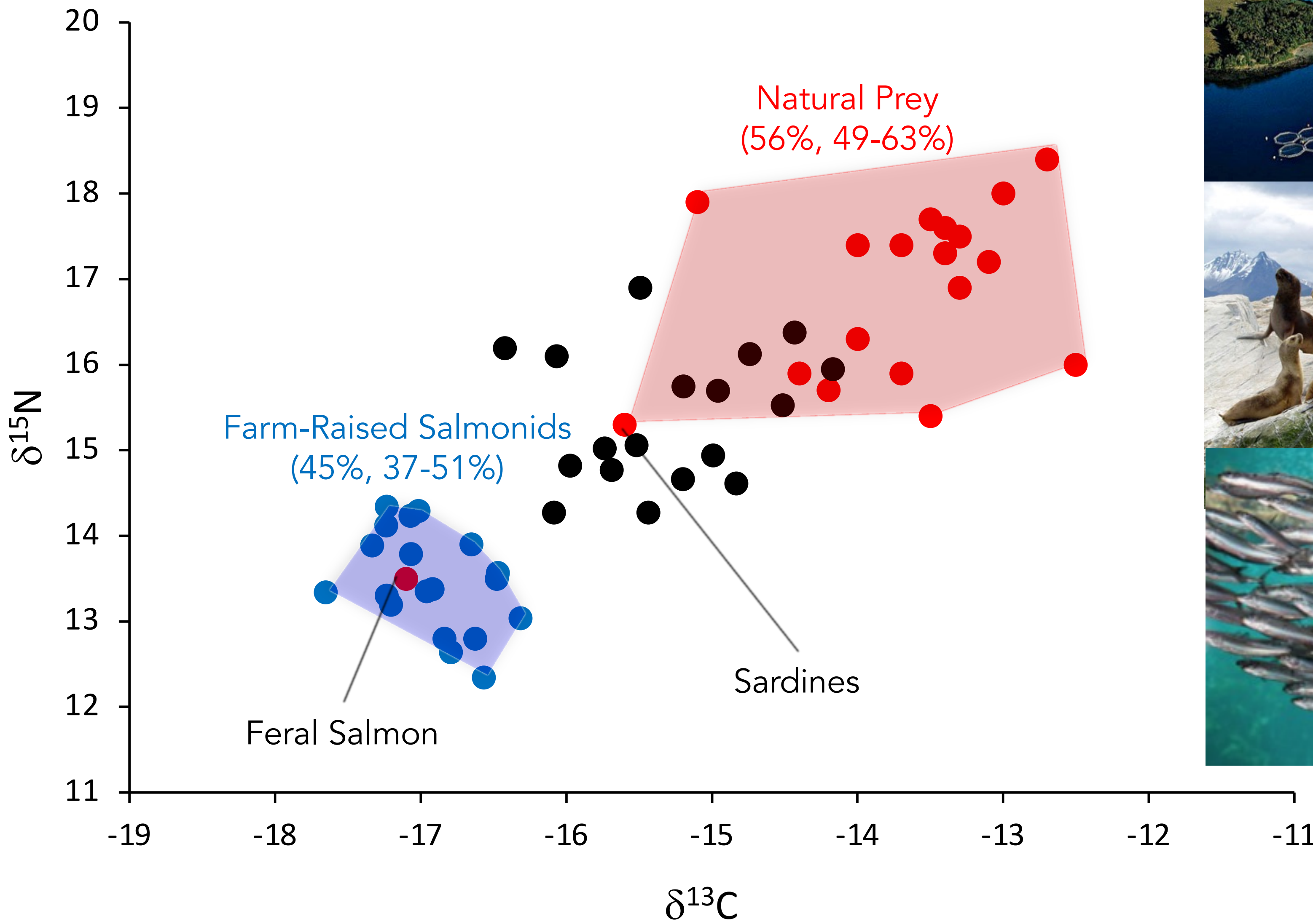
# Do South American Sea Lions Eat Farmed Salmon?




# Outline

"Mixing Models: Often Used, Rarely Understood"

>1000 publications have used mixing models in the past decade.

