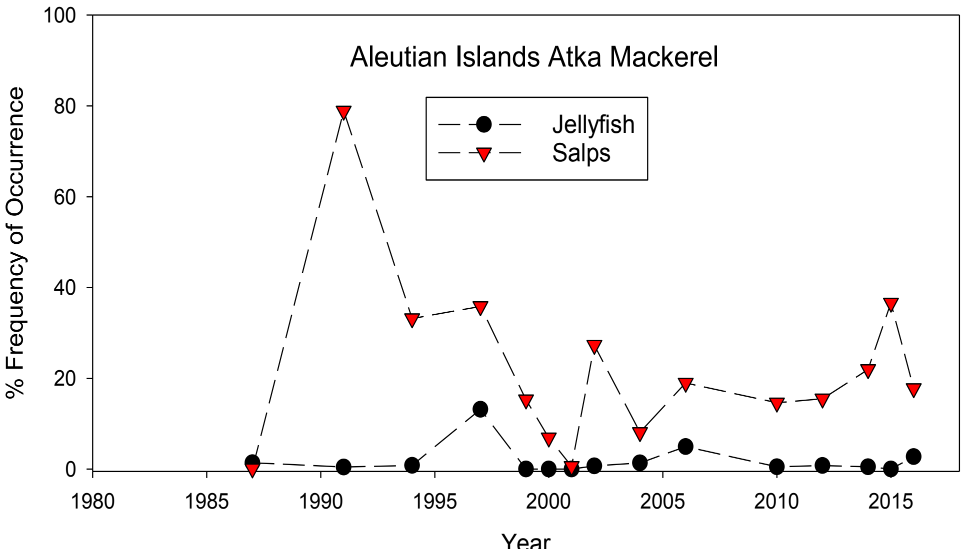
Interannual Variation in the Occurrence of Jellyfish and Salps In the Diet of Walleye Pollock in Different Geographical Regions

