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FOURTH AUTUMN COURSE ON MATHEMATICAL ECOLOGY

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"Rationale for Modelling Bioaccumulation of Chemicals in Aquatic Food Webs"

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These are preliminary lecture notes, intended only for distribution to participants.

RATIONALE FOR MODELING BIOACCUMULATION OF CHEMICALS IN AQUATIC FOOD WEBS

HUMAN OR AQUATIC WILDLIFE

ALLOWABLE DOSE (mg/d) = WATER INTAKE (L/d) * WATER CONC(mg/L)

+ FISH CONSUMP. (kg/d)* FISH CHEMICAL CONC. (mg chem./kg)

BIOACCUMULATION FACTOR-BAF(l/kg) = C(fish)/C(water)

or

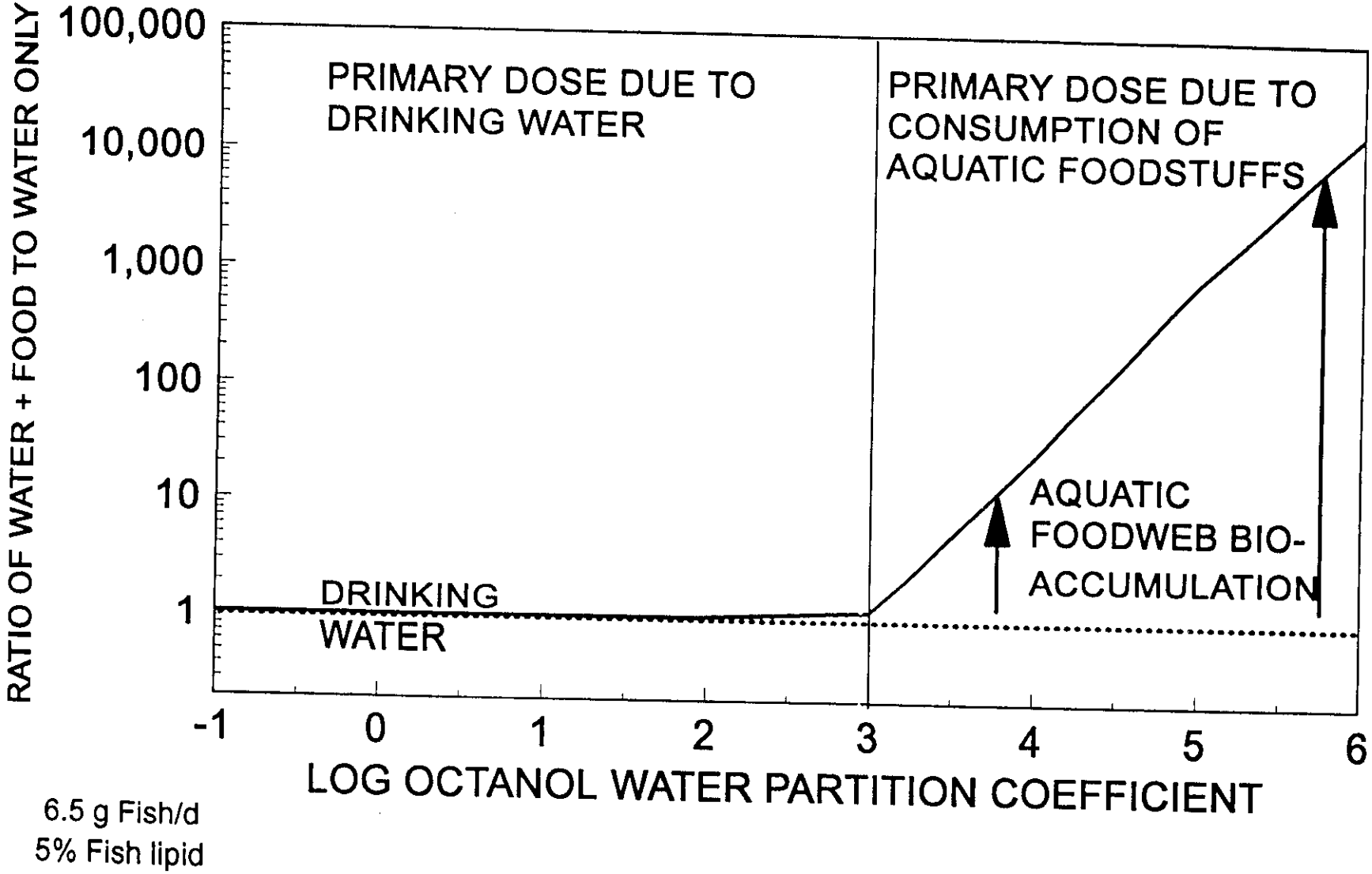
$$C(fish) = BAF * C(water)$$

and the required water concentration is then

$$\text{REQUIRED } C(water) = \frac{[\text{ALLOWABLE DOSE}]}{\{\text{Water Intake} + (\text{Fish Consump.} * \text{BAF})\}}$$

