General Overview -Deliberations of the Scientific Advisory Group (SAG)

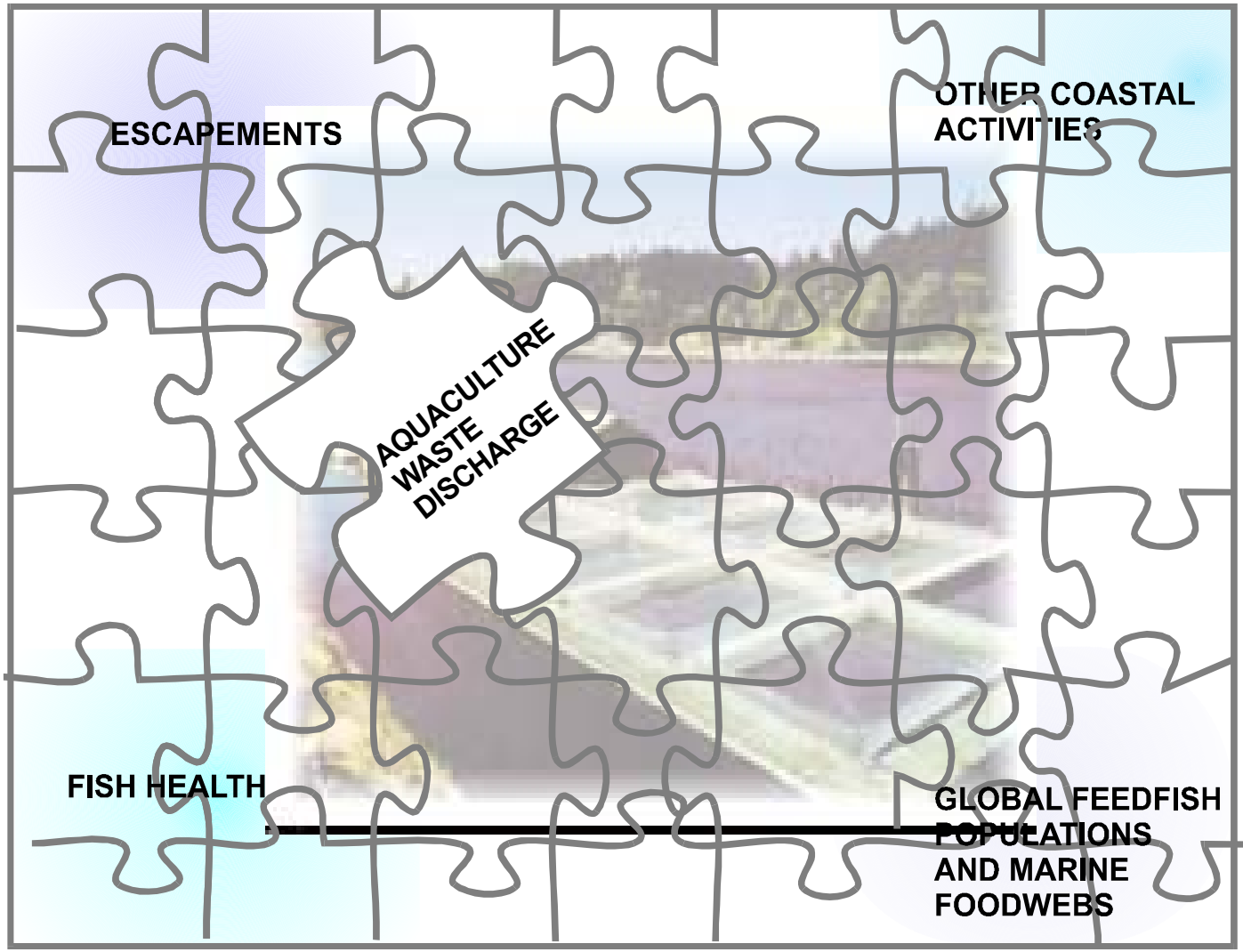
SAG Members and Terms of Reference

- **Doug Bright**, Professor-Applied Research, RRU
- **Asit Mazumder**, Professor, and NSERC Senior Research Chair in Environmental Management of Drinking Water, Ecosystems, and Watersheds, UVic
- **Scott McKinley**, Professor, NSERC Research Chair (Biotelemetry) and Canada Research Chair (Aquaculture and the Environment),UBC
- **Tom Pedersen**, Professor, Department of Earth and Ocean Sciences, and Associate Dean, Faculty of Graduate Studies, UBC

…the Scientific Advisory Group has been asked by WLAP to "review and advise this Ministry on development of a new Aquaculture Waste Control Regulation".

- *…review will include*
  - *the draft methods of analysis for a performance-based assessment of waste discharge,*
  - *the proposed draft regulation itself, and*
  - *stakeholder comments on the draft reg., including methodology.*

SAG limited their suggestions to those based on peer-reviewed science and where discrepancies were present SAG suggested the measurements of "things" only on an interim basis.


ESCAPEMENTS
OTHER COASTAL ACTIVITIES
AQUACULTURE WASTE DISCHARGE
FISH HEALTH
GLOBAL FEEDFISH POPULATIONS AND MARINE FOODWEBS

Critically Important Issues Not Addressed Under the Draft Regulation

- **Cumulative Effects Not Addressed Within Framework: Waste Management Act as Enabling Legislation is Best Suited to Managing Individual Operations**

"With regard to substances released from aquacultural operations, the SAG offers the view that the approaches being entertained and that seem feasible as part of a regulation under the Waste Management Act theoretically have the potential to address waste-related impacts of aquaculture on a site-by-site basis. The regulation, however, would lack the structure, the focused interest in, and the power to detect, monitor, and manage cumulative effects of multiple aquacultural operations in a larger defined coastal ecosystem. We were unable to envision mechanisms that would allow a performance-based, practical regulation aimed at individual operators that could address cumulative ecosystem effects of many aquaculture operations. This is an especially important issue if the geographic density of operations is likely to increase in the future."

- **Maximum Loading Based on Assimilative Capacity**
  (Need to manage in consideration of all coastal inputs, not just aquaculture)

- **Formalized Mechanism for Resolving Several Important Knowledge Gaps That Relate to Our Immediate and Longer-Term Ability to Ensure Ecologically Sustainable Economic Development in the Coastal Aquaculture Sector**

Focus on Waste - The Impact Hypotheses

"The main effects associated with eutrophication are -

- *nutrient enrichment;*
- *organic enrichment (silting and sedimentation);*
- *oxygen depletion in the water column, and within and above the sediments; and*
- *changes in benthic biomass and community structure."*

(OSPAR Convention, 2000. Nutrient Discharges from Fish Farming in the OSPAR Convention Area. 40 pp).