Linear Mass Balance Mixing Models

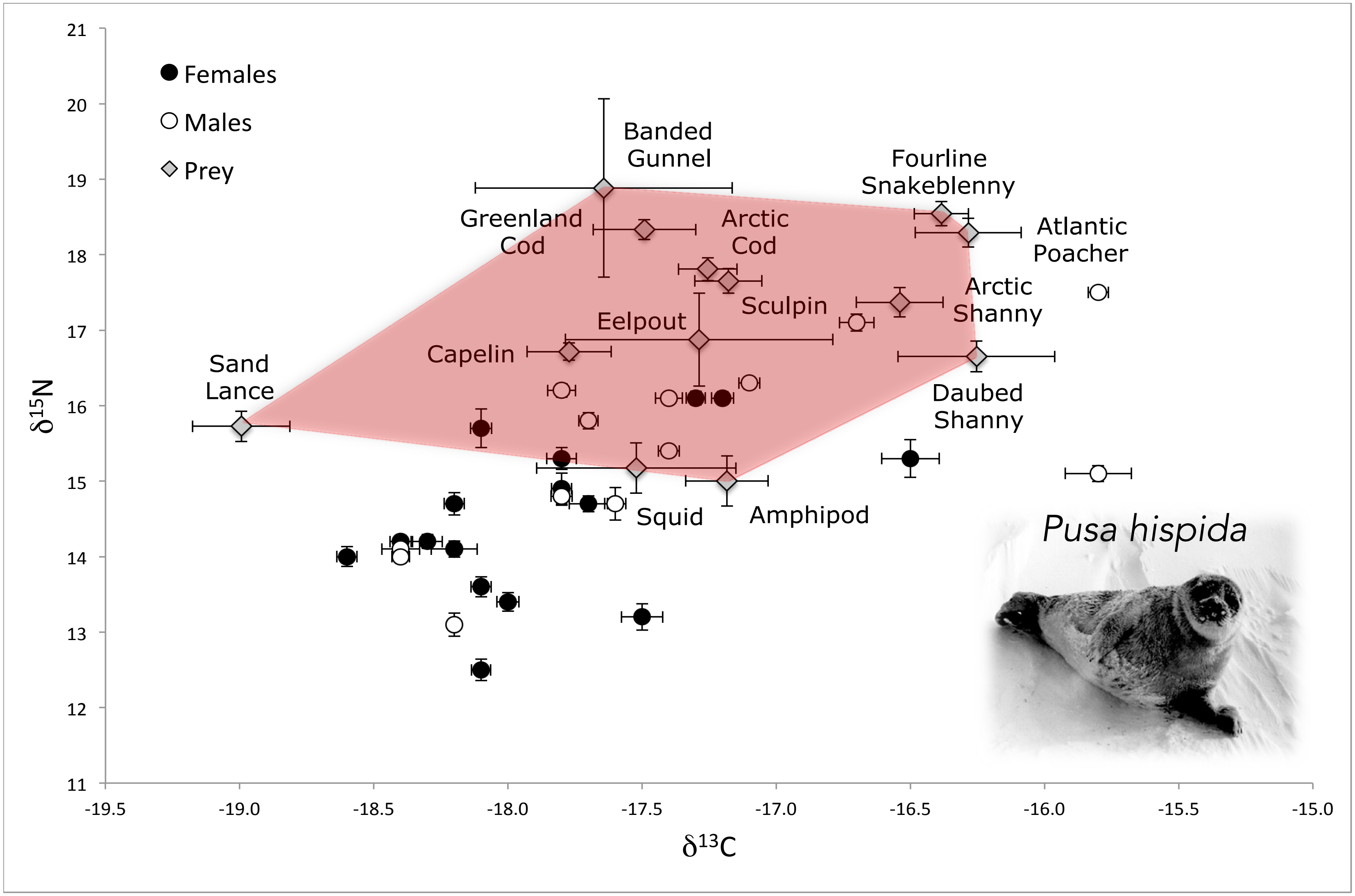
Concentration-Dependent Mixing Models

The Assumption of Isotopic Routing

# Mixing Model Assumptions

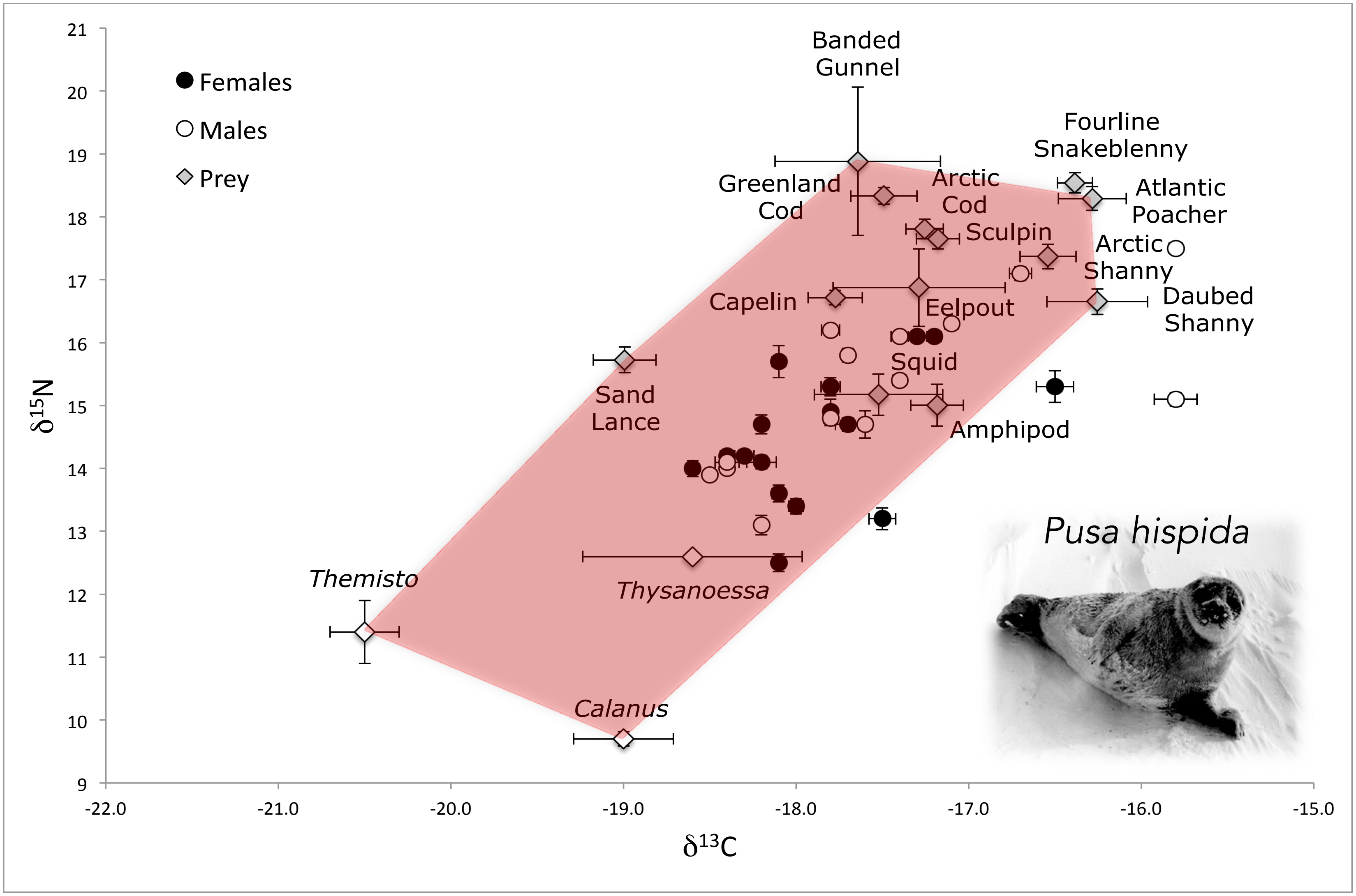
(1) You know and have measured all potential (prey) sources.

