MACROECOLOGICAL PATTERNS IN NORTH PACIFIC ECOSYSTEM DYNAMICS: SPATIO-TEMPORAL CO-VARIATION IN UPPER AND LOWER TROPHIC LEVEL DIVERSITY AND PRODUCTIVITY FROM CANADA TO JAPAN

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OVERVIEW:

Purpose - test hypothesis that abundance and diversity of upper-trophic level predators are related to underlying abundance and diversity of prey and to energy availability over macro-scales. 2002 - initiated a program to tri-annually survey seabirds and zooplankton (ZP) along 7,500 km transect between Canada and Japan (fig. 1).

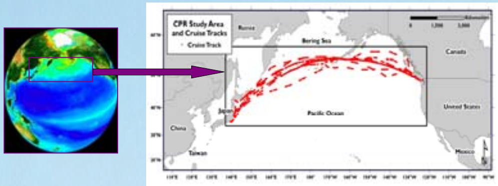


Fig. 1. Location of survey route between Canada and Japan, showing cruise track variability.

HYPOTHESIS:

Seabird/ZP abundance and community structure in N Pacific is influenced by lower-trophic level standing stock and diversity at a macro scale (i.e., 1000's km).

SEABIRD OBSERVATIONS:

- survey platform: ***M.V. Skaubryn*** (observations made approx. 28 m above water - see fig. 2); vessel speed: 4.0 - 14.0 knots
- standardized seabird surveys: strip transects (400 m) one-side of ship
- surveyed East to West only (150-200 km surveyed/day)
- 16 cruises completed to date (see table 1 for timing)

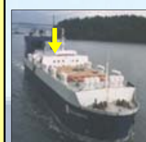


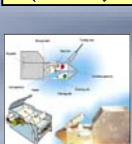
Fig. 2 (right). *M.V. Skaubryn.* Yellow arrow indicates approx. location where observations were made.

Year \ Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2002				■				■
2003		■		■				■
2004		■		■				■
2005		■		■			■	
2006			■		■		■	
2007	■			■				

Table 1. Approximate timing of surveys.

ZOOPLANKTON SAMPLING (ZP):

- Continuous Plankton Recorder (CPR, fig 3) towed behind ship (10 m below surface)
- CPR filters plankton over long distances (up to 500 nmiles) on a moving silk filter band
- filter band wound through CPR on rollers turned by gears, powered by impeller
- post-cruise, filter band removed and cut into 10 nmiles (18.52 km) blocks
- blocks sub-sampled and examined to count phytoplankton and to identify/count small (< 2 mm) and large (> 2 mm) ZP



PRE-ANALYSIS DATA FILTERING:

- included only days that had a minimum of three 18 km ZP blocks (= 54 km) as close to 12 noon as possible (to avoid early morning and late afternoon diel migrations) and with at least 100 km of seabird surveys (resulted in 112 [of 199] days included in analyses)

Fig. 3. Schematic of the CPR (from http://192.171.163.165/cpr_survey.htm).

ESTIMATING NET PRIMARY PRODUCTION (NPP):

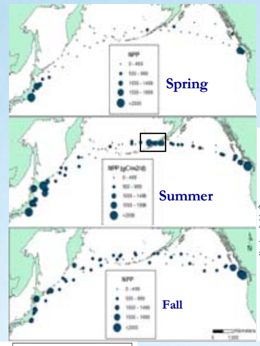
- remotely sensed data (Chl, SST, photosynethetically active radiation [PAR], estimate of the depth of the euphotic zone [z_{eu}]) were entered into Vertically Generalized Production Model (VGPM) to derive daily averaged estimates of NPP over the cruise track (available from ***http://web.science.oregonstate.edu/ocean.productivity***)

DATA ANALYSIS:

- General Linear Model (backward-stepwise regression) - used ZP Independent Variables: (abundance [#/km], biomass, Spp. Richness [#spp/daily transect], Spp. Diversity [Shannon Index: $-\sum p_i \log p_i$], Evenness [Shannon Index/ln Spp. Richness], NPP, z_{eu}) to describe seabird Dependent Variables (DV): (density [#/km^2], biomass, Spp. Richness, Spp. Diversity);
- Compared seasonal NPP with GLM (ANOVA) and multiple comparison tests ($p<0.05$)

RESULTS:

A



Net Primary Production

Season

Spring NPP sign. less than in Summer or Fall

Domain

Coastal NPP sign. greater than Oceanic

B1 B2

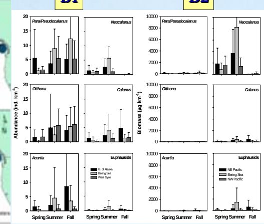
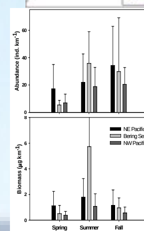


Fig. 4. (A) Seasonal NPP and (B1) ZP abundance and (B2) ZP biomass of important N Pacific genera.