- **Cumulative build-up (longer term) and short term effects of substances capable of acting as toxicants, before or after metabolic modification, from discharged wastes.**

SAG Recommendations

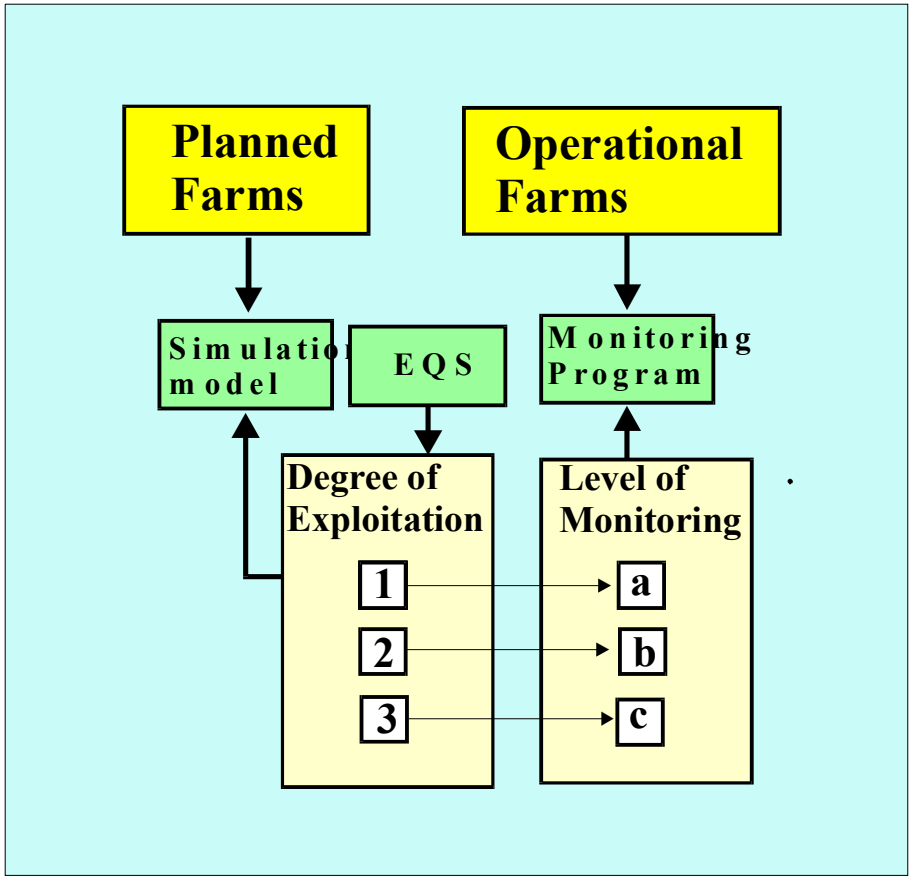
#1. SAG a**dvocates a tiered approach**:

Monitoring and compliance effort should be commensurate with actual extent of problem.

Parties should be afforded opportunity to carry out detailed (credible and objective) scientific studies to show actual risks (e.g. issue of total versus bioavailable Zn).

Monitoring data should be useful to effect decrease in spatiotemporal components of organic matter loading to the environment.

#2 **Harmonization** (also a recommendation of the SAR)



For planned fish farms, a model may be used to determine a preliminary degree of exploitaion. For fish farms in operation, a monitoring investigation is performed and, provided EQS (environmental quality standards) have been set which can discriminate between different levels of impact, a degree of exploitation can be determined. The level of monitoring is chosen and followed. (from, Ervik et al 1997).

Norwegian situation

Preventing Serious Waste-Related Impacts (Minimizing Potential for Unappreciated or Societally Unacceptable Externalities):

Enabling Tools

- Prior Knowledge and Detailed Understanding
- Monitoring - Chemical/Geochemical Surrogates of Biological Responses
- Monitoring - Biological Indicators
- Predictive Models

Depositional Environments

Chemical/Geochemical:

Seabed	*Water Column*
ORP	BOD,COD under or near operation
Total Volatile Solids	Total Suspended Solids
Organic C	Nutrients, including ammonium
Organic N, P fraction	Other Contaminants
S^{2-}	
Other Contaminants	

Performance-Based Measures at Point of Impact

Prerequisite Data for Managing Based on Maximum Allowable Load; Important for Cumulative Effects Assessment

Depositional Environments

Chemical/Geochemical:

Seabed

ORP

Total Volatile Solids

Little confidence in these

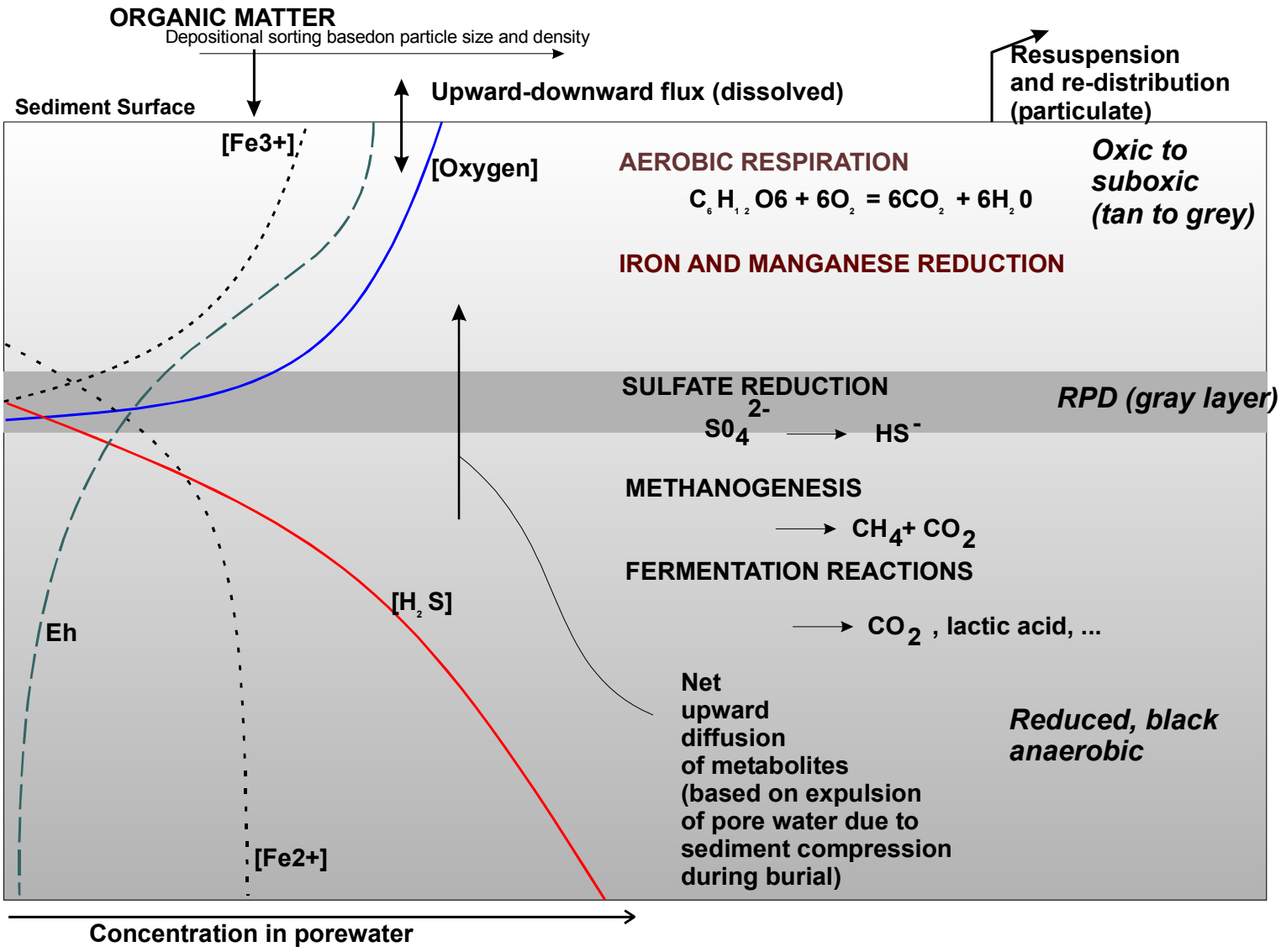
S^{2-}

Other Contaminants (Zn, Cu)

 # 2. SAG expressed concern that an operational use of sediment sulfide concentrations as a regulatory tool could be problematic given the anticipated lack of precision of the performance indicator.

- **Therefore, at important decision points, need increased reliance on biological effects measures, as opposed to chemical surrogates.**

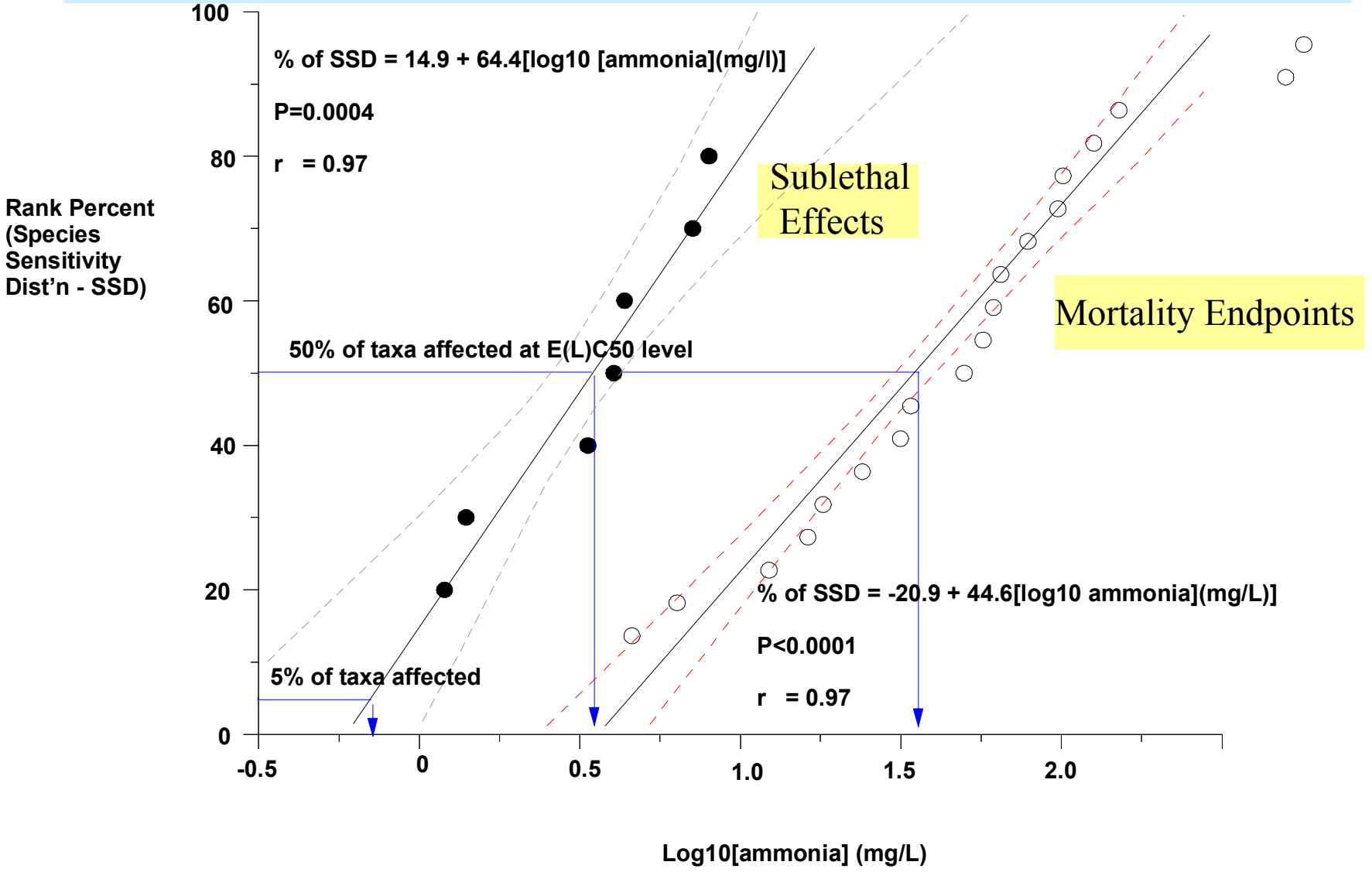
- **Variability of sulfide measures may in many cases require increased sampling effort (and replication) to demonstrate significance of result relative to regulatory thresholds.**


ORGANIC MATTER
Depositional sorting basedon particle size and density
Resuspension
and re-distribution
(particulate)
Upward-downward flux (dissolved)
Sediment Surface
[Fe3+]
[Oxygen]
AEROBIC RESPIRATION
C6H12O6 + 6O2 = 6CO2 + 6H20
Oxic to
suboxic
(tan to grey)
IRON AND MANGANESE REDUCTION
SULFATE REDUCTION
SO4 2- → HS-
RPD (gray layer)
METHANOGENESIS
→ CH4+ CO2
FERMENTATION REACTIONS
→ CO2 , lactic acid, ...
[H2 S]
Eh
[Fe2+]
Net
upward
diffusion
of metabolites
(based on expulsion
of pore water due to
sediment compression
during burial)
Reduced, black
anaerobic
Concentration in porewater

Depth matters

- A 5 cm thick,organically enriched layer will have very different potential for recovery than a 50 cm thick layer;
- …lots of gross generalizations about transient nature of impacts from organic loading, and time to recovery during fallowing,*etc.*
- *Some merits to argument; however, if want to invoke it, then have a responsibility to quantify both loading rates and decomposition rates.*
- A large component of biological responses is due to sensitivity to metabolites (sulfide, ammonia) and only secondarily to availability of O_2 or $S0_4^{2-}$ as oxidants (and to decomposition rates)
- What is acceptability and larger ecological consequences of maintaining areas of seabed in early successional stages?

