# What's at Risk from Bioaccumulative and Persistent Substances ?

- Substances categorized as PBT or vP vB should be examined in risk assessment using predatory wildlife (and humans) as the ultimate target receptor
  - i.e., the T should relate to effects in mammals/avians/humans

# Canadian Focal Species for Wildlife ERA

- For aquatic habitats, the default focal species are mink and/or, river otter and/or, heron and/or kingfisher because:
  - Consumers of aquatic life (30% to 100% fish in diet)
  - Good life history data (diet, metabolic rates, range, etc.)
  - Well distributed throughout Canada in both freshwater and marine/estuarine habitats
  - Relatively high metabolic needs
  - Exposed to contaminants in food and drinking water
- For sediments, sediment-probing birds can be used (e.g., sandpiper)
- For soils, fox, bald eagle and shrew/mouse can be used
- Other focal species can be used if they have the above characteristics

# Candidate Substances for Wildlife ERA

- Have moderate to high repeated oral dose toxicity (mg/kg bw/day)
- Have sufficient residence time in the environment for longer-term exposures (but not as defined using the P criterion)
- Are bioaccumulative, but not necessarily highly bioaccumulative (as defined by the B criterion)
- Are released or could be released to local environments in relatively high quantities

$$= P + B + T_{mammalian} + R$$

or roughly “PCB-like”

- Inherent mammalian or avian toxicity can drive the risk

# Wildlife Exposure Model: Bioenergetic Approach

$$TDI = \left[ FMR \left( \frac{C_i \cdot P_i}{GE_i \cdot AE_i} \right) + (C_s \cdot IR_s) + (C_w \cdot IR_w) \right] \cdot Pt$$

$C_i$ = BAF x $C_w$ when no tissue residue data

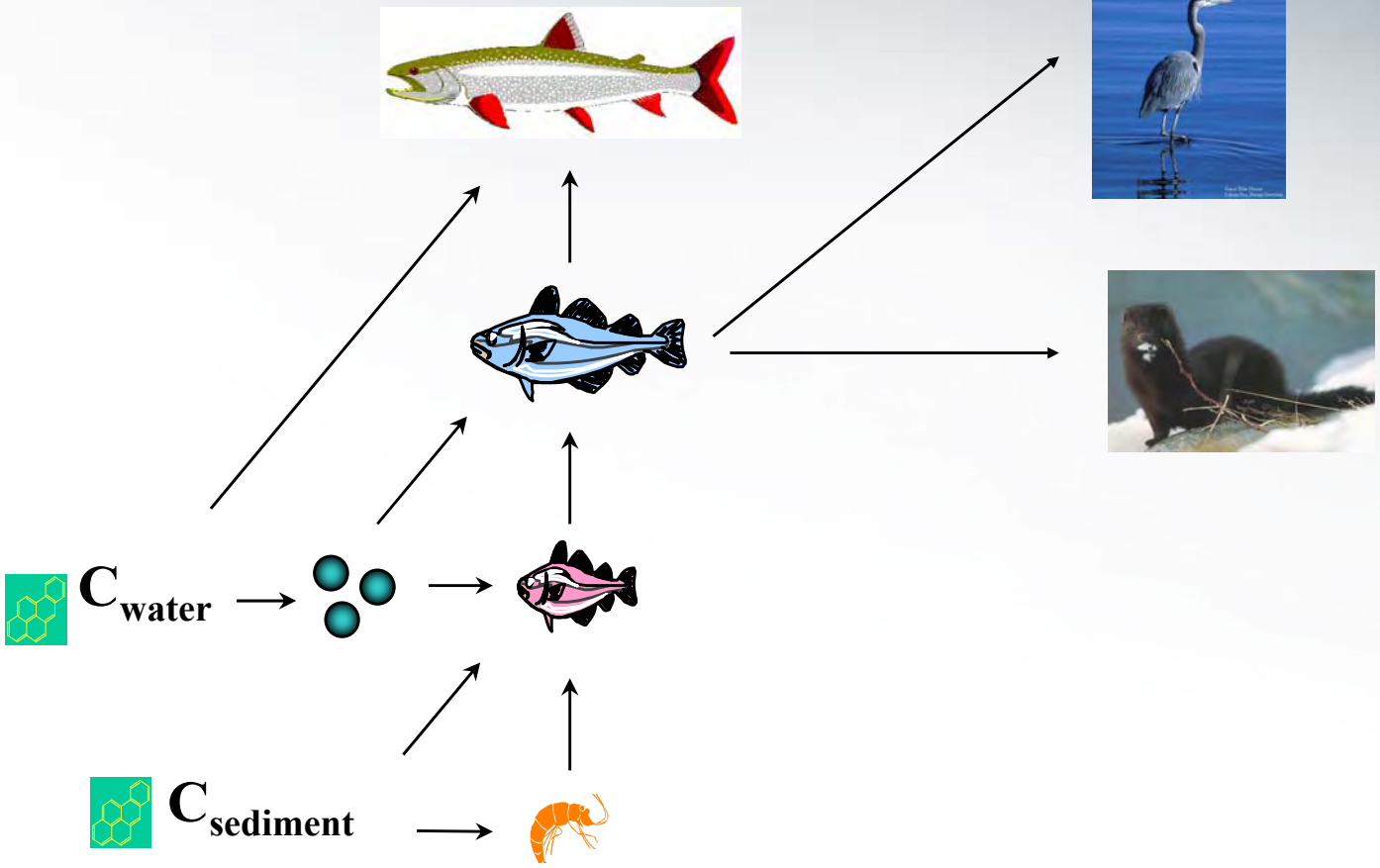
where:

*TDI* = total daily intake (mg/kg bw/day)
*FMR* = free metabolic rate of wildlife receptor of interest (kcal/kg bw/day)
$C_i$ = concentration of contaminant in the *i*th prey species (mg/kg)
$P_i$ = proportion of the *i*th prey species in the diet (unitless)
$GE_i$ = gross energy of the *i*th prey species (kcal/kg)
$AE_i$ = assimilation efficiency of the *i*th prey species by the wildlife receptor (unitless)
$C_s$ = concentration of contaminant in the sediments (mg/kg dw)
$IR_s$ = intake rate of sediments (kg/kg bw/day dw)
$C_w$ = concentration of contaminant in the water (mg/L)
$IR_w$ = intake rate of water (L/kg bw day)
*Pt* = proportion of the time the receptor spends in the contaminated area (unitless).

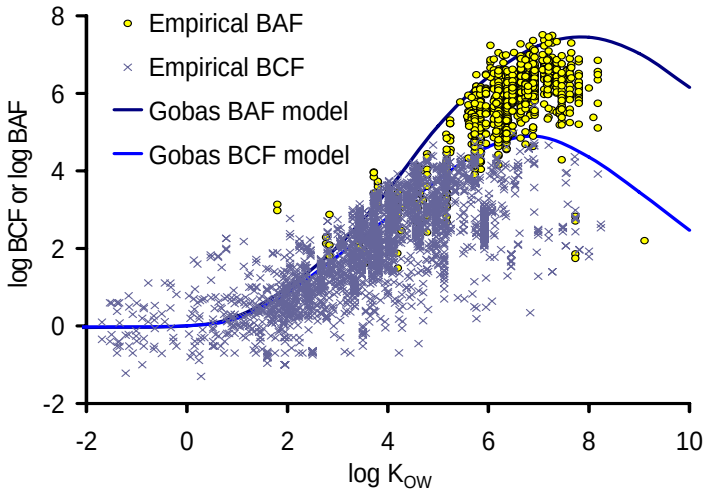
# BAF as Food Web Surrogate

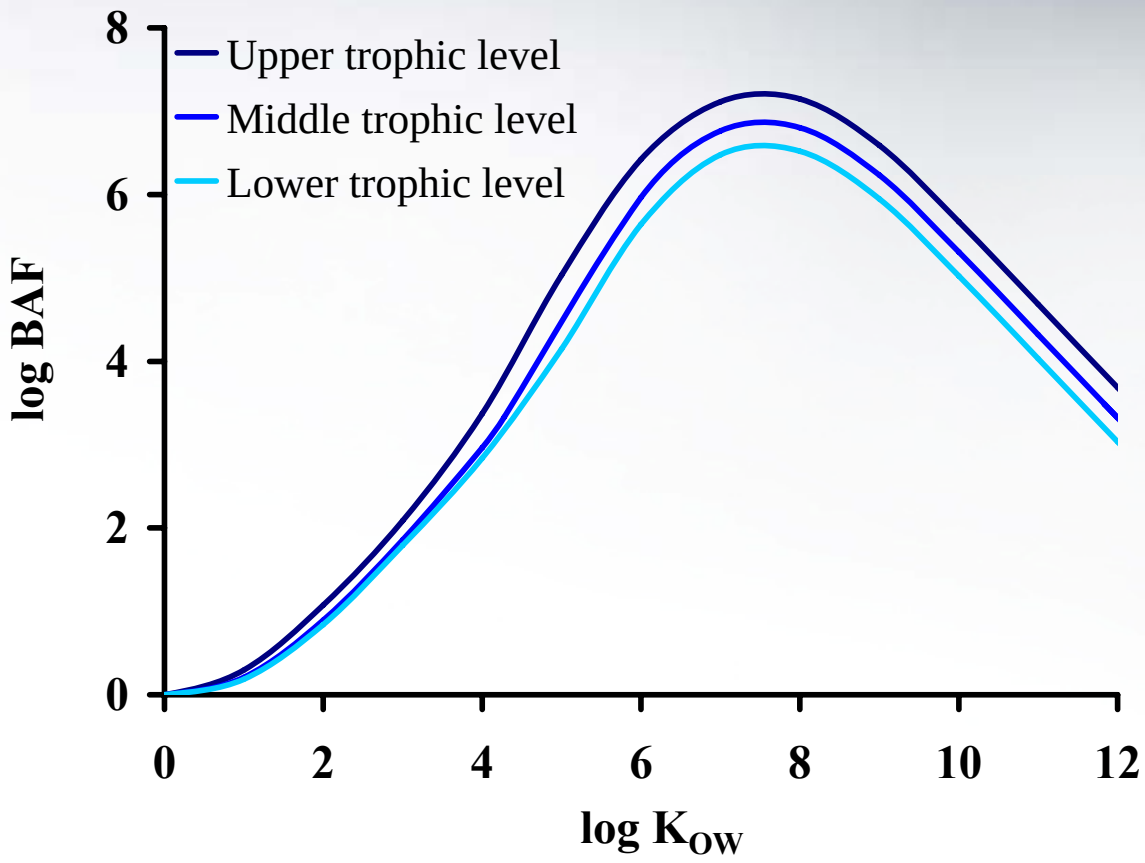
- BAF estimated using the Modified Gobas Model
- BAF can be estimated to account for uptake and accumulation in an upper, mid and lower trophic level fish (various sizes and lipid contents)
- Lower to mid-trophic level/lipid content (5-6%) typically fish eaten by mink and otter
- BAF considered “reasonable substitute” for a food web model (Arnot and Gobas 2003)