Although small ZP (*Oithona*, *Para/Pseudocalanus*, *Acartia*) were the most abundant spp., most biomass (esp. in the Bering Sea in summer) was from *Neocalanus*.



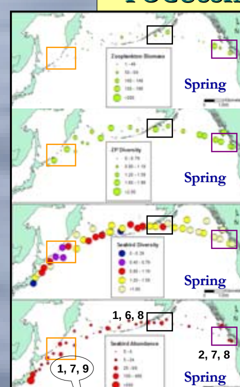
ZP - NPP Relationships

Response Variable	Model R^2	Model p value	NPP	Season	Domain	Basin	Interactions
ZP Abundance	0.30	<0.001	*	**			SxD ***
ZP Biomass	0.43	<0.001	*	***		**	SxD *
							SxB *
ZP Richness	0.16	<0.001	***				SxD **
ZP Evenness	0.12	<0.025	*				SxDxB *

Predictor Variables: NPP, Season, Domain, Basin, Interactions

Fig. 5 (left). Seasonal ZP abundance and biomass distributed across N Pacific by Ocean Basin. NPP and ZP variables significantly associated (above). (* p=0.05-0.01, ** p=0.01-0.001, *** p<0.001)

FOCUSSING ON SPRING and SUMMER RESULTS:

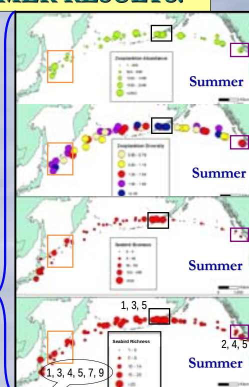


SPRING

Seabird DV	R^2	Sign Predictors
Abundance	0.52	*Depth* (-)
		Biomass (-)
Diversity	0.40	*NPP*
		Biomass

SUMMER

Seabird DV	R^2	Sign Predictors
Abundance	0.38	*Depth* (-)
		Richness
Biomass	0.41	*Depth* (-)
		Abundance
Richness	0.52	*Depth* (-)
		Abundance
Diversity	0.11	*Diversity* (-)



Important Seabird Species - Spring & Summer

Note: Numbers in figures ABOVE refer to species BELOW

Northern Fulmar: NOFU
Sooty Shearwater: SOSH
Short-tailed Shearwater: STSH
Leach's Storm-Petrel: LHSP
Fork-tailed Storm-Petrel: FTSP
Glaucous-winged Gull: GWGU
Black-legged Kittiwake: BLKI
Common &/or Thick-billed Murre: MURR
Crested Auklet: CRAU

SPRING: Coastal Seabird Community dominated by NOFU, BLKI, and CRAU (NW Pacific); NOFU, MURR and GWGU (Bering Sea); and SOSH, BLKI and MURR (NE Pacific).

SUMMER: Coastal Seabird Community dominated by NOFU, STSH, LHSP, FTSP, BLKI AND CRAU (NW Pacific); NOFU, STSH and FTSP (Bering Sea); and SOSH, LHSP and FTSP (NE Pacific).

SUMMARY:

- The strongest relationships between seabird variables and lower trophic levels occurred during summer; significant relationships also found in spring, but none in fall.
- Overall, ZP abundance and biomass explained dominant portion of seabird abundance and indices (Spp. Richness, Spp. Diversity, and Evenness); ZP diversity appeared to be less important in structuring the seabird communities.
- NPP was important to ZP standing stock and diversity, but had less influence at structuring seabird abundance and diversity. The importance of NPP to seabirds may be indirectly related through its influence on ZP.
- Findings underscore hypothesis that severe perturbations of ocean productivity and lower trophic level ecosystem constituents (e.g., climate change causing shifts in timing and synchronicity), could have far-reaching impacts on entire marine food web, including seabirds.

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