The following supplements accompany the article

Kittiwake diets and chick production signal a 2008 regime shift in the Northeast Pacific

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Supplement 1. Table S1. *Rissa tridactyla*. Relative occurrence and percent mass of fish and invertebrate prey in the diet of blacklegged kittiwakes on Middleton Island, 1978 to 2011. Frequency is (occurrence of listed prey type) × (summed occurrences of all identified prey types)$^{-1}$ (see 'Materials and methods' and Supplement 2)

Common name	Scientific name	Taxonomic level	Prey category	Mean rank	Frequency		Mass	
					Mean	Rank	Mean	Rank
Pacific sand lance	*Ammodytes hexapterus*	Species	Fish	1	0.3406	1	0.362534	1
Capelin	*Mallotus villosus*	Species	Fish	2	0.2105	2	0.250252	2
Pacific herring	*Clupea pallasii*	Species	Fish	3	0.0658	3	0.069791	3
Sablefish	*Anoplopoma fimbria*	Species	Fish	4	0.0553	5	0.064720	4
Krill[a]	Euphausiidae	Family	Invertebrate	5	0.0639	4	0.047189	6
Salmon[b]	*Oncorhynchus*	Genus	Fish	6	0.0347	7	0.056808	5
Myctophid	Myctophidae	Family	Fish	7	0.0551	6	0.041086	7
Eulachon	*Thaleichthys pacificus*	Species	Fish	8	0.0221	9	0.029596	8
Copepod[c]	Copepoda	Subclass	Invertebrate	9	0.0218	10	0.013133	9
Fish[d]	Actinopterygii	Class	Fish	10	0.0216	11	0.011104	10
Squid	Cephalopoda:Gonatidae	Family	Invertebrate	11	0.0207	12	0.010176	11
Greenling[e]	Hexagrammidae	Family	Fish	12	0.0099	13	0.009406	12

Polychaete	Polychaeta	Class	Invertebrate	13	0.0067	15	0.007226	13
Amphipod[f]	Amphipoda	Class	Invertebrate	14	0.0237	8	0.000810	21
Smelt	Osmeridae	Family	Fish	15	0.0073	14	0.004411	15
Offal	Animalia	Kingdom	Offal	16	0.0064	16	0.005620	14
Pacific sandfish	*Trichodon trichodon*	Species	Fish	17	0.0055	18	0.002654	18
Prowfish	*Zaprora silenus*	Species	Fish	18	0.0031	22	0.003514	16
Walleye pollock	*Theragra chalcogramma*	Species	Fish	19	0.0035	21	0.003099	17
Pteropod[g]	Thecosomata	Order	Invertebrate	20	0.0038	19	0.001579	20
Threespine stickleback	*Gasterosteus aculeatus*	Species	Fish	21	0.0036	20	0.001754	19
Shrimp[a]	Decapoda:Caridea	Infraorder	Invertebrate	22	0.0063	17	0.000636	23
Rockfish	*Sebastes*	Genus	Fish	23	0.0013	24	0.000745	22
Lingcod	*Ophiodon elongatus*	Species	Fish	24	0.0010	27	0.000445	26
Octopus	Octopoda	Order	Invertebrate	25	0.0005	29	0.000611	24
Isopod	Isopoda	Order	Invertebrate	26	0.0014	23	0.000049	31
Flatfish	Pleuronectidae	Family	Fish	27	0.0006	28	0.000229	27
Melamphaid	Melamphaidae	Family	Fish	28	0.0005	30	0.000447	25
Bigeye lanternfish	*Protomyctophum thompsoni*	Species	Fish	29	0.0012	26	0.000057	30
Crustacea	Crustacea	Subphylum	Invertebrate	30	0.0012	25	0.000020	32
Pacific tomcod	*Microgadus proximus*	Species	Fish	31	0.0001	33	0.000158	28
Sculpin	Cottidae	Family	Fish	32	0.0003	32	0.000114	29
Bivalve	Bivalvia	Class	Invertebrate	33	0.0003	31	0.000003	35
Chiton	Neoloricata	Order	Invertebrate	34	0.0001	34	0.000014	33
Limpet	Protobranchia	Subclass	Invertebrate	35	0.0001	35	0.000007	34
Mussel	Mytiloida	Order	Invertebrate	36	0.0001	36	0.000003	36

[a]Taxon includes 2 or more unidentified species
[b]Includes pink salmon *Oncorhynchus gorbuscha* and chum salmon *O. keta*
[c]Includes *Neocalanus plumchrus* and *N. cristatus*
[d]Includes larval fish unidentified to species but thought to be mostly capelin and/or Pacific sand lance
[e]Includes kelp greenling *Hexagrammos decagrammus* and rock greenling *H. lagocephalus*
[f]Mostly *Paracallisoma alberti*; other, unidentified amphipods infrequently
[g]Probably *Limacina helicina*

Supplement 2. Analytical methods in seabird diet studies

The best practice for quantifying prey types in the diets of marine birds and mammals from partially digested food material is a persistent issue. Ashmole & Ashmole (1967) discussed and contrasted 3 basic measures — percent mass or volume (*M*), percent numbers (*N*), and frequency of occurrence (*F*). They declined to combine the 3 in any way directly, but suggested diet could be summarized by ranking prey types separately for each method of analysis and then summing the ranks, an approach also advocated by Duffy & Jackson (1986). Supplement 1 lists kittiwake prey in order of the summed ranks for percent mass and relative occurrence — omitting percent numbers, which tends to introduce excessive bias (see below).

