NUMERICAL RESPONSES OF KRILL PREDATORS TO VARIATION IN KRILL ABUNDANCE AND SPATIAL ORGANIZATION

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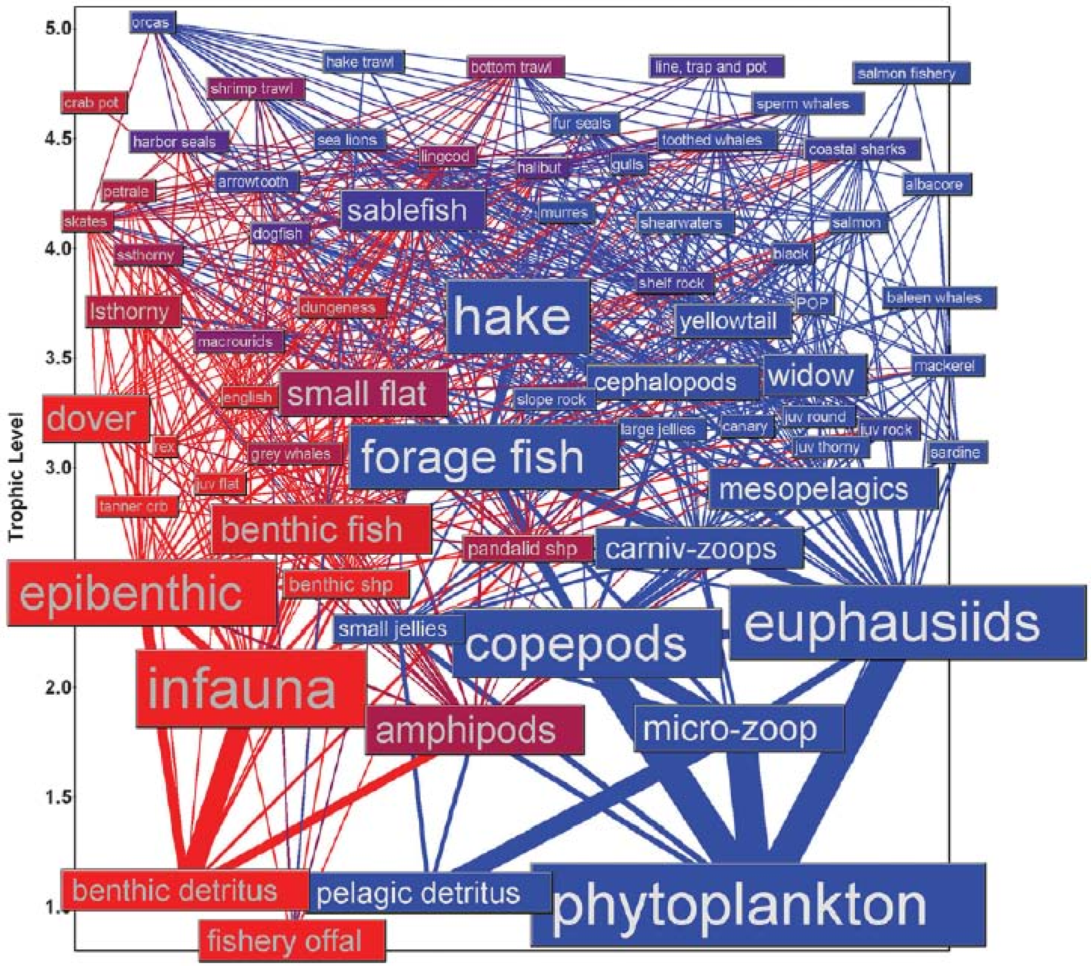
EUPHAUSIID CRUSTACEANS: KEY TO PELAGIC FOOD WEBS GLOBALLY

