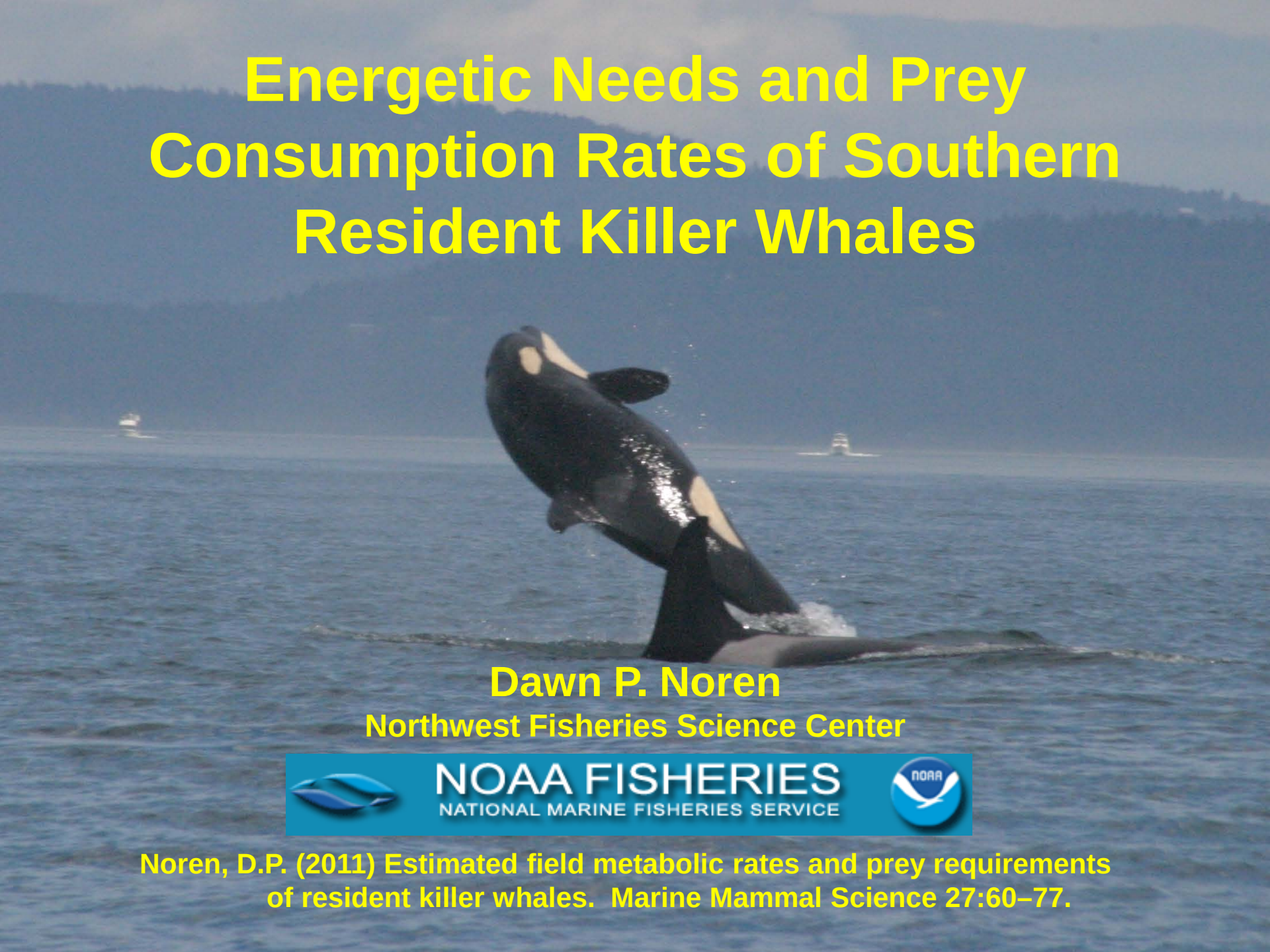
Energetic Needs and Prey Consumption Rates of Southern Resident Killer Whales



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NOAA FISHERIES
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Noren, D.P. (2011) Estimated field metabolic rates and prey requirements of resident killer whales. Marine Mammal Science 27:60–77.