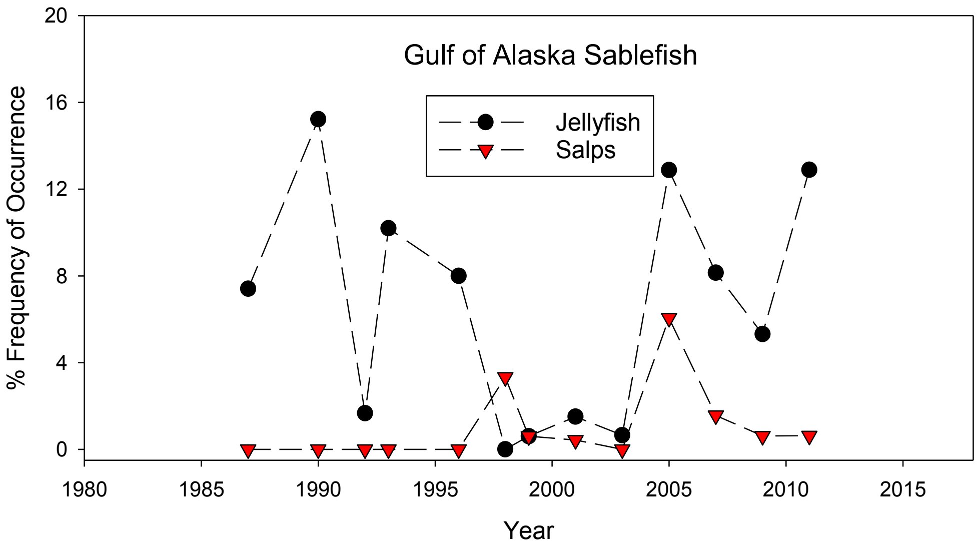




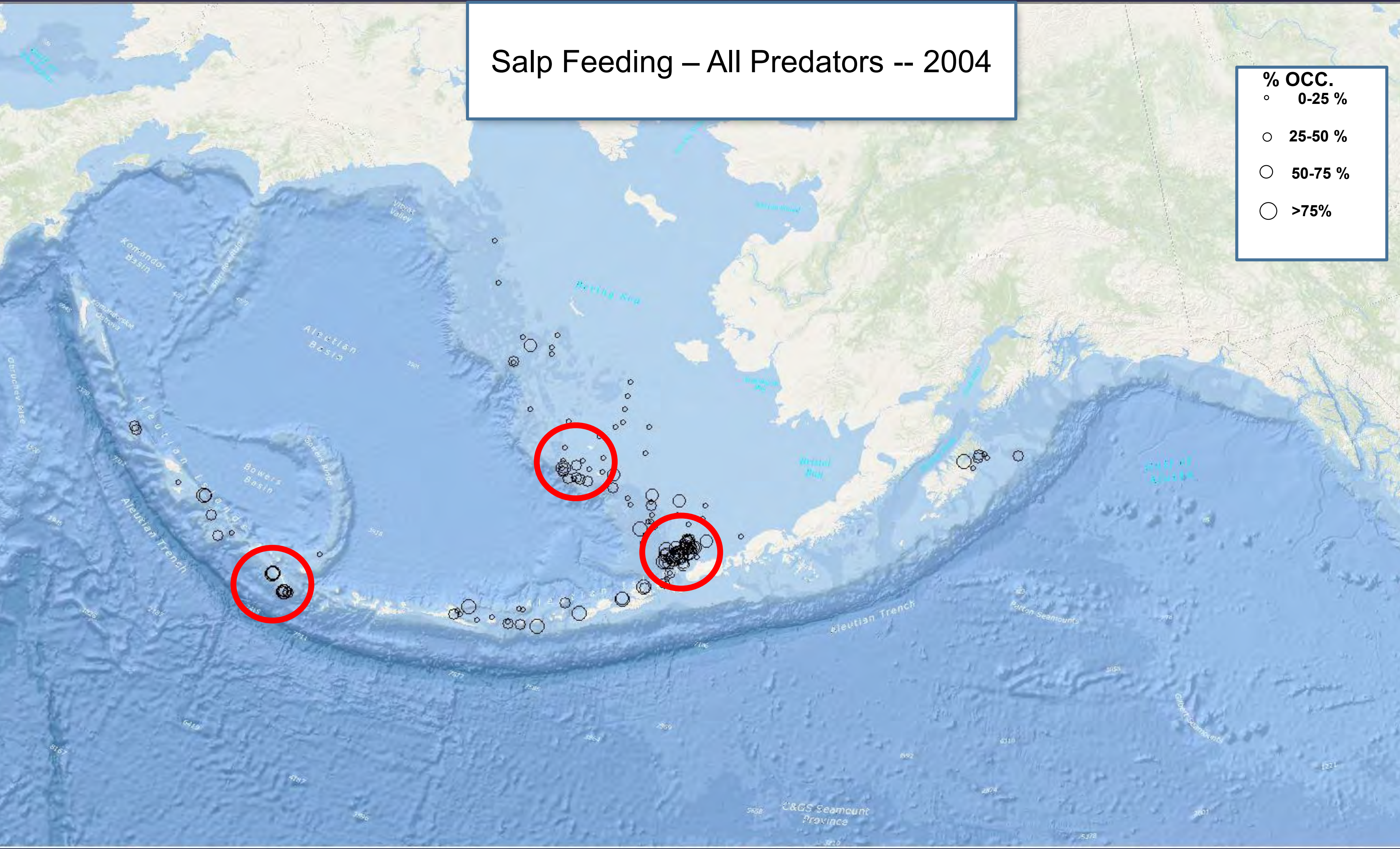


Interannual Variation in the Occurrence of Jellyfish and Salps in the Diet of Atka Mackerel in the Aleutian Islands (top) and Sablefish in the Gulf of Alaska (bottom)