Laboratory Toxicity Test Data - Marine Spp. (Aquire Database)



Laboratory Toxicity Test Data - Marine Spp. (Aquire Database)

Est. % of spp. adversely affected	Corresponding Exposure Concentration			
	Ammonia (mg/L)	**Ammonia (μM)**	**Sulphide (mg/L)**	**Sulphide (μM)**
5%	3.8	210	0.053	1.6
25%	11	590	0.21	6.2
50%	39	2,200	1.2	35
75%	140	7,800	6.8	200
95%	400	22,000	27	800

Relationship between benthic community impairment (loss of biodiversity) and sediment sulfide levels (adapted from Brooks, 2001). Open symbols are data for reference sites (≥ 300 m)

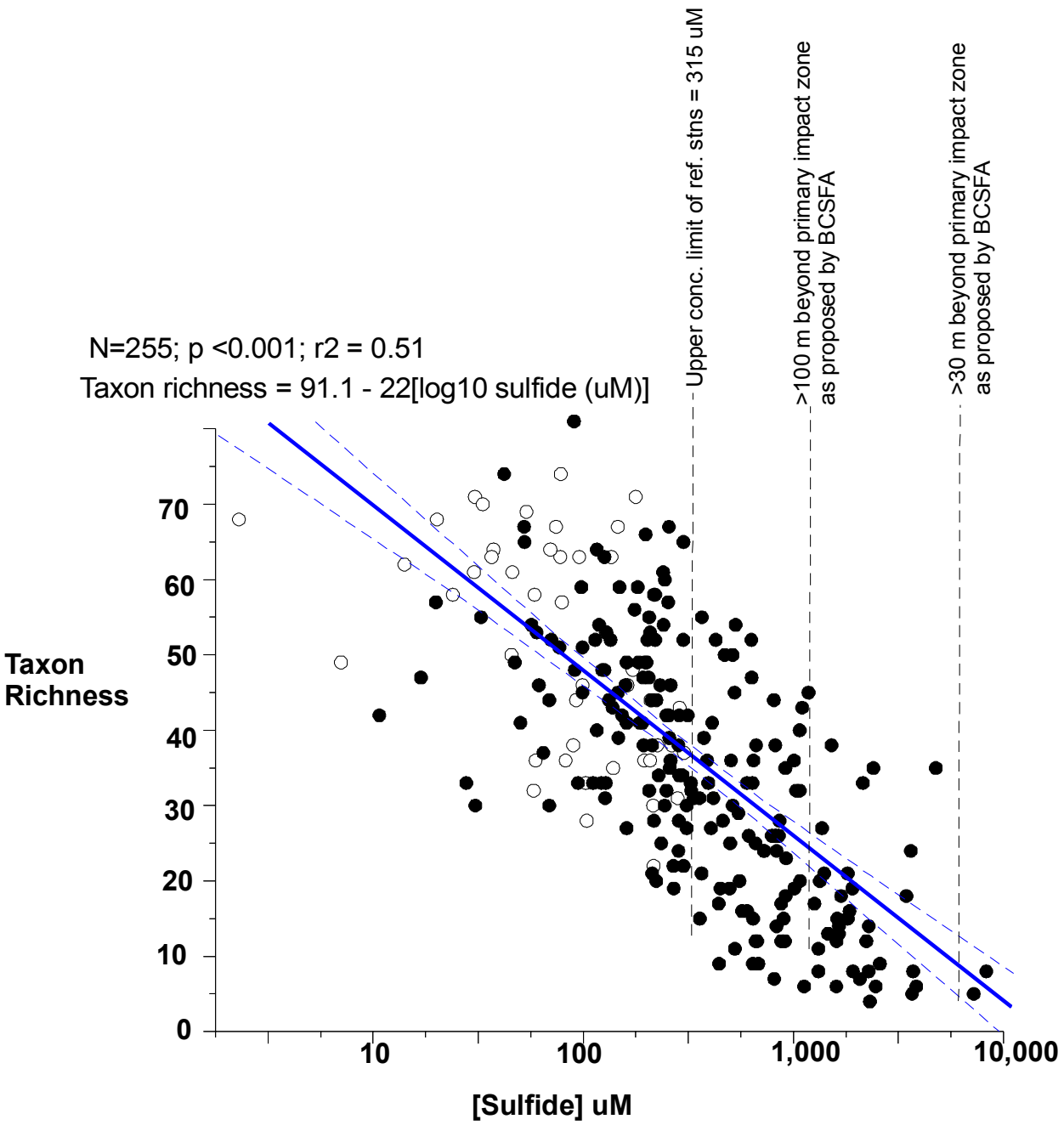


Table 1: Predicted reduction in taxon richness across a range of sediment sulfide concentrations

% reduction / no. of taxa in a 0.1m^2 grab)	log10 [s^{2-}] (μM)	[s^{2-}] (μM)
10% (45)	2.095	125
20% (40)	2.323	210
30% (35)	**2.550**	**355**
40% (30)	**2.777**	**599**
50% (25)	**3.005**	**1011**
60% (20)	**3.232**	**1705**
70% (15)	**3.459**	**2878**
80% (10)	**3.686**	**4857**
90% (5)	**3.914**	**8197**