Risk Factor: Reduced Prey Quality and Availability

SRKW diet

Prey abundance and quality

SRKW metabolism and prey requirements

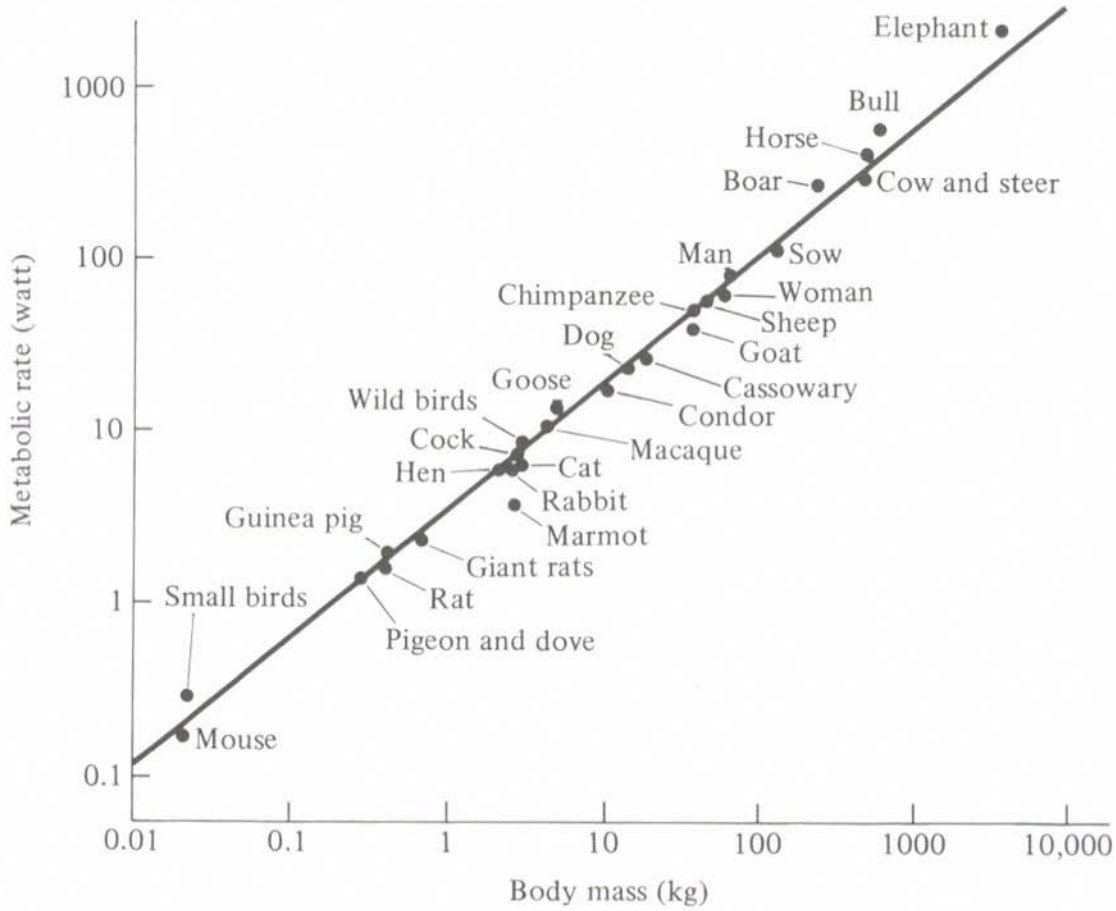
Energy In < Energy Out
(Negative: Mass Loss → Starvation → Death)

Energy In = Energy Out
(Neutral: Balanced, Maintain Status)

Energy In > Energy Out
(Positive: Growth, Reproduction, Lactation)

Kleiber (1975) Predicted BMR

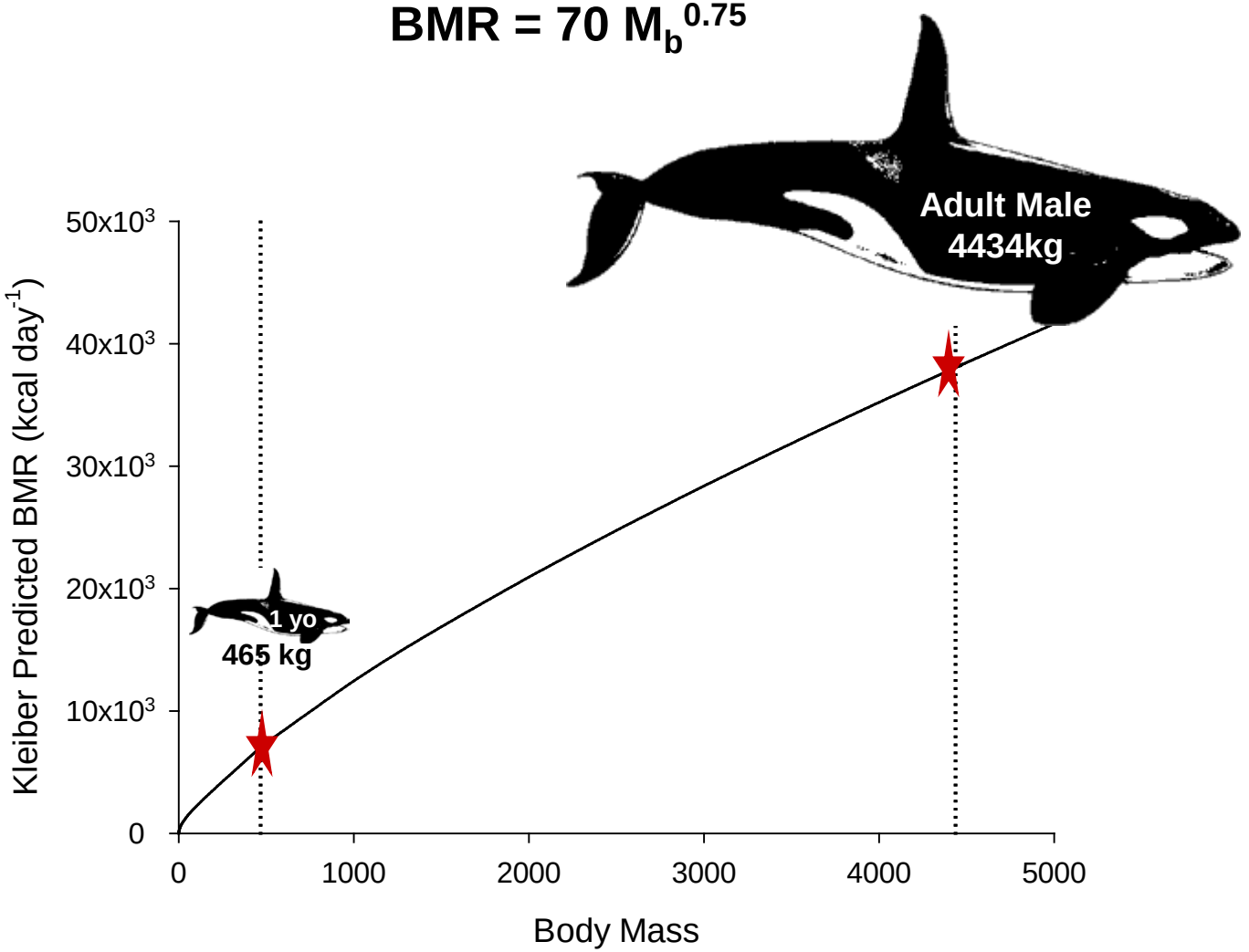
(Mouse to Elephant Curve)



