Status of Krill
(*Euphausia pacifica* and *Thysanoessa spinifera*)
in the northern California Current :
a review of sampling methods and data sets

Jennifer Menkel and William T. Peterson

"Most marine species (including humans) are only one or two trophic levels away from krill. That is, they are either prey of krill, predators of krill or predators of krill predators."

Baldo Marinovic, *Ecology Letters* (1999)

California Current

California Current flows from Vancouver Island, Canada towards California

Euphausia pacifica (Epac) and *Thysanoessa spinifera* (Tspin) are the dominant euphausiids in the California current

They have a very patchy spatial distribution

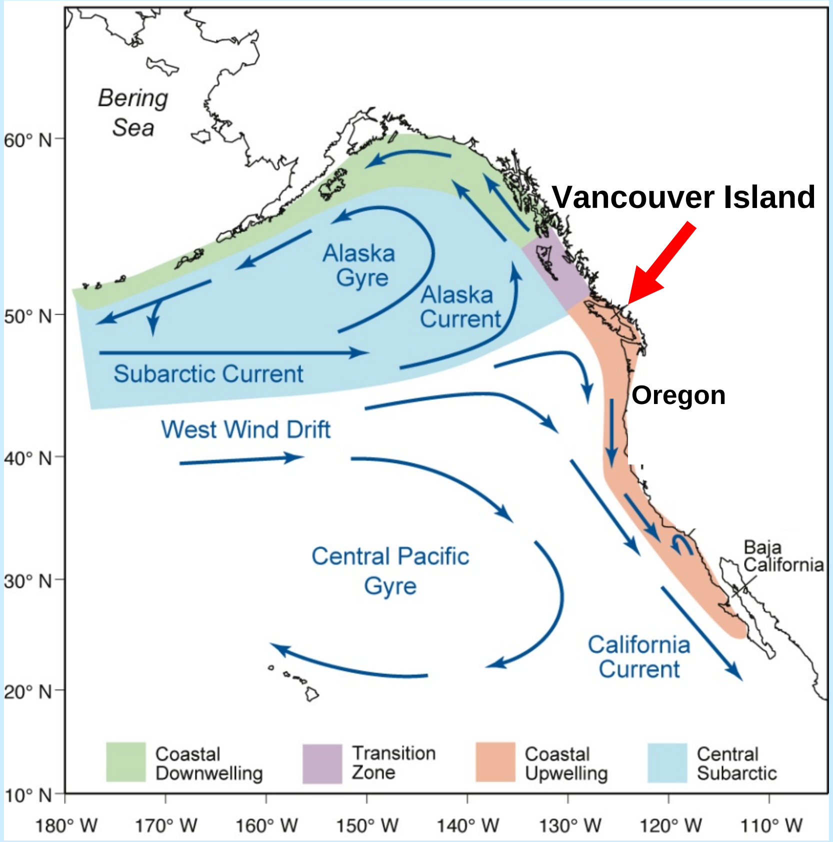
Increased upwelling = increased biomass

Aggregations possibly due to ocean bottom topography and flow fields (Mackas, 1997)

Adult Epac biomass is concentrated at the shelf break

Tspin is concentrated on the shelf and in retention areas such as Heceta bank.

“Epac is more abundant than Tspin”



Outline

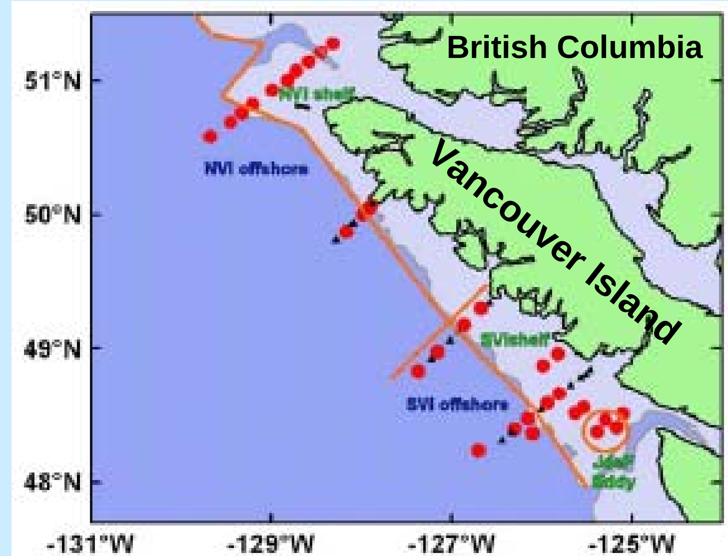
- Review of the coast-wide data sets – Starting at Vancouver Island, Canada working south to California
- Trends in the data – What is the current pattern?
- Net review – “Catchability” by different nets
- Acoustics and Patchiness
- Trophic Interactions

Vancouver Island

D.L. Mackas et al.
State of the Pacific Ocean 2007

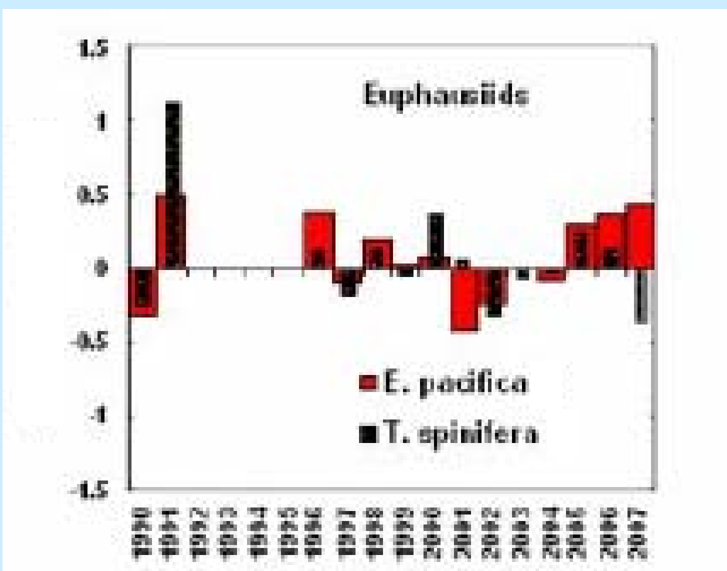
Euphausiid anomalies are logarithmic: an annual anomaly of +1 means that the euphausiids were on average ten times more common than their within-region average seasonal cycle; an anomaly of -1 means they were one tenth as common.

