Stephan et al 1985: Guidelines

- Field experiments are not feasible therefore
  - “describe an **objective, internally consistent, appropriate, and feasible** way of deriving national criteria…
  - ***provide the same level of protection*** as the infeasible field testing approach….
- **modified whenever** sound scientific evidence indicates …Guidelines would probably be **substantially overprotective or underprotective**

Bodies of water differ

- if bodies of water and the aquatic communities in them do differ substantially in their sensitivities to a material, **national criteria should be at least somewhat overprotective for a majority of the bodies of water**"…
- Protective measures:
  - Include sensitive species– 95% of species
  - Use waters low in Differences in characteristics of water
    - Adjust for geochemistry
  - Application factors

Maintaining balance of uncertainties

- **Geochemistry**: most guidelines over-protective relative to most natural waters in geochemical terms alone.
- **Biology:** Simplifications of bioassays result in under-protective values…exposure time, choices of species, type of exposure, chronic vs. acute
- **Application factors**: arbitrary, difficult to justify
- **Definition of acceptable data** is narrow: traditional toxicology

Parallel Literature

- One paradigm does not work for all chemicals
  - Metals/metalloids and organic chemicals represent different problems
  - Endocrine disruption represents a different type of problem?
- Metals/metalloids
  - Fugacity concept does not work: Biological and chemical mechanisms differ for metals and among metals/metalloids
  - Organic chemicals: many chemicals; common QSAR
  - Metals/metalloids: few chemicals; depth of knowledge of each

Parallel literature: metals/metalloids

- Combine controlled studies and observations of nature
  - Robust, clean chemistry shows low dissolved concentrations.
  - Speciation and partitioning among water, sediments and food webs are linked although in complex ways (one ecosystem).
  - Exposure routes are more complex than just dissolved fraction.
    - Experimental studies and models show dietary exposure cannot be ignored, including trophic transfer.
  - Taxon specific bioaccumulation, detoxification and tolerances.
  - Taxon-specific sensitivities in field do not necessarily agree with traditional tests.
  - Biology: Links between full exposure and chemical-specific signs of stress.
  - Ecology: loss of sensitive species or functions tied to exposures to chemicals.
    - Somewhat chemical specific.

New Generation of AqLifeCriteria: Bridges or road blocks?

- Can we accept field observations?
  - What are uses of field data?
  - Define acceptable bodies of information?
- Should “acceptable data” be defined by protocol or by addition to understanding?
- Acceptable geochemistry?
- Dietary bioassays, bioaccumulation and toxicity?
- Bioavailability: Role of bioaccumulation?
- Ecological bodies of work: Dose-response and change through time and space?
- Mesocosms and transplant studies?
- Weight of evidence?
- Models: e.g. combine BLM and Biodynamic modeling?

Is there a need for change?

- DDT/Organochlorines: Under protection
- TriBuytl Tin: Under protection
  - Field studies: snails, oysters
    - Observe: Deformed adults, disappearance of species
    - Closer observations: imposex
    - Bioassays show strong bioaccumulation, reproductive sensitivities & deformations
    - High quality chemistry: Concentrations near toxic levels
    - Transplant studies (field mesocosms)
    - Recoveries when banned