Some workers are tempted to combine diet measures into a summary statistic for purposes of simplifying and reporting diet information while still making use of all the available data. The most widely adopted approach is called the index of relative importance (IRI), attributed to Pinkas et al. (1971) and calculated as $F(N + M) = \text{IRI}$. However, the IRI (expressed as a raw value or as a percentage of total IRI) is an arbitrary calculation that should not be used. It gives a misleading impression of prey 'importance' when prey items differ in size. (Consider, for example, 2 kittiwake samples each containing one 30 g fish and 500 copepods totaling 5 g. The diet according to %IRI is 42% fish and 57% copepods — clearly off base, as the composition by percent mass is 86% fish and 14% copepods.)

Frequency of occurrence (*F*) is usually calculated on a per-sample basis: (number of samples containing prey type) × (number of samples analyzed)$^{-1}$ × 100 (Ashmole & Ashmole 1967, Duffy & Jackson 1986, Barrett et al. 2007). Unlike percent mass or percent numbers, however, the sum of *F* over all prey types is an arbitrary value >100; thus, the relative contributions of prey types is obscured. I chose an alternative measure of occurrence, the *frequency of occurrence per prey type*, denoted *R* for *relative occurrence*: (number of samples containing prey type) × (total of prey-type identifications made in all samples)$^{-1}$ (× 100 if a percentage value is desired). *R* values sum to 1.0 (or 100), which is useful for drawing standard pie or bar charts.

To judge the effectiveness of *R* as an estimator of kittiwake diet, I computed pairwise correlations among relative occurrence, percent mass, and percent numbers for the Middleton samples (Table S2). Each value in the table is the mean correlation between 2 candidate diet indices calculated separately for each prey type, with sample sizes being the number of years a prey type was present and available for the comparison. The number of correlations (prey types) included in each mean depended on the minimum number of years (3, 5, or 10) a prey type was required to be present for inclusion. Finally, I ran the correlations with krill and copepods either included or excluded to see the effect of variable prey size on the coherence among dietary measures. Results indicate that when prey differing greatly in size (e.g. fish and zooplankton) are present in a collection of samples, percent numbers (*N*) is poorly correlated with either percent mass (*M*) or relative occurrence of prey (*R*). This suggests it is best simply to ignore percent numbers in characterizing the diet and to rely instead on either percent mass or relative occurrence. Conversely, correlations exceeding 0.9 (higher with more years available for comparison) between relative occurrence and percent mass suggest that either measure conveys approximately the same information. Agreement between *R* and *M* was evident also for prey differing substantially in size, such as age-0 and older fish of the same species (Table 2 in 'Results').

Another issue is how to calculate overall means from yearly estimates of diet in a multi-year study. The choices are a simple arithmetic mean of annual measures for each prey type (*mean of proportions*) or lumping all material as though it constituted a single sample before calculating percentages (*pooled sample proportion*). The latter approach is a weighted mean that uses within-year sample sizes as the weighting factor. I chose to report unweighted values (*means of proportions*) on the premise that each year's data was adequate for characterizing real differences that existed between years (except the years with meager data — 1989, 1992, and 1994 — which I lumped together before calculating multi-year averages).

For seabirds such as kittiwakes, whose regurgitations consist of slightly to moderately digested material, percent mass at ingestion is probably estimated reasonably well by percent mass in the sample. Moreover, relative occurrence is a good surrogate for percent mass, and it is less prone to measurement error. For many species, therefore, *R* will be the best option for quantifying the prey composition of food samples.

Table S2. *Rissa tridactyla*. Mean coefficients of correlation between annual diet indices — relative occurrence (*R*), percent mass (*M*), and percent numbers (*N*)—in 2502 kittiwake samples collected on Middleton Island in 15 yr, 1997 to 2011, excluding years with minimal data (1989, 1992, 1994), values missing for *M* or *N* (1978, 1994, 1996), or non-standard sampling (offshore collection of adults in 1990). Years refers to the number of years a given prey type is required to be present for its r or rho value to be included in calculations of mean correlation. Prey types excluded from all analyses for lack of usable data on prey numbers were crustaceans (except copepods and krill), pteropods, offal, and unidentified fish (mostly larvae)

Years	Include krill/copepods	Prey types	Pearson's r			Spearman's rho		
			$R \times M$	$R \times N$	$M \times N$	$R \times M$	$R \times N$	$M \times N$
≥3	Yes	21	0.880	0.575	0.583	0.844	0.539	0.558
	No	19	0.880	0.871	0.855	0.834	0.839	0.809
≥5	Yes	17	0.888	0.659	0.644	0.849	0.620	0.560
	No	15	0.888	0.883	0.848	0.850	0.856	0.784
≥10	Yes	11	0.910	0.652	0.725	0.909	0.656	0.684
	No	10	0.918	0.842	0.875	0.921	0.863	0.863

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