



# Preliminary estimates of Chinook salmon consumption rates by Resident killer whales



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Analysis\* involved the following four general steps:

- 1) Estimate the metabolic needs of resident killer whales
- 2) Estimate the caloric value of Chinook salmon consumed by killer whales based on prey size and energy density
- 3) Estimate the numbers of Chinook salmon needed to meet daily energy requirements
- 4) Estimate the total numbers of Chinook salmon consumed by the NR and SR killer whale populations based on proportion in diet

## 1) Metabolic needs of killer whales:

- Followed methods of recent analysis by Dawn Noren, NWFSC (Noren 2011)
- Requires accurate estimates of body mass of individuals
- Whales < 1 yr old discounted from analysis as dependent on mom
- For whales 1-12 years old, sexual dimorphism is minimal so males and females were combined
- For whales 13 years or older, separate categories were made for each sex by age in years
- Changes in energetic requirements for adult females during pregnancy and lactation were not accounted for in the calculations.

## 1) Metabolic needs of killer whales (cont'd):

- For whales aged  $\leq 12$  years, body mass was derived from estimates body weight based on age in days for captive female killer whales (Clark et al. 2000)
- For adult ( $>20$  yrs) body masses, used recent measurements of length of southern resident killer whales by aerial photogrammetry (Fearnbach et al. in press) – mean for males: 677 cm, for females: 600 cm
- Body lengths converted to mass with equation developed by Bigg & Wolman (1975) from measurements of live-captured killer whales:

$$M = 0.000208L^{2.577}$$

where M = body mass in kg, and L = length in cm

## 1) Metabolic needs of killer whales (cont'd):

- Daily prey energy requirements (DPER) of individual resident killer whales were calculated using formulae developed by Noren (2011):

$$DPER_{\min} = 413.2M_b^{0.75}$$

$$DPER_{\max} = 495.9M_b^{0.75}$$

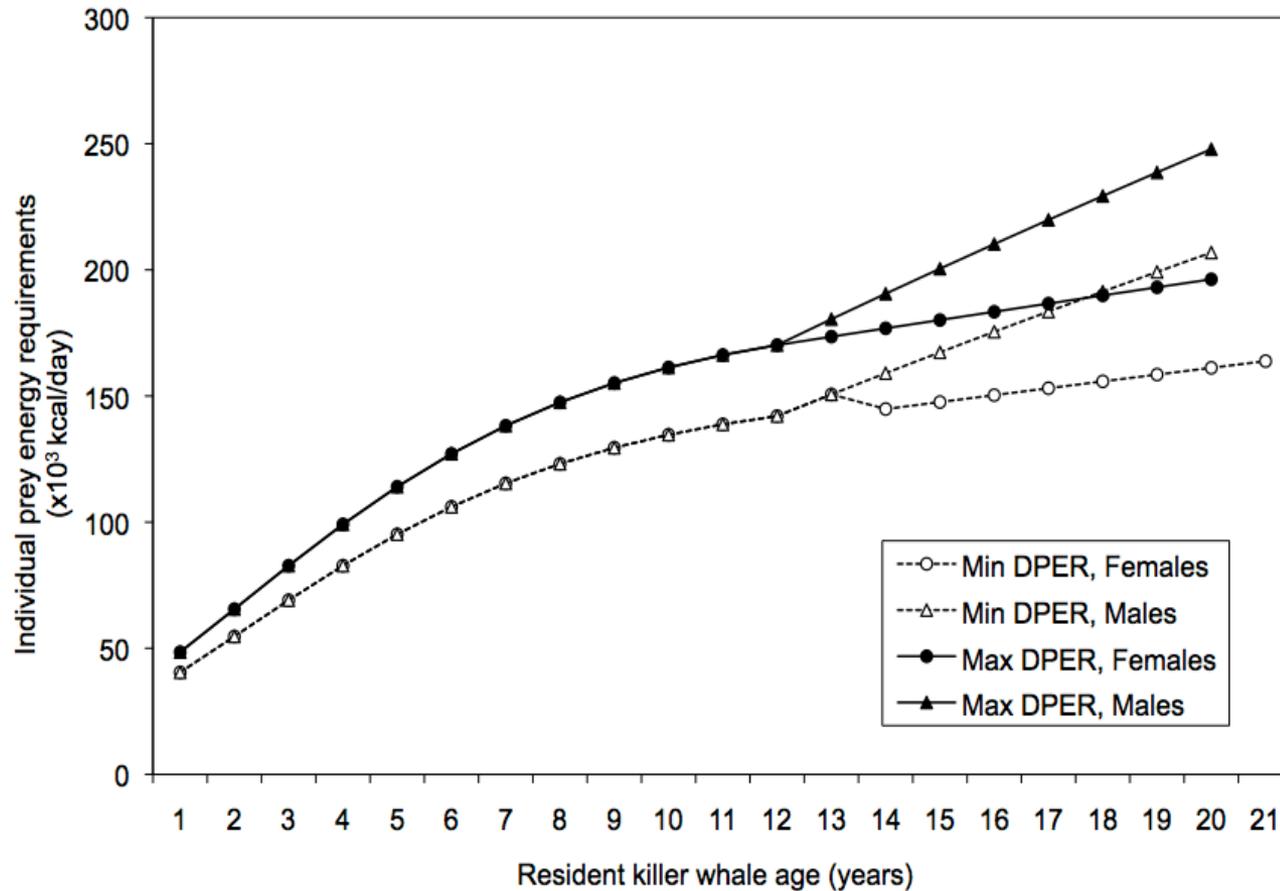
where  $DPER$  = daily prey energy requirements in kcal/d and  $M_b$  = body mass in kg.