Samples Collected
29 year data set 1979-2008
4-5 Seasonally spaced surveys
Yearly averaged anomalies
Net – Bongos 60cm 233um black mesh

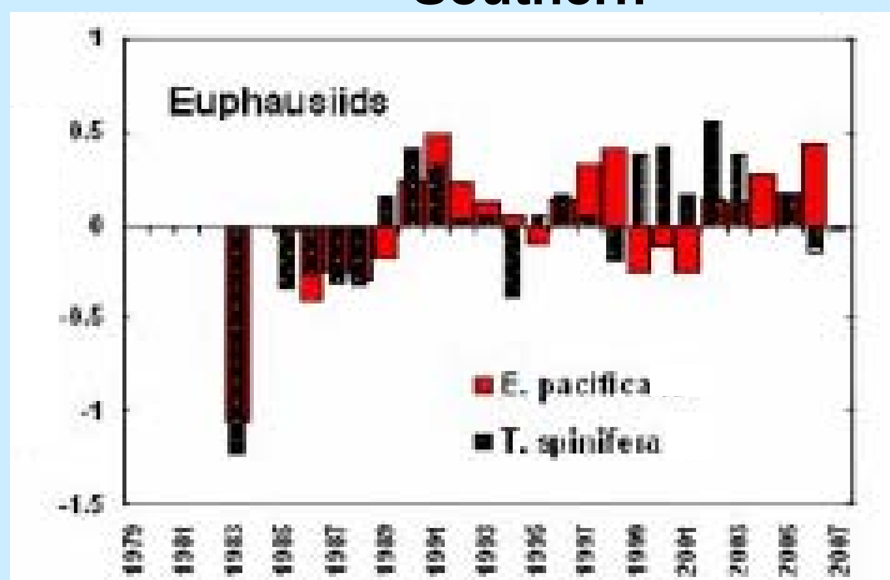


Biomass Anomaly (log10)

Northern



Southern

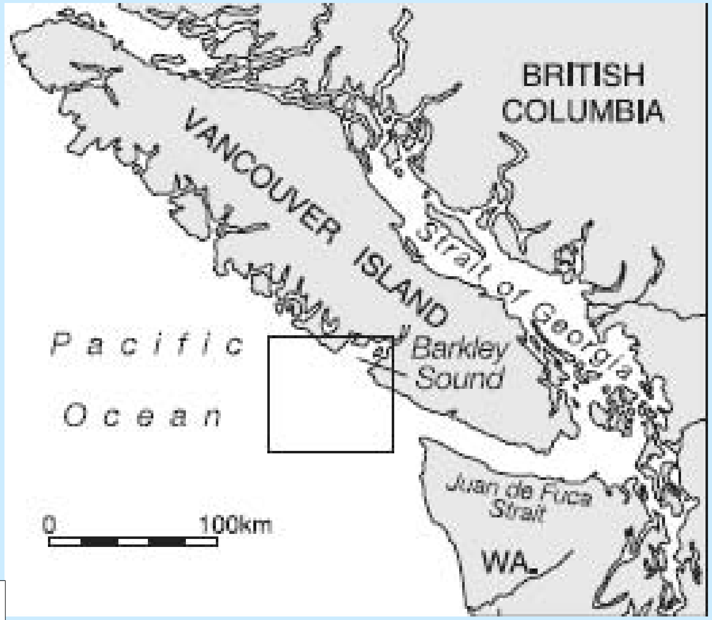


Vancouver Island

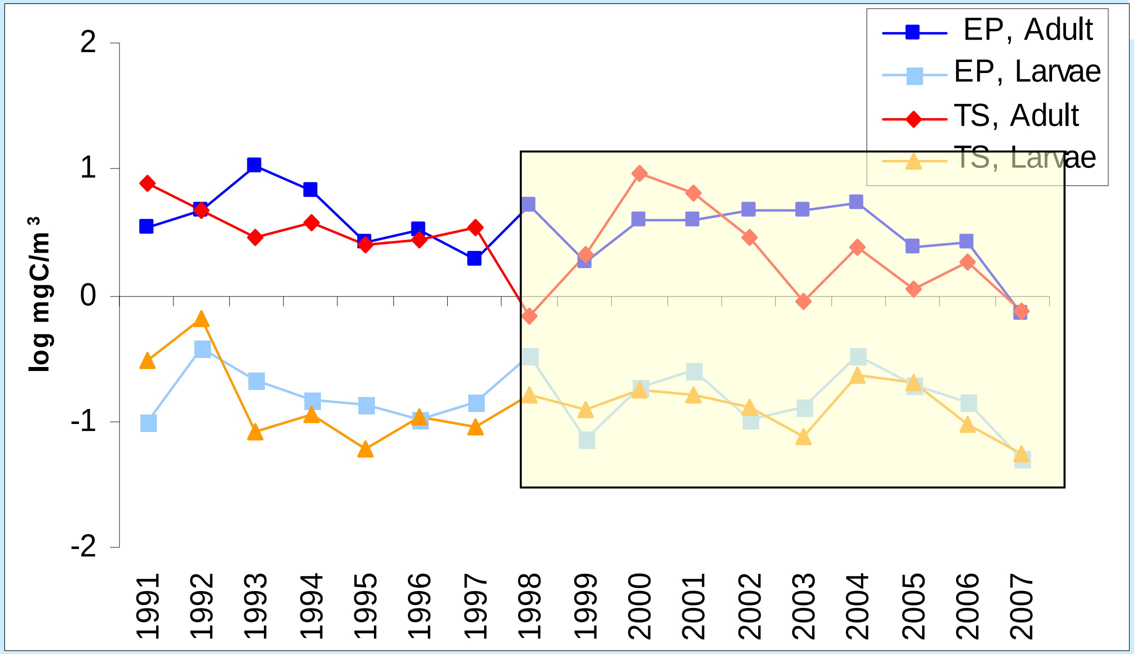
Ron Tanasichuk – personal communication

Samples Collected
17 year data set 1991-2008
Comprised of 580 samples
Monthly: March-November and January