# Ringed Seals (Hudson Bay, Canada)




*seal values have been corrected for trophic discrimination

# Missing Prey: Copepods and Amphipods




*seal values have been corrected for trophic discrimination

# Mixing Model Assumptions

(1) You know and have measured all potential (prey) sources.

(2) Trophic discrimination factors are known.

# 2 Source, 1 Isotope Mass Balance Mixing Model

# Trophic Discrimination Factors?

$$\delta^{13}C_{consumer} = p_X(\delta^{13}C_X + \Delta^{13}C_X) + p_Y(\delta^{13}C_Y + \Delta^{13}C_Y)$$
$$1 = p_X + p_Y$$

$C_3$ Tree ($\delta^{13}C_X$)

$\delta^{13}C_{Consumer}$

$C_4$ Grass ($\delta^{13}C_Y$)

Trophic Discrimination Factors

$\Delta^{13}C_{tissue}$ = ???

# Mixing Model Assumptions

(1) You know and have measured all potential sources

(2) Trophic discrimination factors are known (and do not vary)

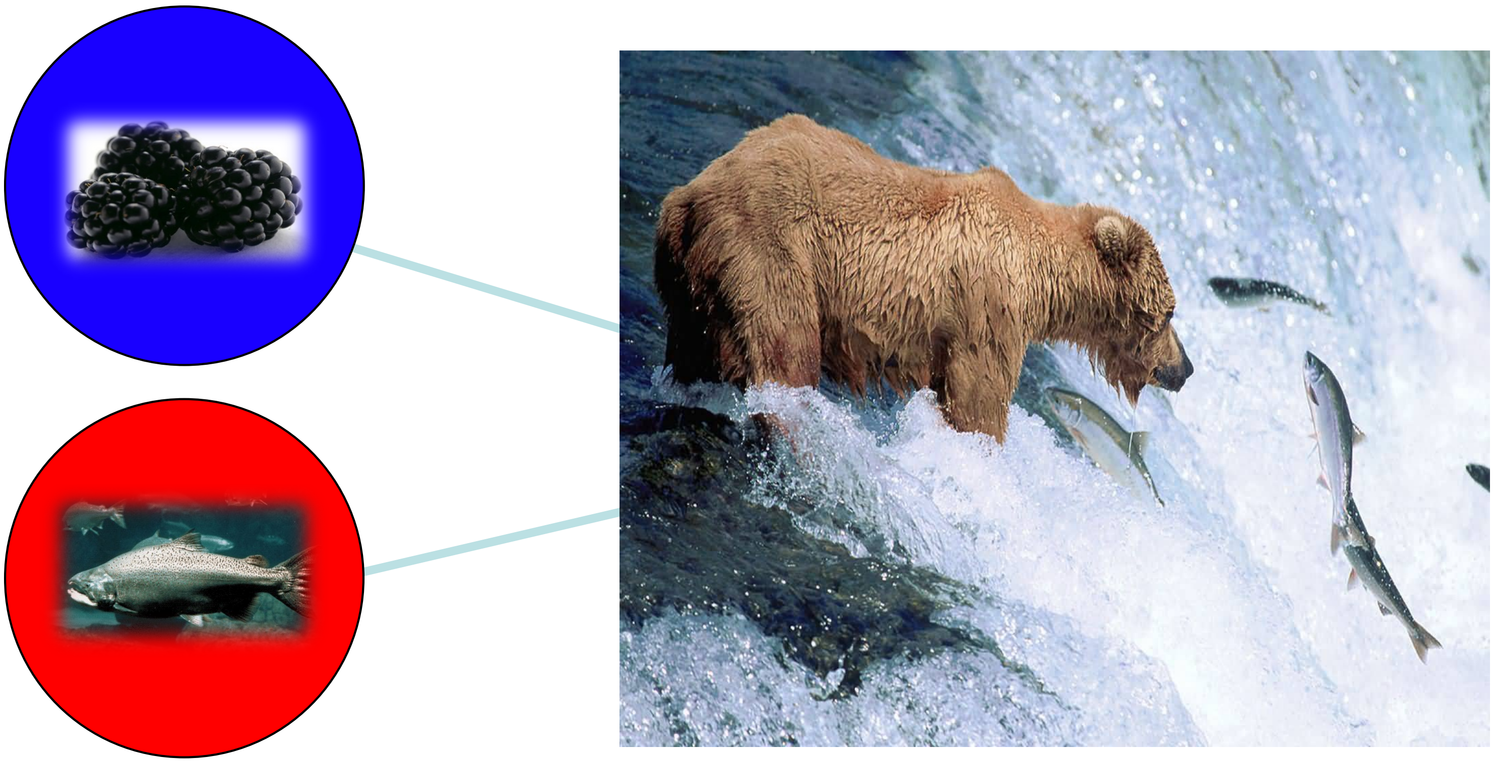
(3) Equal concentration of elements in dietary sources