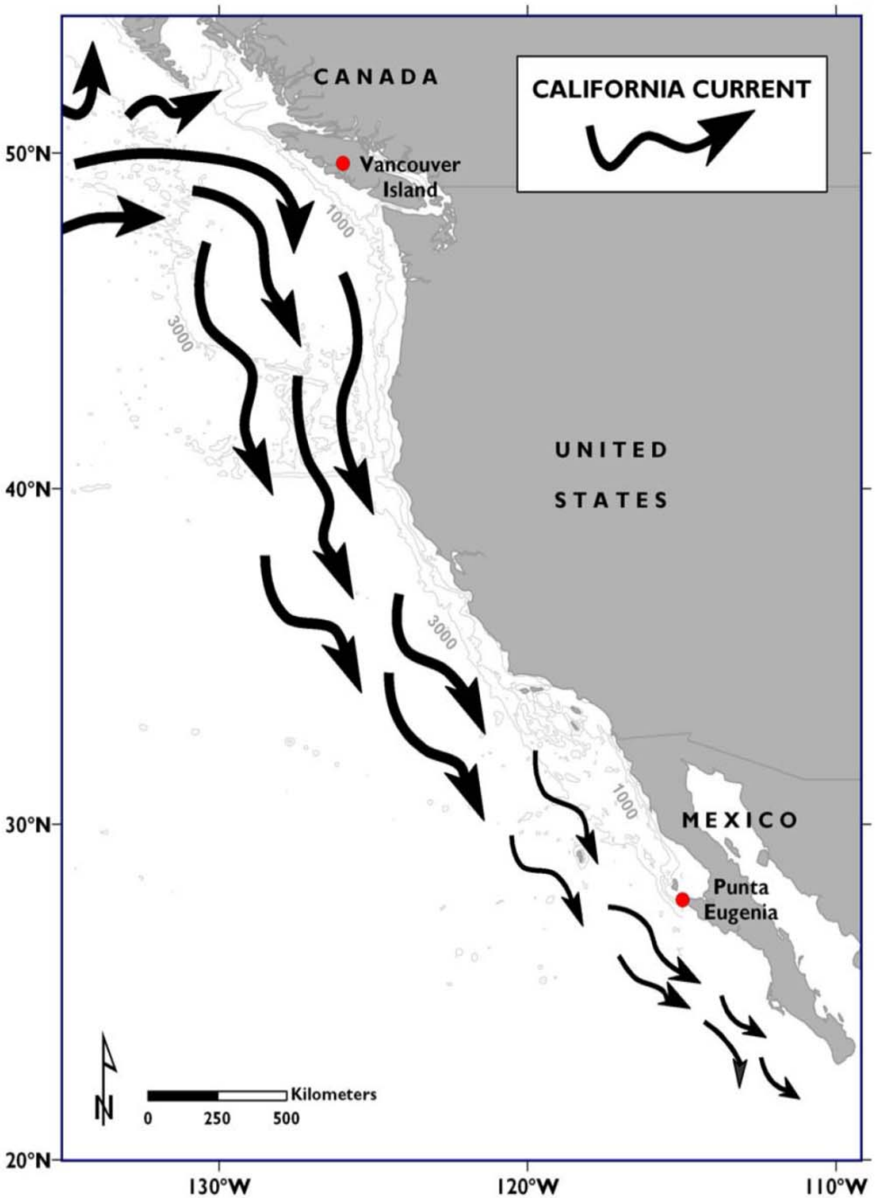


Field et al. 2006 PiO

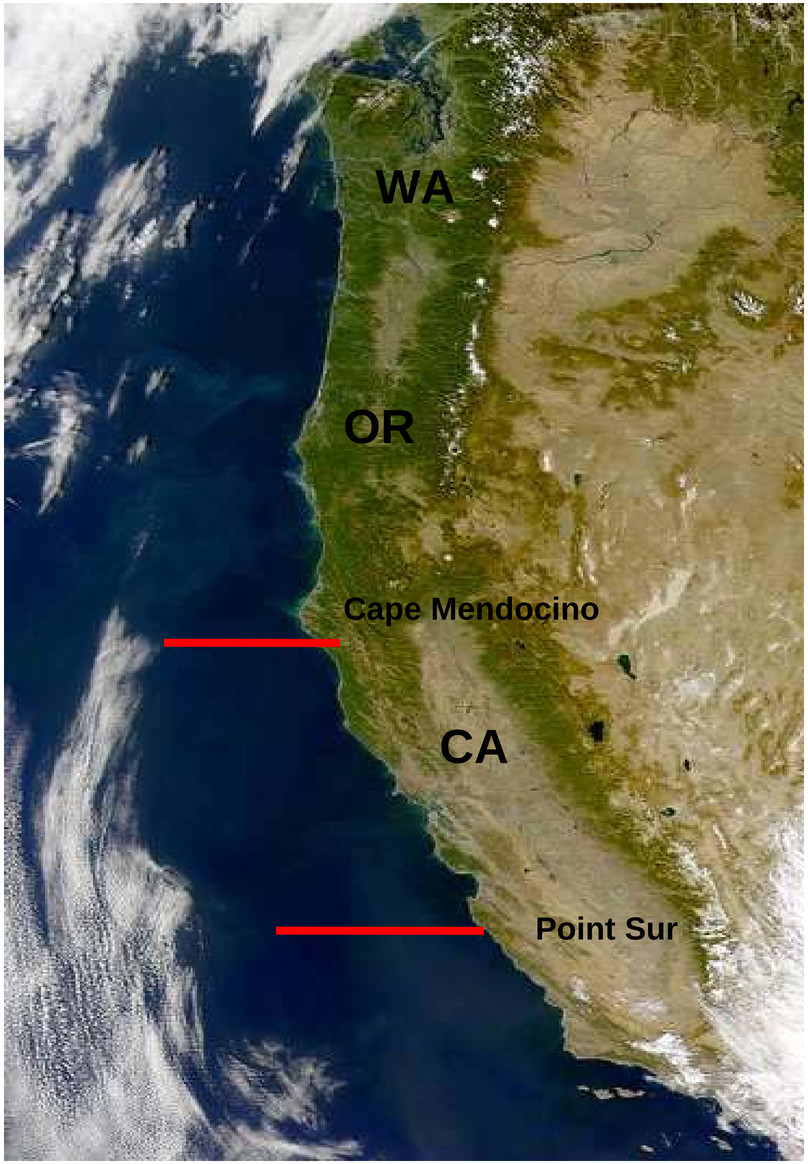
QUESTIONS

- Shape (Type I, II, or III, sensu Holling 1959) of numerical responses of predators to variation in prey (krill) abundance and distribution?
- Are numerical responses modified (amplified or dampened) by change in ocean climate (SST)?
- Can these relationships be used in understanding and forecasting climate impacts on marine ecosystems? …and fisheries?