Net – Bongos 60cm 330µm black mesh



Log of the yearly medians mgC/m^3



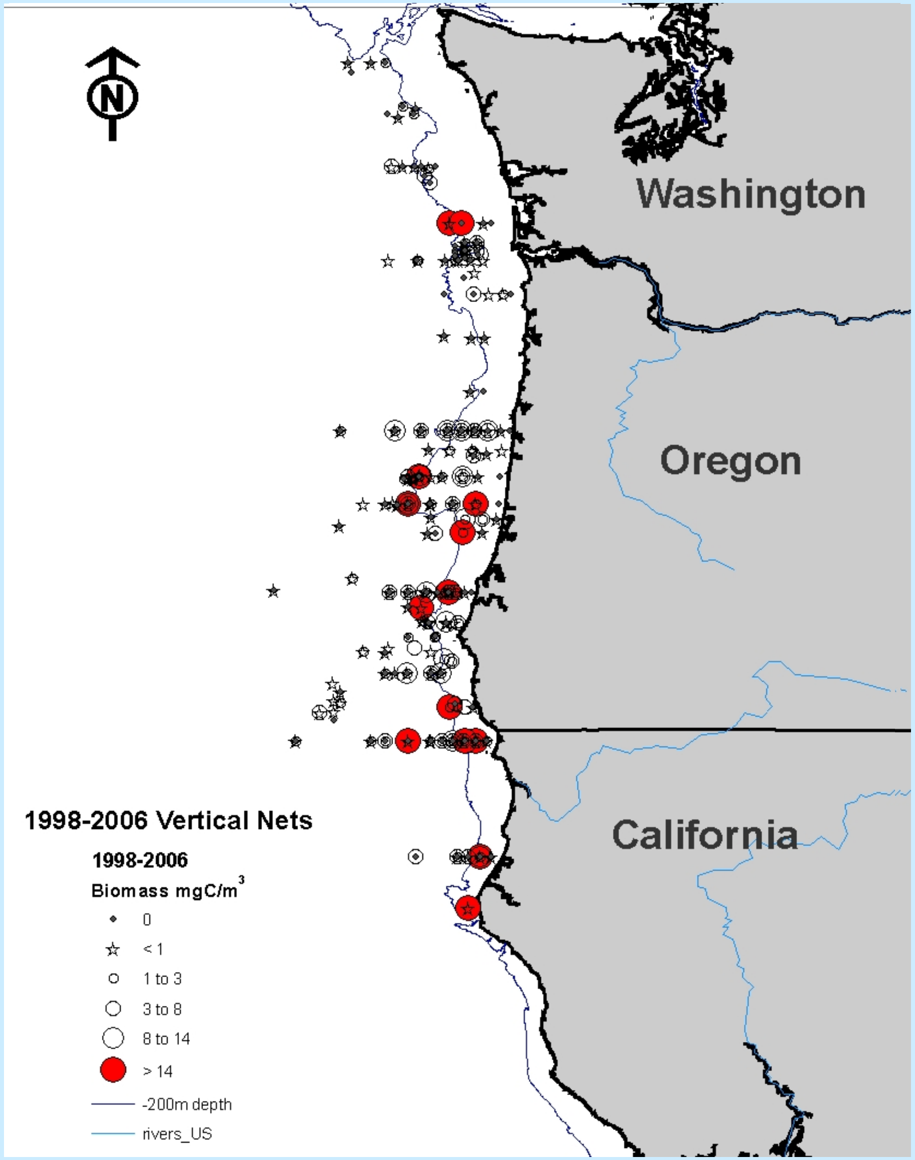
All samples
Epac 4 ± 2.3 mgC/m^3
Tspin 3.3 ± 2.5 mgC/m^3