Kleiber (1975) Predicted BMR

(Mouse to Elephant Curve)

$BMR = 70\ M_b^{0.75}$



Estimated Body Mass for SRKWs

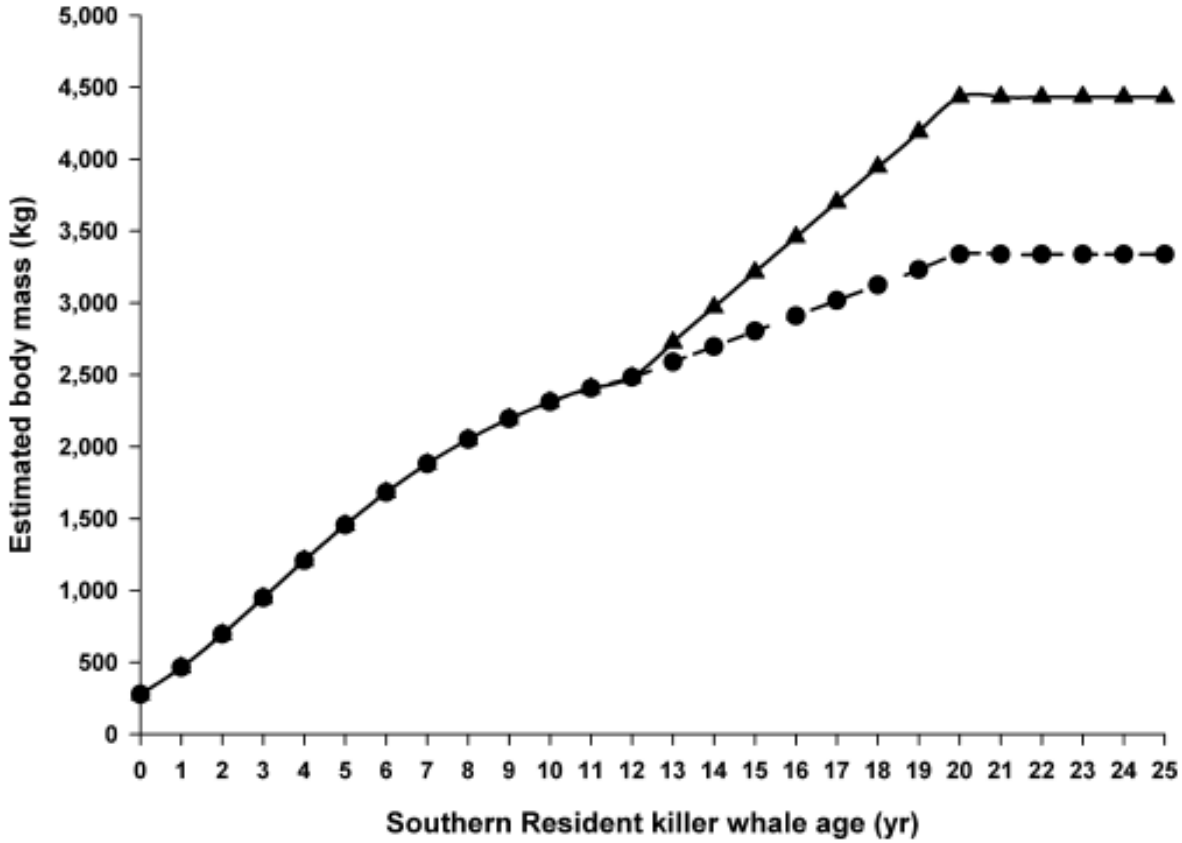
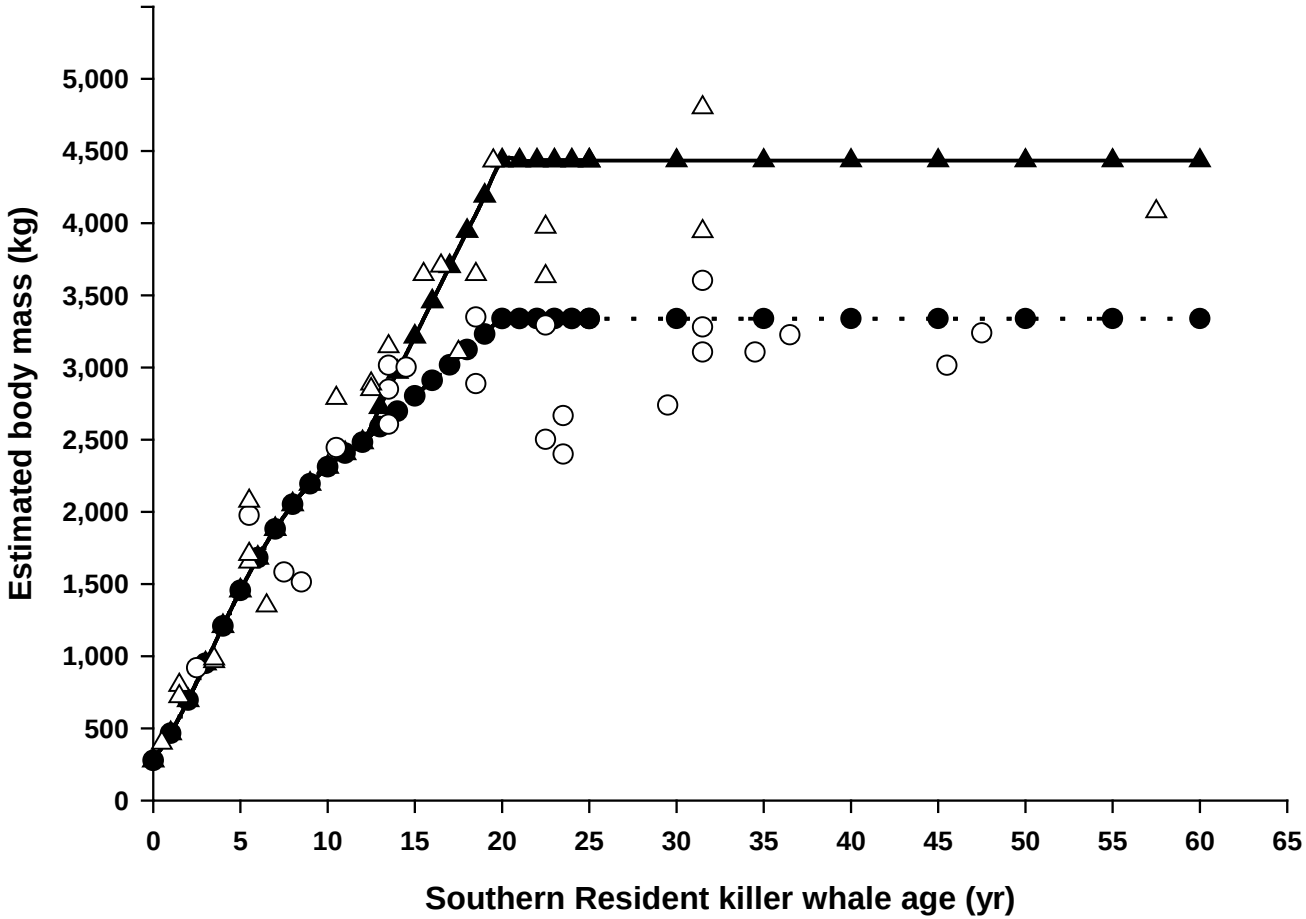