Selenium: Precedent for new approach

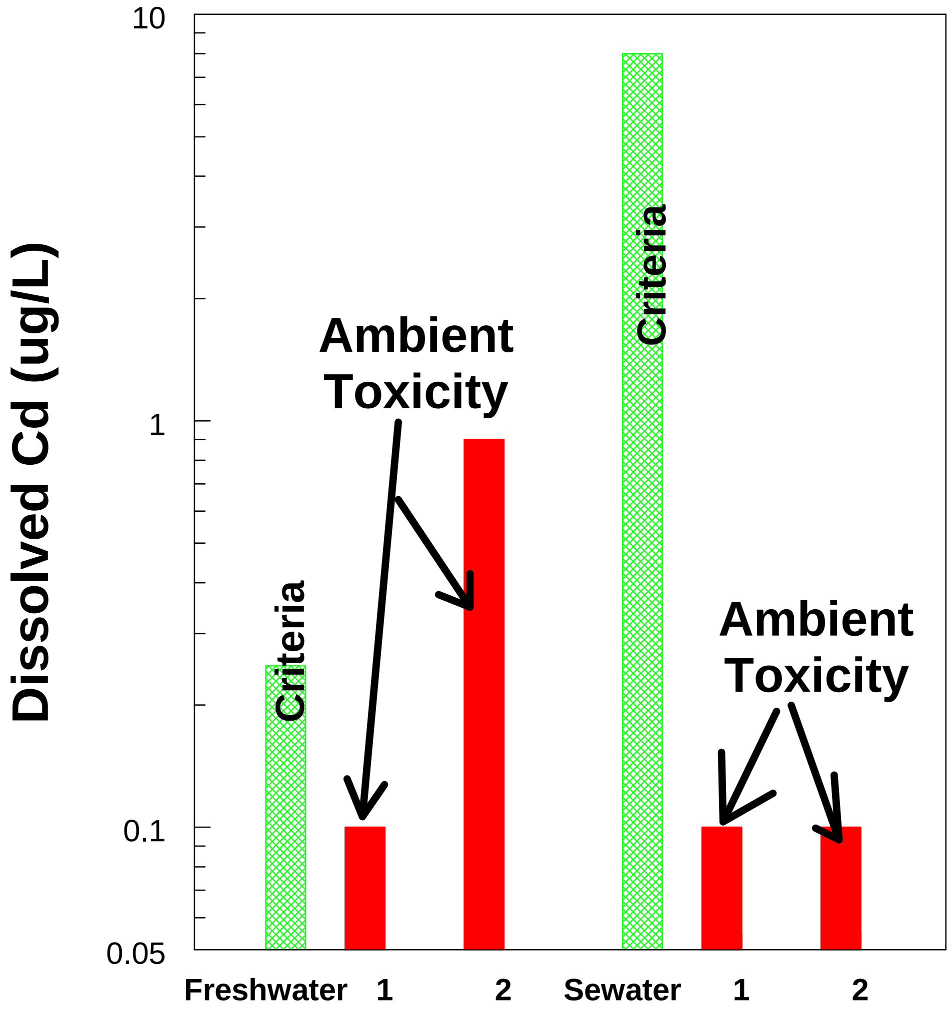
- Traditional EC50's: Low sensitivity
- Key observations
  - Field observations of deformations (Kesterson); extirpation of populations
  - Good chemistry showed concentrations below EC50's but symptoms typical of selenium poisoning
    - Good chemistry shows importance of speciation; environmental dynamics
  - Trophic transfer primary route of exposure;
  - Dietary toxicity assays developed for wildlife (& fish); link between bioaccumulated concentrations and toxicity ; Fish tissue guidelines
  - Models quantify trophic transfer; species specific bioaccumulation
  - Models allow extrapolation to dissolved concentrations for TMDL development
  - Treat ecosystems differently (lentic vs lotic)
  - Low level guidelines "incentivize" site-specific data collection

How to proceed: Prioritize needs for new criteria

- Systematic evaluation of each metal/metalloid criterion using full suite of knowledge
  - Sufficient EC50 knowledge to identify hazard?
  - Geochemistry: How does criterion level compare to knowledge of concentrations in contaminated situations.
  - Trophic transfer/dietary exposure & toxicity?
    - Compare effect levels
  - Species sensitivity:
    - Field vs EC50's
    - Dietary exposure
  - Acute vs chronic vs signs of stress (biological and ecologic
  - Examples of field studies?
    - What were (suspected) effect levels; compare multiple studies.
  - Recovery?

Ambient Cd Criteria (USA)