STUDY SYSTEM



STUDY REGION

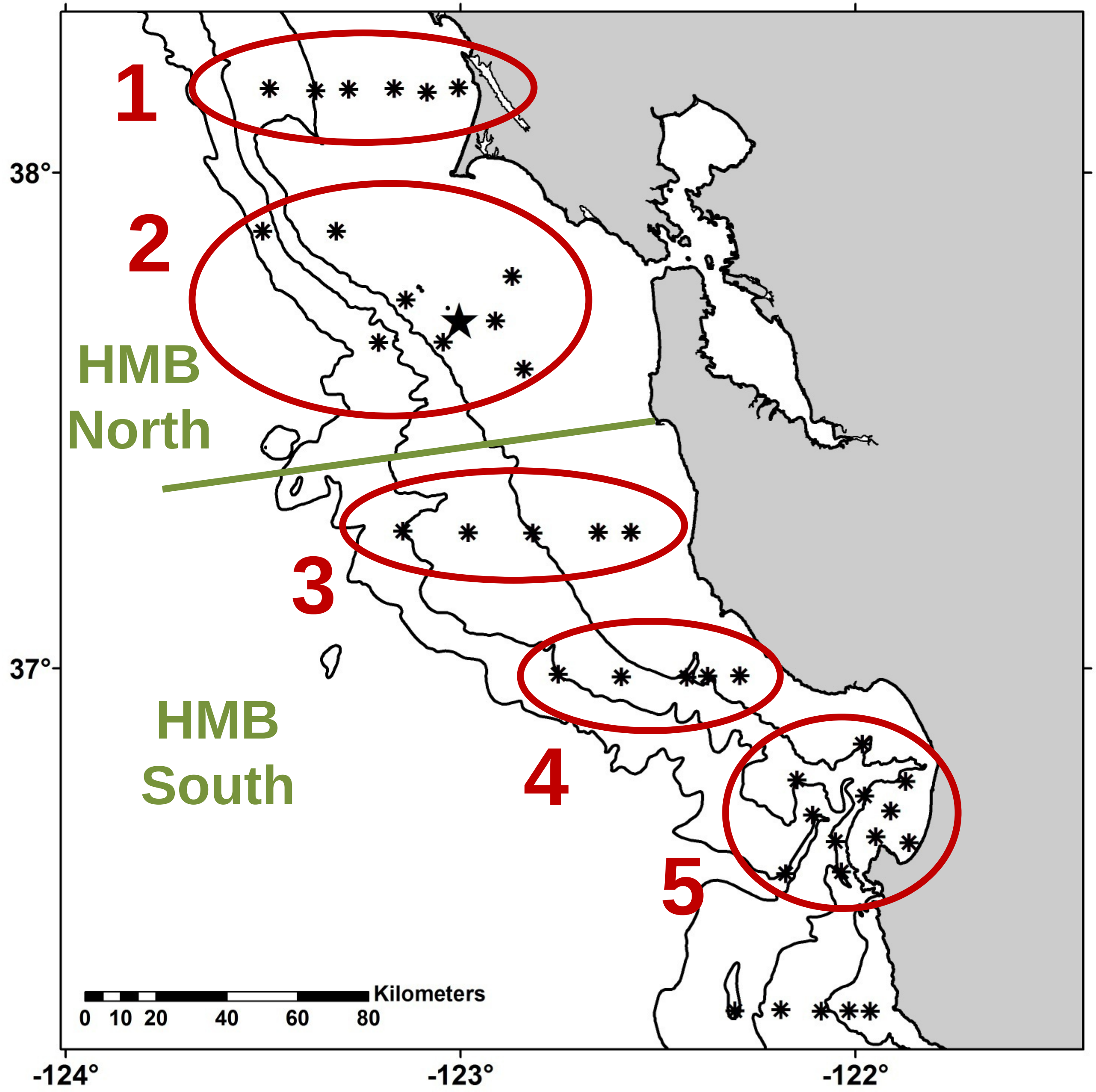


Imagery courtesy C. Harvey – NOAA/NMFS

MEASURING KRILL ABUNDANCE

- Problematic due to *patchiness.*
- Used station-based net sampling and continuous underway acoustic sampling from NOAA/NMFS Juvenile Rockfish/Ecosystem Survey (Field and Ralston, co-PI).
- Information content varies - one provides information on species composition, the other provides comprehensive spatial coverage.
- Need both to address questions of interest…

NMFS JUVENILE ROCKFISH SURVEY (MAY/JUNE



*= sampling stations

Indices of abundance computed for each of 5 strata plus 2 regions and total for study area