Figure 1. Relationship between body mass and age in years for male and female killer whales. The growth curves for male (▲) and female (●) killer whales are denoted by the solid and broken lines, respectively.

Body mass estimated from growth patterns, lengths during different life history stages, and relationships between lengths and weights in killer whales (Duffield & Miller 1988; Clark *et al.* 2000; Christensen 1988; Bigg and Wolman 1975).

Estimated Body Mass for SRKWs



Corresponding open symbols represent masses estimated by max lengths measured by Fearnbach *et al.* (2011) using the equation from Bigg and Wolman (1975).

Daily Field Metabolic Rate (FMR)

- **Odontocete and otariid FMRs in scientific peer-reviewed literature**
  - ~5 to 6X Kleiber (1975) predicted BMR
  - adult males, adult females, lactating females, juveniles

- **Adult killer whale FMRs estimated by using daily activity budgets (Ford 1989, Noren unpublished data) and COT curves (Williams and Noren 2009)**
  - 5.0 to 7.4X Kleiber predicted BMR (Noren 2011)

- **Estimated FMR for killer whales (~5 to 6X Kleiber predicted BMR)**
  - Lower Bound FMR = $350Mb^{0.75}$
  - Upper Bound FMR = $420Mb^{0.75}$

Daily Prey Energy Requirements (DPERs)

Digestive efficiency ~ 84.7%

(estimated for killer whales, Williams *et al.* 2004)

Daily Prey Energy Requirements

Lower Bound DPER = $413.2Mb^{0.75}$

Upper Bound DPER = $495.9Mb^{0.75}$

Potential Factors Affecting DPERs

- **Energetic costs of gestation, lactation, and growth**

- **No change in food consumption during gestation in killer whales (Kriete 1995, Kastelein *et al.* 2003a) or bottlenose dolphins (Kastelein *et al.* 2002, 2003b)**

- **Increased food consumption in lactating *O.o.* and *T.t.* highly variable across individuals, across different lactation periods, within one lactation period (Kreite 1995, Kastelein *et al.* 2002, 2003a, b).**
  - **Pre-lactation food consumption levels resume within several months of birth in *T.t.* (Kastelein *et al.* 2003b)**

