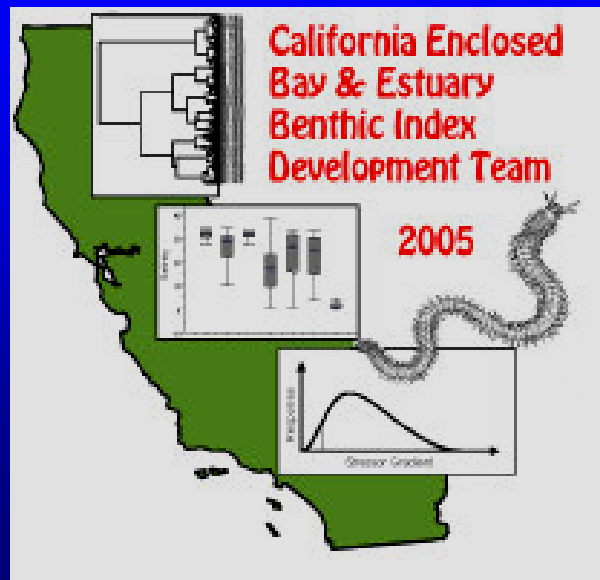
Sediment Quality Objectives
for California Enclosed Bays and Estuaries

Benthic Indicator Development

- Scientific Steering Committee
- 28th February 2006



Overview

- Previous accomplishments
  - Select a “benthic index” approach
  - Identify habitats and develop candidate indices
    - Developed five benthic indices in two habitats
- Subsequent activities
  - Evaluate indices
  - Select benthic index(es)
  - Develop index application strategy

Previous Accomplishments

- Compiled database
  - Standardized taxonomy
- Defined six habitat strata
  - Two with sufficient data for index development
    - Southern California euhaline bays
    - Polyhaline San Francisco Bay
- Identified five candidate indices
- Calibrated candidate indices in both habitats

Identified Six Habitats

1	Southern California Euhaline Bays*
2	Polyhaline San Francisco Bay*
3	Estuaries and Wetlands
4	Very Coarse Sediments
5	Mesohaline San Francisco Bay
6	Limnetic or Freshwater

* Habitats with sufficient data for index development

Five Candidate Indices

Acronym	Name
IBI	Index of Biotic Integrity
RBI	Relative Benthic Index
BRI	Benthic Response Index
RIVPACS	River Invertebrate Prediction and Classification System
BQI	Benthic Quality Index

Index Composition

Candidate Index	Data
IBI	Community measures
RBI	Community measures
BRI	Species abundances
RIVPACS	Presence/absence of multiple species
BQI	Species abundances & community measures

Overview

- Previous accomplishments
  - Select a “benthic index” approach
  - Identify habitats and develop candidate indices
    - Developed five benthic indices in two habitats
- Subsequent activities
  - Evaluate indices
  - Select benthic index(es)
  - Develop index application strategy

Index Evaluation

- Screening-level evaluation
  - Species richness
  - Independence from natural gradients
- Classification accuracy
  - Biologist best professional judgment