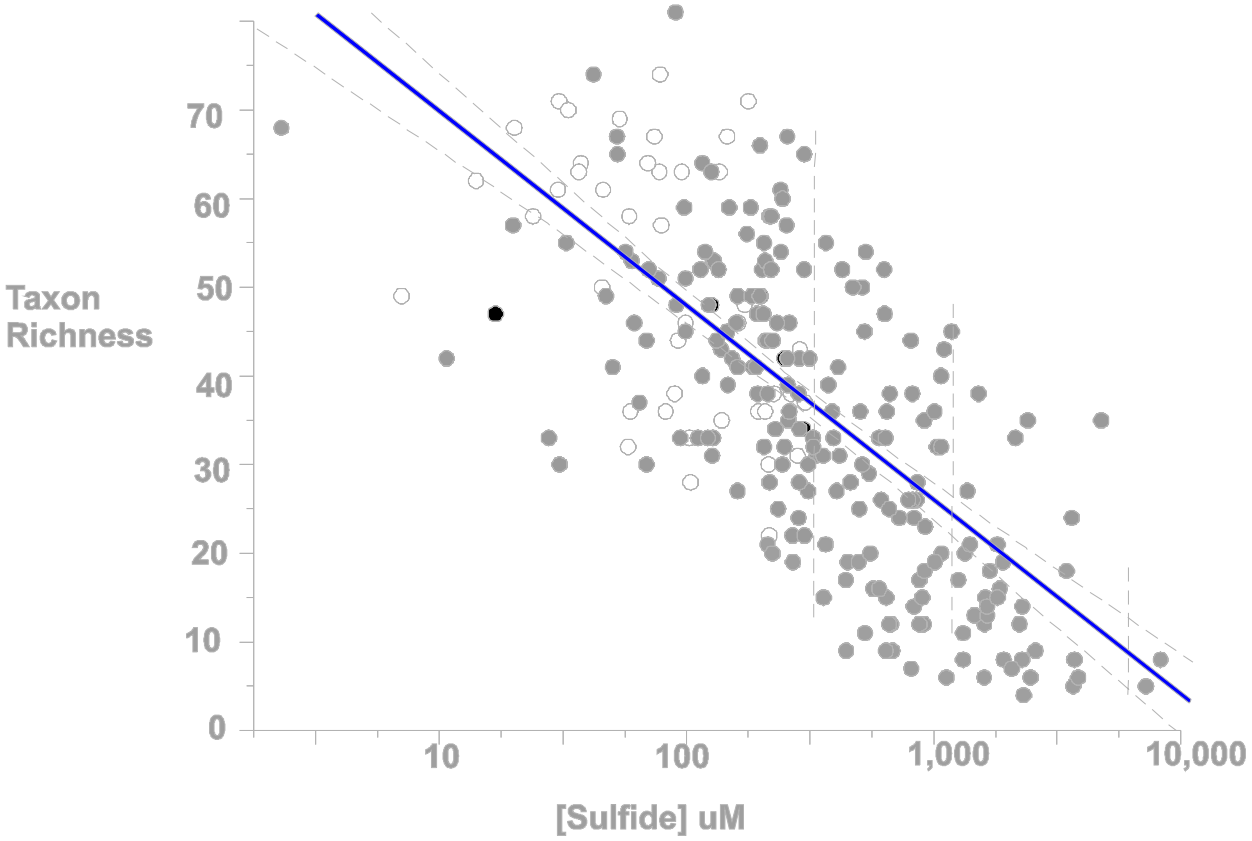
Table 2: Other predictors of reduced taxon richness at seven BC salmon aquaculture sites

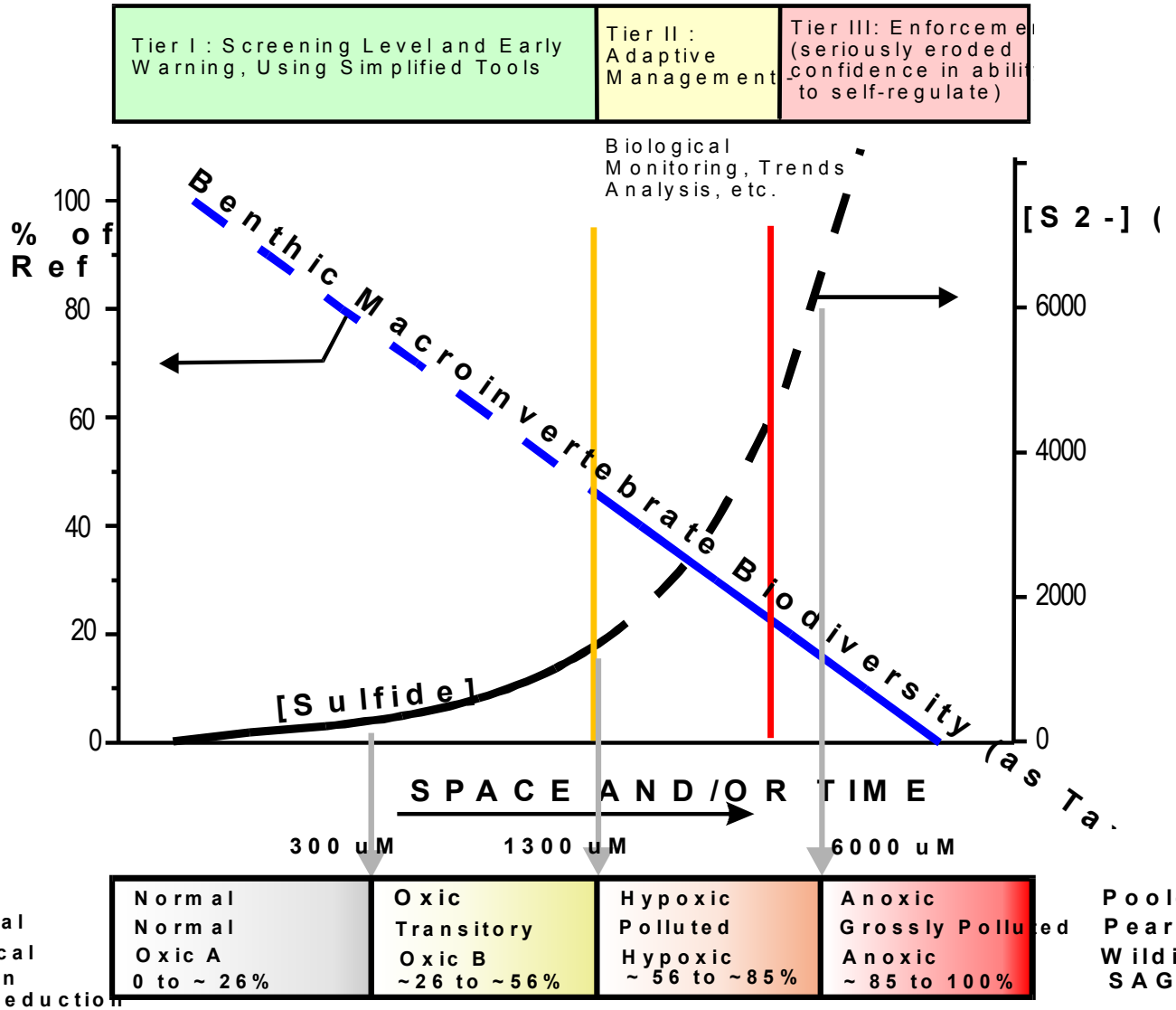
Variable	Partial Correlation	F	P
$Log_{10}\ s^{2-}$	-0.711	258.8	0.000
Distance (m) from net pen	0.629	165.8	0.000
ORP	0.604	145.1	0.000
TVS	-0.462	68.6	0.000
% siltclay	0.311	29.3	0.000
Salinity (ppt)	-0.322	27.1	0.000
Depth (m)	-0.162	6.80	0.010
pH	0.116	3.43	0.065

Taxon Richness =

$$-11.9 \log_{10}[s^{2-}] + 0.067\ [\text{distance (m)}] + 2.15[\text{salinity } (^{o}/oo) - 15.6[\text{silt-clay}]$$