IS THE WATER ROUTE OR THE FOOD ROUTE MORE IMPORTANT? DOES THE BAF MATTER?

RELATIVE CHEMICAL DOSE TO HUMANS DUE TO DRINKING WATER AND CONSUMPTION OF CONTAMINATED AQUATIC FOODSTUFFS



BASIC STRUCTURE OF BIOACCUMULATION MODELING IN AQUATIC SYSTEMS

ROUTES OF CHEMICAL EXPOSURE:

1. UPTAKE OF "AVAILABLE" CHEMICAL IN WATER COLUMN OR SEDIMENT PORE WATER

2. UPTAKE OF CHEMICAL FROM INGESTION OF CONTAMINATED PREY

3. UPTAKE OF CHEMICAL FROM INGESTION OF CONTAMINATED SEDIMENT

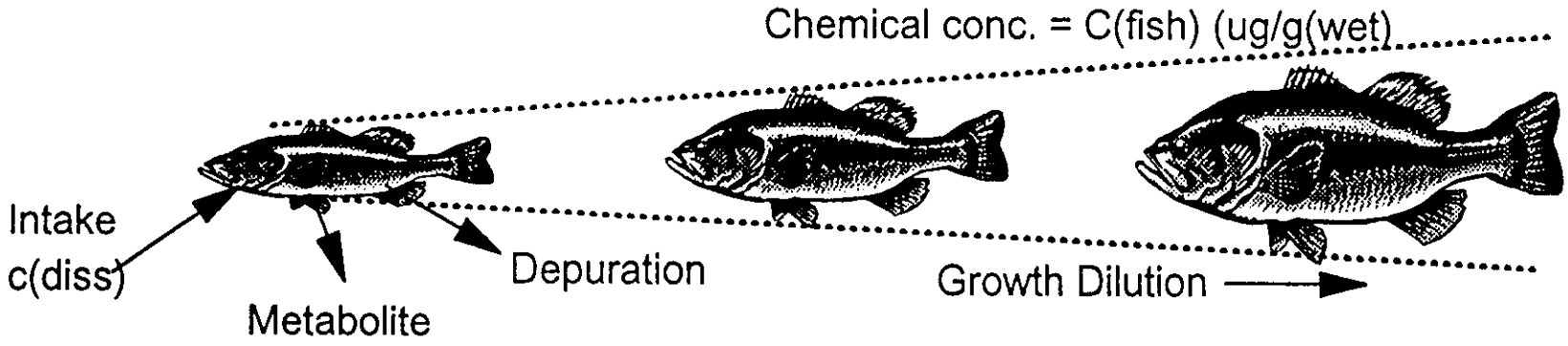
UPTAKE FROM WATER ***ONLY***

BIOCONCENTRATION

CHEMICAL CONCENTRATION IN ORGANISM DUE TO EXPOSURE TO WATER COLUMN, SEDIMENT PORE WATER OR BOTH

DETERMINED BY EXPERIMENT :
NO CONTAMINATED FOOD
CONSTANT WATER CONCENTRATION

ASSUME UPTAKE LINEAR TO WATER CONC.