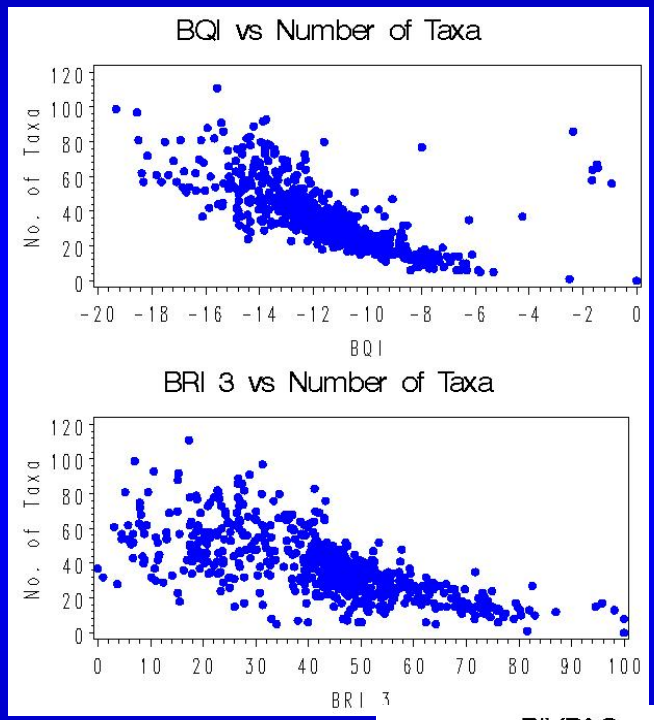
Conclusions

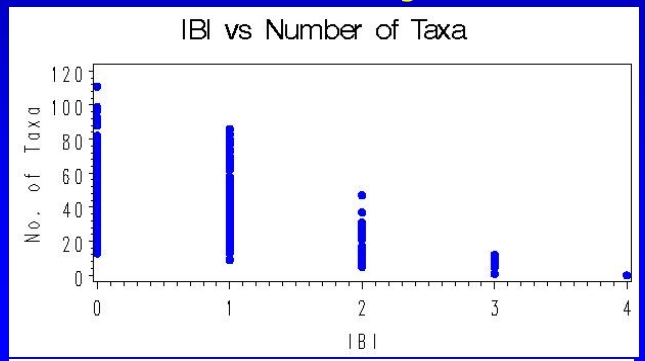
(Sneak Peek)

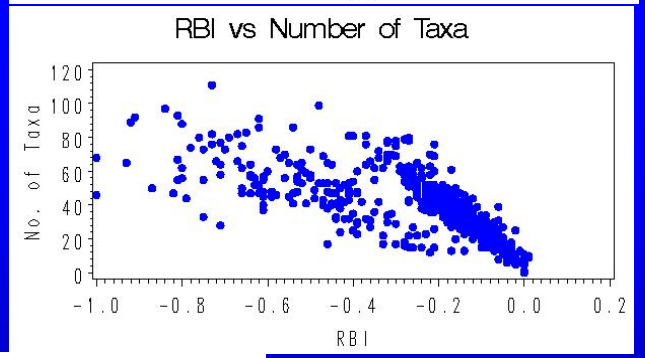
- All indices performed well
  - None stood out as much better or worse than the others