- Min and max values of DPER reflect range of field metabolic rates estimated by Noren (2011) to be 5 to 6 times the basal metabolic rates predicted for mammals by Kleiber (1975)
- DPER values also take into account digestive efficiency for killer whales, estimated at about 84.7%

Estimated body masses and minimum and maximum Daily Prey Energy Requirements (DPER) for individual resident killer whales, based on age- and sex-class membership.

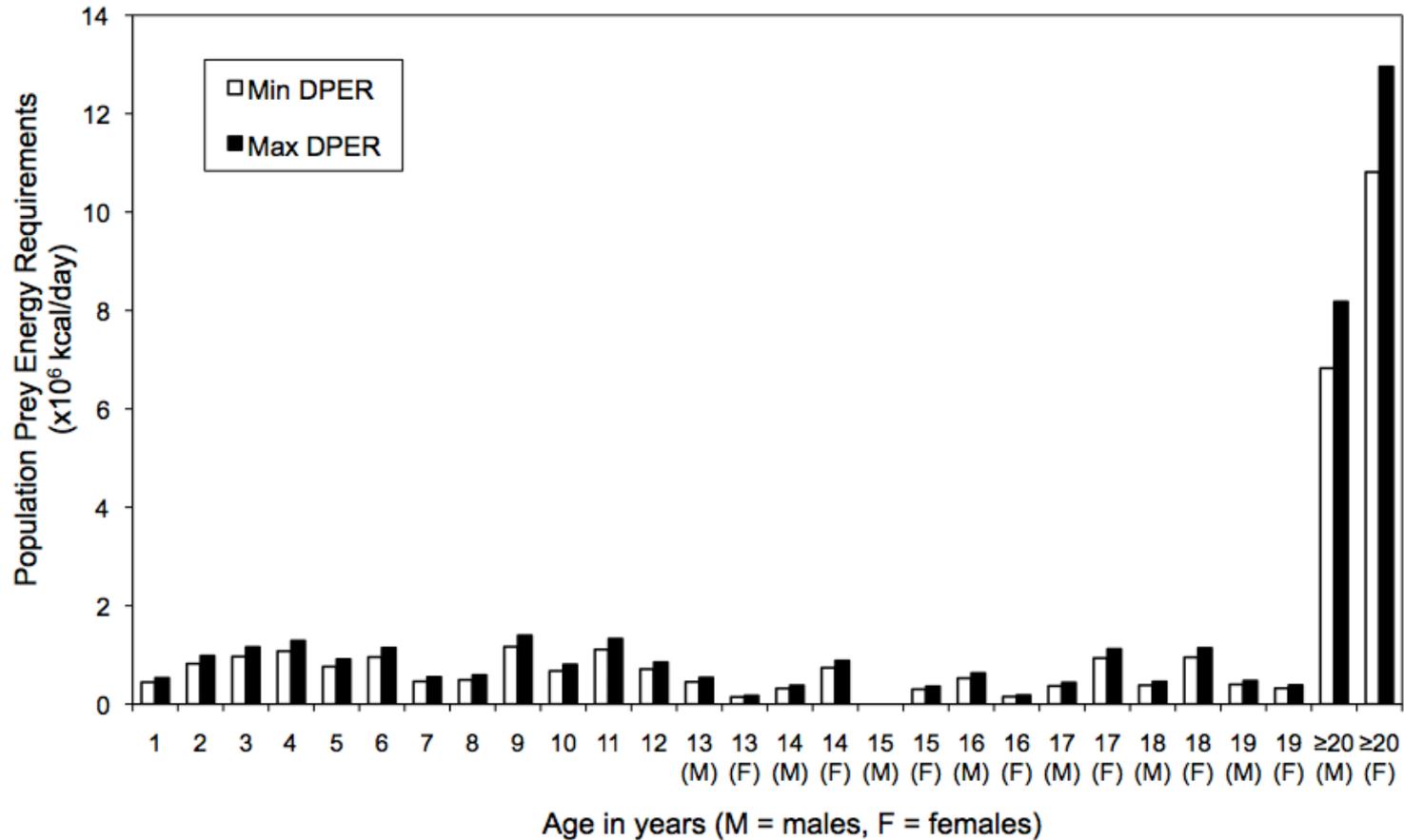
Age- and Sex- Class	Age (days)	Body Mass (kg)	Min DPER (kcal/day)	Max DPER (kcal/day)
age 1	365	465	41396	49681
age 2	730	695	55949	67146
age 3	1095	949	70650	84790
age 4	1460	1208	84645	101587
age 5	1825	1455	97359	116845
age 6	2190	1682	108510	130228
age 7	2555	1881	118014	141634
age 8	2920	2051	125941	151147
age 9	3285	2194	132447	158956
age 10	3650	2311	137720	165284
age 11	4015	2406	141944	170354
age 12	4380	2482	145303	174385
age 13, male	4745	2684	154076	184914
age 13, female	4745	2547	148143	177793
age 14, male	5110	2886	162688	195249
age 14, female	5110	2612	150970	181186
age 15, male	5475	3088	171151	205406
age 15, female	5475	2677	153779	184557
age 16, male	5840	3290	179477	215398
age 16, female	5840	2742	156571	187908
age 17, male	6205	3491	187676	225238
age 17, female	6205	2807	159346	191239
age 18, male	6570	3693	195757	234937
age 18, female	6570	2872	162106	194551
age 19, male	6935	3895	203728	244504
age 19, female	6935	2937	164850	197844
age ≥20, male	≥7300	4097	211597	253947
age ≥20, female	≥7300	3002	167562	201098

Upper and lower bound Daily Prey Energy Requirements (DPER) for male and female resident killer whales by age-class (years).



Lower and upper bound population daily prey energy requirements (DPERs) for northern resident killer whales (n = 241 in 2008) by age- and sex-class

Est. total DPER = 34,025,721 – 40,835,806 kcal/day



## 2) Energy value of Chinook salmon consumed by resident killer whales:

- Wide range of sizes of Chinook salmon taken by killer whales, thus wide range in energy value
- Needed to factor in size distribution of Chinook taken by northern and southern residents:

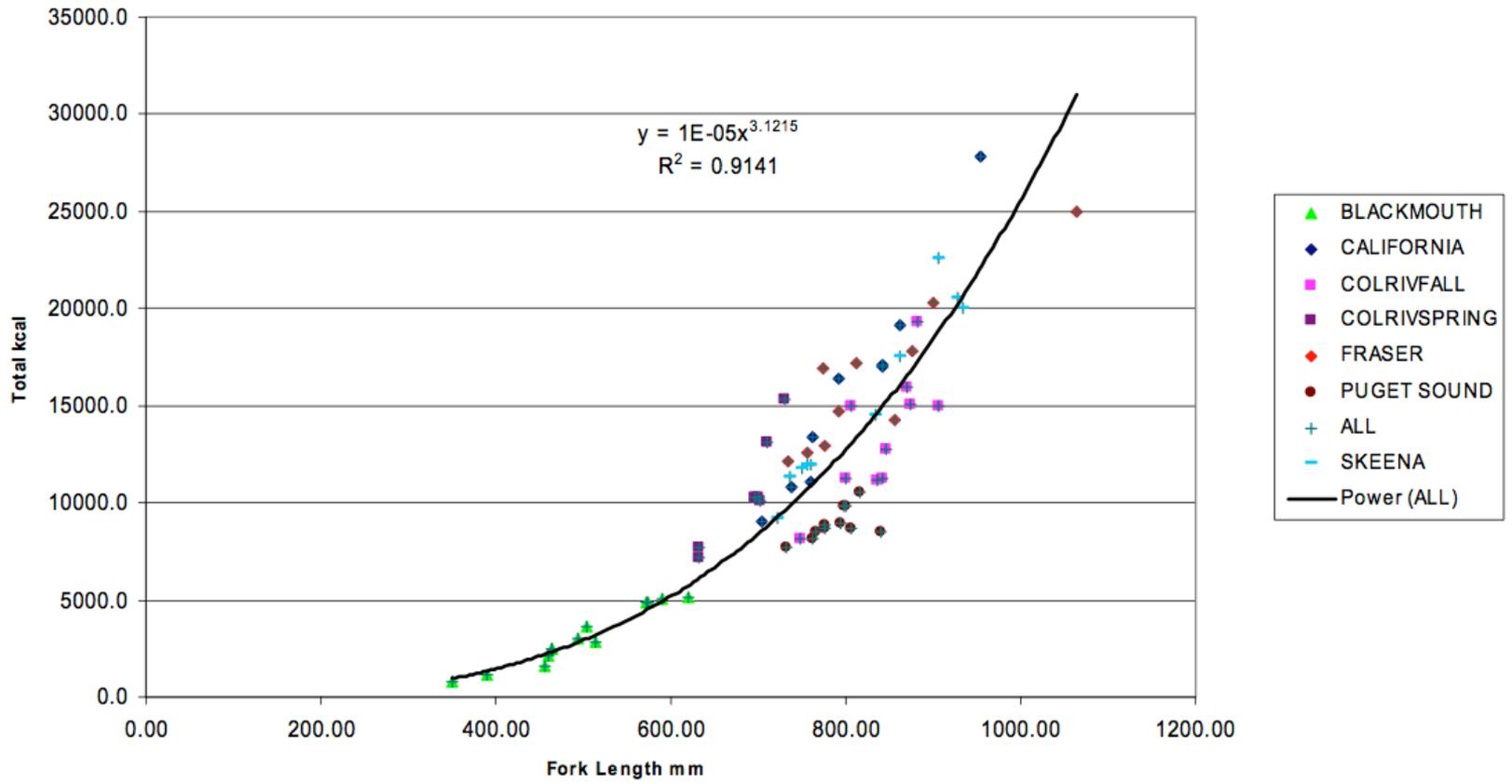
Chinook Age (years)	Northern Residents		Southern Residents	
	n	%	n	%
2	1	0.3	6	3.8
3	36	11.3	15	9.4
4	153	48.1	69	43.4
5	111	34.9	60	37.7
6	16	5.0	7	4.4
7	1	0.3	2	1.3
<i>Total</i>	<i>318</i>	<i>100</i>	<i>159</i>	<i>100</i>

## 2) Energy value of Chinook salmon consumed by resident killer whales (cont'd):

- Energy content of different age classes of Chinook salmon was determined using average fork lengths by age from Ford & Ellis (2006) and a regression of fork length to energy content developed by O'Neill et al. (in prep.):

Age (year)	Length (mm)	Energy content (kcal/fish)
2	425 ± 1.19	1601.5
3	581 ± 2.14	4249.9
4	808 ± 3.43	11898.3
5	939 ± 4.21	19018.5
6	961 ± 15.0	20444.2

# Regression of fork-length of Chinook salmon to energy density in kilocalories (from O'Neill et al., in prep.)



### 3) Estimate numbers of Chinook salmon needed to meet daily energy requirements

- Next, divided DPER values by estimated energy content per fish for each age class of Chinook salmon, then calculated the number of fish each age class in each resident population would have to consume in order to meet their daily energy requirements:

Northern resident:

Chinook Age (years)	% of kills	Min DPER	Max DPER	Min fish per day	Max fish per day
2	0.31	106,999	128,414	66.8	80.2
3	11.32	3,851,968	4,622,921	906.4	1087.8
4	48.11	16,370,866	19,647,416	1375.9	1651.3
5	34.91	11,876,903	14,254,008	624.5	749.5
6	5.03	1,711,986	2,054,632	83.7	100.5
7*	0.31	106,999	128,414	5.2	6.3
<i>Total</i>	<i>100</i>	<i>34,025,721</i>	<i>40,835,806</i>	<i>3063</i>	<i>3676</i>