1998-2006
Epac 3.5 ± 1.5 mgC/m^3
Tspin 2.8 ± 2.8 mgC/m^3

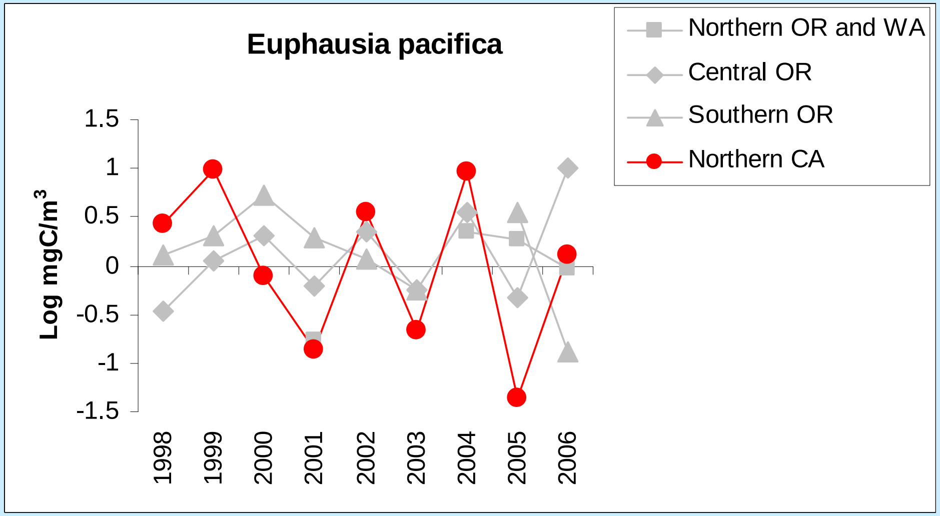
Washington and Oregon

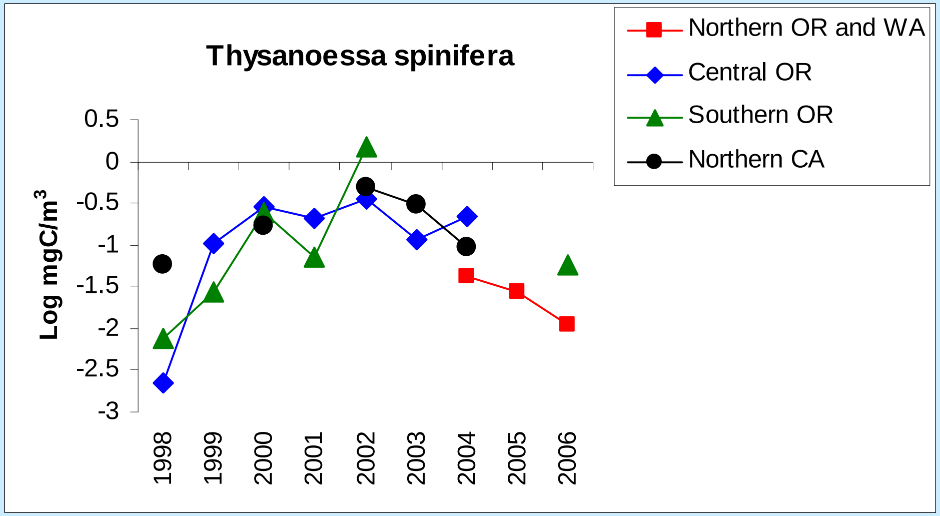
Peterson Group

Samples Collected
12 year data set 1996-2008
1998 - 2006 presented
Nets
Vertical ½ meter net
    202µm white mesh
    3056 samples
    432 night-time
Bongos 70cm
    Black 333µm mesh
    1137 samples
    383 night-time
    NH line samples
MOCNESS net 1sq meter
    Black 333µm mesh
    401 stations
    41 stations



Washington and Oregon





Northern OR and WA

Epac 1.31 ± 0.94 mgC/m^3

Tspin 0.02 ± 0.02 mgC/m^3

n=61

Central OR

Epac 2.34 ± 3.14 mgC/m^3

Tspin 0.14 ± 0.13 mgC/m^3

n=183

Southern OR

Epac 2.00 ± 1.70 mgC/m^3

Tspin 0.23 ± 0.51 mgC/m^3

n=119

Northern CA

Epac 3.09 ± 3.88 mgC/m^3

Tspin 0.12 ± 0.17 mgC/m^3

n=69

“Good years”

Epac 3.0 ± 0.73 mgC/m^3

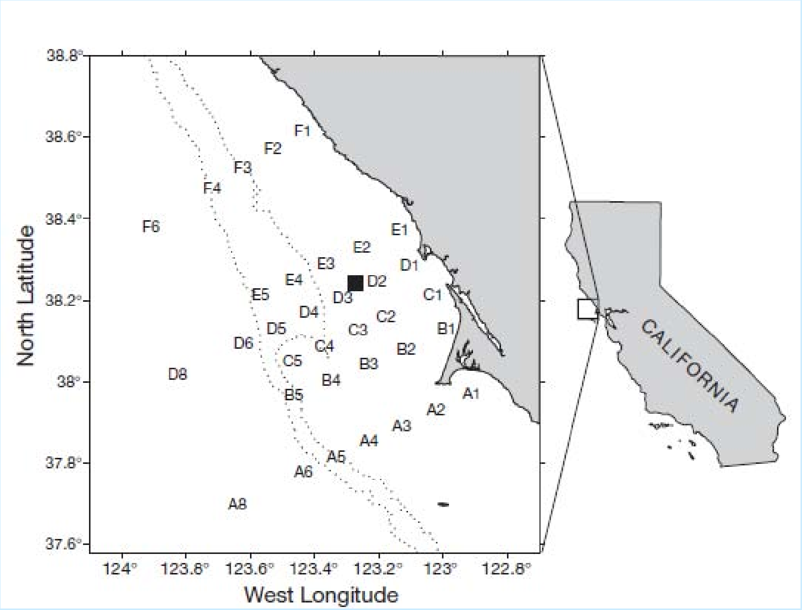
“Bad years”

Epac 0.87 ± 0.42 mgC/m^3

California: Northern

Jeffrey G. Dorman et al., Mar Ecol Prog Ser 288: 183–198, 2005

Samples Collected
2000 – June (28 samples)
2001 - May and June (32 samples)
2002 – January (27 samples)
Net
Bongo - 335 and 500µm mesh
200m to the surface or 5m of the bottom



Used juvenile and adult Epac and Tspin animals 3mm or greater

2000 (June)
Epac 7.9±1.63 #/m^3
Mean Size 9.16±0.06mm
3.7 mgC/m^3

2001 (May-June)
Epac 3.6±1.03 #/m^3
Mean Size11.19±0.01mm
3.2 mgC/m^3

California: Southern and Central

B.E. Lavaniegos, M.D. Ohman, Progress in Oceanography 75: 42–69, 2007

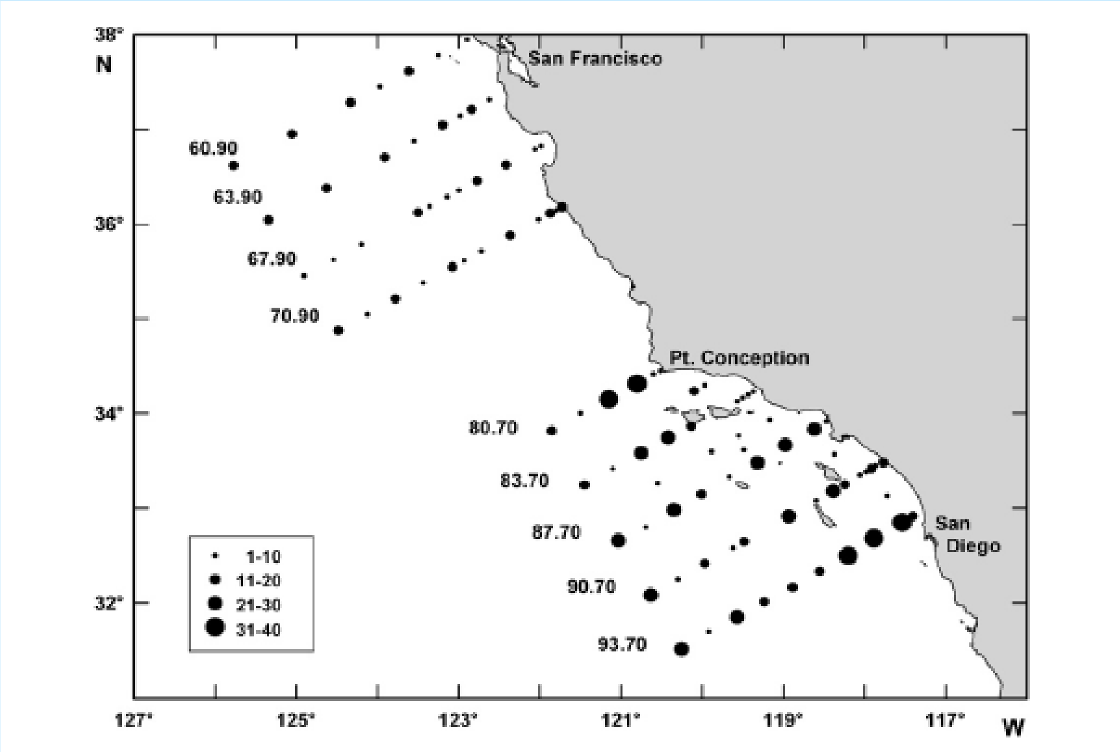
E. Brinton, A. Townsend, Deep-Sea Research II 50: 2449–2472, 2003