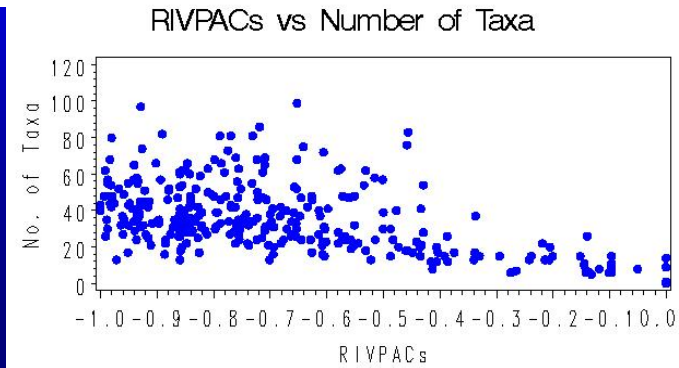
Correlations With No. of Taxa

Southern California Euhaline Bays



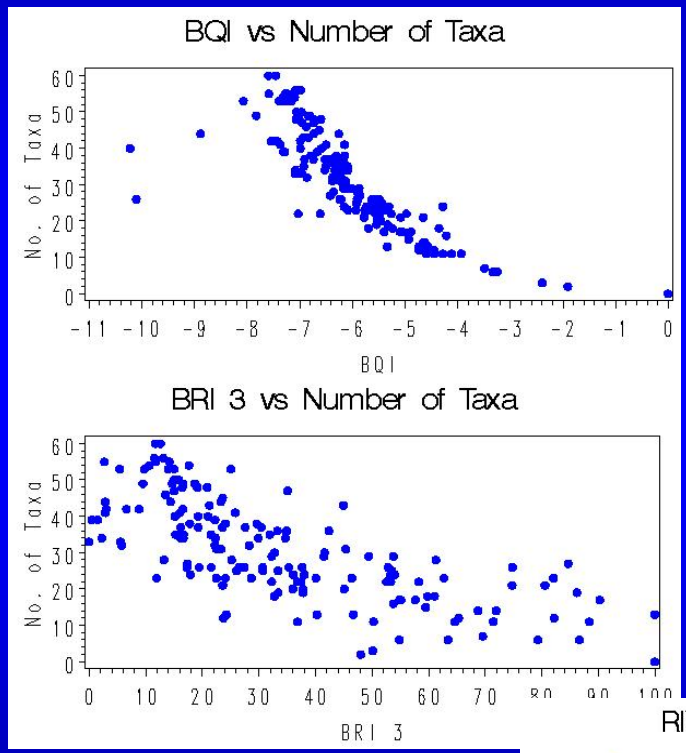


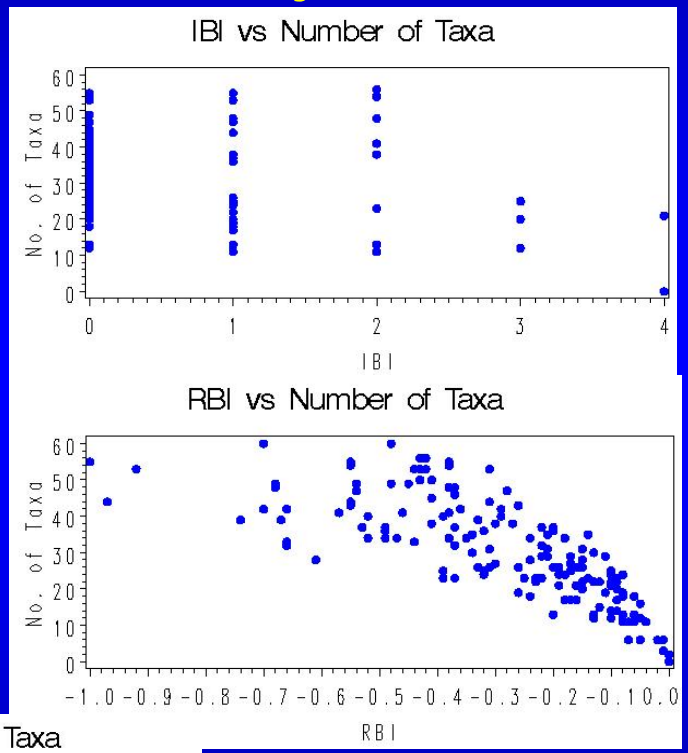


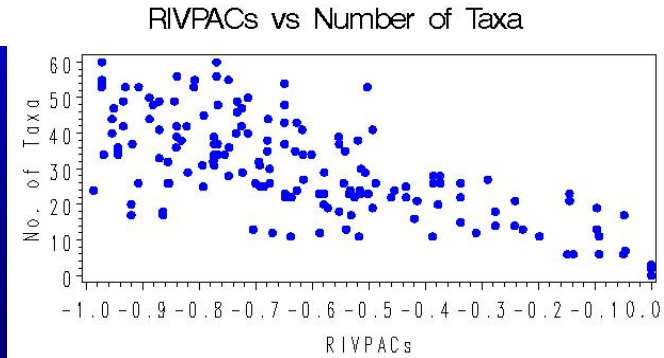


Correlations With No. of Taxa

Polyhaline San Francisco Bay





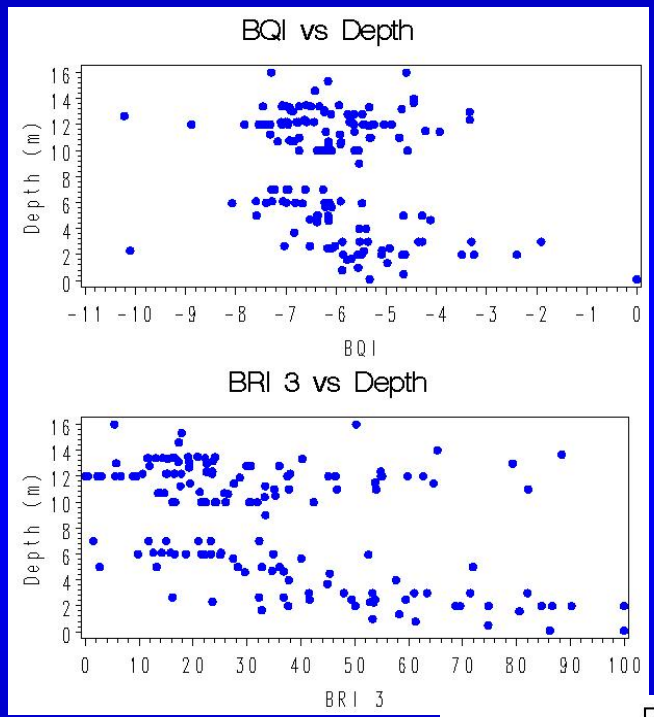


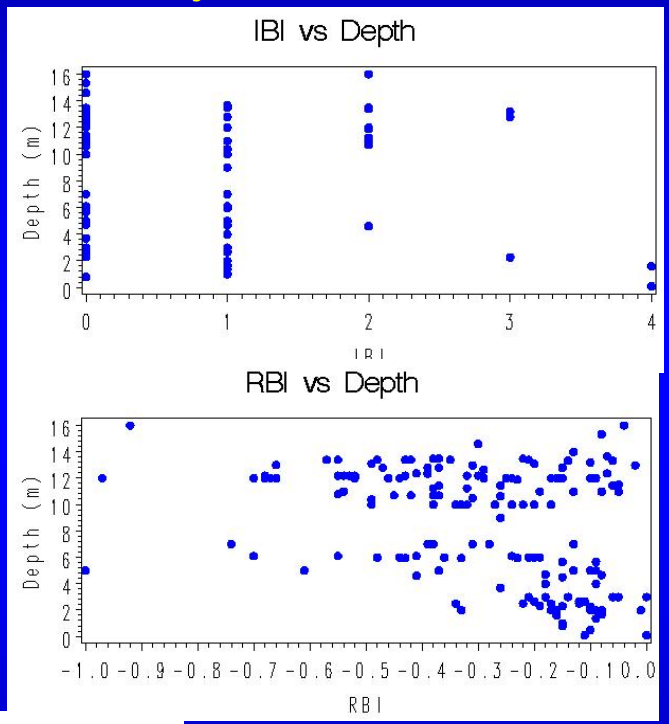
Independence From Natural Gradients

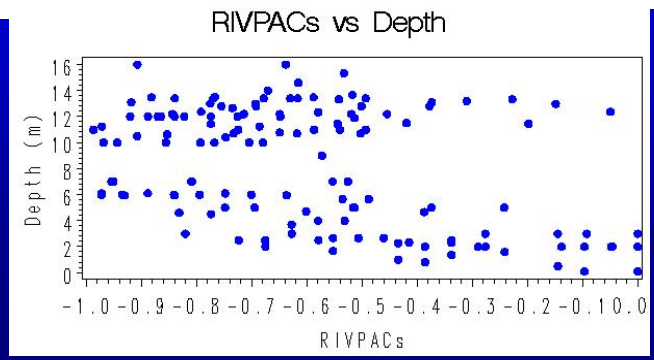
- Benthic indices should measure habitat condition
  - Rather than habitat factors
- Tested by plotting benthic indices against
  - Depth
  - Percent fines
  - Salinity
  - TOC
  - Latitude, and
  - Longitude
- Conclusion
  - The indices are not overly sensitive to habitat factors