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ug chem/g(wet) per day = Intake - Depuration - Metabolism - Growth dilutio

dC(fish)/dt = k c(diss) - KC(fish) - (Km)C(fish) - GC(fish)

ug chem/g(wet) per day = Intake - Loss, transformation, dilution routes

$$\frac{dC(fish)}{dt} = kc(diss) - K'C(fish)$$

Continue lab exposure until steady state is reached. Then, intake = losses and

$$C(fish) = kc(diss)/K'$$

Define a <u>BIOCONCENTRATION FACTOR (BCF)</u> as ratio fish conc./diss. water conc. for exposure to water only:

$$BCF = C(fish)/c(diss)$$

NOTE:

1. BCF is an equilibrium ratio for exposure to **water only**
2. In the field, the organism experiences all routes of exposure. Therefore, not possible to measure BCF in the field. BCF is a laboratory determined number.

UPTAKE FROM WATER + FOOD

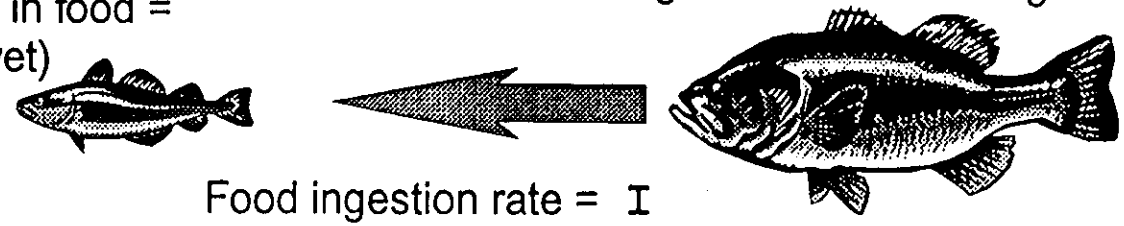
BIOACCUMULATION

CHEMICAL CONCENTRATION IN ORGANISM DUE TO EXPOSURE TO WATER+CONTAMINATED PREY AND/OR SEDIMENT

GENERALLY A FIELD DETERMINED QUANTITY
CHEMICAL FROM FOOD ADDITIVE TO WATER ROUTE

Chemical assimilation efficiency = e
ug chem. absorbed/ug chem. ingested

Chemical conc. in food =
C(food) (ug/g(wet)



Food ingestion rate = I
(g(prey)/g(predator) per day

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ug chem/g(wet) per day = Intake - Loss + Net chemical from food

$$\frac{dC(fish)}{dt} = kc(diss) - K'C(fish) + e\,I\,C(food)$$

At steady state:

$$C(fish) = BCFc(diss) + g\,C(food)$$

where g = biomagnification ratio = e_I/K'