- **Negligible energy intake for growth relative to total intake in *O.o.* (Kriete 1995)**
  - 0 -1.29 kg day^{-1} growth = max increase of 7,700 kcal day^{-1} in DPER

DPERs for Individual SRKWs

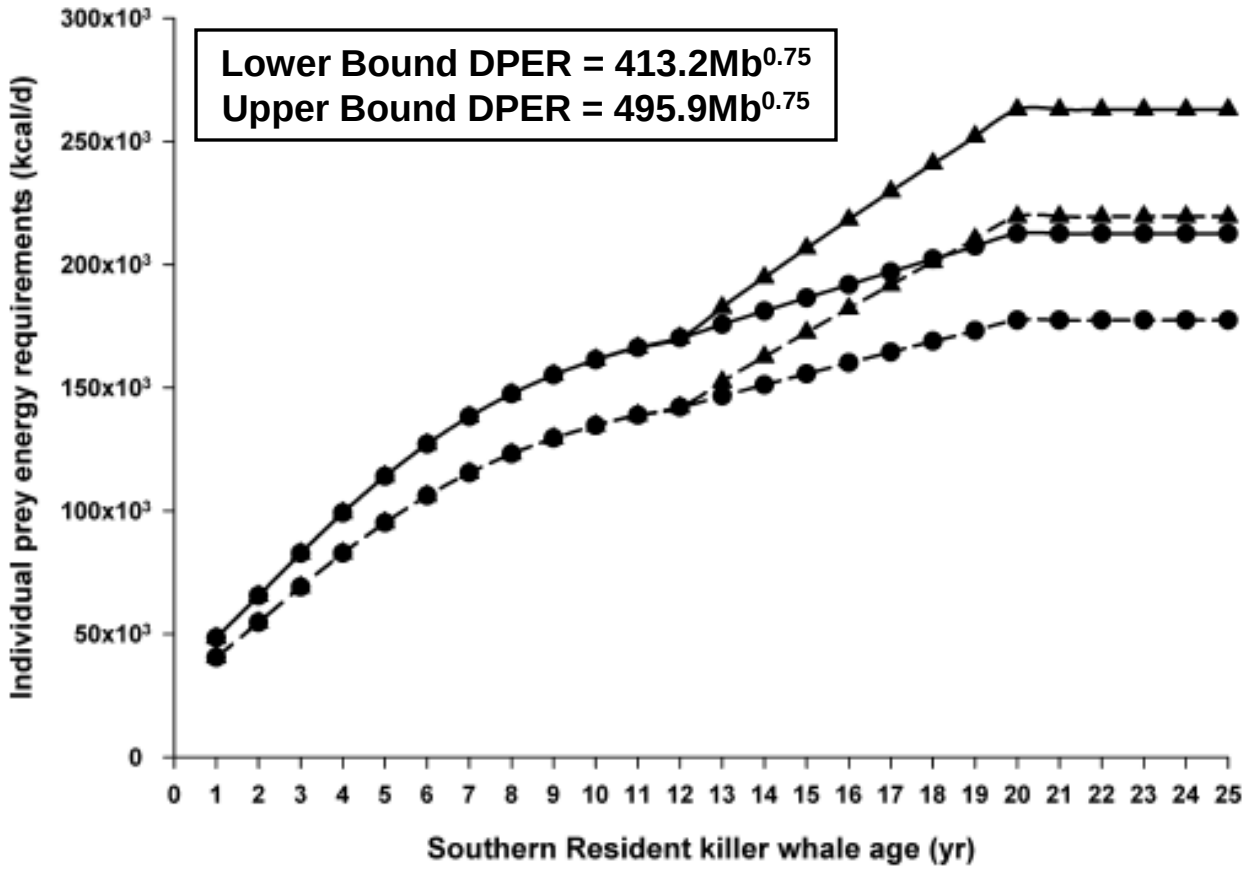
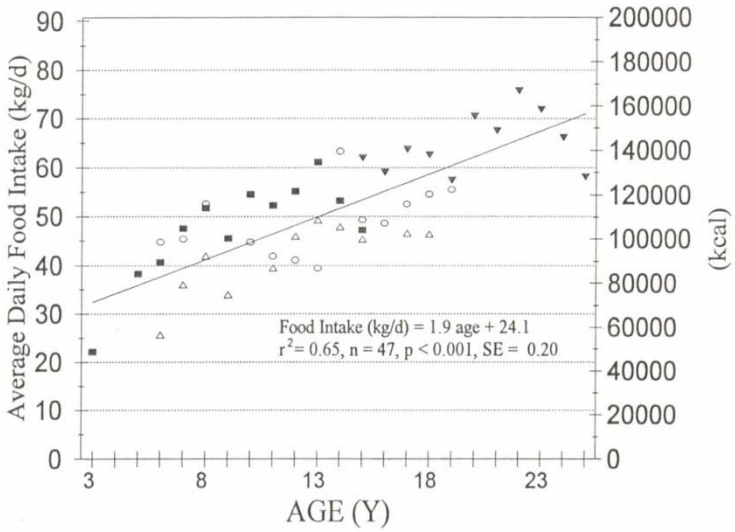


Figure 2. Relationship between daily prey energy requirements (DPERs) and age in years for male and female killer whales. Lower bound (broken lines) and upper bound (solid lines) estimates of DPERs (kcal/d) are presented for male (▲) and female (●) killer whales.