Compared to ambient Cd toxicity



1. Cladoceran toxicity
2. Trout toxicity

1. Marine algae toxicity
2. Dietary toxicity (zooplankton)

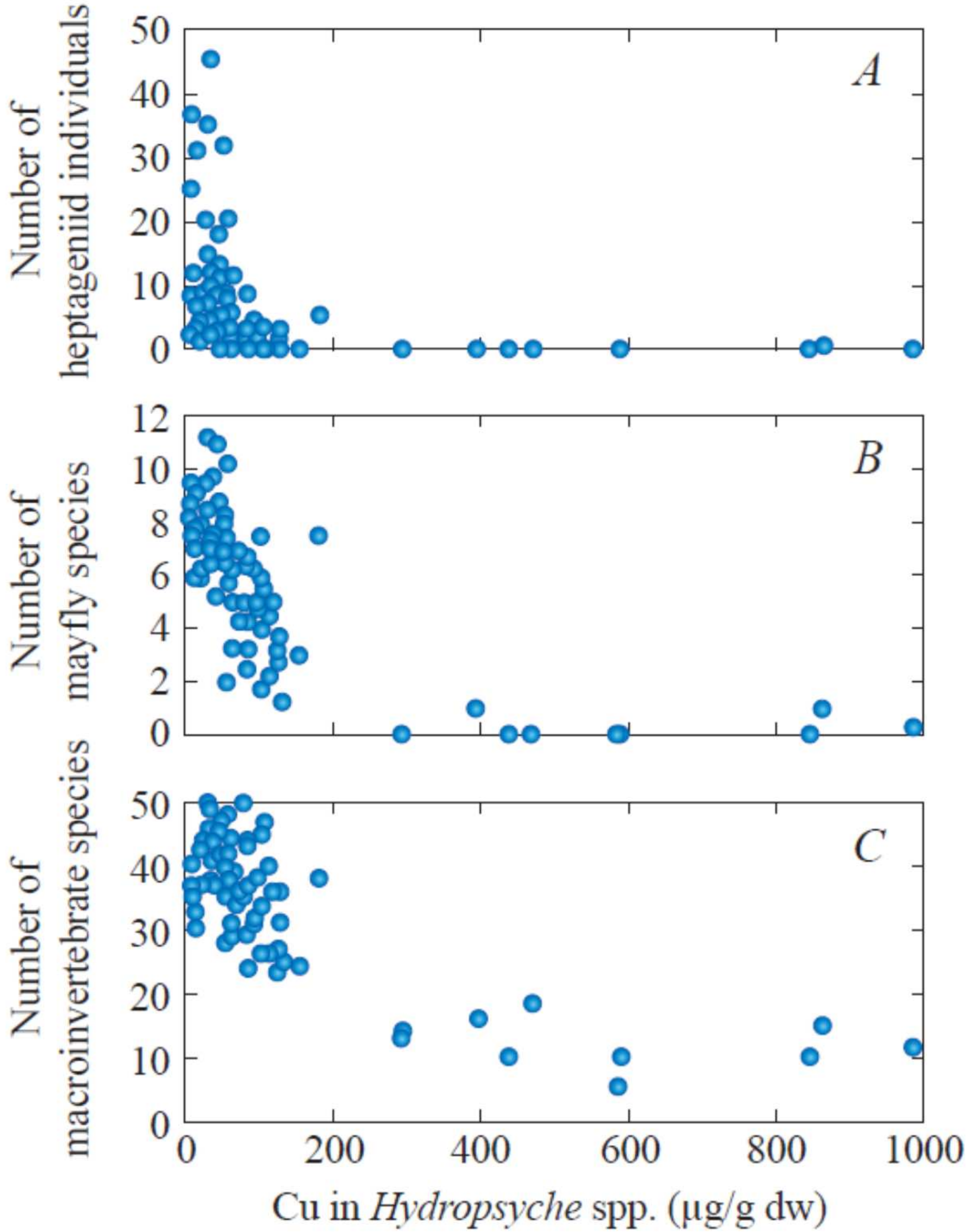
Silver: Compliance vs. reality

(*Zhang et al, 2001; Raville & Flegal, 2005)

Ocean surface	Pacific Ocean Off Asia: surface	So SF Bay: 2003	Toxicity: Dietary & SF Bay: 1980	Ambient WQ Criteria (US, Canada)
*0.1 – 0.4 (ng/Kg)	*0.4 – 4.7 (ng/Kg)	4 - 6 (ng/Kg)	~100 (ng/Kg)	1,500 (ng/Kg)