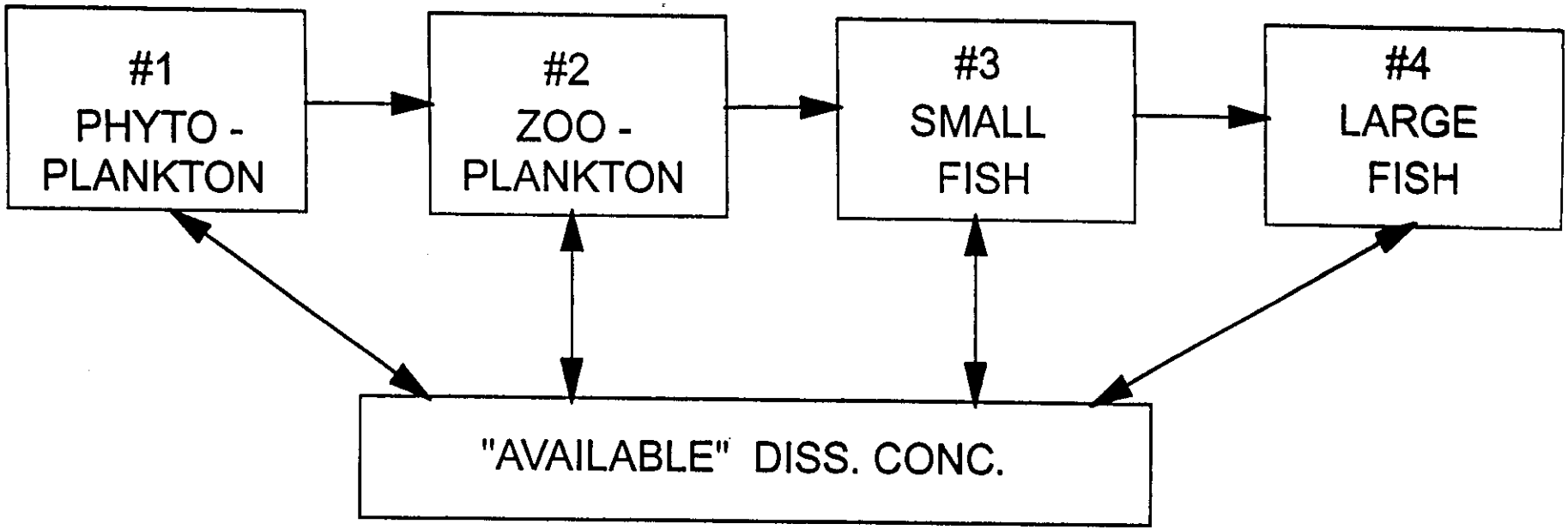
Define a **BIOACCUMULATION FACTOR (BAF)** as ratio fish conc./diss. water conc. where **all routes are included**:

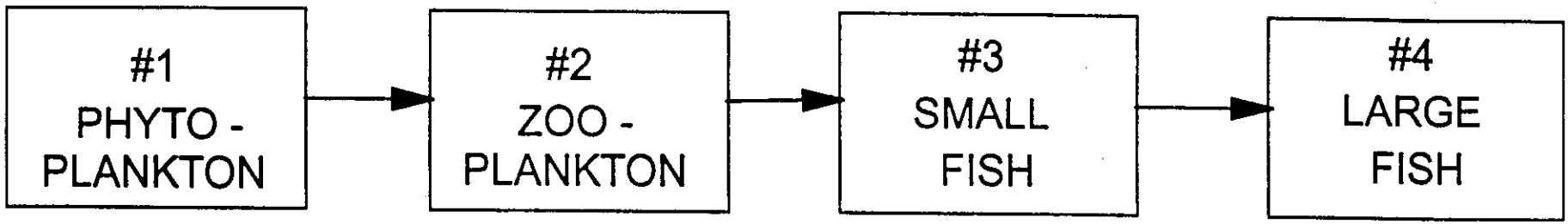
$$BAF(fish) = C(fish)/c(diss) = BCF + g\,BAF(food)$$

NOTE:

1. Accumulation due to food depends on biomagnification ratio: g (a function of chemical assimialtion eff., ingestion rate and loss rate)
2. If g "large"(e.g. >1), food route important. If g "small", (e.g.<<1), food route not important.

A SIMPLE FOUR LEVEL PELAGIC FOOD CHAIN





BCF(Phyto)