OMNIVORES

(4) Equal assimilation of dietary sources

# The Omnivore's Dilemma:
# Unequal Concentration of Elements in Diet

CARBON
Berries
(carbohydrates)



Salmon
(protein & lipid)
CARBON + NITROGEN

Grizzly Bear Protein?
(muscle/hair/blood)

# Concentration-Dependent Mixing Models

Incorporating concentration dependence in stable isotope mixing models
(Phillips and Koch 2002)
(http://www.epa.gov/wed/pages/models/stableIsotopes/isotopes.htm)

## Concentration-Dependent Mixing Model:

$$\delta^{15}N_{consumer} = ('[N_X])(\delta^{15}N_X + \Delta^{15}N_X) + ('[N_Y])(\delta^{15}N_Y + \Delta^{15}N_Y)$$

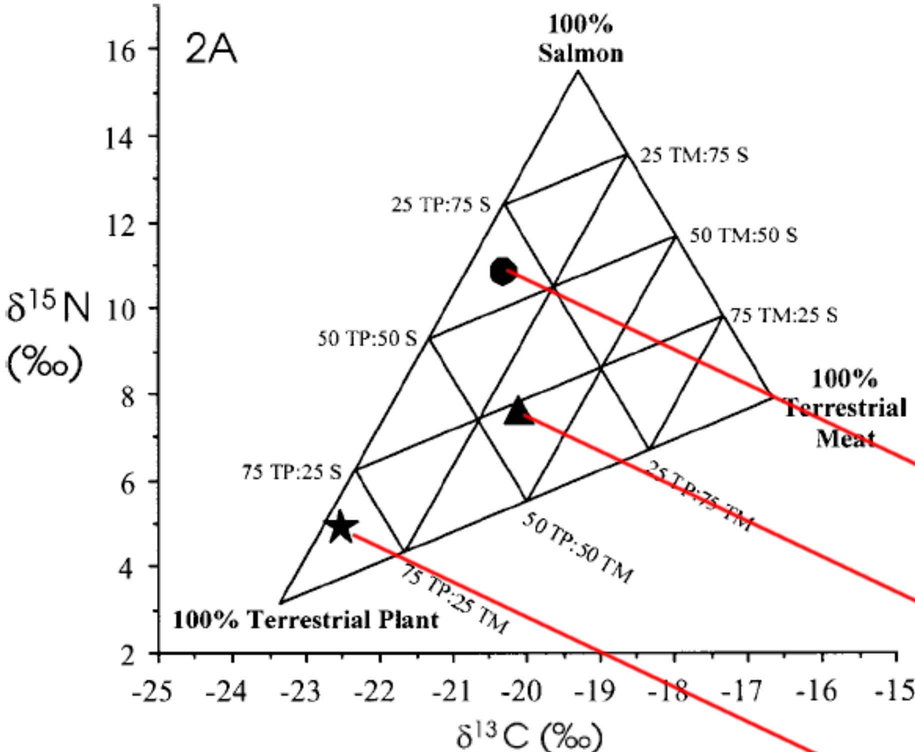
$$'[N_X] = (p_X)[N_X] / ((p_X)[N_X] + (p_Y)[N_Y])$$

$$'[N_Y] = (p_Y)[N_Y] / ((p_X)[N_X] + (p_Y)[N_Y])$$

$$p_X + p_Y = 1$$

The model assumes that for each element, the contribution of a food source to a consumer is proportional to the assimilated biomass times the proportional element concentration in that source.

# Normal versus Twisted Triangles

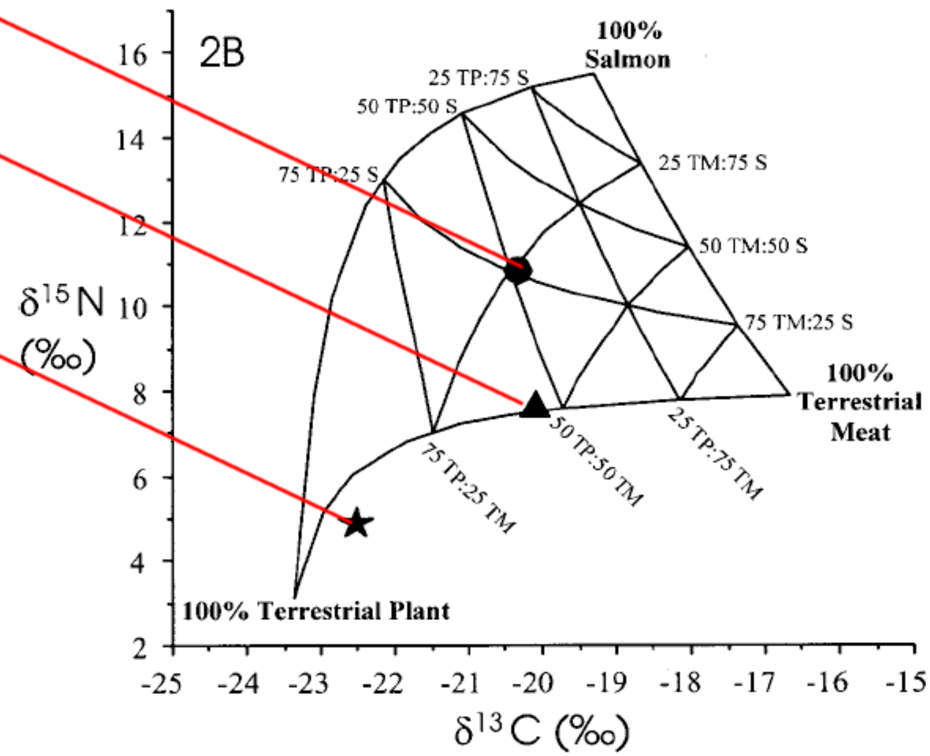



## Linear Mixing Model

Brown Bear (Sympatric): 59%S, 31%TP, 10%TM
Black Bear (Sympatric): 12%S, 83%TP, 5%TM
Black Bear (Allopatric): 23%S, 43%TP, 34%TM