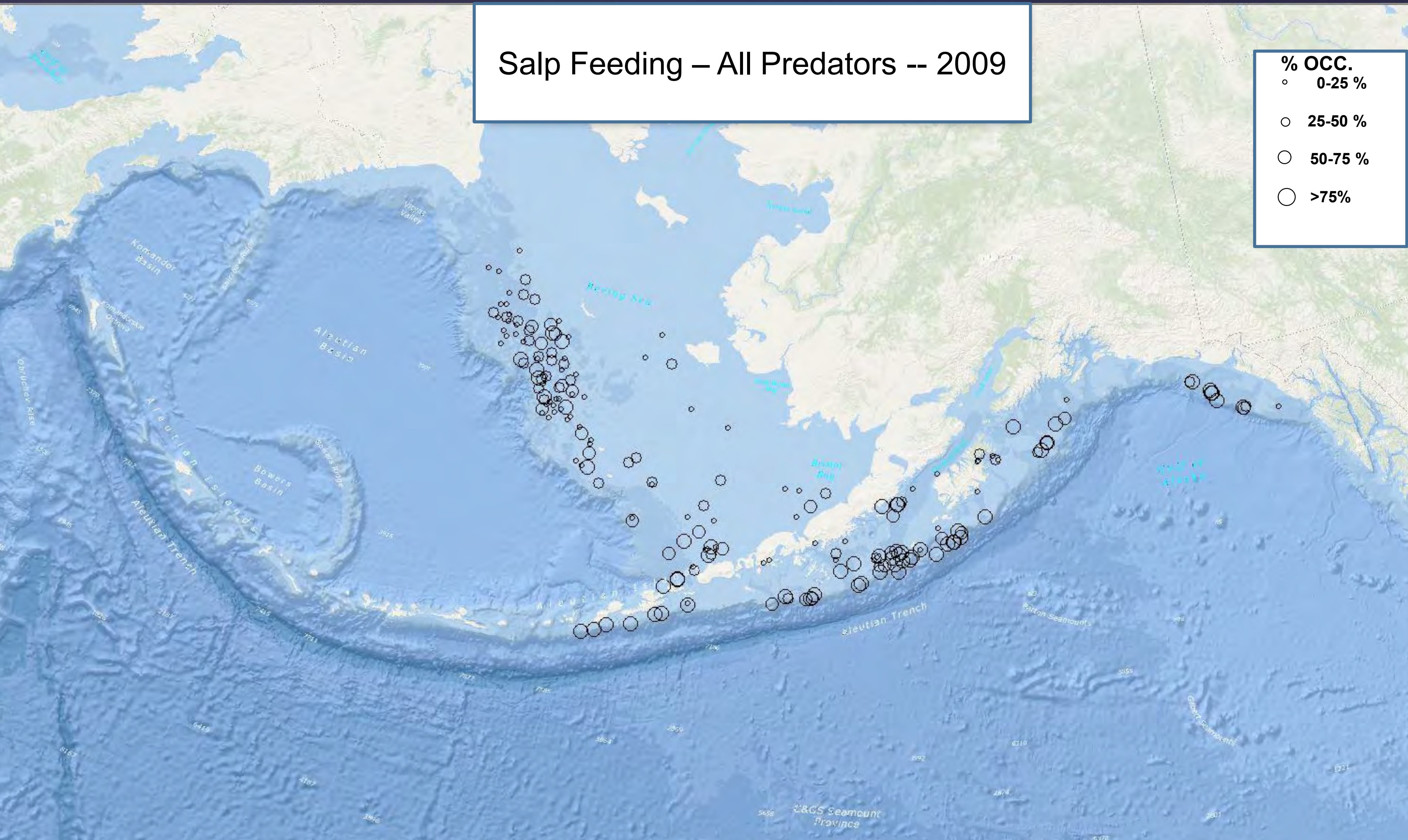




Salp Feeding – All Predators -- 2004

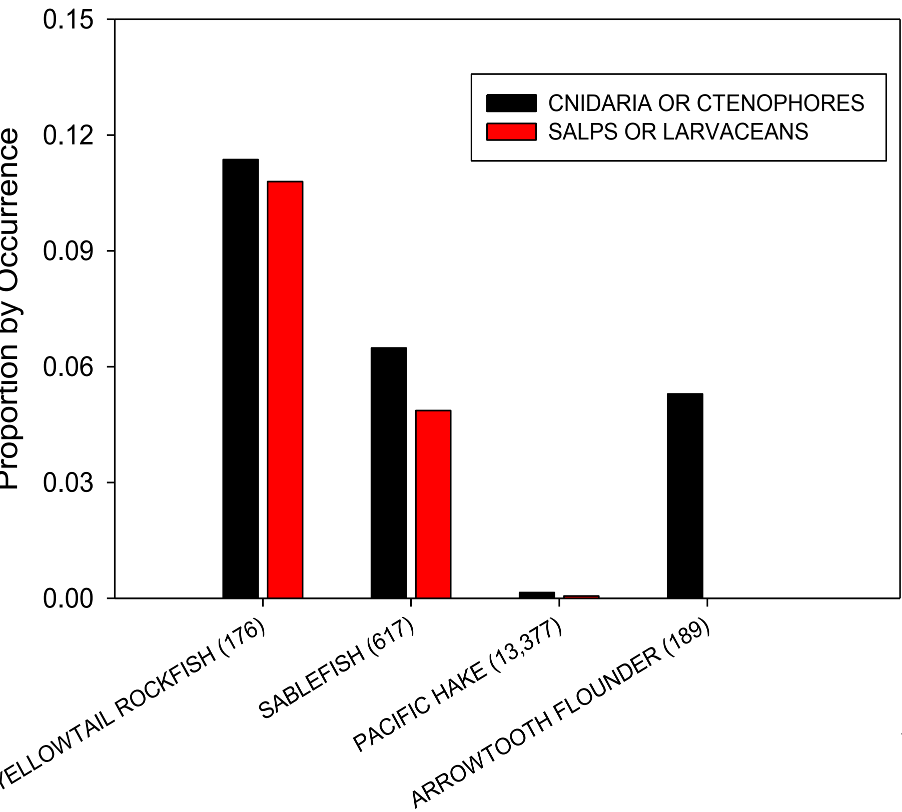


Salp Feeding – All Predators -- 2009

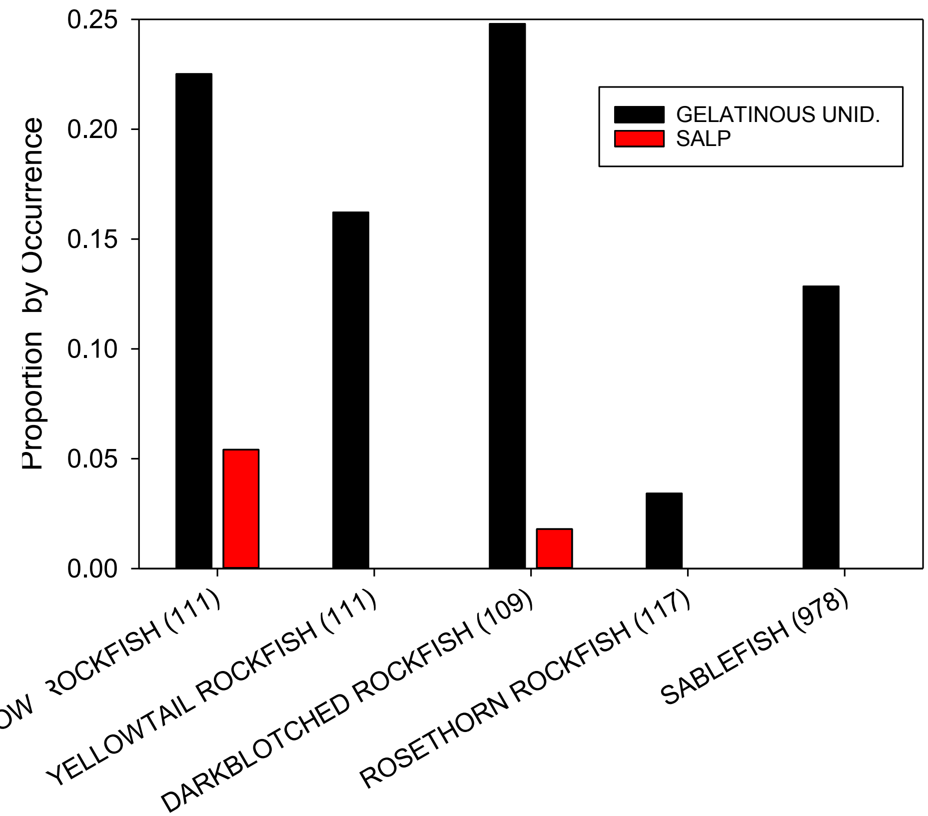


West Coast Demersal Fishes

AFSC 1980-1992



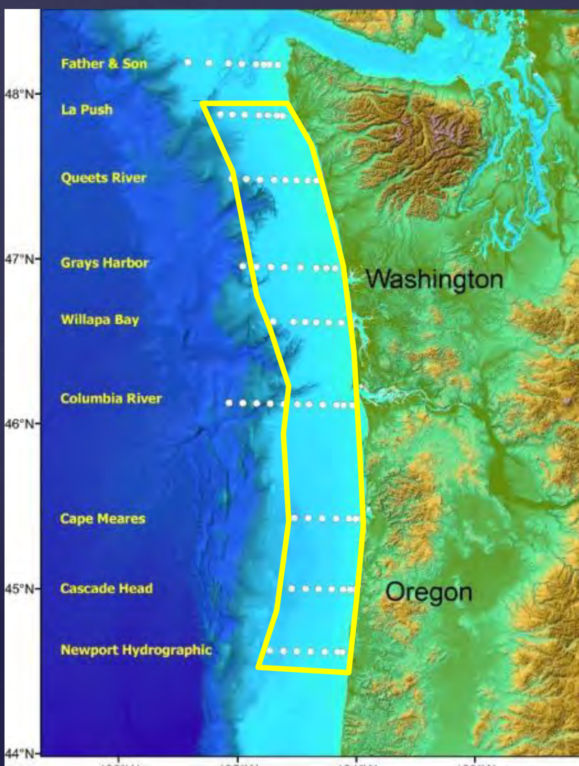
NWFSC 2005-2017



Pelagic Fish Surveys

- Mainly in early summer and fall
- 1981 – 85 OSU purse seining off WA/OR
- 1998 – present – NMFS trawling in surface waters off WA and OR
- 2000 and 2002 – GLOBEC surface trawling off OR/CA