Prey Consumption in Captive Killer Whales

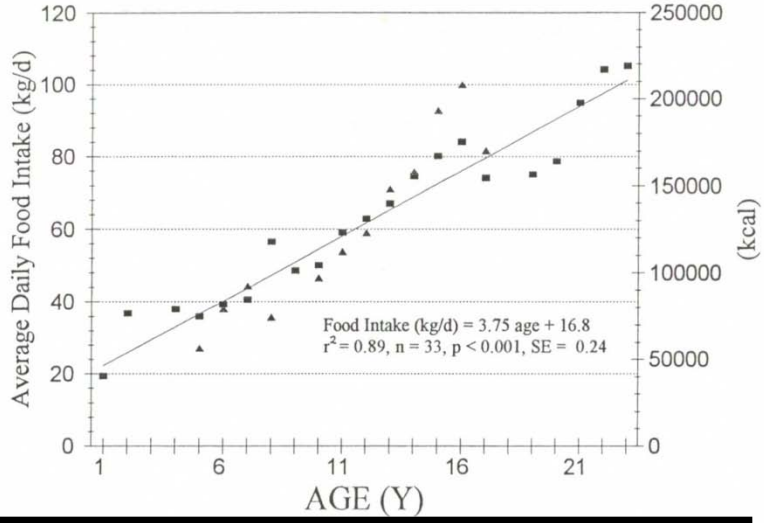
Females (3-25 years old)



594 - 2800 kg (Icelandic, Kriete 1995); 949 - 3338 kg (SRKW, Noren 2011)

△ BJOSSA ○ SKANA ■ VIGGA ▼ YAKA

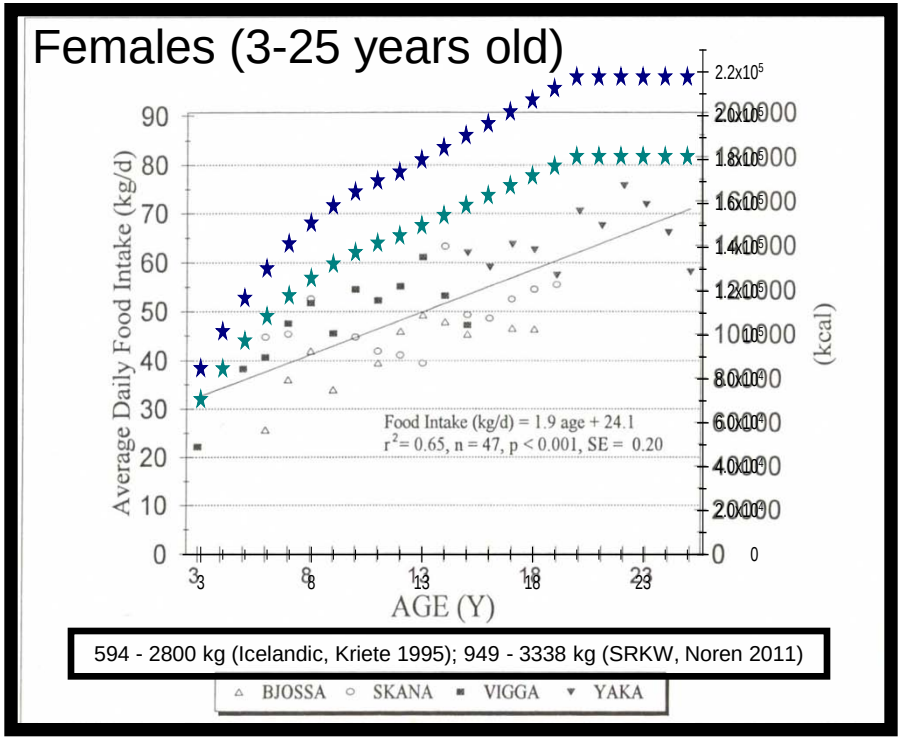
Males (1-23 years old)