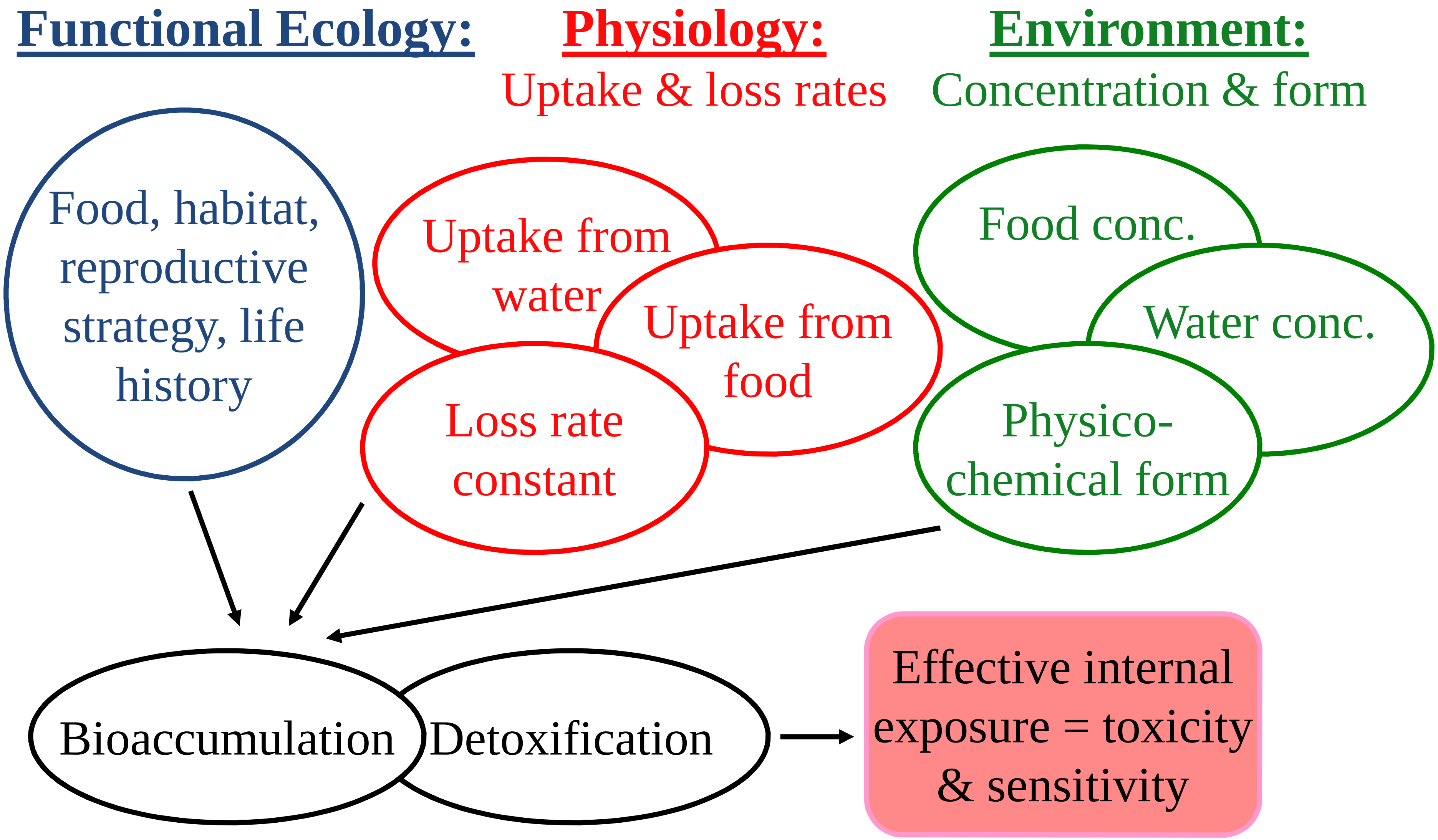
Ingredients: Lateral approach

- Find conceptual bridges among key disciplines
- Mechanistic understanding aids robust policy
- Biological traits of sensitive and insensitive species predict nature of ecological response.
- Future guidelines use integrated approaches to both exposure and effect.
- Geochemistry, biology and ecology provide critical bridges to better policy.



Number of heptageniid individuals
A
Number of mayfly species
B
Number of macroinvertebrate species
C
0
10
20
30
40
50
0
2
4
6
8
10
12
0
200
400
600
800
1000
Cu in *Hydropsyche* spp. (μg/g dw)

Biodynamics: A multi-discipline bridge



Technical approach, 1

Dose Response

EC's for different community metrics with Cu in *Hydropsyche sp.* as measure of exposure.