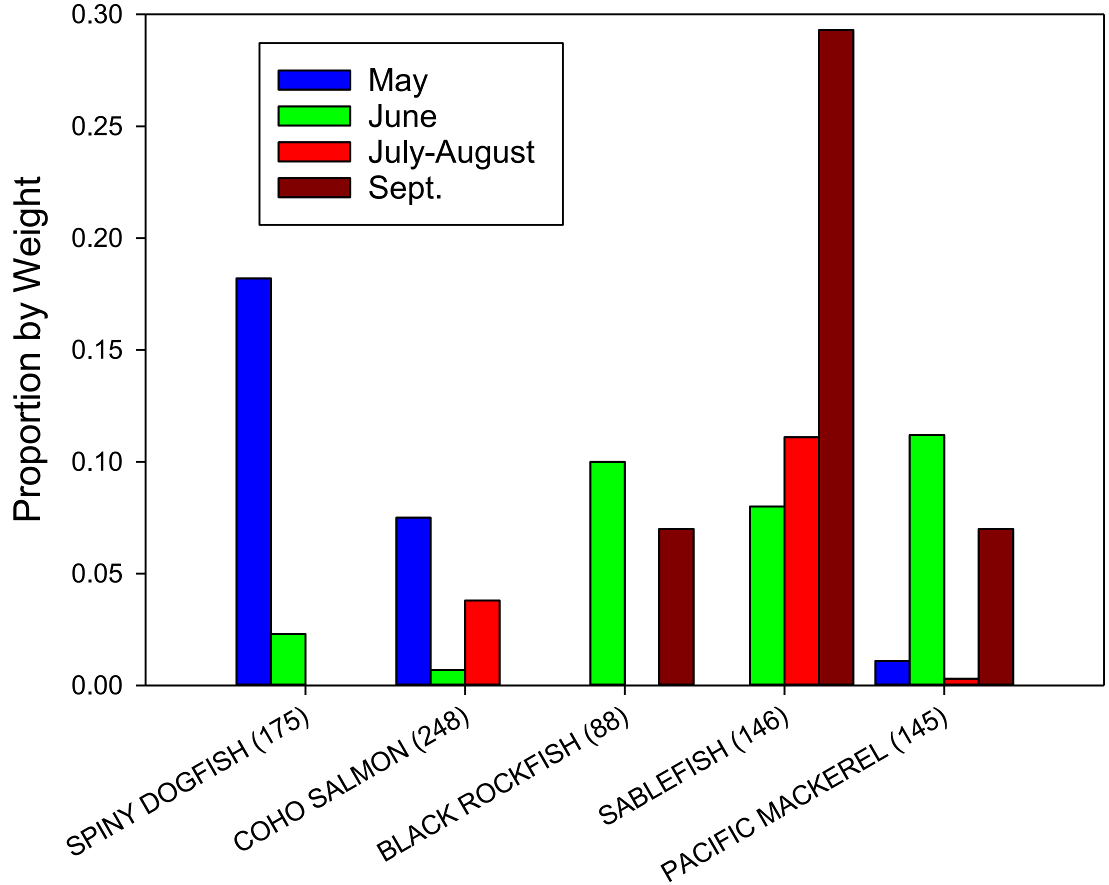





Northern California Current Pelagic Fishes

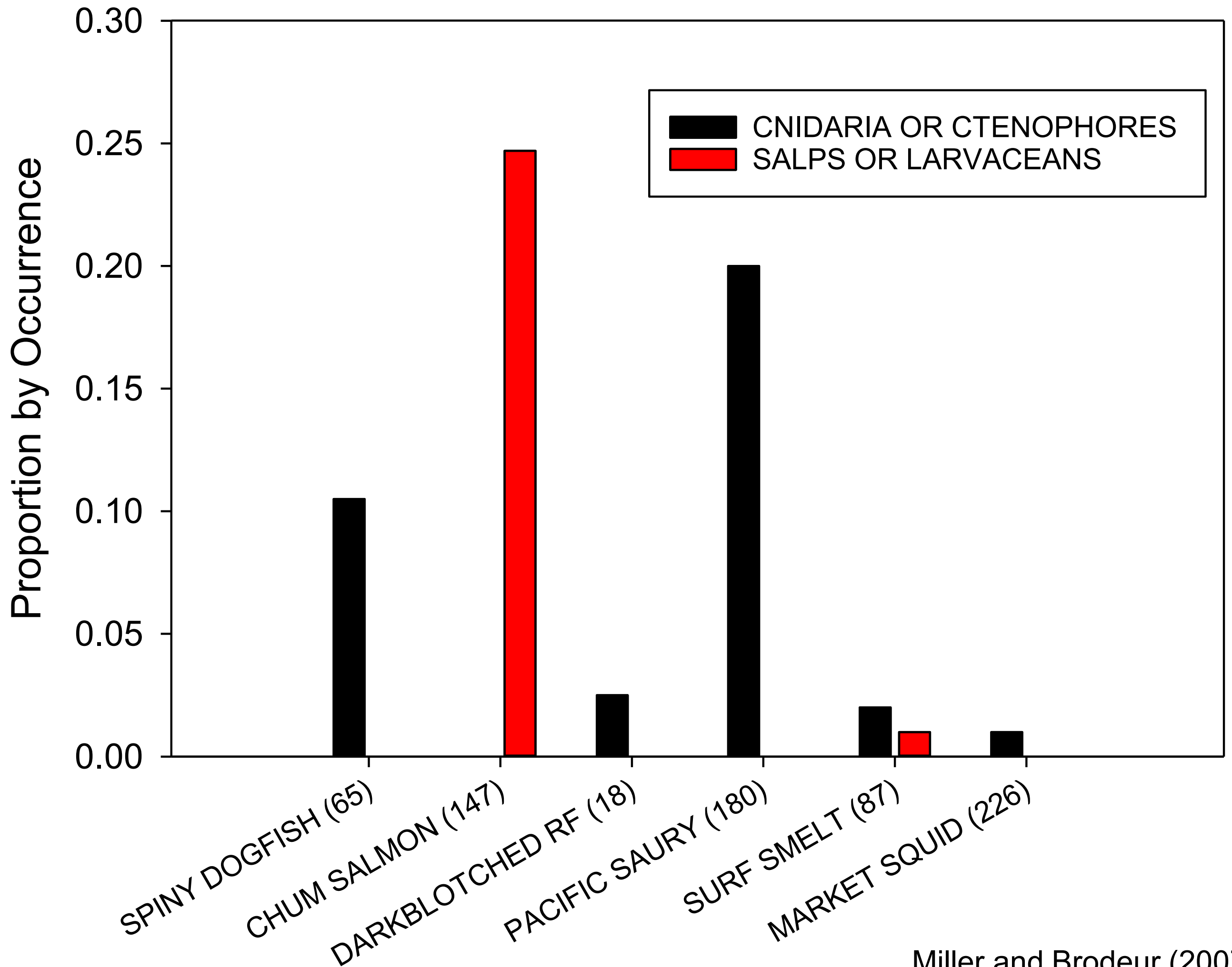
OSU Purse Seine Surveys (May – September)