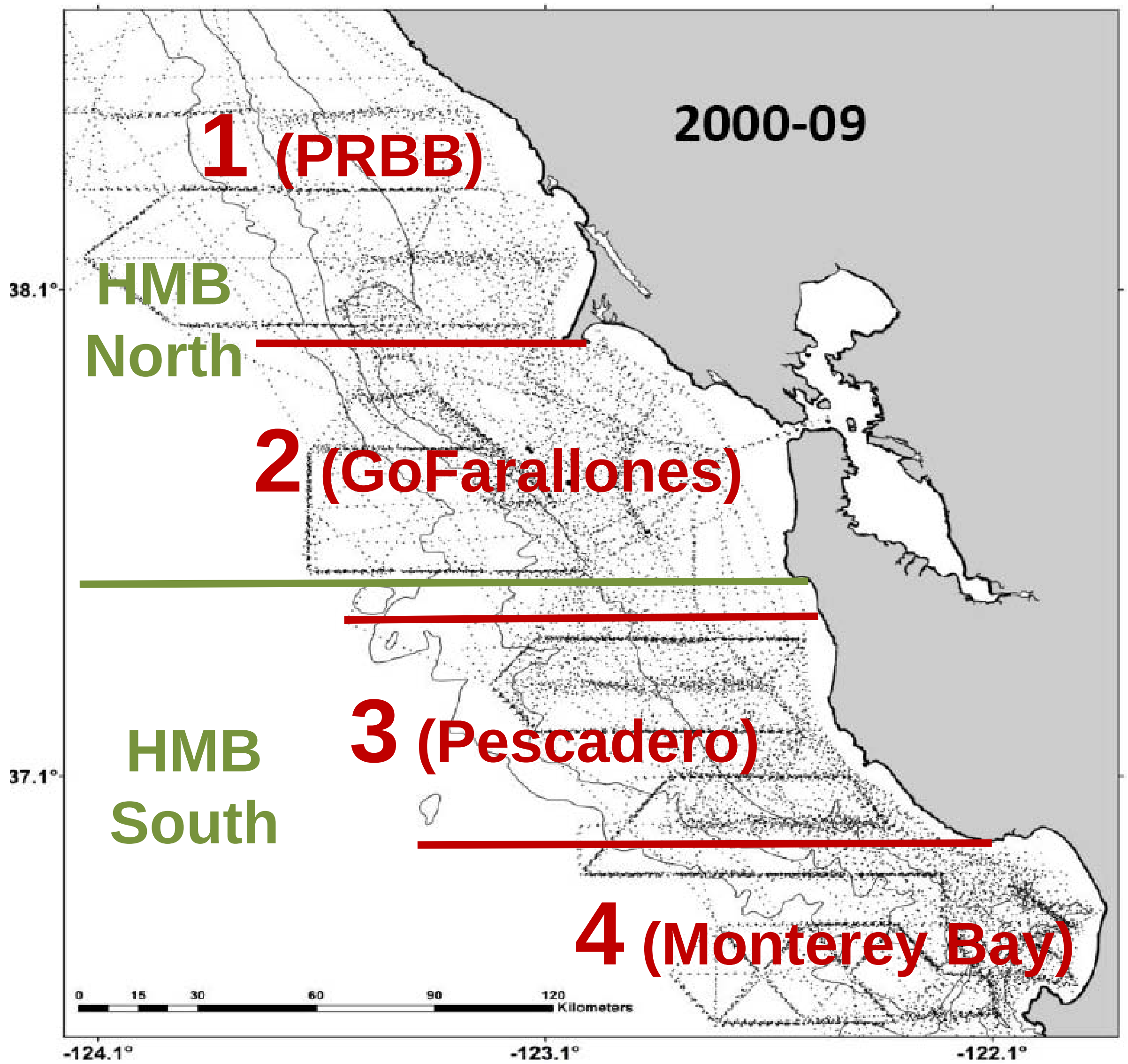
8 indices reduced to one using PCA

..by species:
T. spinifera
E. Pacifica

Same net samples used to index age-0 (Sebastes) rockfish abundance = "reproductive success" – more on this later…

BETWEEN STATION ACOUSTIC SURVEYS

(1 NMI DATA; NASC; INTEGRATED TO BOTTOM (OR 400M)



total n= ~13,000 nmi

4 strata

2 regions

reduced using PCA to one index of abundance

RESULTS OF PCA ON NET-BASED AND ACOUSTIC SAMPLES

E. pacifica

Component	Eigenvalue	Difference	Proportion	Cumulative
1	6.41893	0.65639	0.8024	0.8024
2	0.76254	0.27078	0.0953	0.8977
3	0.49176	0.23682	0.0615	0.9592

	Eigenvectors		
Variable	1	2	3
Point Reyes-Bodega Bay	0.34894	-0.47557	0.16505
Gulf of the Farallones	0.36350	-0.09910	0.40627
Pescadero	0.34890	0.20660	-0.26980
Davenport	0.27118	0.71637	0.46773
Monterey Bay	0.34932	-0.03314	-0.52702
Half Moon Bay-North	0.36383	-0.38139	0.27807
Half Moon Bay-South	0.37564	0.24753	-0.30255
All	0.39414	-0.01782	-0.05187

T. spinifera

Component	Eigenvalue	Difference	Proportion	Cumulative
1	6.32523	5.26021	0.7907	0.7907
2	1.06502	0.65363	0.1331	0.9238
3	0.41139	0.24018	0.0514	0.9752

	Eigenvectors		
Variable	1	2	3
Point Reyes-Bodega Bay	0.17046	0.84985	0.32575
Gulf of the Farallones	0.39296	-0.06395	-0.21078
Pescadero	0.36736	-0.06816	0.34457
Davenport	0.31290	-0.42124	0.60672
Monterey Bay	0.36665	-0.02475	-0.58743
Half Moon Bay-North	0.37383	0.24762	-0.12261
Half Moon Bay-South	0.39030	-0.16585	-0.03700
All	0.39642	0.04628	-0.03396

NASC

Component	Eigenvalue	Difference	Proportion	Cumulative
1	5.87954	5.42295	0.8399	0.8399
2	0.45659	0.08219	0.0652	0.9052
3	0.3744	0.0945	0.0535	0.9586

	Eigenvectors		
Variable	1	2	3
Region 1	0.34171	-0.13408	0.85184
Region 2	0.37662	-0.50464	-0.35839
Region 3	0.35777	0.58328	-0.25917
Region 4	0.37567	0.05547	0.16746
Half Moon Bay-North	0.38517	-0.47714	-0.18858
Half Moon Bay-South	0.39474	0.38417	-0.00838
All	0.41000	0.09387	-0.12280

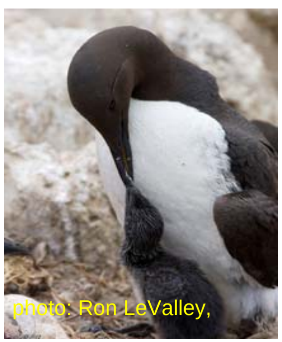
ROCKFISH, SEABIRD, SALMON: PREDATOR DATA

yelloweye rockfish
(piscivorous)

splitnose rockfish
(planktivorous)

- “reproductive success” (CPUE age-0 [juvenile] abundance); <u>10 species</u>

cassin’s auklet
(planktivorous)