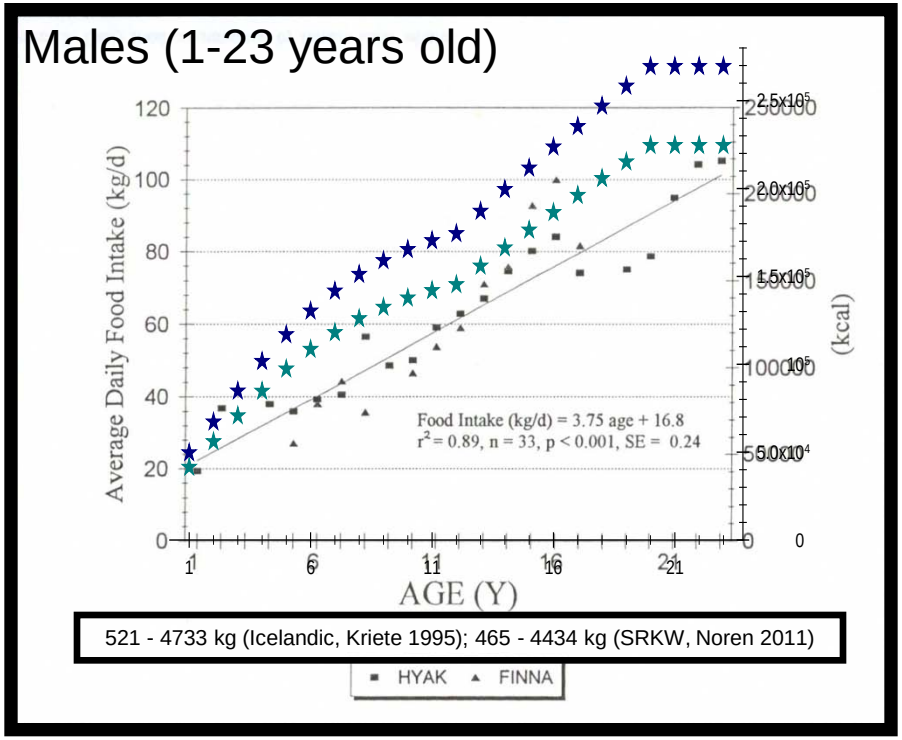


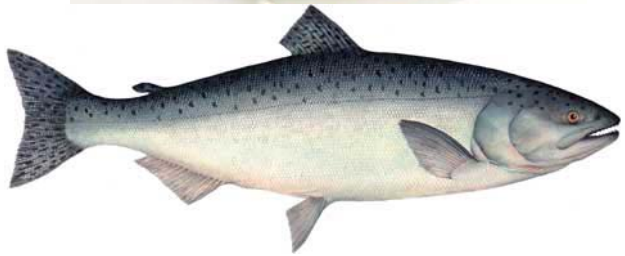
521 - 4733 kg (Icelandic, Kriete 1995); 465 - 4434 kg (SRKW, Noren 2011)

■ HYAK ▲ FINNA

Prey Consumption in Captive Killer Whales



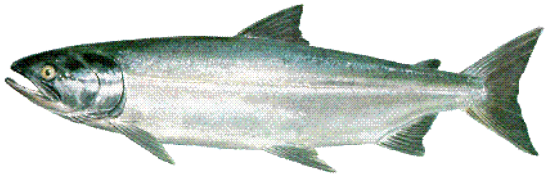




Chinook (16,386 kcal/fish)

3338 kg Adult F: 11.1-13.3 fish/day

4434 kg Adult M: 13.7-16.4 fish/day

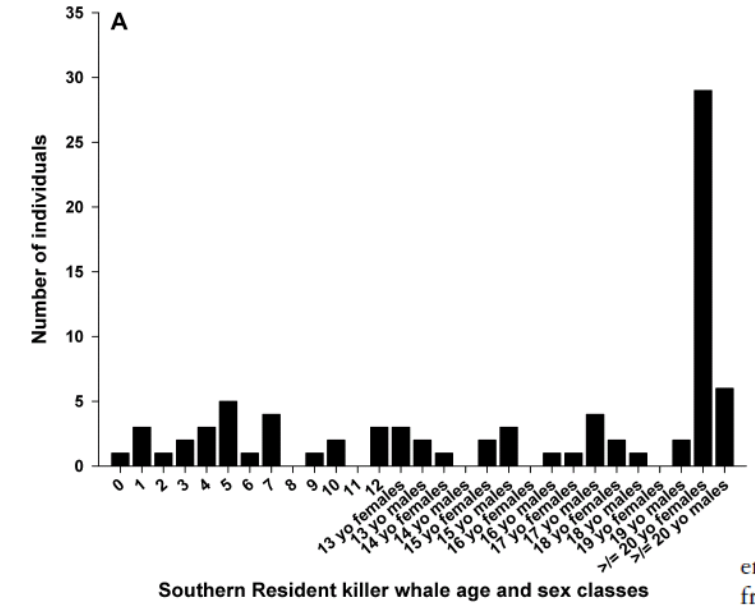


Chum (3,877 kcal/fish)