(1981-1984, N = 18 Species, 2,663 Stomachs)



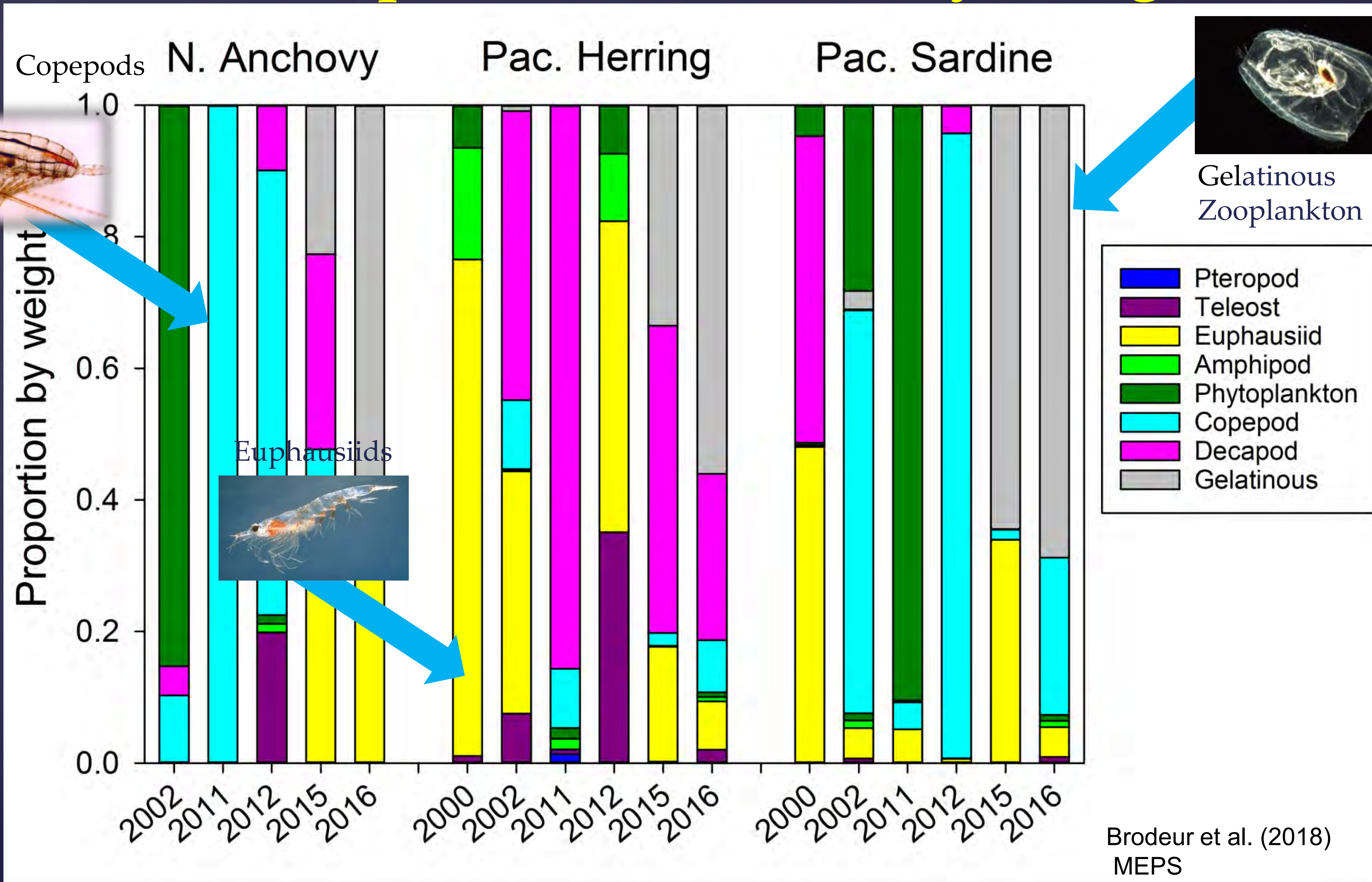
Northern California Current Pelagic Fishes

NWFSC GLOBEC Surveys (2000 and 2002)
(N = 26 species, 3,161 stomachs)