## Concentration Dependent Model

Brown Bear (Sympatric): 26%S, 48%TP, 26%TM
Black Bear (Sympatric): 0%S, 92%TP, 8%TM
Black Bear (Allopatric): 1%S, 56%TP, 43%TM



# Mixing Model Assumptions

(1) You know and have measured all of your sources

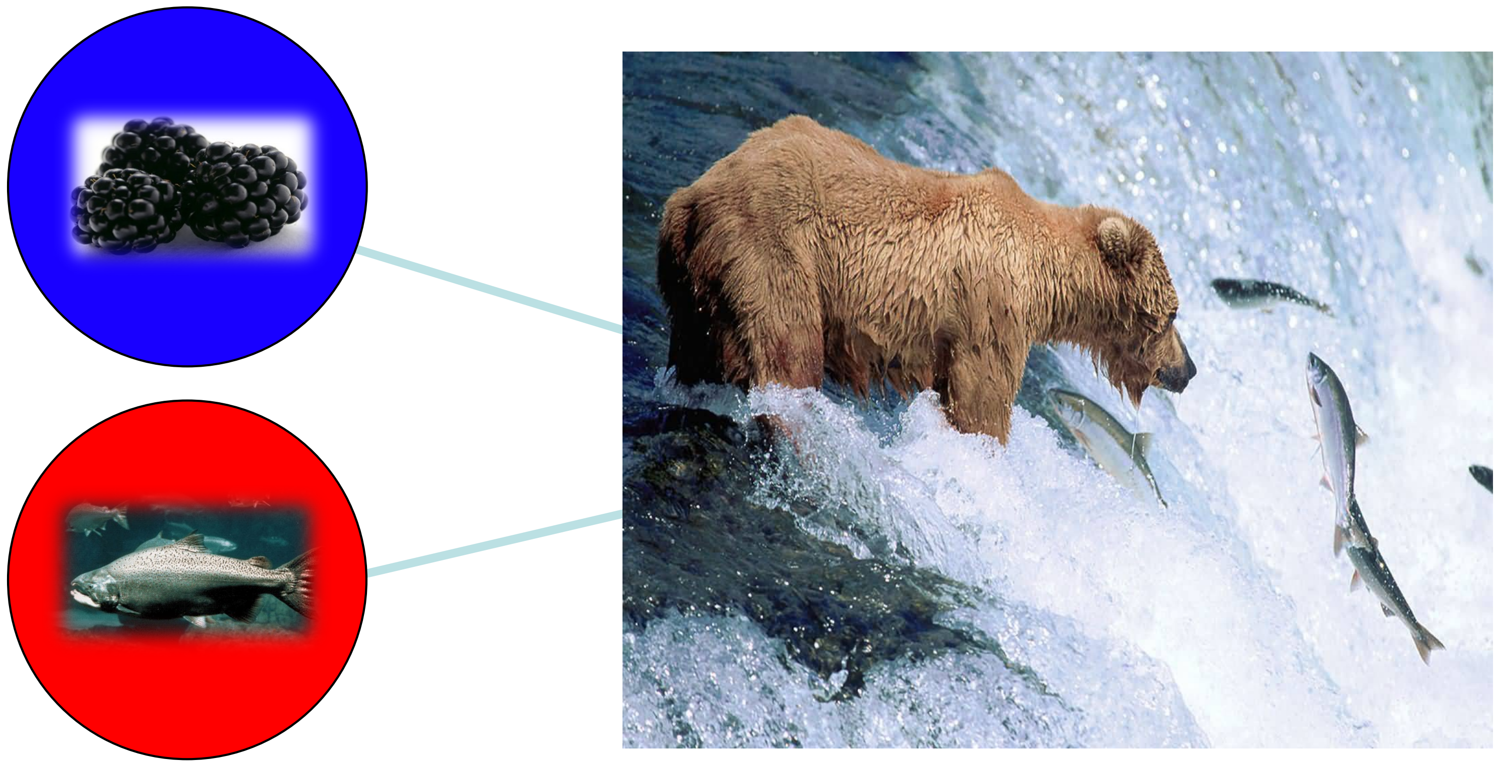
(2) Trophic discrimination factors are known (and do not vary)

(3) Equal concentration of elements in dietary sources

(4) Equal assimilation of dietary sources

# The Omnivore's Dilemma: Isotopic Routing

Berries
(carbohydrates)



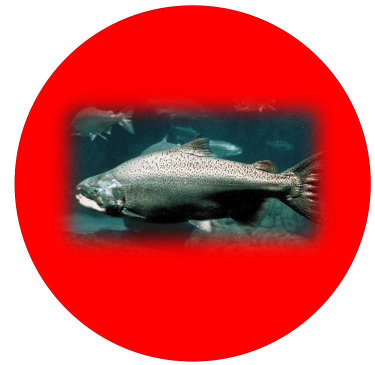
Salmon
(protein)