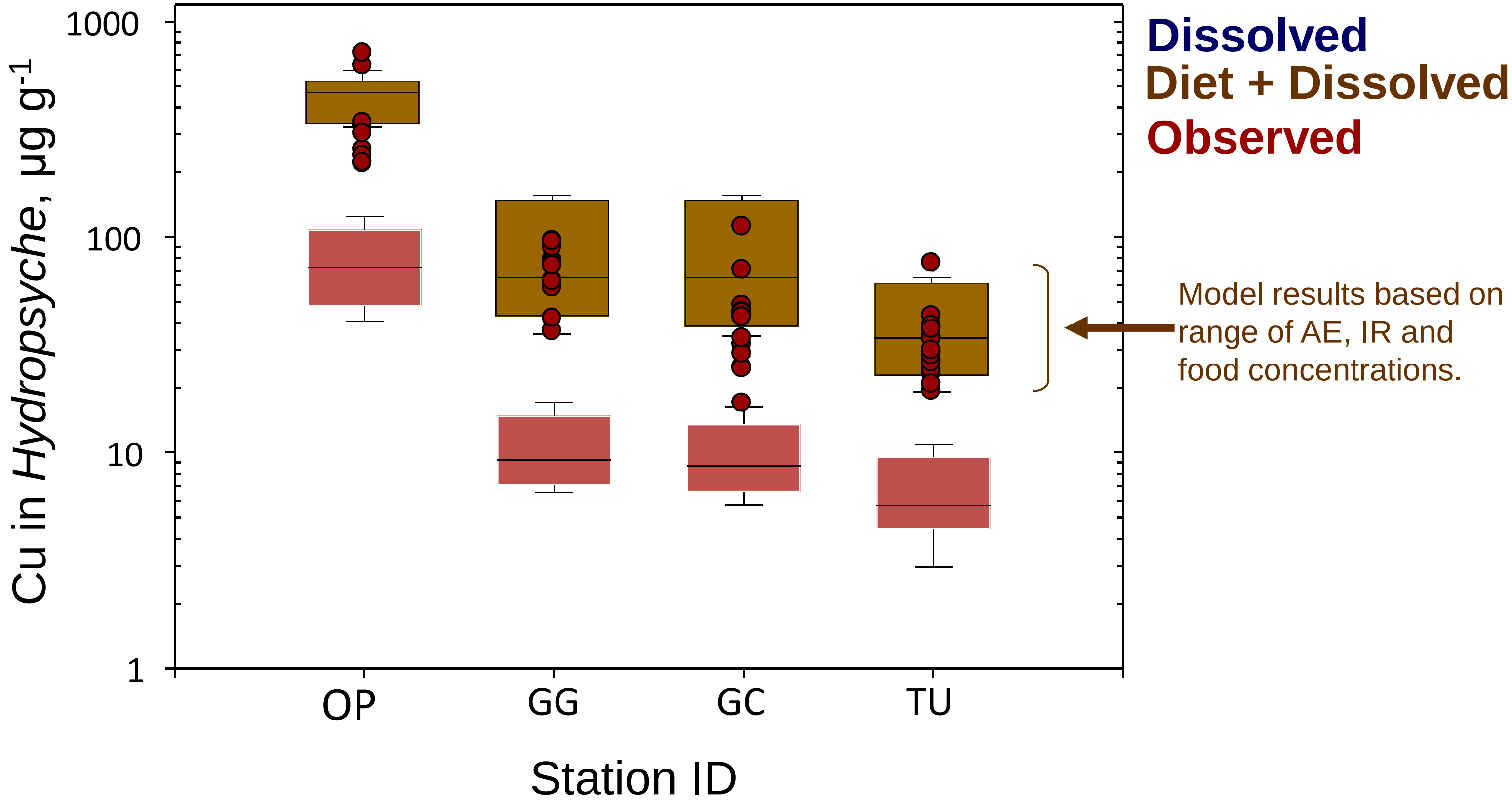
Metric	EPT richness	Species richness	Mayfly richness	Hepta-geniid richness	Heptageniid abundance
EC (µg/g dw in *Hdyro-psyche sp.*)	175	267	70 - 90	50 - 60	50 - 60

Remediation: What community is the desired endpoint?