3338 kg Adult F: 46.8-56.2 fish/day

4434 kg Adult M: 57.9-69.5 fish/day

November 2008 SRKW population (n=83) DPERs



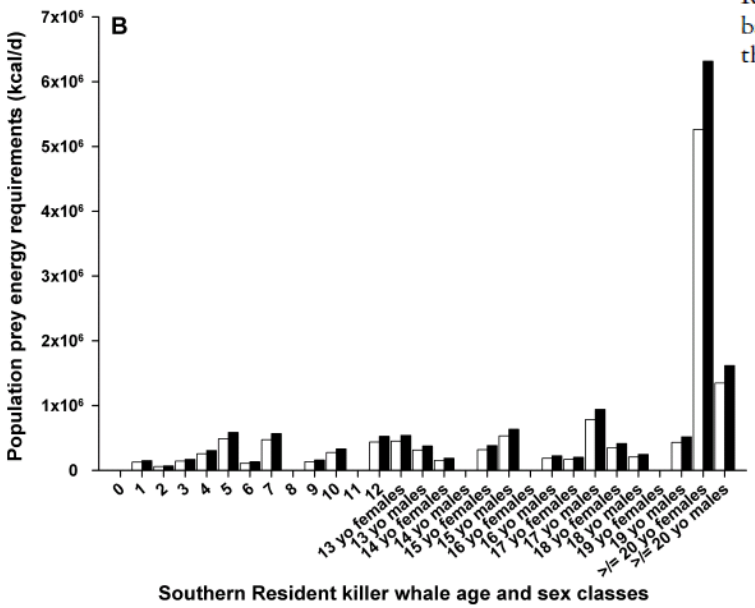
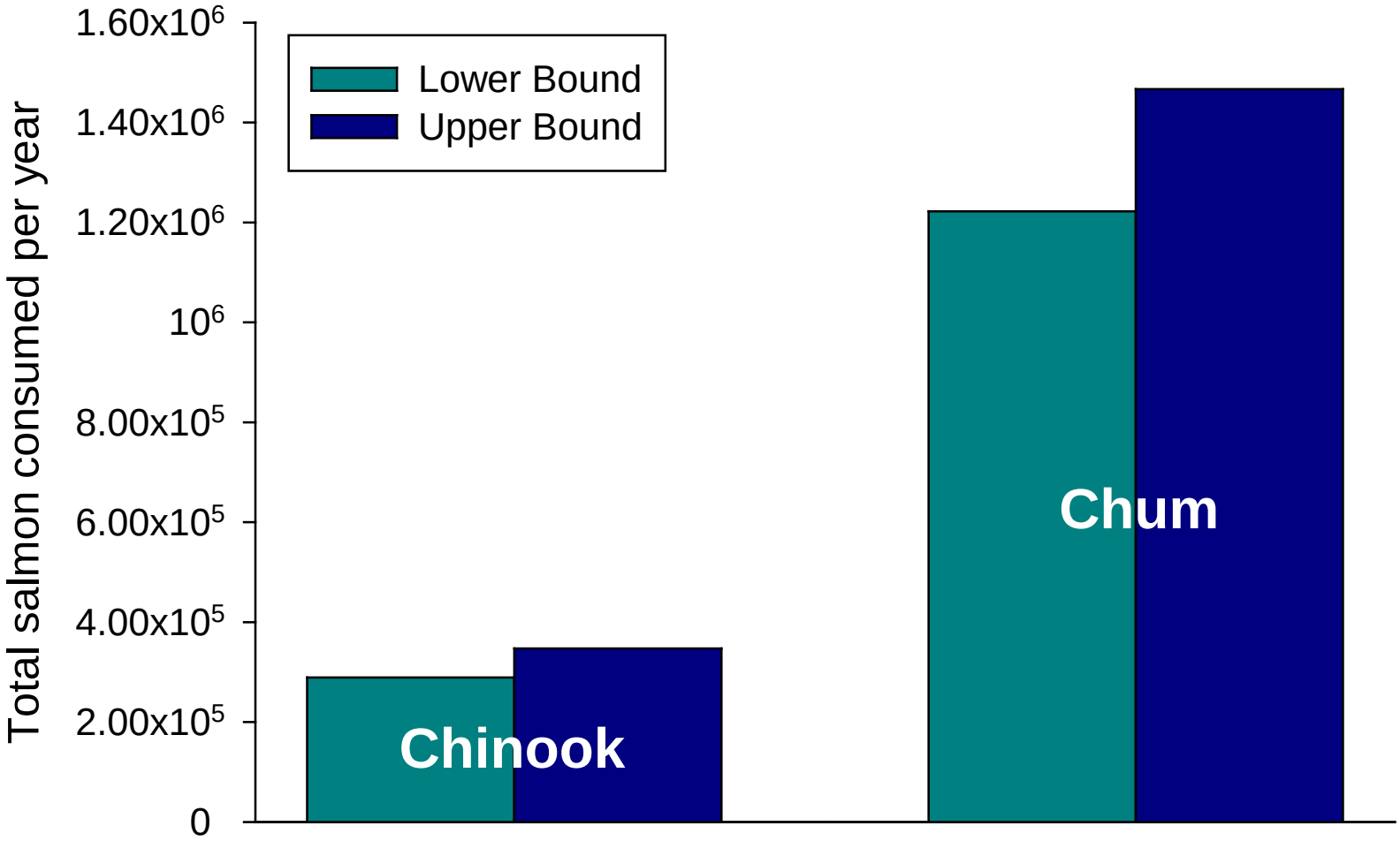


Figure 3. Number of individuals within each age and sex class (a) and total daily prey energy requirements (DPERs) for all killer whales combined within each age and sex class (b) from the Southern Resident killer whale population in November 2008 (Center for Whale Research, http://www.whaleresearch.com). Lower bound (white bars) and upper bound (black bars) estimated DPERs are presented. It is assumed that calves <1 yr of age receive all of their daily energy requirements through their mothers' milk, not *via* ingestion of fish.

November 2008 SRKW population (n=83) Annual Fish Consumption



Conclusions

- **Necessary to estimate DPERs and food consumption rates at the level of individual whales in the population**
- **Energetic costs of growth in immature whales and lactation in females could increase DPERs**
  - Should use upper bound DPERs, which are 1.2X greater than lower bound DPERs, for all individuals
- **Food consumption rates should be estimated for specific species, runs, and age-classes of fish consumed**
  - all fish are not created equal (O'Neill)
- **Number of prey items available must be greater than the estimated total number of prey consumed to account for foraging area and search effort**

Next Steps

- **Update age/body mass curves as additional data on whale body lengths become available to ensure that relevant body sizes for individual SRKWs are used in future bioenergetic models (Fearnbach *et al.* 2011, Bigg and Wolman 1975)**
  - **10% increase in body mass results in 7% increase in individual FMR and DPER values (Noren 2011)**

- **Update DPERs for growing immature animals and lactating females as additional data on the energetic costs of these activities become available**

- **Construct bioenergetic models to estimate consumption rates of specific salmon runs consumed**

GUARANTEED
WHALE WATCHING TOURS