# BAF is Representative of Benthic/Pelagic Food Chain



# Generic BAF Model – 3 Trophic Level (Arnot and Gobas 2005)

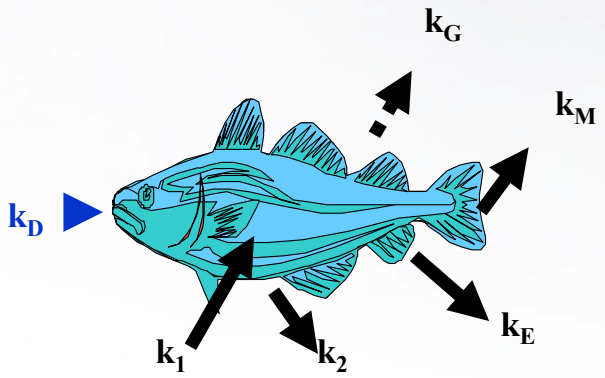


# Generic Three Tropic Level BAF Model (Arnot and Gobas 2005)

$$BAF = (1 - L_B) + ((k_1 \bullet \varphi + (k_D \bullet \beta \bullet \tau \bullet \varphi \bullet L_D \bullet 1/\delta_L \bullet K_{OW})) / (k_2 + k_E + k_G + k_M))$$

$L_B$ = lipid content of organism
$k_1$ = gill uptake rate constant
$\Phi$ = freely dissolved fraction
$k_D$ = dietary uptake rate constant
$\beta$ = overall foodweb biomagnification factor
$\tau$ = trophic dilution factor
$L_D$ = lipid content of primary producer
$\delta_L$ = lipid density
$K_{OW}$ = octanol-water partition coefficient
$k_2$ = gill elimination rate constant
$k_e$ = egestion rate
$k_g$ = growth rate constant
$K_m$ = rate of biotransformation




Generic BAF Model Arnot and Gobas 2005

# Generic Wildlife Exposure Model: Bioenergetic Approach (Bonnell 2005)

$$TDI = \left[ FMR \left( \frac{C_i \cdot P_i}{GE_i \cdot AE_i} \right) + (C_s \cdot IR_s) + (C_w \cdot IR_w) \right] \cdot Pt$$

where:

*TDI* = total daily intake (mg/kg bw/day)
*FMR* = free metabolic rate of wildlife receptor of interest (kcal/kg bw/day)
$C_i$ = concentration of contaminant in the *i*th prey species (mg/kg)
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$C_w$ = concentration of contaminant in the water (mg/L)
$IR_w$ = intake rate of water (L/kg bw day)
*Pt* = proportion of the time the receptor spends in the contaminated area (unitless).