Grizzly Bear Tissues (Protein)
(muscle/hair/blood)

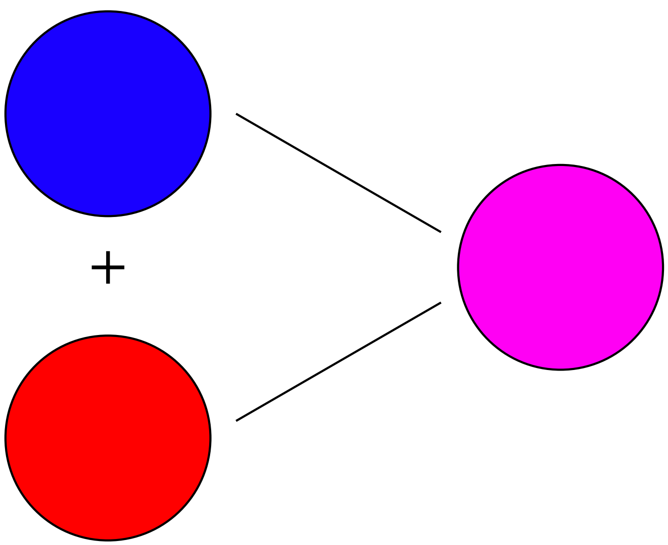
# Perfect Mixing versus Perfect Routing

Berries
(carbohydrates)

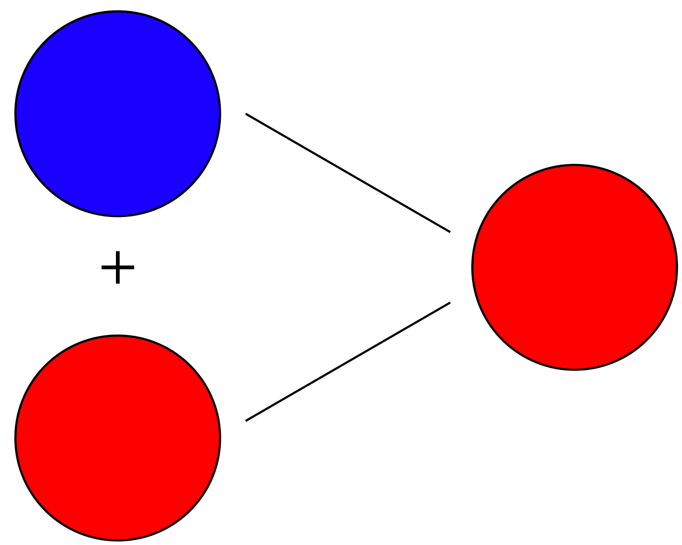
Salmon
(protein & lipid)