56 years of sampling
(32 for this data)

1951-1968 1m ring net
0.55mm mesh
depth 140m
1969-1977 1m ring net
0.505mm mesh
depth 210m
Dec. 1977-present
0.71m bongo net
0.505mm mesh
depth 210m

Spring Cruises: March through April or May

CalCOFI; Sampling area



Legend: Symbol diameter is proportional to the number of times each station is represented in the zooplankton time series.

California: Central and Southern

B.E. Lavaniegos, M.D. Ohman, Progress in Oceanography 75: 42–69, 2007

Geometric mean carbon biomass

Central CA 294.0 mgC/m^2
Southern CA 141.0 mgC/m^2

Euphausiids - not just Epac and Tspin - **Stages?**

(*Nyctiphanes simplex*, and *Nematoscelis difficilis?)*.

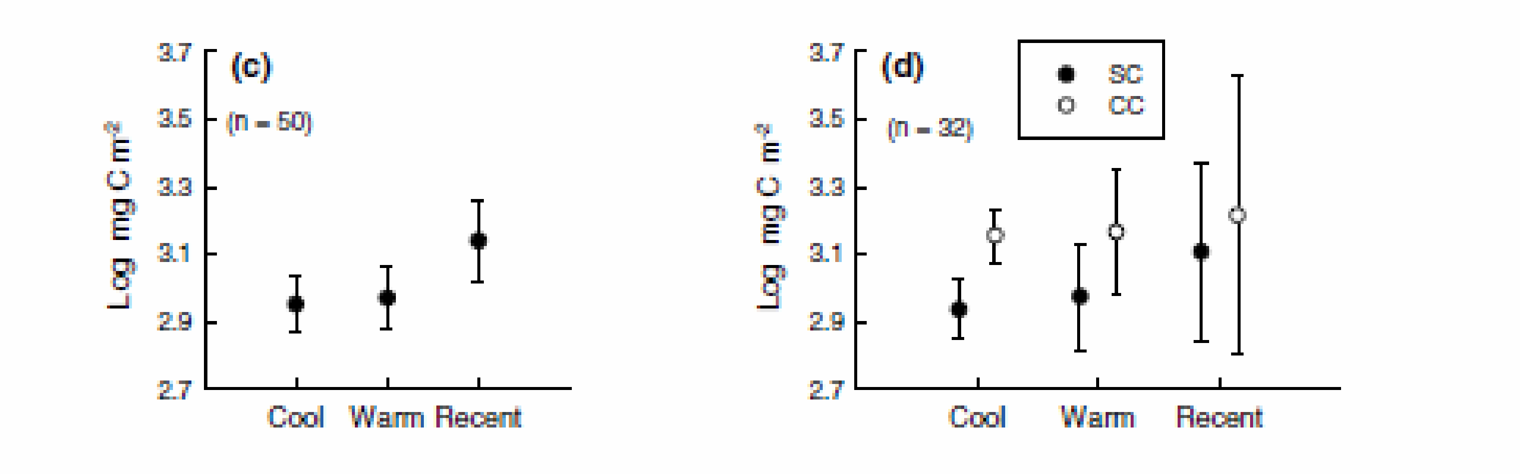


Fig. 5, pg. 50. Mean biomass ± 95% confidence intervals in three climate periods (cool [1951–1976], warm [1977–1998], and recent [1999–2005]) in (c) Southern California alone and (d) Southern California compared with Central California. Stations shallower than 140m or 210m were omitted from the pooled samples. The total number of nighttime samples selected for SC was 619 (8-19 per cruise) and 266 for CC (2-16 per cruise).

Overall Trends

Vancouver Island	Epac	Tspin
Tanasichuk bongo	3.55 ± 1.58	2.83 ± 2.83
Central Oregon		
Peterson vert	2.34 ± 3.14	0.14 ± 0.13
Southern Oregon		
Peterson vert	2.00 ± 1.70	0.23 ± 0.51
Northern California		
Peterson vert	3.09 ± 3.88	0.12 ± 0.17
Dorman bongo	3.45	
Central California		
CalCOFI	*****294.0 mgC/m^2 ÷ 175m = 1.7mgC/m^3	
Southern California		
CalCOFI	*****141.0 mgC/m^2 ÷ 175m =0.80mgC/m^3	

*****Confounded with other warm water species and timing of sampling

Calculation of mean biomass for the EEZ

We are getting close……..

We have long term, spatially distributed sampling programs.
We have standardized the collection system – 60-70cm bongos.

The data suggests

“Good years”

Epac ~3 - 4 mgC/m^3

“Bad years”

Epac ~ 1 mgC/m^3

But……

What stages are in the “biomass summaries”?

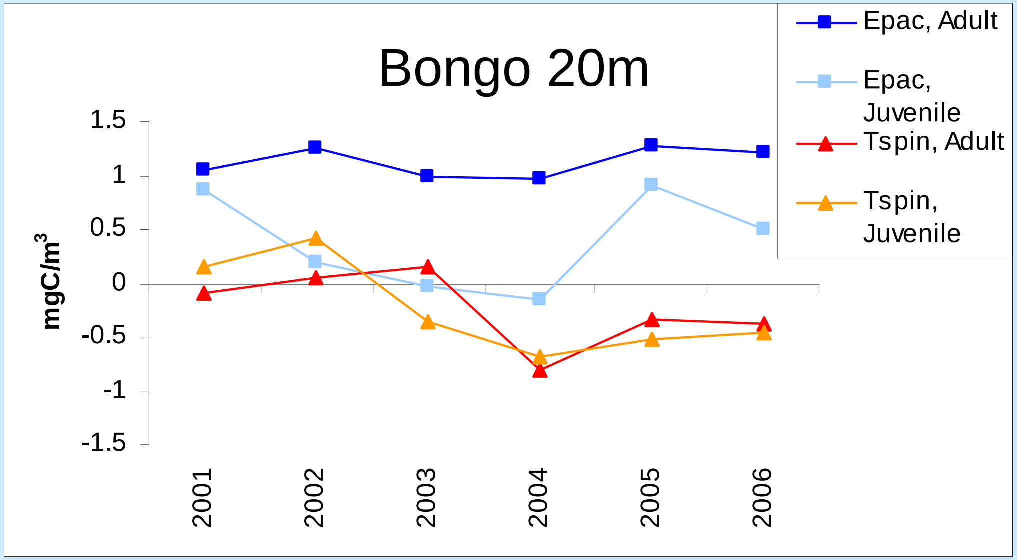
Depth of tow over which numbers are integrated?