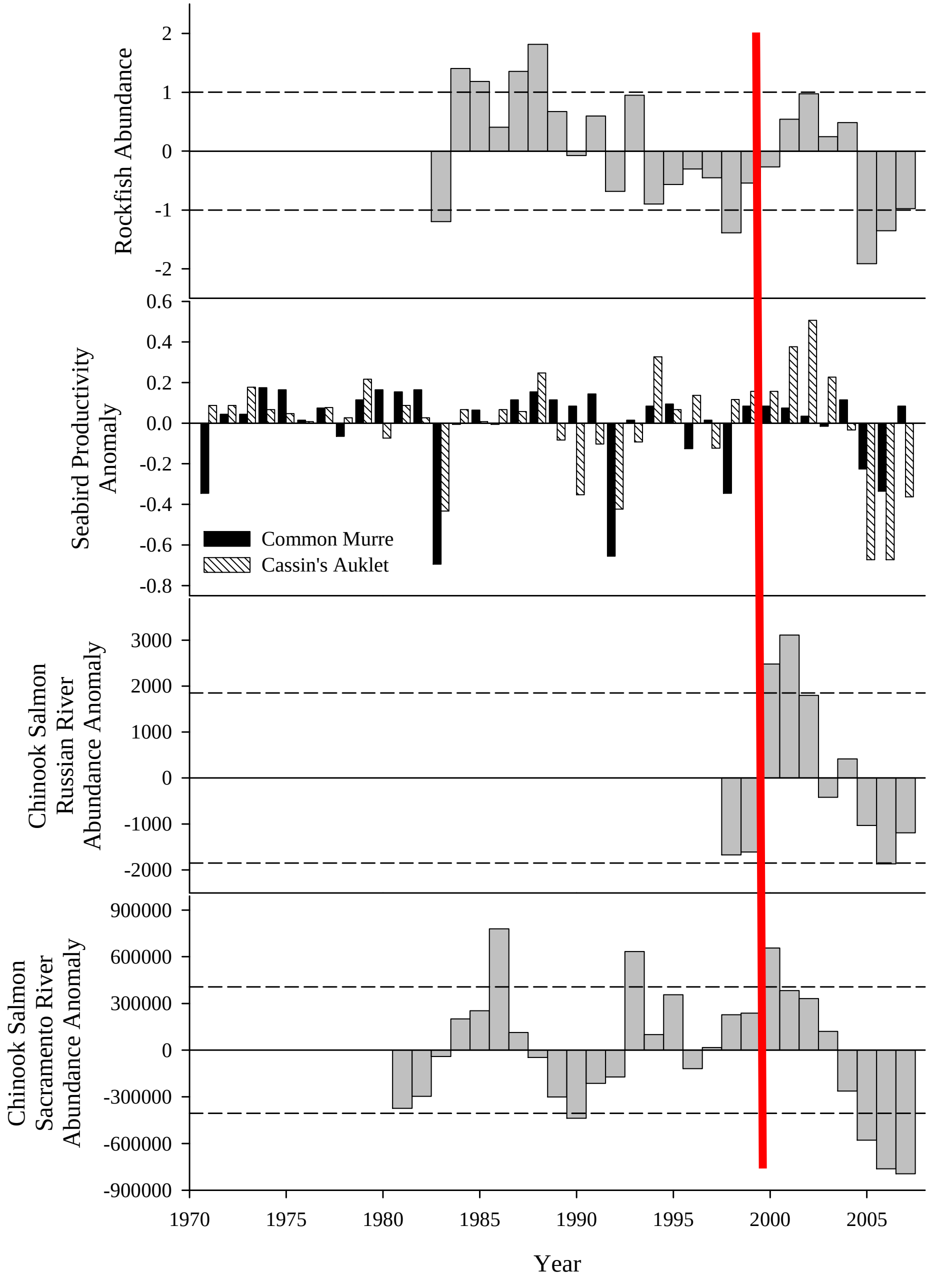


common murre
(omnivorous)

- timing of breeding (mean egg-laying date) & reproductive success (fledglings/pair) from Farallon Islands; at sea density (no./km^2) from NMFS survey; <u>6 species</u>

- returns (number): Sacramento & Russian River fall-run chinook; <u>2 populations , lagged 2 years</u>

INTERANNUAL VARIABILITY IN PREDATOR PRODUC



- Rockfish, seabirds salmon show similar patterns of variability – not surprising given similarity in trophic ecology

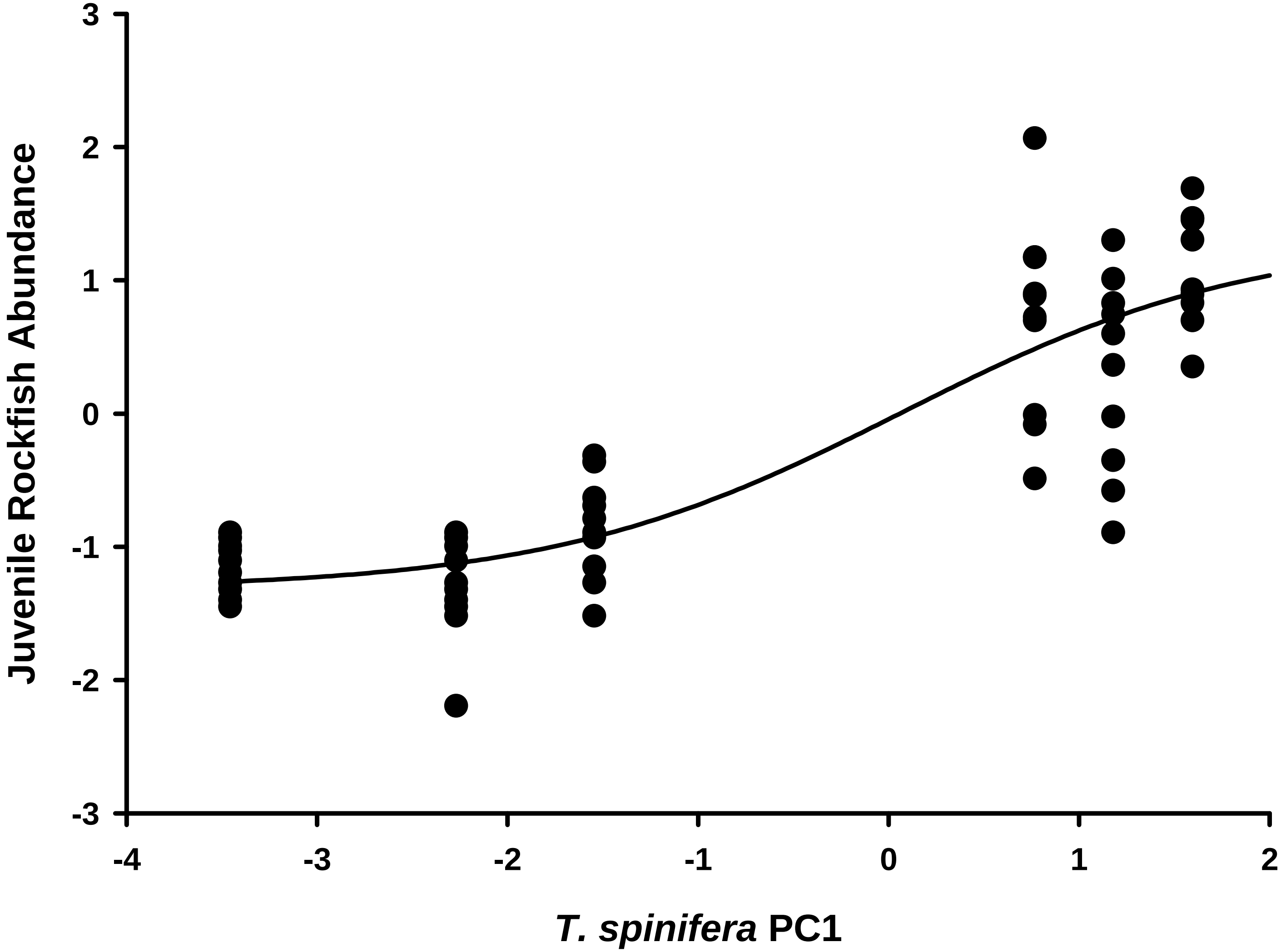
- Krill data overlap with predator data from 2000 to 2007 (lagged to 2009 for salmon returns)