Scenario #1: Perfect Mixing




Scenario #2: Perfect Routing



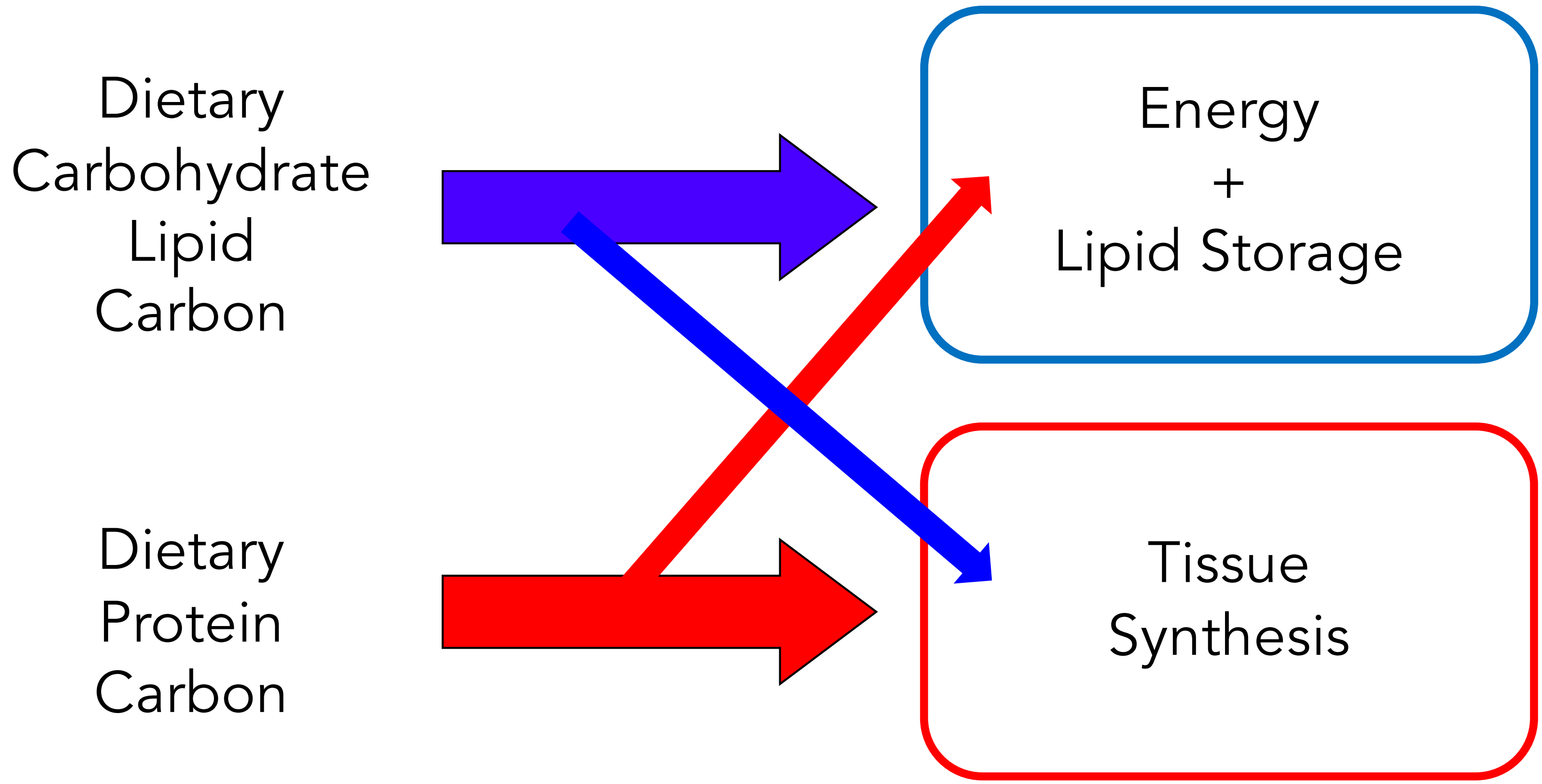

Mixing Models Assume Perfect Mixing

$\delta^{13}C_{tissues} = (p)\delta^{13}C_{salmon} + (1\text{-}p)\delta^{13}C_{berries}$

Sample Preparation Protocols
(i.e., lipid-extraction)
Assume Perfect Routing of Protein

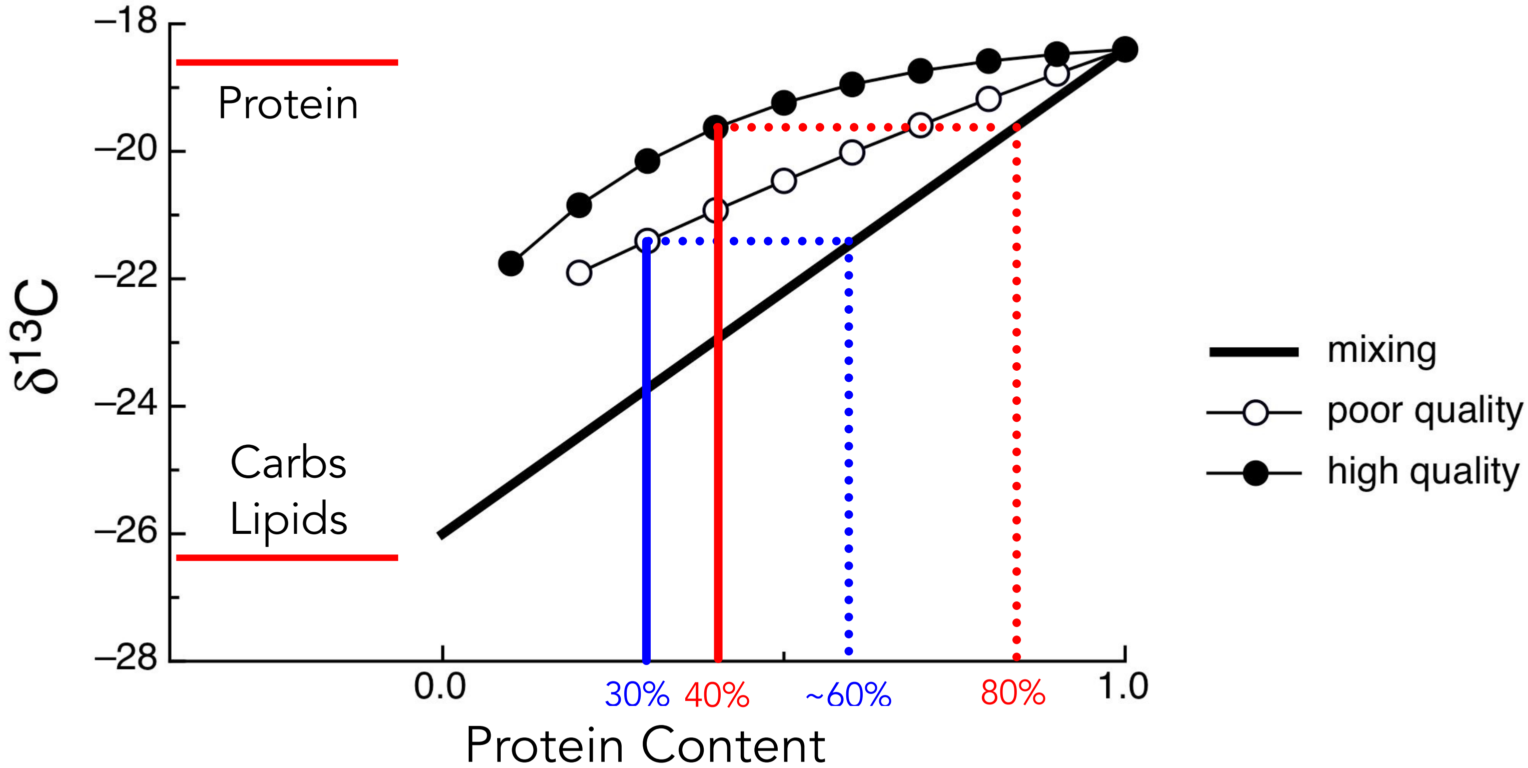
# Why Expect Routing?

Classic (Textbook) Animal Ecophysiology:




Remember, the size of arrows depends on relative intake…

# Isotopic Routing versus Mixing Model Output




When routing occurs, mixing models ***overestimate*** proportion of dietary protein in diet, and the degree of overestimation depends on protein quality.