Dietary influx ~3x greater than dissolved influx…

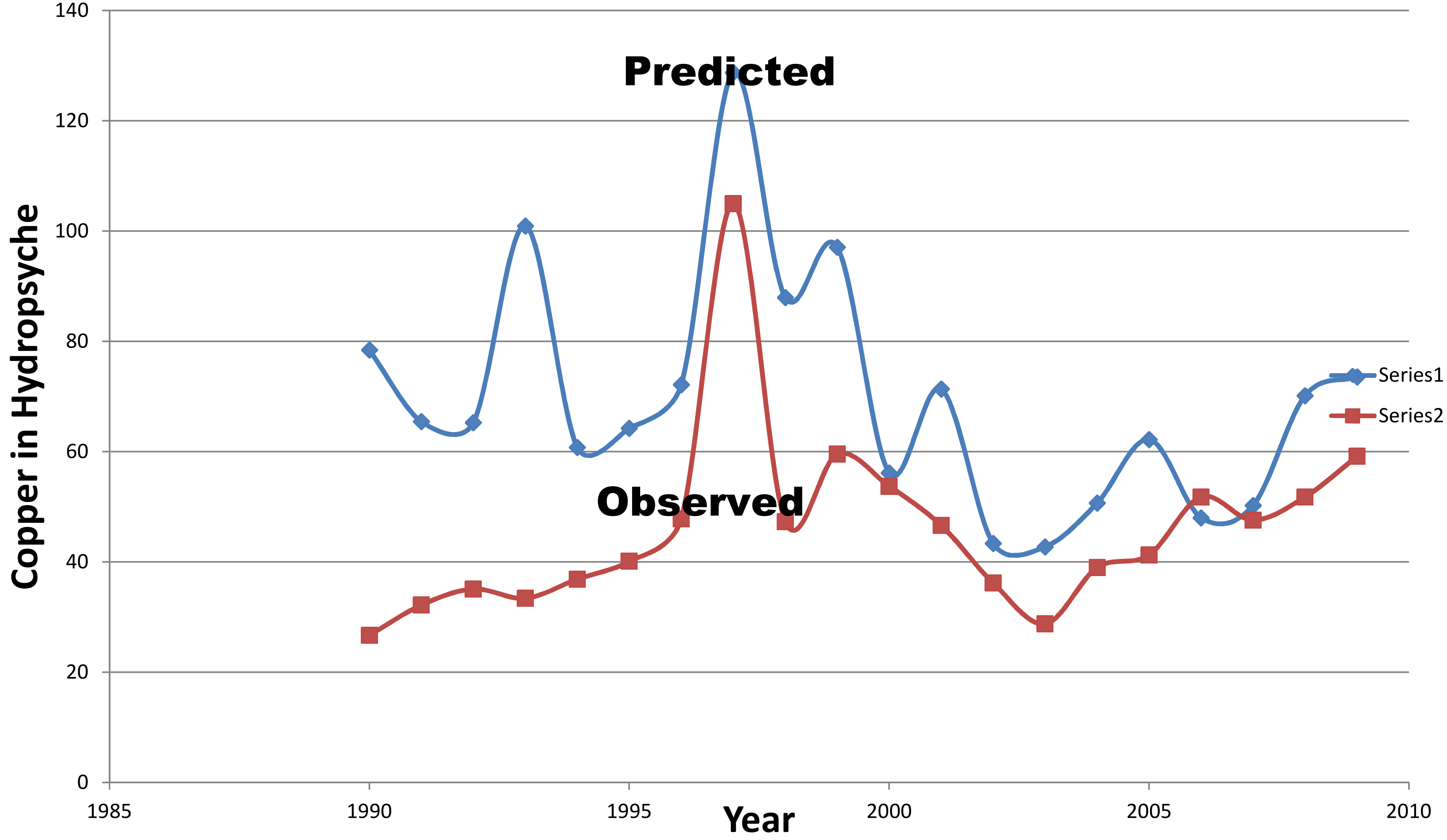
$$[Cu]_{hydro} = \frac{(k_u\,[Cu]_{diss^*}) + (AE \cdot IR \cdot [Cu]_f)}{k_e}$$