- Pattern during this period:
  - i) Increase from 2000 to 2002-2003;
  - ii) Decrease thereafter

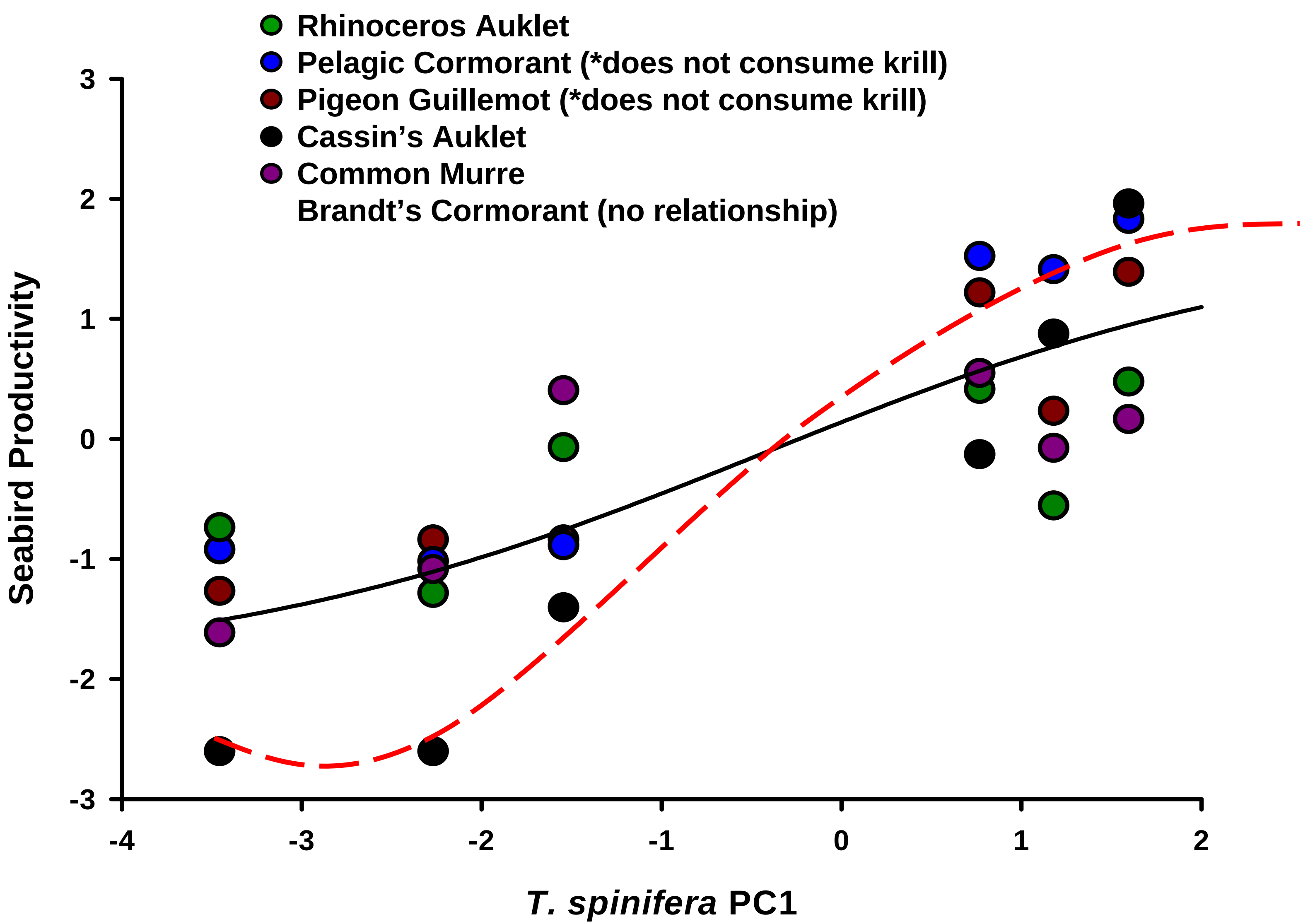
MODEL (ANCOVA) EFFECTS OF CPUE *T. SPIN* CPUE *E. PAC* AND SST ON SEABIRDS, SALMON, AND ROCKFISH

Parameter	*T. spinifera*	*E. pacifica*	SST Feb-May	Species/Population	*T. spinifera* x Species/Population	*E. pacifica* x Species/Population
Seabird Density At Sea	NS	NS	NS	NS	NS	NS
Seabird Timing of Breeding	NS	NS	0.0617 (+)	NS	NS	NS
Seabird Productivity	<0.0001 (+)	0.0714 (-)	0.0104 (-)	NS	0.0003	NS
Juvenile Rockfish Abundance	<0.0001 (+)	0.0023 (-)	0.0125 (-)	0.013	0.0323	NS
Chinook Salmon Abundance	0.0046 (+)	0.0566 (-)	NS	NS	NS	NS