# Real Data

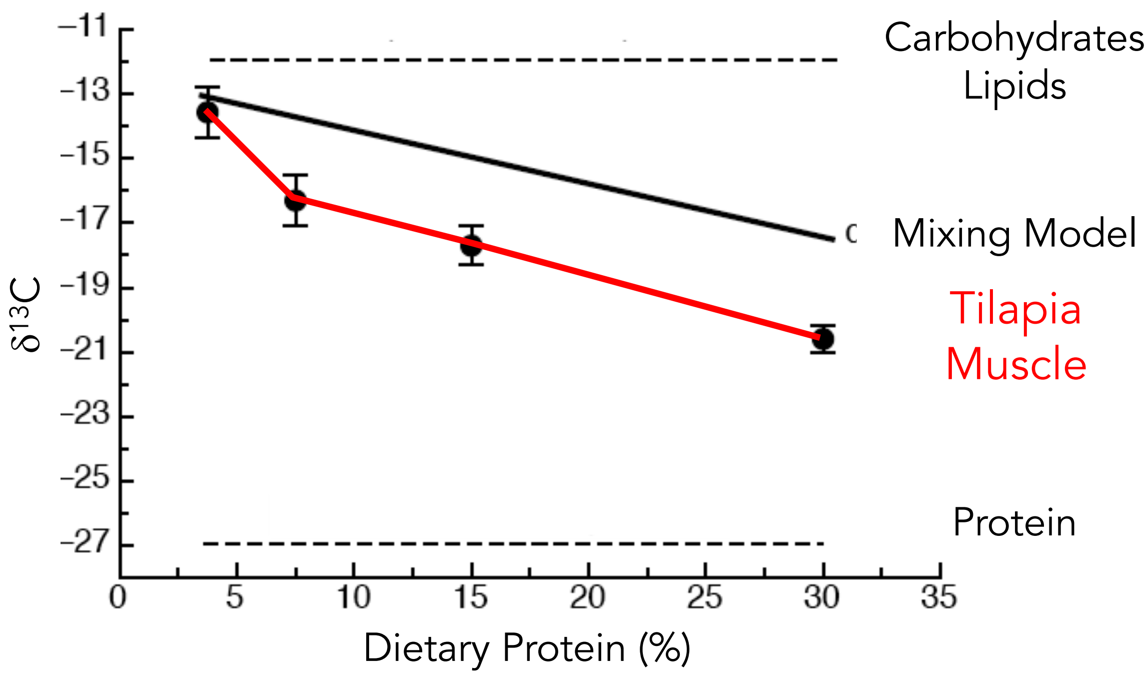
Nile tilapia fingerlings grown on a synthetic diet
$C_3$ protein (casein, $\delta^{13}C$ = -27‰)
$C_4$ carbohydrate & lipid ($\delta^{13}C$ = -12‰)

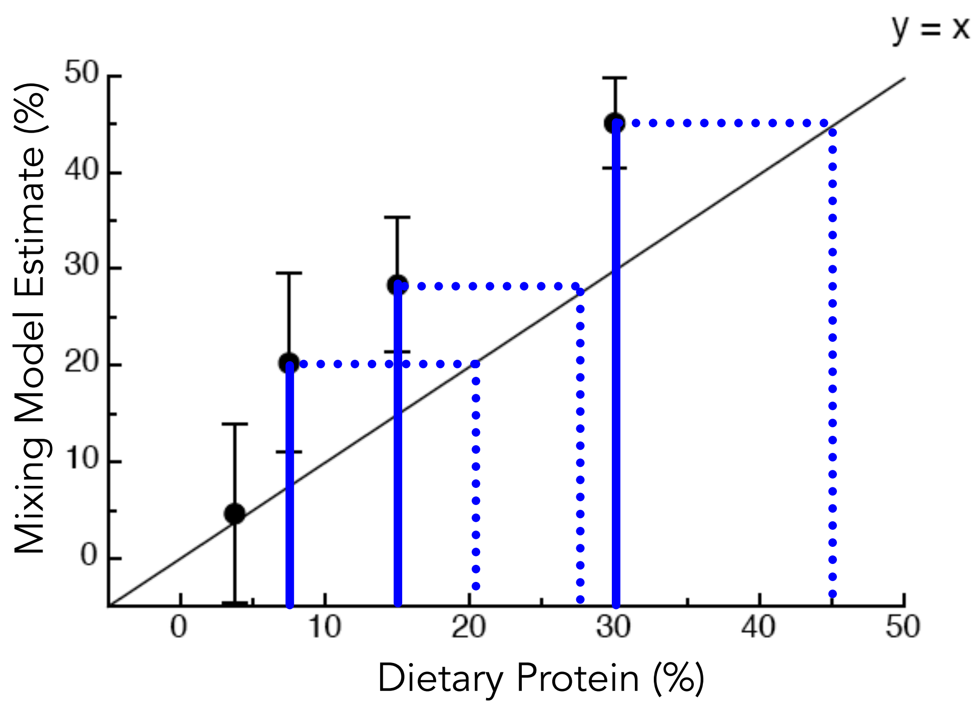
Triple Weight to Insure Isotopic Incorporation!

4 Protein Levels (3.75%, 7.5%, 15%, 30%)
5 individual fish per treatment

Kelly and Martinez del Rio 2010

# Results




ROUTING!
(muscle)

Mixing models overestimate contribution of dietary protein to overall diet by ~10–15%.

Kelly and Martinez del Rio 2010