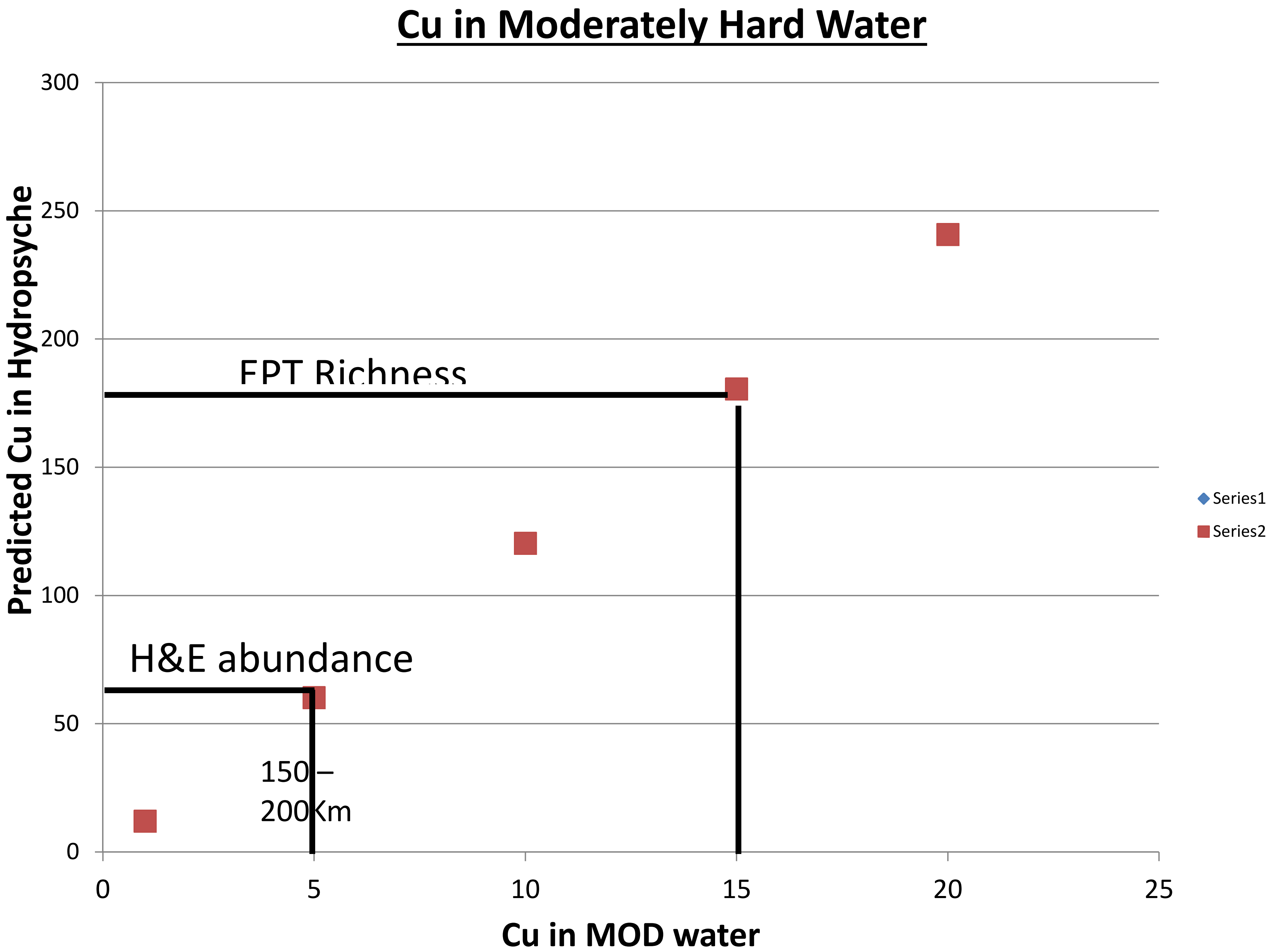
* $[Cu]_{diss}$ = Seasonal mean at each station



Hornberger et al., in prep.

200 Km from tailing ponds




Cu in Moderately Hard Water
300
250
200
150
100
50
0
0
5
10
15
20
25
Predicted Cu in Hydropsyche
Cu in MOD water
FPT Richness
H&E abundance
150 –
200Km
Series1
Series2

Conclusions

- Tolerant biomonitor species present where sensitive species are eliminated.
- All species respond with internal consistency to a metal gradient (common to all streams)
- Feasible to calibrate exposure response of a tolerant biomonitor to the effects response of the more sensitive community.
- The threshold of effects seems similar in different streams at genus level in exposure biomonitor.
- Feasible to model dissolved concentrations at which biomonitor dose results in effect, either generically or site-specifically.
  - Combine BLM and biodynamics
  - Validate with dietary or combined exposure mesocosm tests