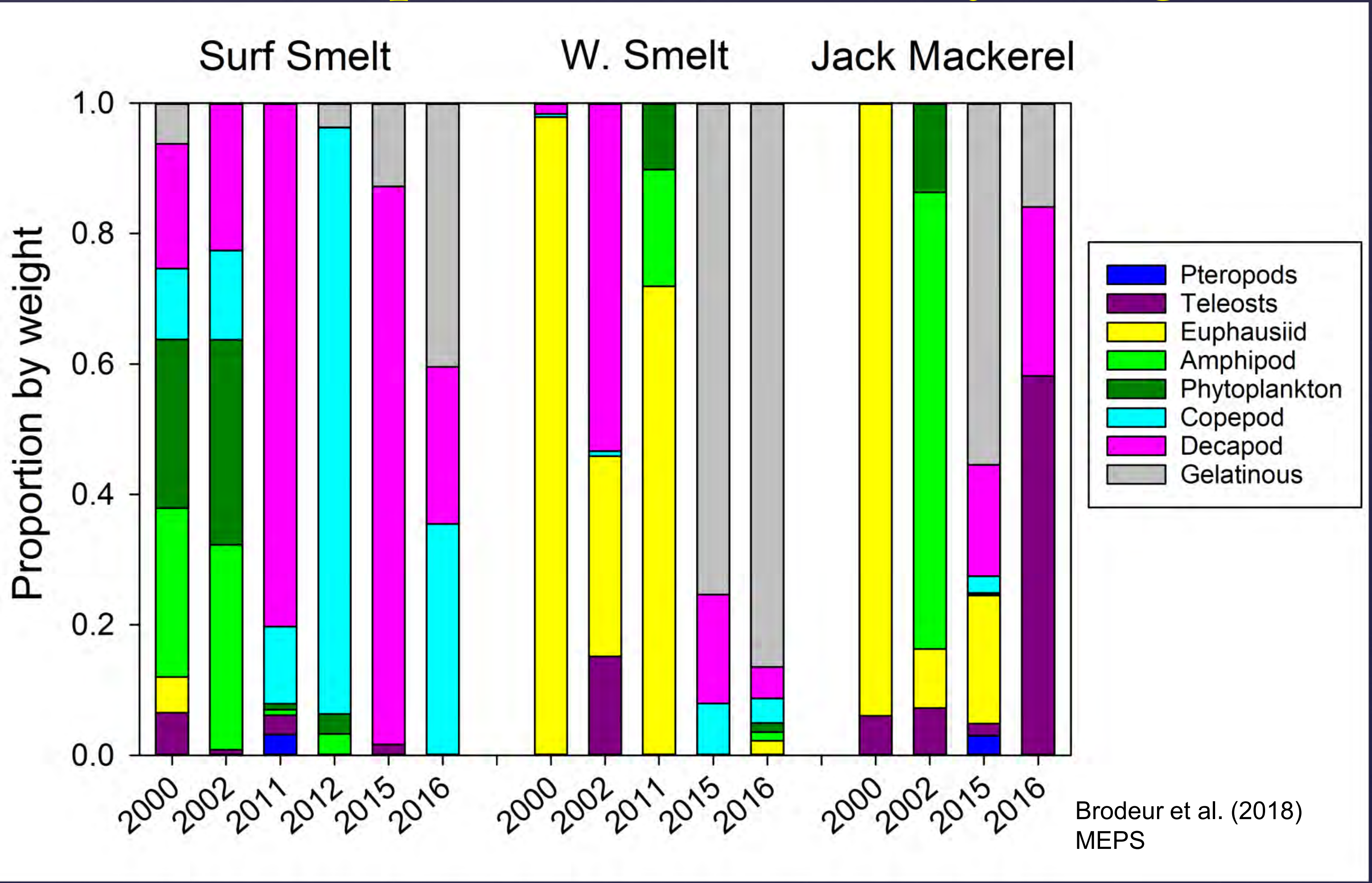
Miller and Brodeur (2007) Fish Bull

Diet composition in June by weight



A C C W W   A A C C W W   A A C C W W

Diet composition in June by weight



A A C C W W A A C W W A A W W

Frequency of Occurrence of Gelatinous Material in Forage Fish Stomachs (%)

	2000	2002	2011	2012	2015	2016
Northern anchovy	0	0	0	5.3	60.1	78.4
Pacific herring	0	12.0	0	0	64.3	51.4
Pacific sardine	16.7	45.7	0	0	92.3	39.5
Jack mackerel	0	0	---	---	60.0	33.3
Whitebait smelt	0	0	0	---	---	92.6
Surf smelt	40.6	71.7	0	66.7	---	100.0
PDO Regime	Neutral	Neutral	Cool	Cool	Warm	Warm

Biases with diet studies

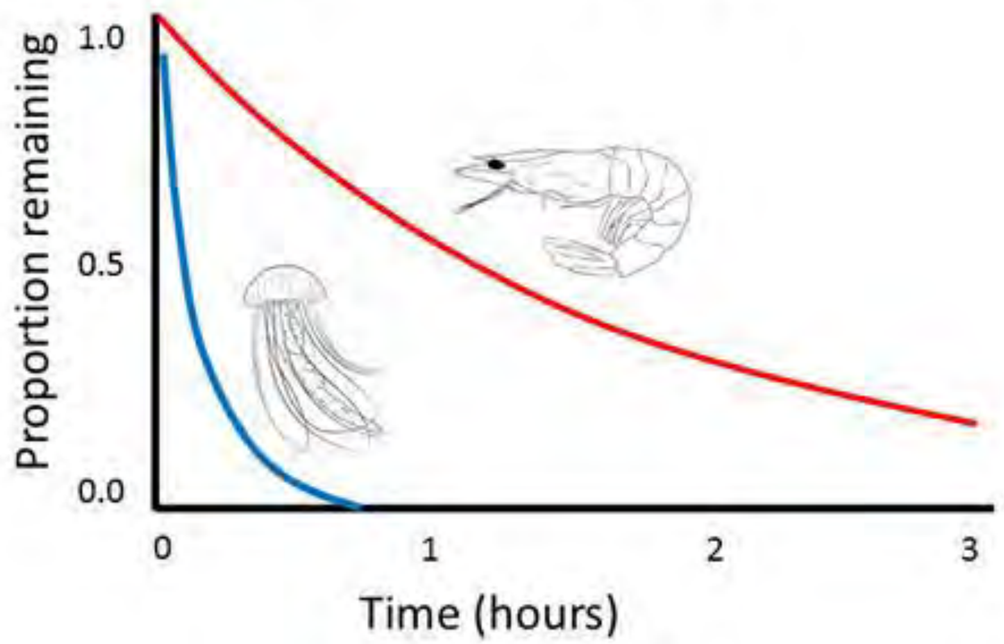
- **Loss of prey quality through preservation and rapid digestion**

At-sea vs Laboratory Analysis of Gelatinous Material

Values with asterisks were significantly different by method.