$(n=255;\ R^2(adj) = 0.929;\ p < 0.0001)$


Taxon Richness
70
60
50
40
30
20
10
0
10
100
1,000
10,000
[Sulfide] uM


Tier I : Screening Level and Early Warning, Using Simplified Tools
Tier II : Adaptive Management
Tier III: Enforcem
(seriously eroded confidence in abili
to self-regulate)
Biological Monitoring, Trends Analysis, etc.
% of Ref
100
80
60
40
20
0
Benthic Macroinvertebrate Biodiversity
[Sulfide]
[S 2 -] (
6000
4000
2000
0
SPACE AND/OR TIME
300 uM
1300 uM
6000 uM
Microbial
Macrofaunal
Geochemical
Mean Taxon Richness Reduction
Normal
Normal
Oxic A
0 to ~ 26%
Oxic
Transitory
Oxic B
~26 to ~56%
Hypoxic
Polluted
Hypoxic
~ 56 to ~85%
Anoxic
Grossly Pollu ed
Anoxic
~ 85 to 100%
Poole et al., 1978
Pearson and Rosenb
Wildish et al, 2001
SAG, 2002

• Mean sulfide concentrations shall be significantly ≤ 6000 µM at 30 metres outside of the Direct Impact Zone (statistical test: one-sided *t-test*, α= 0.05).