Southern resident:

Chinook Age (years)	% of kills	Min DPER	Max DPER	Min fish per day	Max fish per day
2	3.8	484,619	581,613	302.6	363.2
3	9.4	1,198,793	1,438,726	282.1	338.5
4	43.4	5,534,854	6,642,628	465.2	558.3
5	37.7	4,807,926	5,770,210	252.8	303.4
6	4.4	561,137	673,446	27.4	32.9
7*	1.3	165,791	198,973	8.1	9.7
<i>Total</i>	<i>100</i>	<i>12,753,120</i>	<i>15,305,596</i>	<i>1338</i>	<i>1606</i>

#### 4) Estimate the number of Chinook taken by residents based on proportion in diet:

##### Northern resident:

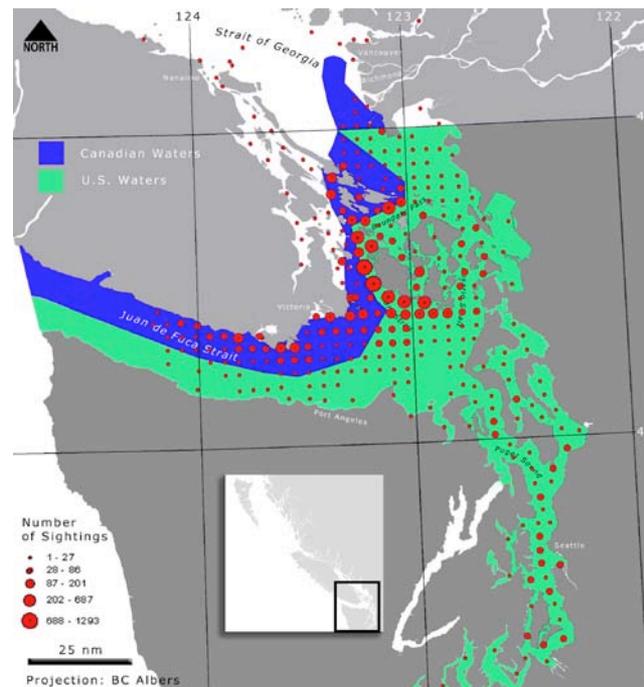
% Chinook in diet	Min DPER	Max DPER	Min fish/d	Max fish/d	Min fish/yr	Max fish/yr
100	34,025,721	40,835,806	3063	3676	1,117,832	1,341,561
90	30,623,149	36,752,226	2756	3308	1,006,049	1,207,404
70	23,818,005	28,585,064	2144	2573	782,482	939,092
50	17,012,861	20,417,903	1531	1838	558,916	670,780

##### Southern resident:

% Chinook in diet	Min DPER	Max DPER	Min fish/d	Max fish/d	Min fish/yr	Max fish/yr
100	12,753,120	15,305,596	1338	1606	488,453	586,215
90	11,477,808	13,775,036	1204	1445	439,608	527,593
70	8,927,184	10,713,917	937	1124	341,917	410,350
50	6,376,560	7,652,798	669	803	244,227	293,107

# Estimated numbers of Chinook salmon consumed by resident killer whales in Critical Habitats:

- Confined estimate to July-August, peak months of foraging in CH and prevalence of Chinook in diet (~ 90% of prey)
- Assumed entire southern resident population spends 90% of days within Critical Habitat
- Total estimate 1200 to 1400 fish per day, or 67,000 to 81,000 fish



# Estimated numbers of Chinook salmon consumed by resident killer whales in Critical Habitats:

- Estimate for northern residents more complicated as only portion of population uses Critical Habitat in any year
- Average of 32.1 whales used CH per day, 1998-2008 (14% of NR)
- Partitioned these into average demographic composition of population (number of juveniles, adult males, adult females)
- Total estimate 420-500 fish per day, or 26,000 to 31,000 fish



Many thanks to....

Ken Balcomb, John Durban, Holly Fearnbach, Dawn Noren, Sandi O'Neill

*Support*

SARA program, Fisheries and Oceans Canada