Patchiness – use “known areas” of abundance i.e. shelf break, and areas of retention?

Patchiness within the water column.

Bongo Net

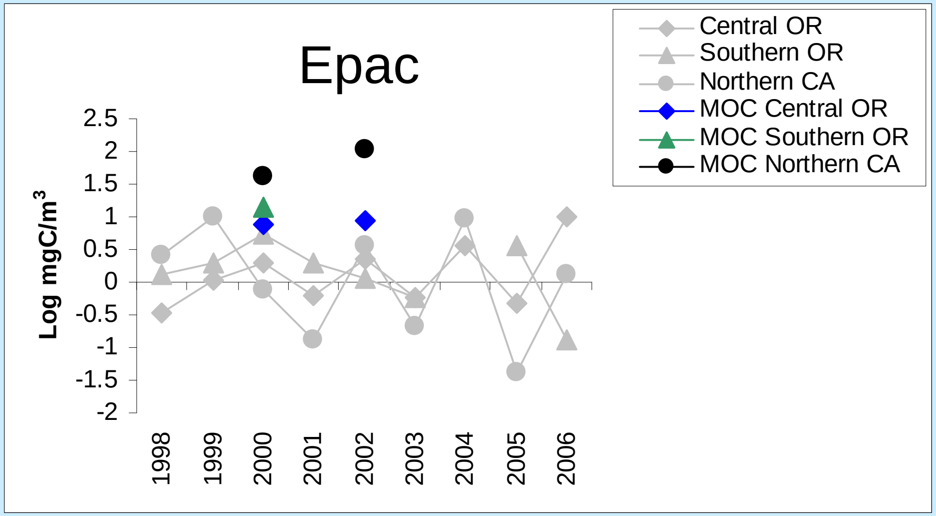
Central coast – Newport hydrographic line only

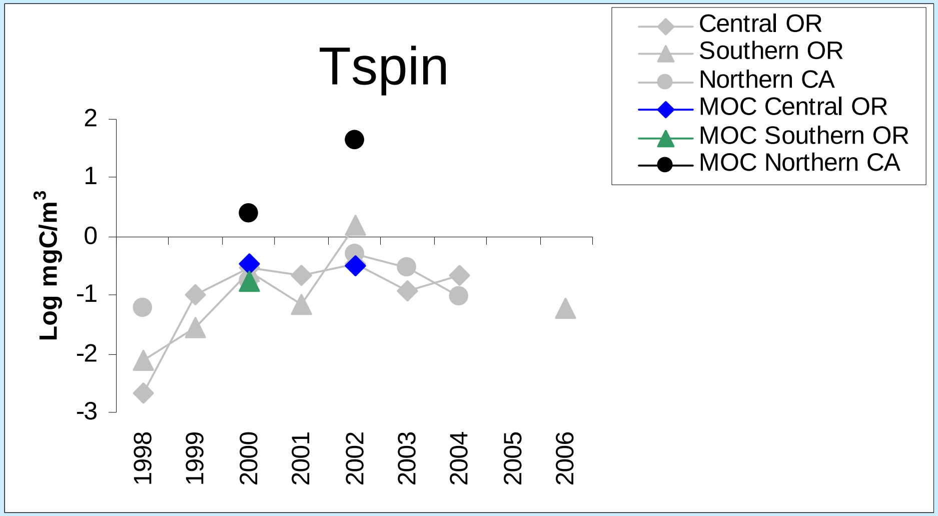


Central OR
Epac 13.8 ± 4.3 mgC/m^3
Tspin 0.74 ± 0.48 mgC/m^3

The weighted mean depth of adult euphausiids during the night-time is less than 30m from the surface. (Vance et al. AGU 2003)