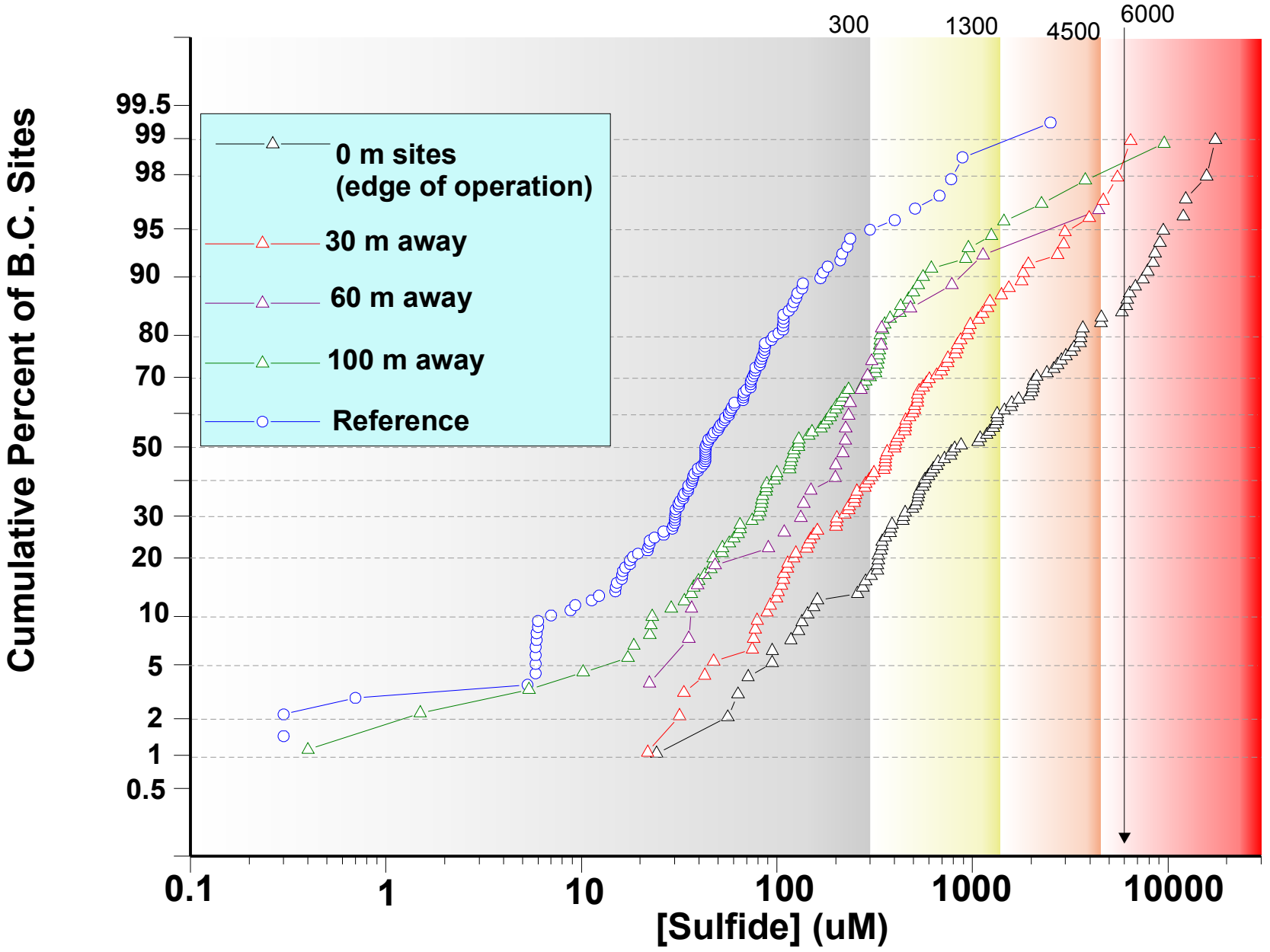
Supporting Comments

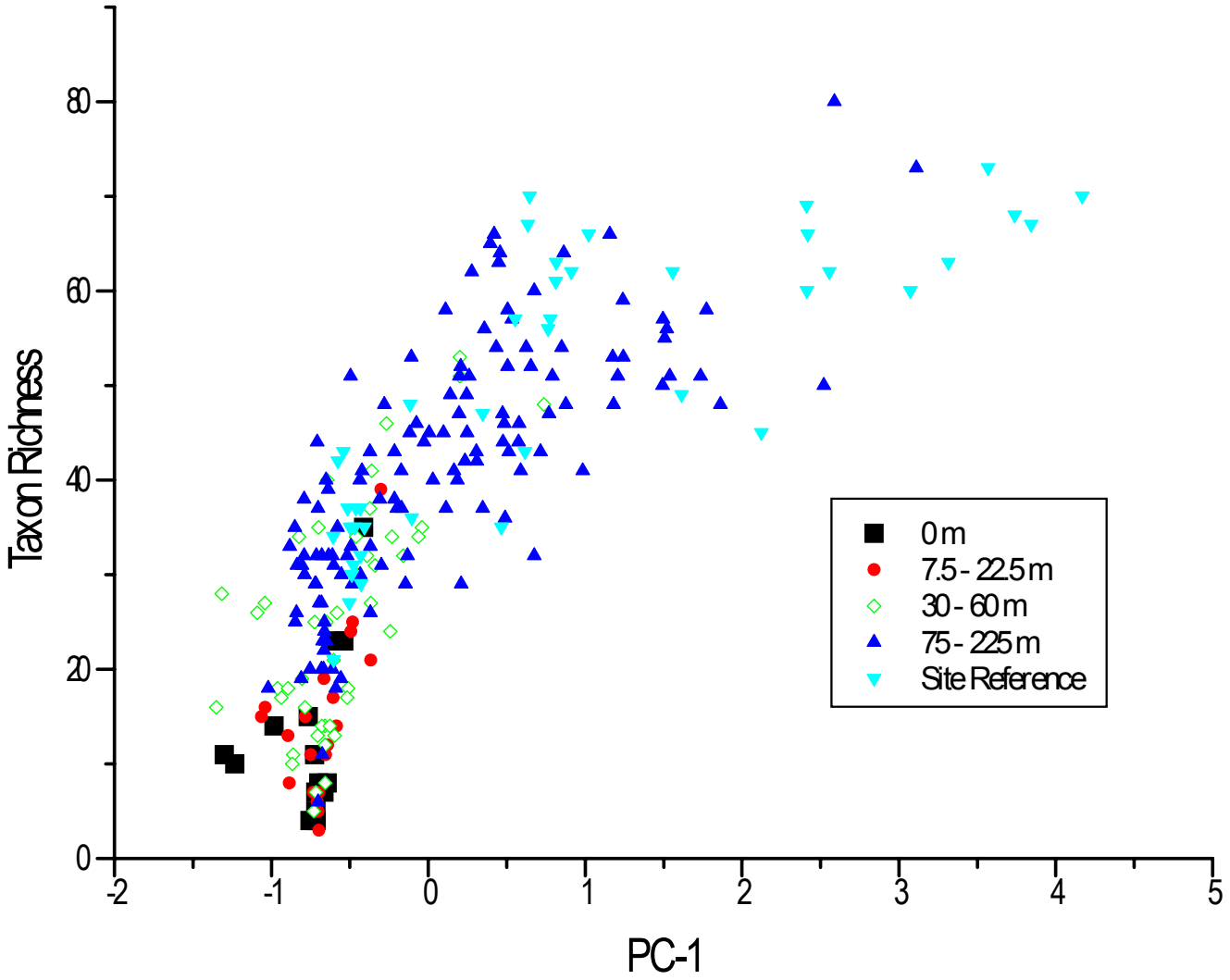
Sulfide levels below this level generally support a high level of biodiversity & sediment impacts that may occur remediate very quickly. A sulfide level of 6,000 µM is considered the transition to an anaerobic environmental condition (Wildish, 2001).