			Sample size		Coelenterates %FO		Urochordates %FO	
Predator	**Year**	**Region**	**Lab**	**Scan**	**Lab**	**Scan**	**Lab**	**Scan**
Dark Rockfish	2010	AI	10	17	0.0	52.9*	0.0	17.6
Dusky Rockfish	2010	AI	8	4	0.0	100*	12.5	0.0
Prowfish	2010	AI	2	18	0.0	100*	0.0	5.6
Sablefish	2007	GOA	113	119	4.4	18.5*	0.9	3.4
Sablefish	2009	GOA	225	109	4.0	16.5*	0.9	0.9
Sablefish	2010	AI	13	11	30.8	36.4	0.0	0.0
Atka Mackerel	2007	GOA	23	11	0.0	0.0	21.7	63.6*
Atka Mackerel	2009	GOA	17	15	0.0	0.0	11.8	13.3
Atka Mackerel	2010	AI	283	107	0.0	1.9	15.9	13.1
Walleye Pollock	2007	GOA	347	442	0.0	1.8	20.2	18.3
Walleye Pollock	2009	GOA	659	359	0.0	0.3	38.8*	11.1
Walleye Pollock	2010	AI	284	137	0.4	1.5	27.1	24.1

Rapid Digestion and Evacuation Rates for Gelatinous Zooplankton



Arai, M.N. *et al.* (2003) Digestion of pelagic Ctenophora and Cnidaria by fish. *Can. J. Fish. Aquat. Sci.* 60, 825–829.

Biases with diet studies

- Loss of prey quality through preservation and rapid digestion
- Alternative methods of detecting gelatinous prey
  1. Biochemical analysis of muscle tissue (stable isotopes, fatty acids)

Stable Isotope Analysis

Advantages:

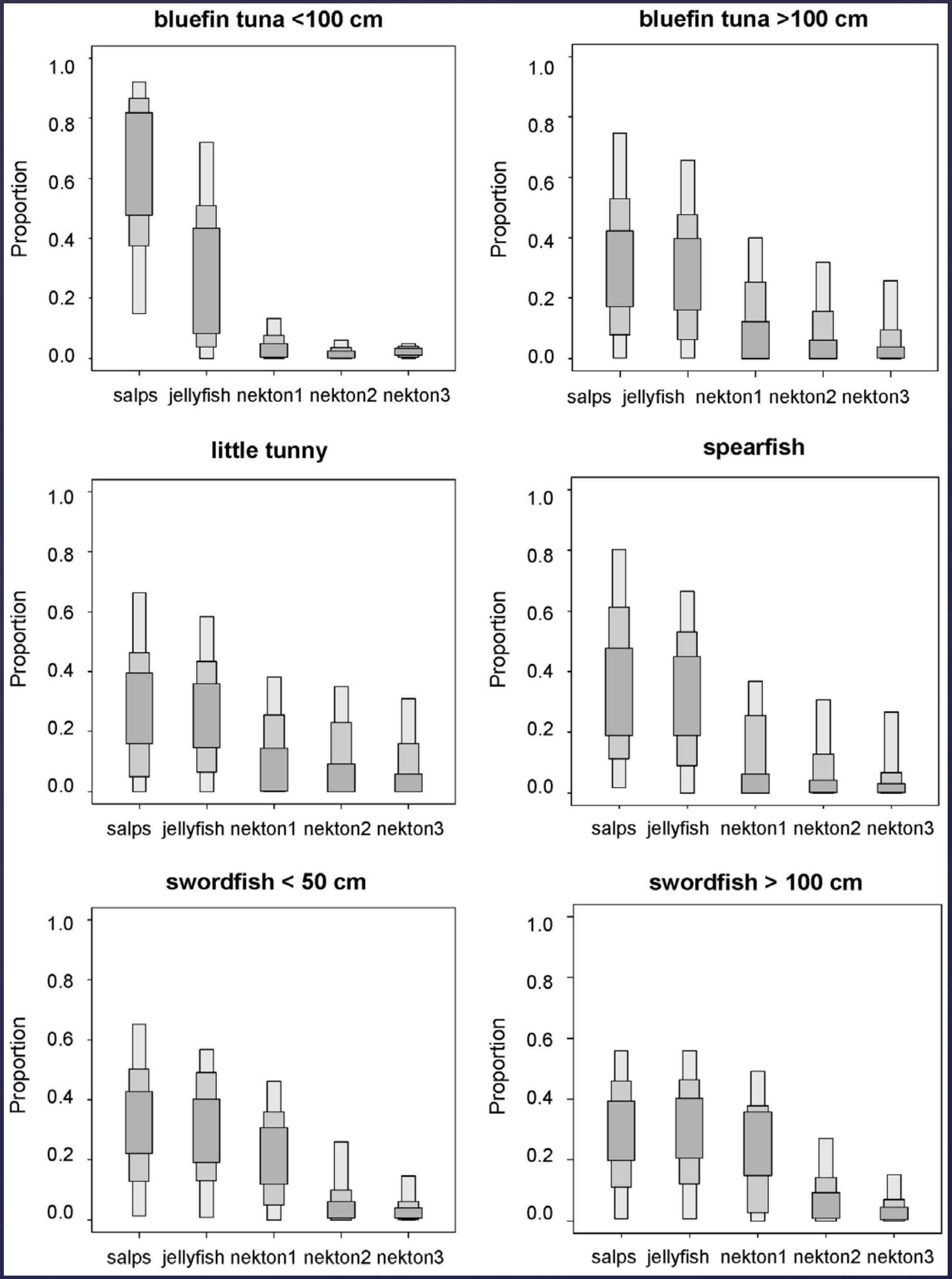
- Allows for longer term diet analysis
- Not biased for rapidly digested prey
- Tells exact trophic level and food source

Disadvantages:

- Requires specialized equipment
- Difficult to tell species eaten
- Trophic discrimination factors can be highly variable

Stable Isotope Analysis

Feasible contribution of potential prey to the diet of bluefin tuna, little tunny, spearfish and swordfish according to mixing model estimates based on stable isotope analysis

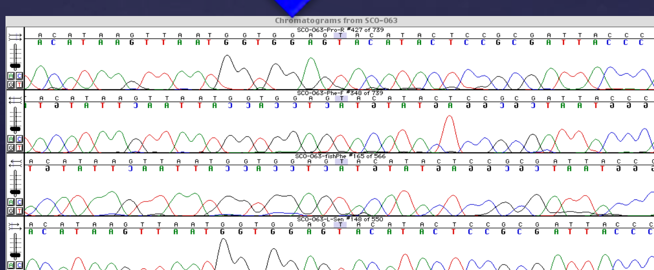


Cardona L, Álvarez de Quevedo I, Borrell A, Aguilar A. 2012. Massive consumption of gelatinous plankton by Mediterranean apex predators. PLoS One 7(3):e31329.