Net Comparisons





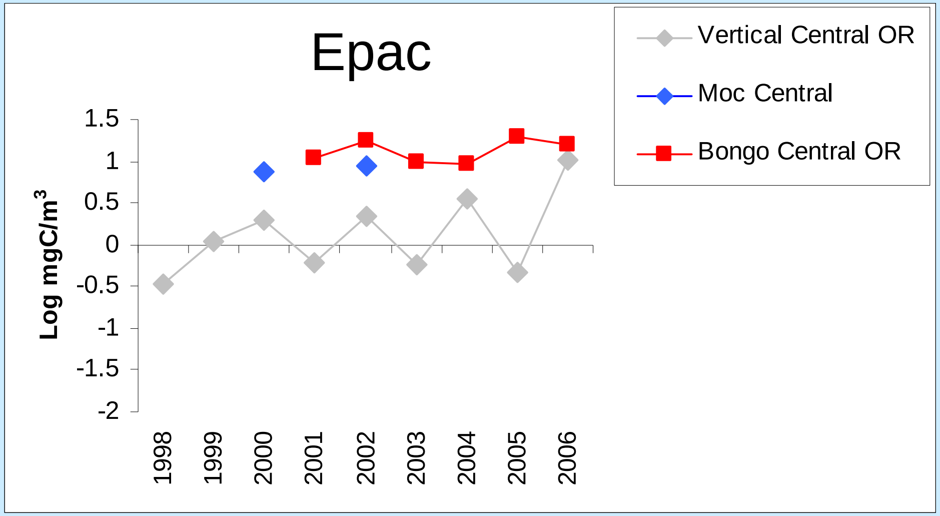
Paired Vertical and MOCNESS nets

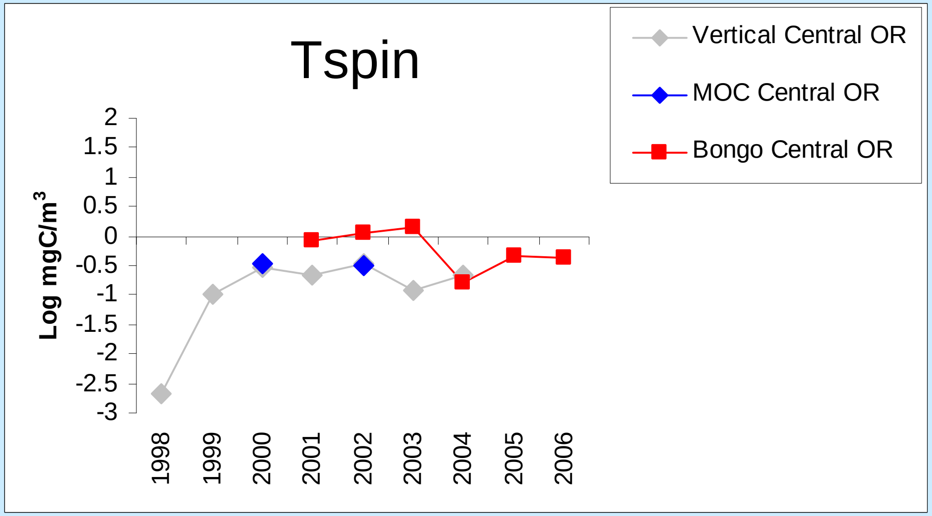
N=17	Epac	Tspin
Vertical	4.8 ± 7.7	0.6 ± 1.0
MOCNESS	99 ± 214	26.7 ± 84.6

Or in other words……
The MOCNESS net catches 21 times more Epac and 45 times more Tspin

Net Comparisons

Central OR only non-paired samples





Lengths mm

	Epac		Tspin	
	Male	**Female**	**Male**	**Female**
Vertical	16.7	16.8	18.1	18.9
Bongo	15.6	16.2	17.5	20.7
MOCNESS	18.2	19.1	19.2	21

Vertical	n = 183
Bongo	n = 383
MOC	n = 37

Acoustics

Patrick Ressler, et al. Deep-Sea Research II 52, 89–108 (2005)

Acoustics

July through August 2000
36 east – west transects
38 and 120 kHz data only
Day time only
8 - 150m depth

Patches were detected along only 17% of the tracks

Euphausiids are concentrated at Heceta Head (HH) and Cape Blanco (CB)

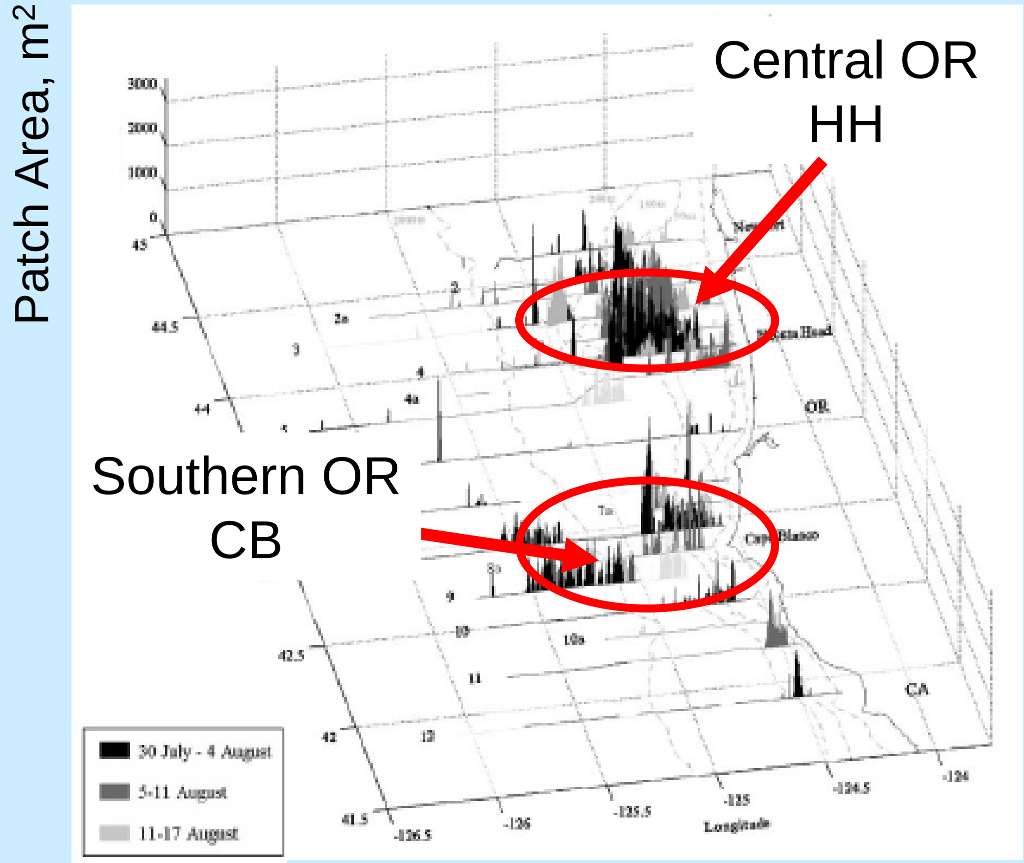
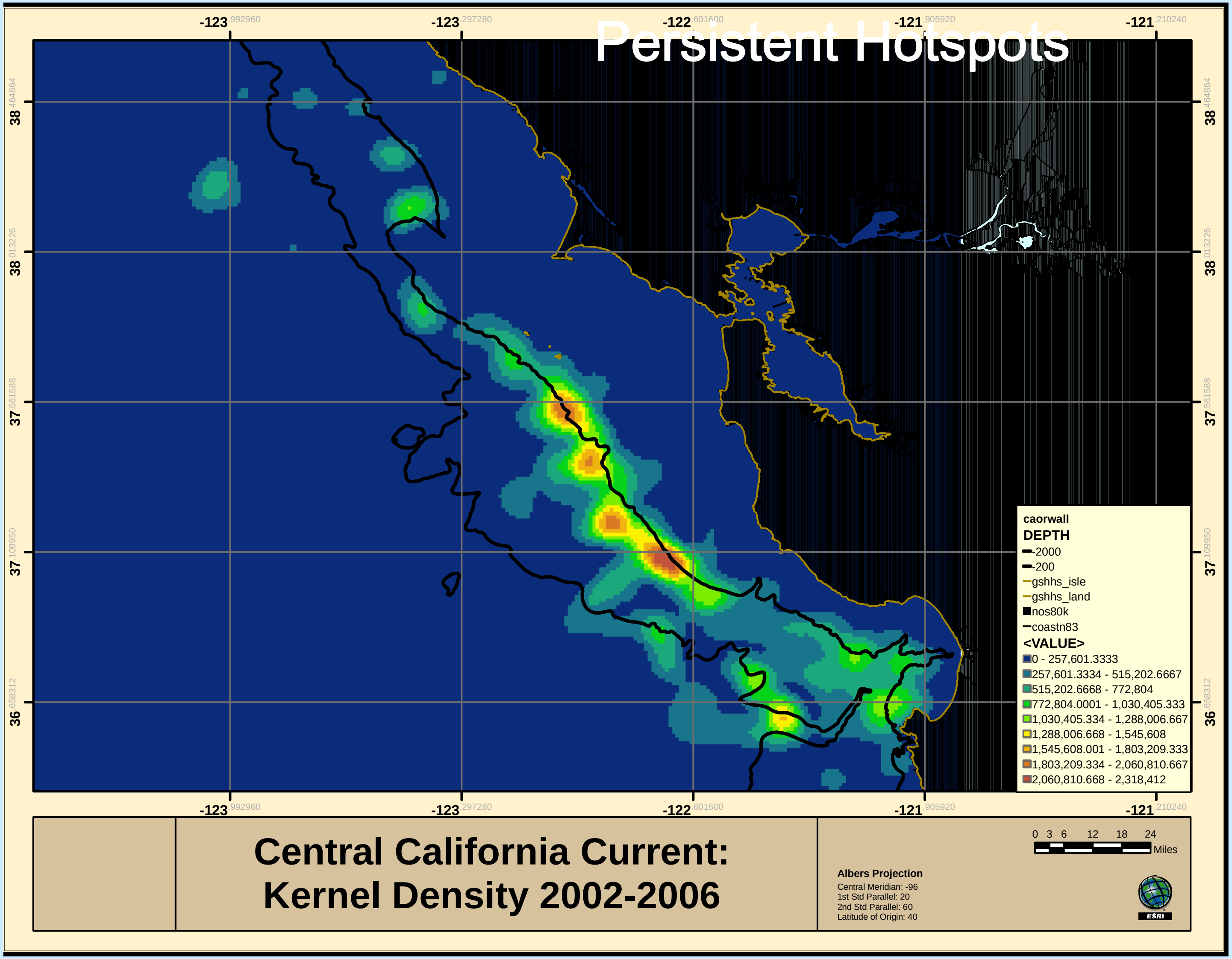