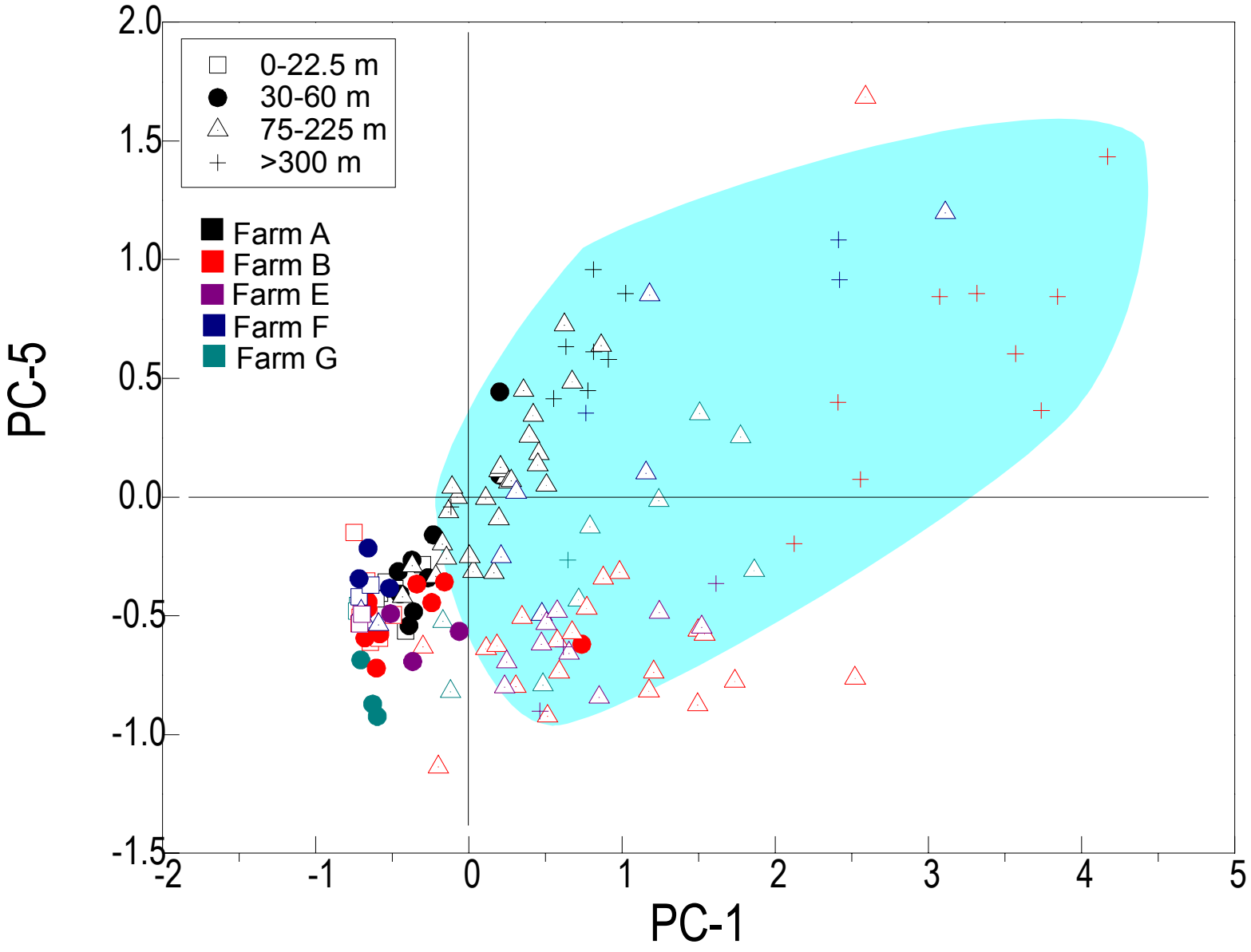
BCSFA, Oct. 2001

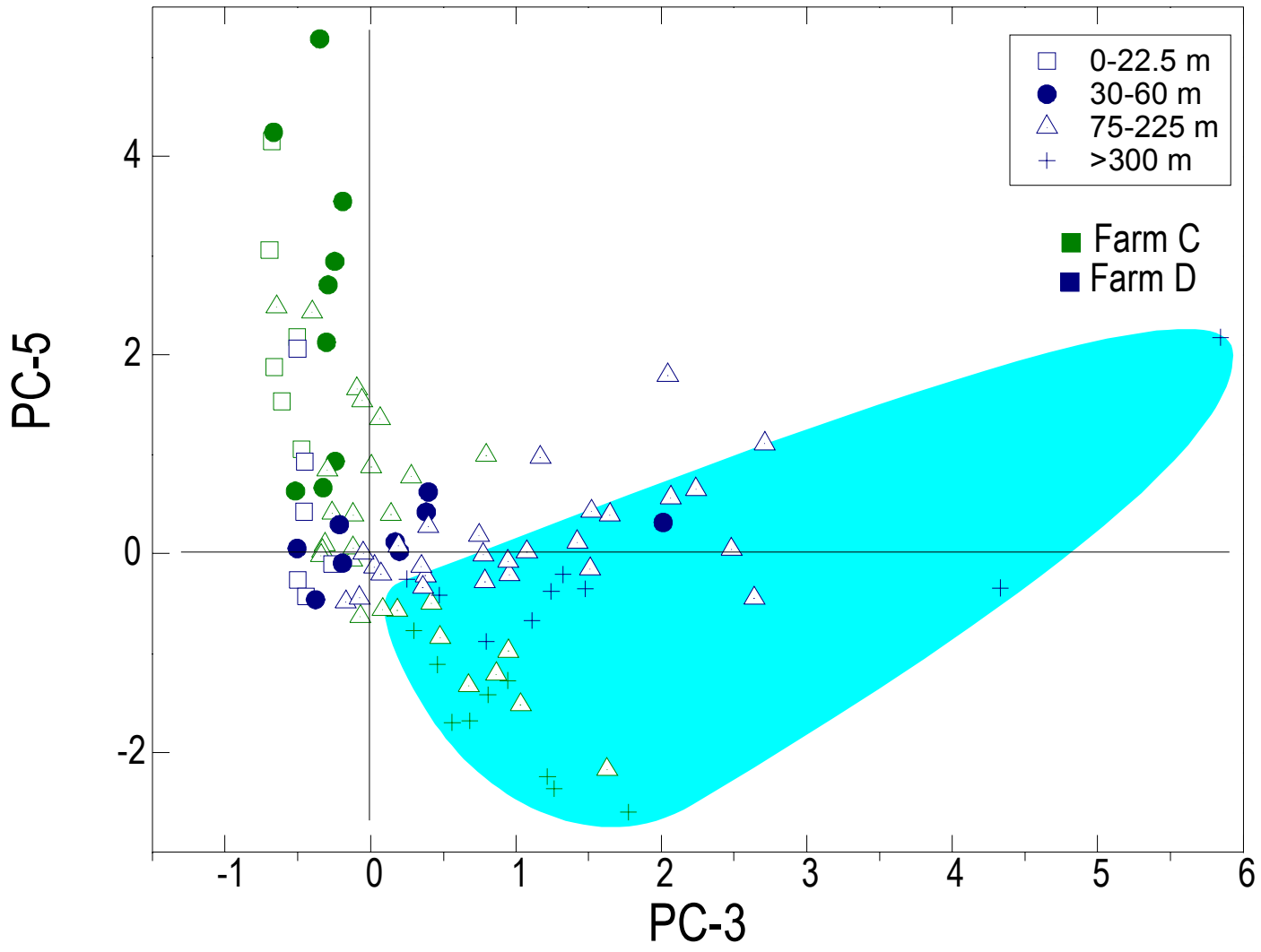
What Wildish *et al.* (2001) actually said:

"In the present study we identified organic enrichment impacts of the order of tens of meters. This is consistent with a severe effect near the centre of the steel cage array, which persisted with negative redox and sulfide > 6000 uM, for ~12 mo after cessation of salmon feeding."


Cumulative Percent of B.C. Sites
99.5
99
98
95
90
80
70
50
30
20
10
5
2
1
0.5
0.1
1
10
100
1000
10000
[Sulfide] (uM)
300
1300
4500
6000
0 m sites
(edge of operation)
30 m away
60 m away
100 m away
Reference


Taxon Richness
PC-1
0
20
40
60
80
-2
-1
0
1
2
3
4
5
0 m
7.5 - 22.5 m
30 - 60 m
75 - 225 m
Site Reference


0-22.5 m
30-60 m
75-225 m
>300 m
Farm A
Farm B
Farm E
Farm F
Farm G
PC-5
PC-1
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2
-1
0
1
2
3
4
5


0-22.5 m
30-60 m
75-225 m
>300 m
Farm C
Farm D
PC-5
PC-3
4
2
0
-2
-1
0
1
2
3
4
5
6

Non-Depositional Environments

#3. SAG felt that video survey techniques have too little power to detect spatiotemporal environmental change (combined issues of inability to see into cracks and crevices where material might accumulate; quantify smaller, more obsure biota; and high degree of spatial heterogeneity);

…Cannot, however, suggest an immediate alternative based on infancy of basic research;

4 Recommend research on hard substrate monitoring techniques in next three years (e.g. hydroacoustics, artificial substrate studies)

5 In interim, quantified video observations should fill void. Any statistically significant deviation between reference and near-site conditions should be a trigger for action, given the relative lack of power of the technique.

Over-Arching Recommendations

 # 6. Need evidence of industry and regulatory commitment to assessing cumulative effects outside of the framework of the aquaculture waste regulation.

 # 7. New reg. should be explicitly introduced as an interim reg (3 to 5 year maximum longevity) to allow for near-term filling of knowledge gaps and demonstration of current and new monitoring and assessment approaches.

 # 8. Data gaps relevant to the above must be addressed by both Federal and Provincial governments through an appropriate mechanism relative to the objectives (approach cannot be ad hoc).

#9. ...need to create an even more firm management link between assessment of the nature of the feed materials and waste discharges.

#10. INDEPENDENT OR REGULATORY AUDIT FUNCTIONS: SAG strongly recommends that the regulation be revised to include a new section on audit/quality assurance requirements.

#11. ...Recommend a **mandatory training program** for field staff doing sulphide analyses as part of QA

#12. Transparency of process: Monitoring data should be publically available. Process needs to be more transparent.

#13. Overview of Knowledge Gaps to be Addressed Over Next Three Years

- Alternatives to use of seabed videos in non-depositional environments;
- larger ecological relevance of decreased species richness; possibility of supplementing or replacing with indices of functional impairment based on ecologically allied taxa?
- Regional carrying or assimilative capacity taking into consideration nutrient flux (N, P, C)
- feed analysis and relationship with waste quality (e.g. -to determine if Hg, other PBTs, is an issue)?

- Validation of chemical surrogates such as S^{2-}, ORP, TVS, where the relationship in the field between these and other more involved measures is assessed. Their continued use for regulating waste is then accepted or rejected.

- relationship between TVS, %N, and %C?