# Experience from Risk Assessment

# Experience: General

- Need to assess current and/or avoid production of substances that have the potential to be found in top predators
- Little to no field information on bioaccumulation/biomagnification of most substances in commercial use (~0.2%)
- Arnot-Gobas BAF approach suitable for screening assessment (will we ever biomonitor !)
- BAF (and BMF) is the correct parameter for understanding the potential risks posed by “PBT-like” or vP vB substances
- Serious lack of wildlife toxicity data (or laboratory data for mammals – less for avians
- Wildlife exposure model can be quite conservative if biotransformation data included and no adjustment of exposure parameters to reflect average conditions

# Experience: Biotransformation in Fish ?

- Measured as $K_m$ (metabolic transformation rate constant) as 1/day
- Very important parameter for correcting BCF/BAF estimates
- Very little data (esters, phenols, neutral organics, vinyl/allyl halides), but should be used when available
- Default in Gobas 2003 model is zero biotransformation
- Gobas and Arnot 2003 have examined using biodegradation results as surrogate for $K_m$
- Mekenyan Baseline B Model (mammalian extrapolation to fish)

# Including Biotransformation to Estimate BAF

**A Summary Of The Available Apparent Metabolic Transformation Rate Data (Km*) For Different Chemical Classes (Gobas And Arnot 2003).**

| Chemical Class | n | Minimum $k_M$* | Maximum $k_M$* | Mean * | S.D. $k_M$* |
|---|---|---|---|---|---|
| Benzyl Halides | 1 | 4.5E-01 | 4.5E-01 | 4.5E-01 | N/A |
| Esters | 5 | 5.3E-03 | 7.7E-01 | 3.0E-01 | 3.7E-01 |
| Esters+Esters (phosphate) | 125 | 1.5E-04 | 2.0E+02 | 1.3E+01 | 2.8E+01 |
| Neutral Organics | 95 | 7.0E-03 | 2.7E+02 | 1.6E+01 | 3.5E+01 |
| Phenols | 42 | 1.5E-03 | 1.6E+01 | 1.8E+00 | 3.0E+00 |
| Phenols (dinitro) | 5 | 2.9E+00 | 9.1E+01 | 2.9E+01 | 3.9E+01 |
| Triazines | 1 | 2.1E+01 | 2.1E+01 | 2.1E+01 | N/A |
| Vinyl/Allyl Ethers | 1 | 8.7E+00 | 8.7E+00 | 8.7E+00 | N/A |
| Vinyl/Allyl Halides | 5 | 2.7E+00 | 6.7E+01 | 3.0E+01 | 3.0E+01 |

# Further Work on Biotransformation Rates

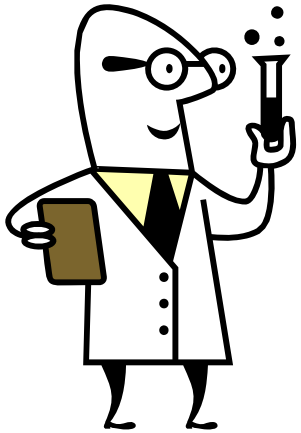
- Arnot (2005, 2006) investigated the relationship empirical biodegradation rates and "apparent" metabolic rates in fish and between predicted biodegradation and "apparent" metabolic rates in fish
- Results are preliminary at this point, but it appears possible to define a baseline "de minimus" metabolic rate for substances that are susceptible to biodegradation
- The de minimus baseline can be moved upwards to more favorable biotransformation rates on a case by case basis

# Experience: Incorporating ADME Information

- Including biotransformation rate information in models can move an estimated BCF and BAF several orders of magnitude lower depending on the rate constant
  - Can mean the difference of finding a risk with a substance based on wildlife exposure or not
- Need to understand how ADME information can be incorporated into regulatory assessment schemes
  - Stand alone estimation of bioaccumulation
  - Models
- Need to understand what information can be obtained from in vitro assays (e.g., absorption rates, distribution, biotransformation rates)
- Need to understand which *in vitro* techniques can supply needed ADME information
- Need to understand the degree of extrapolation involved in going from *in vitro* to *in vivo* system
  - Inter and intra species variability
  - Bins of rate information for ADME

# How Environment Canada is Helping to Resolve ‘B’ Issues: 1

- Accepted data submissions from industry for initial categorization of B
  - Modeled estimates of B were revised based on evidence of ADME processes
  - ICG Aliphatic Working Group submission for aliphatic esters, alcohols and acids (A. Weisbrod et al.)
- HESI Bioaccumulation Subcommittee/SETAC Global Advisory Group
  - HESI *in vivo* B database workshop (design & data quality)
  - HESI *in vitro* workshop (ADME, cross species extrapolation)
  - HESI / ECB /SETAC Workshop on B assessment approaches



# How Environment Canada is Helping to Resolve ‘B’ Issues: 2

- Augmenting ‘B’ Database (with J. Arnot, Trent University)
  - Non-DSL substances (another ~1300 BCFs)
- Biotransformation investigation (with J. Arnot, Trent University)
  - Examining relationships between biodegradation and biotransformation including chemical specific rates and "binning" structural and functional groups for chemical classes
  - Defining classes of chemicals for which these methods are most applicable, i.e., establishing domains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