$$BAF(Zoop) = BCF(Zoop) + g(21)BCF(Phyto)$$

$$BAF(SmF) = BCF(SmF) + g(32)BAF(Zoop)$$

$$BAF(LgF) = BCF(LgF) + g(43)BAF(SmF)$$

FOR ILLUSTRATION OF CLARITY, SUPPOSE ALL BCF's ARE EQUAL AND ALL BIOMAGNIFICATION RATIOS ARE EQUAL. THEN,

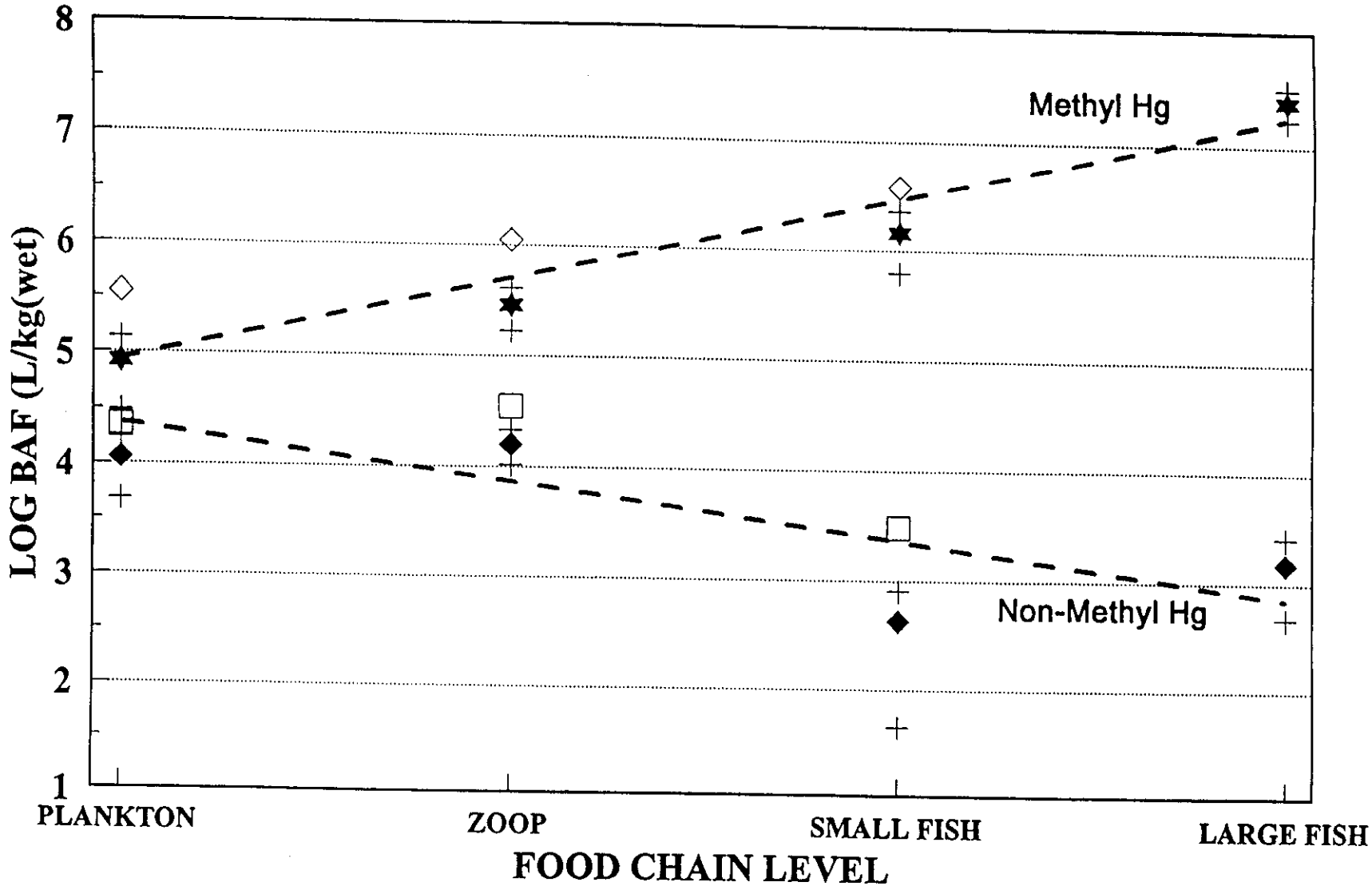
$$BAF(Zoop) = [\,1 + g\,]\,BCF$$

$$BAF(SmF) = [\,1 + g + g*g\,]\,BCF$$

$$BAF(LgF) = [\,1 + g + g*g + g*g*g\,]BCF$$

NOTE: FOOD CHAIN BIOACCUMULATION

VARIATION OF MERCURY BAF WITH TROPHIC LEVEL: CLEAR & LITTLE ROCK LAKES



Clear Lk: Suchanek et al, 1993, Star,Diamond +/- StD.
Little Rock Lk: Watras and Bloom, 1992