ROCKFISH PRODUCTIVITY - SIGMOIDAL

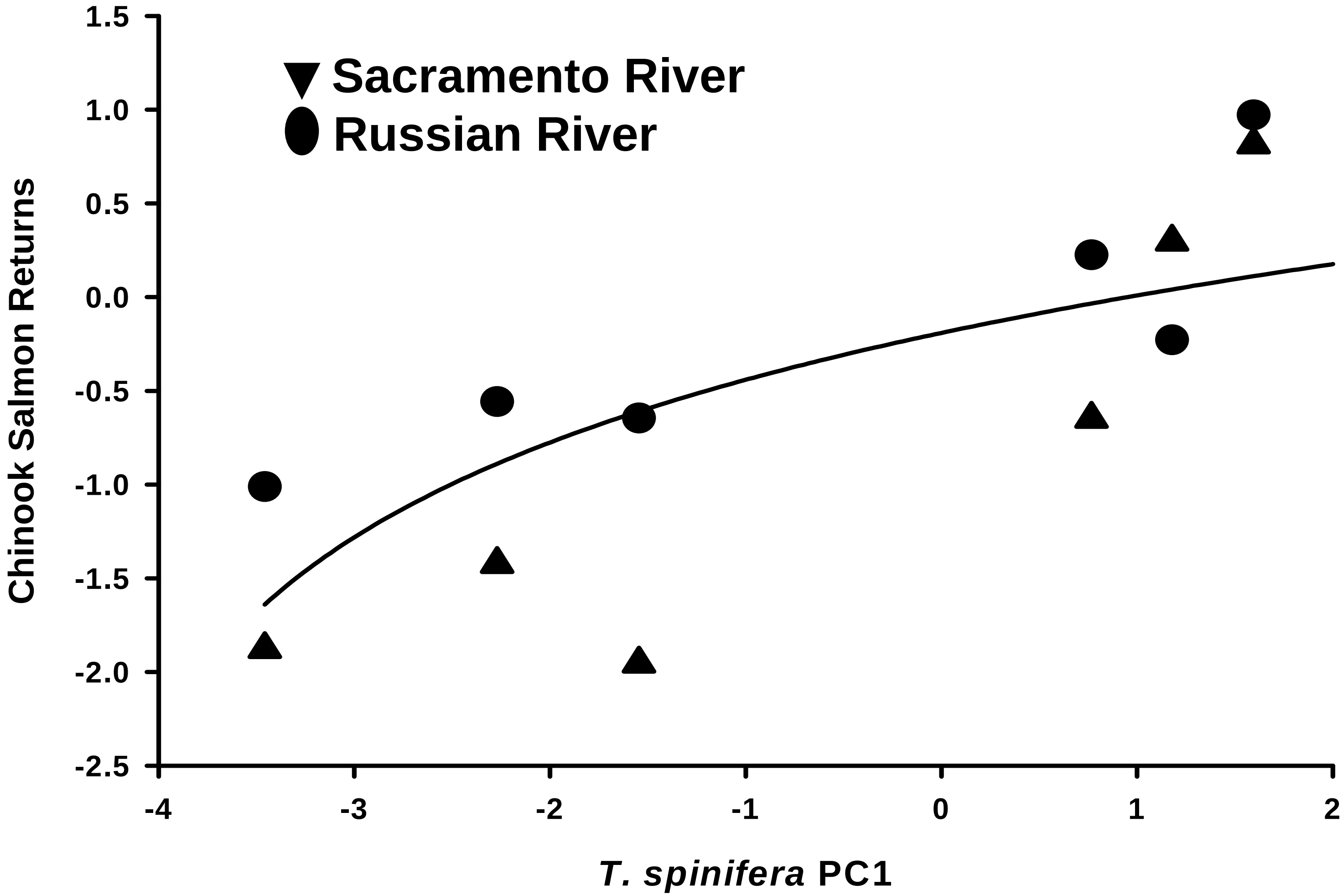


SEABIRD PRODUCTIVITY - SIGMOIDAL

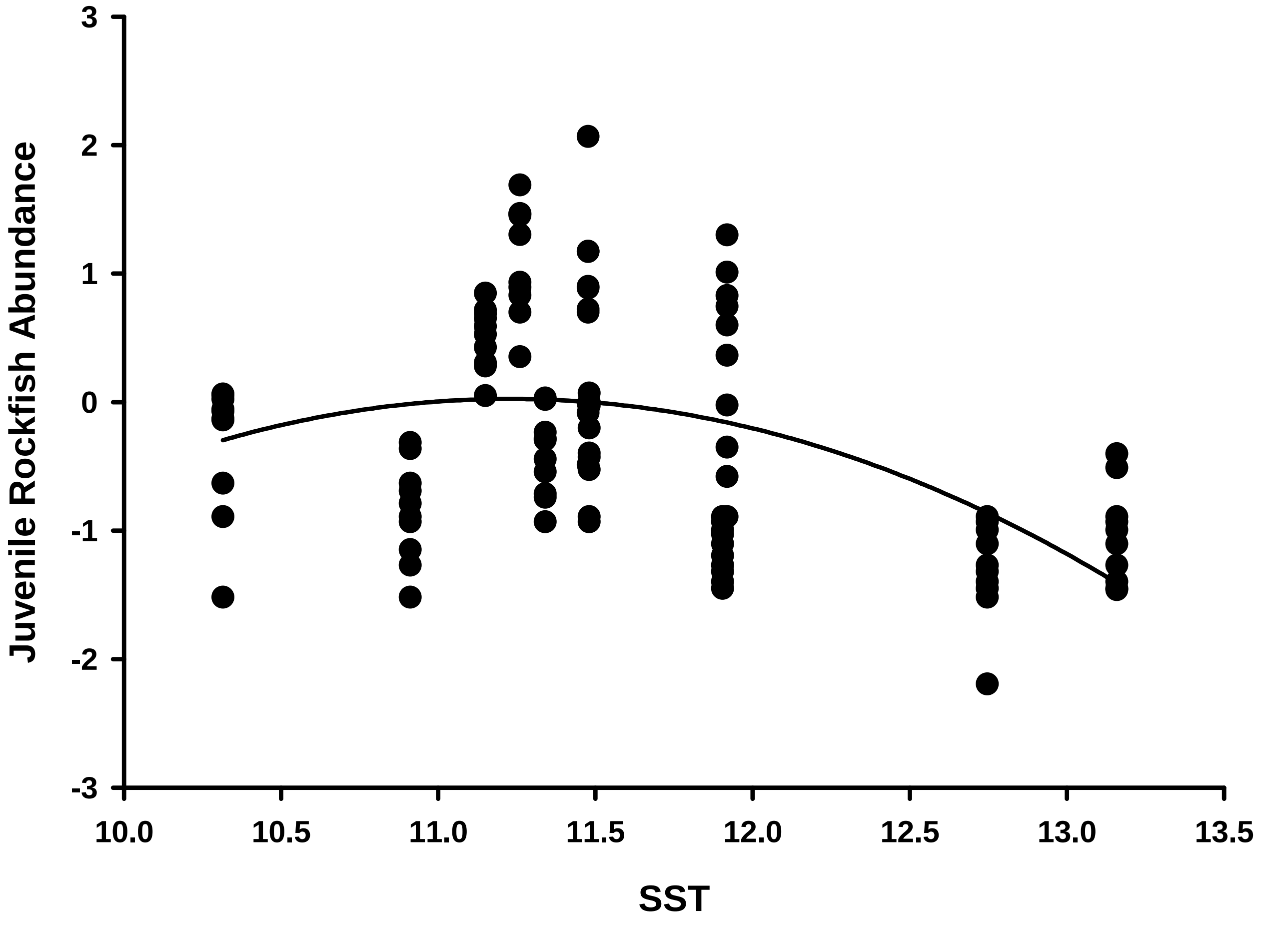


SALMON PRODUCTIVITY – LOGLINEAR

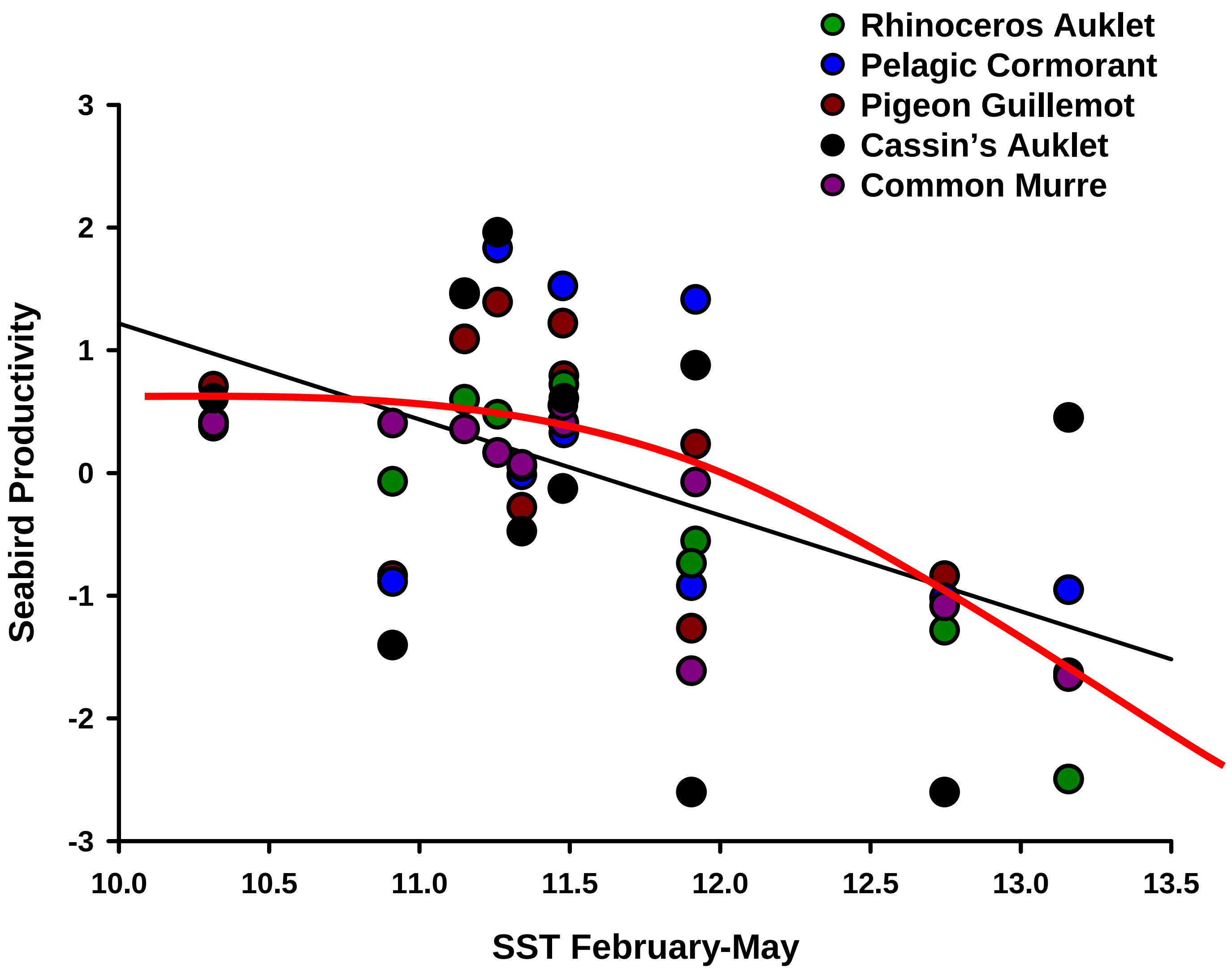
(CPUE *T. SPIN*$_{[YEAR\ X]}$ AND SALMON RETURNS $_{[YEAR\ X+2]}$)



ROCKFISH PRODUCTIVITY & SST



SEABIRD PRODUCTIVITY & SST



CONCLUSIONS

1. **Predator numerical responses**:
    a. sigmoidal, Type III (rockfish, seabirds);
    b. log-linear, Type II (salmon); sigmoidal?
    c. SST has independent effects; apparently <u>does not</u> interact with krill availability to affect predator numerical responses.
2. **Species-specific numerical responses depend on trophic ecology, role of krill in their diet**:
    a. the krill-juvenile rockfish food chain is key for salmon and seabirds in this region.
    b. *T. spinifera* apparently most important, but we suspect both species of krill are important at different times of year (e.g., prey switching demonstrated for auklets, Abraham and Sydeman 2006).
3. **Use both non-linear functional relationships and SST in models of climate-ecosystem dynamics**.
    a. SST relationships apparently non-linear, stressing potential importance of extreme years and events.
4. **Potential to improve forecasting for salmon fisheries in CA**.