Biases with diet studies

- Loss of prey quality through preservation and rapid digestion
- Alternative methods of detecting gelatinous prey
  1. Biochemical analysis of muscle tissue (stable isotopes, fatty acids)
  2. Genetic analysis of stomach contents

Genetic Analysis



Advantages:

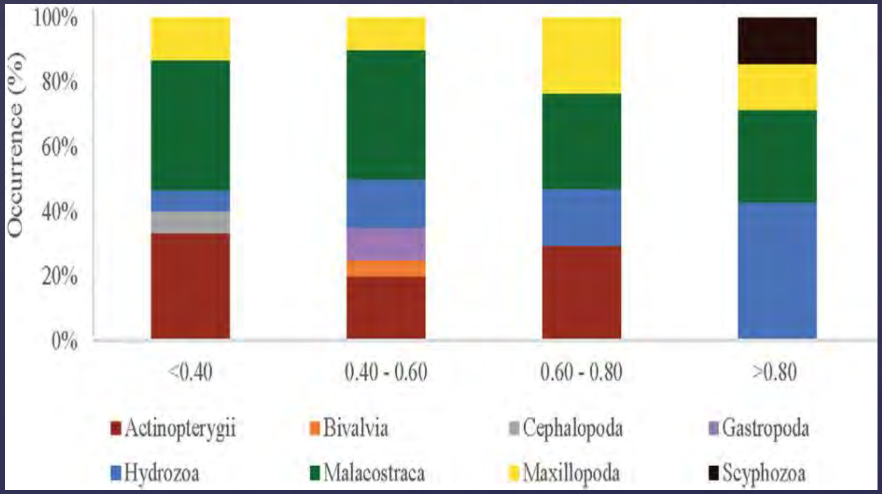
- Can provide exact ID if prey primers are available
- Not biased for rapidly digested prey
- Can detect very minute amounts

Disadvantages:

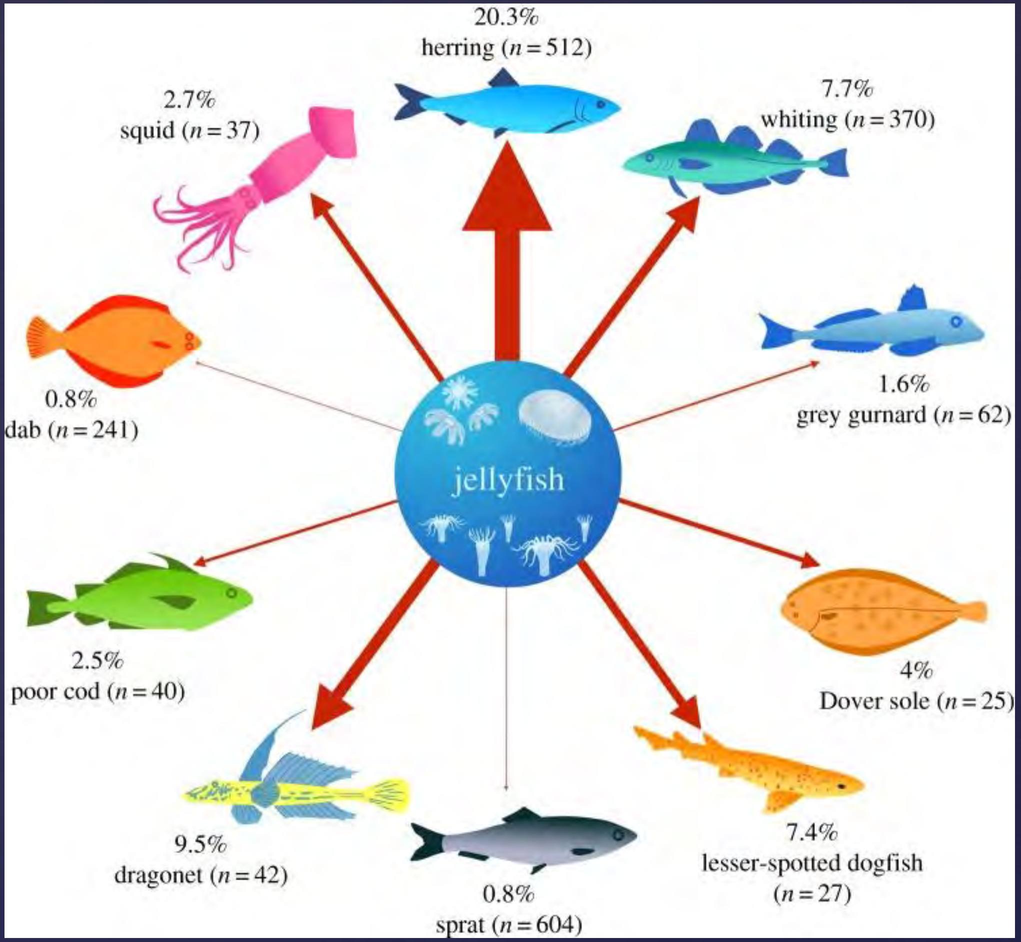
- Requires specialized equipment
- Difficult to quantify total eaten
- May detect secondary prey items

Genetic Analysis

DNA analysis has revealed additional predators on jellyfish that may not be detected through gut analysis



Sousa LL, Xavier R, Costa V, Humphries NE, Trueman C, Rosa R, Sims DW, Queiroz N. 2016 DNA barcoding identifies a cosmopolitan diet in the ocean sunfish. *Sci. Rep.* **6**, 28762.



Lamb PD, Hunter E, Pinnegar JK, Creer S, Davies RG, Taylor MI. 2017. Jellyfish on the menu: mtDNA assay Reveals scyphozoan predation in the Irish Sea. R. Soc. open sci. 4: 171421.

Conclusions

- Gelatinous zooplankton are commonly consumed by a diverse set of fishes although there is substantial temporal and spatial variation
- Many biases associated with our ability to detect soft-bodied prey in diet studies
- May need to re-evaluate the importance of these taxa → Paradigm Shift in the Trophic Importance of Jellyfish – Hays et al. (2018)

Acknowledgments

NOAA Northwest Fisheries Science Center
NOAA Alaska Fisheries Science Center

The many people who helped collect stomachs in the field and process them in the lab over the past 40 years

***Aurelia* sp.**
Saanich Inlet, BC
W. Hamner