Fig. 5

Acoustics

Jarrod Santora, William Sydeman, personal communication

Presented S9 BIO Topic Session 14:50



Trophic Interactions

Donald Croll and Baldo Marinovic et al.
Mar Ecol Prog Ser 289: 117–130, 2005

Acoustic estimate of biomass
117mgC/m^3

Blue whales in Monterey Bay fed primarily upon Tspin 80 ± 22.6%, Epac 13%

Net samples collected at the same time consisted of only 30.17 ± 34.95% Tspin

Lengths of what the whales are feeding on are significantly larger than what the net catches

Tspin $t=9.12$, $d.f.= 260$, $p<0.001$; Epac $t=9.99$, $df = 180$, $p<0.001$

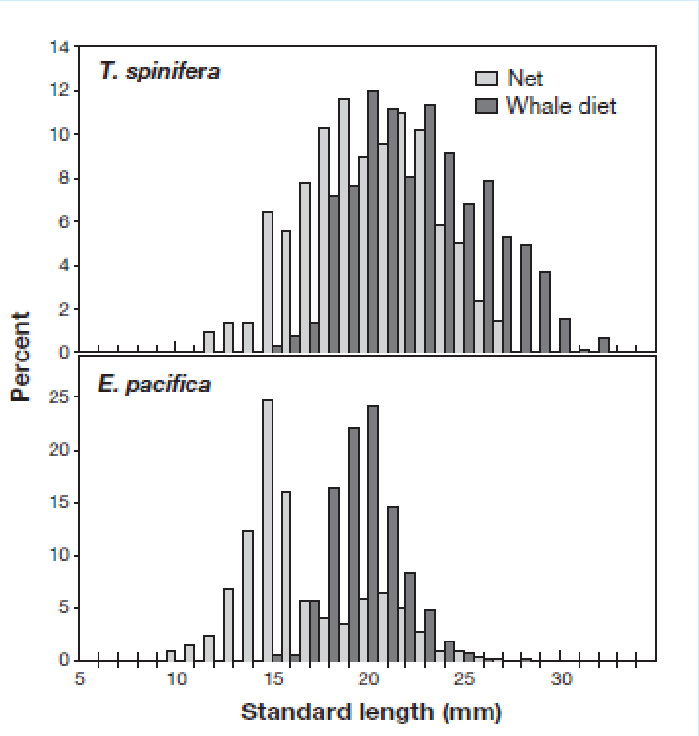


Fig.6

Christine Abraham and William Sydeman Mar Ecol Prog Ser 289: 235-250, 2004
Auklet breading – The primary prey species in the diet are Epac and Tspin.
“Tspin seems to be the most important prey species in terms of growth and productivity”

Conclusions

We are underestimating *Thysanoessa spinifera* in our study area.

We have moved toward a standardized sampling system, 60-70cm bongos
But is this enough………

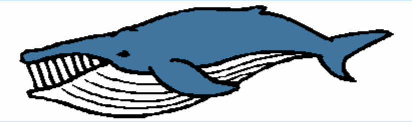
Acoustics help to resolve the patchiness, biomass estimations are considerably higher

We need standardized acoustic backscatter to estimate distribution and biomass of both species - integrated with the net collection data

Where possible net samples need to be collected at night when the euphausiids are concentrated in the upper 20-50m of the water column…. avoiding the need to integrate the biomass over the whole water column

Biomass varies by a factor of 10, rates vary by a factor of 2 – therefore, we need to worry more about getting accurate estimates of the biomass

No matter which net we use we don't capture euphausiids as efficiently as whales do



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