Correlations with Depth

Polyhaline San Francisco Bay

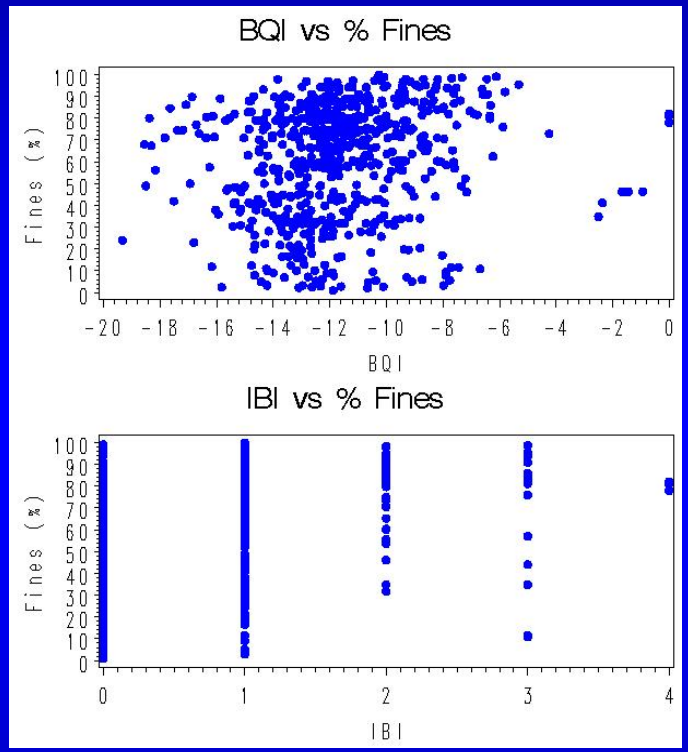


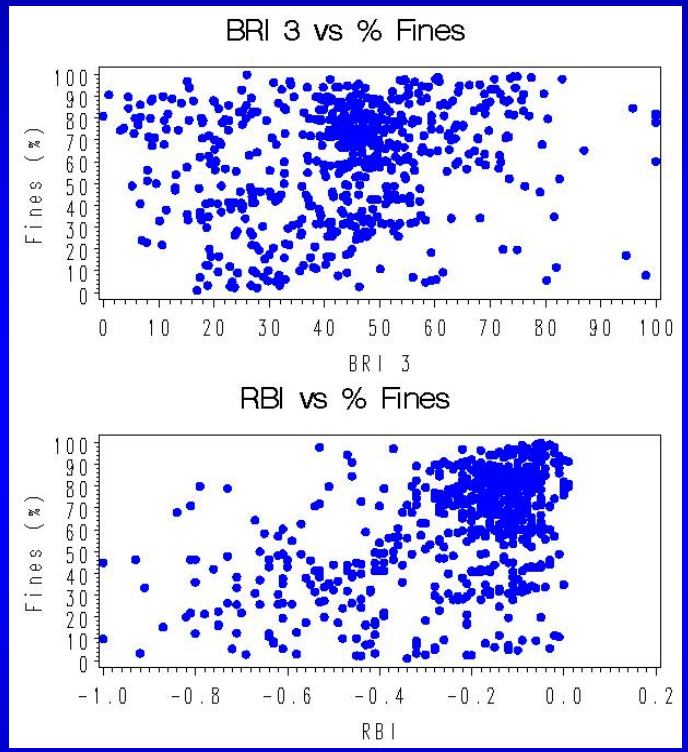


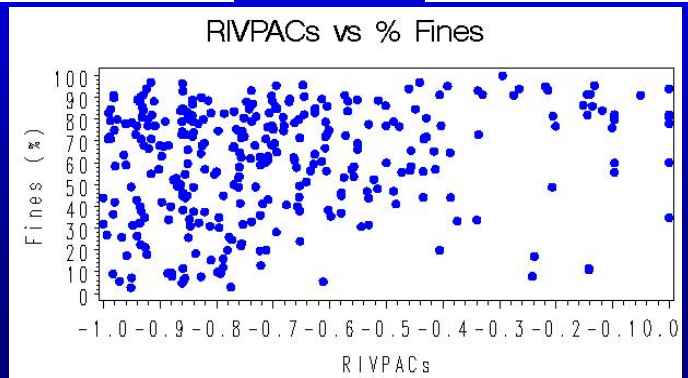


Correlations with Fine Sediments

Southern California Euhaline Bays







Correlations with Habitat Variables

Spearman Correlation Coefficients

	BQI	BRI	IBI	RBI	RIVPACs
Southern California Euhaline Bays					
Depth†	-0.38	-0.52	-0.02	-0.06	-0.05‡
Fines†	0.22	0.23	0.37	0.42	0.19‡
Salinity*	-0.14	-0.28	-0.09	0.02	0.03
TOC†	0.15	0.19	0.36	0.29	0.24‡
Latitude†	-0.05	-0.15	-0.16	-0.12	0,21‡
Longitude†	0.10	0.22	0.21	0.15	-0.15‡
†: n=670; ‡: n=320; *: n=66					
Polyhaline San Francisco Bay					
Depth	-0.29	-0.48	-0.14	-0.38	-0.32
Fines	0.53	0.56	0.25	0.61	0.49
Salinity	-0.38	-0.40	-0.05	-0.42	-0.31
TOC	0.49	0.60	0.21	0.57	0.46
Latitude	-0.39	-0.50	-0.05	-0.32	-0.21
Longitude	0.31	0.54	0.21	0.36	0.05
n=160 for all indices other than the IBI, where n=112					

Classification Accuracy

- Index results compared to biologist BPJ
  - Nine benthic ecologists
    - Ranked samples on condition, and
    - Evaluated on a four-category scale
      - Reference, Marginal, Affected, Severely affected
- 36 samples
  - Covering the range of conditions encountered
    - On a chemical contamination gradient
- Data provided
  - Species abundances
  - Region, depth, salinity, and sediment grain size

Advantages of BPJ Comparison

- Provides an opportunity to assess intermediate samples
  - Previous benthic index efforts focused on extremes
- Quantifies classification consistency
  - Provides a means for assessing how well indices are working
  - The commonly used 80% standard has no basis

Evaluation Process

- Two-step evaluation
  - Quantified expert performance
    - Condition ranks
    - Category concordance
      - Are there “outlier” experts?
  - Compared index and expert results
    - Condition ranks
    - Category concordance

Condition Rank Correlations

Southern California Euhaline Bays

n=24; $p < 0.0001$ for all cases

	C	D	M	N	O	R	T	V
D	0.88							
M	0.91	0.96						
N	0.92	0.90	0.89					
O	0.92	0.93	0.96	0.90				
R	0.92	0.93	0.92	0.93	0.95			
T	0.93	0.92	0.93	0.94	0.92	0.93		
V	0.93	0.91	0.92	0.93	0.93	0.95	0.96	
W	0.81	0.83	0.84	0.80	0.88	0.90	0.80	0.81

Condition Rank Correlations

Polyhaline San Francisco Bay

n=12; $p < 0.001$ for all cases

	C	D	M	N	O	R	T	V
D	0.93							
M	0.97	0.96						
N	0.94	0.84	0.93					
O	0.95	0.91	0.92	0.87				
R	0.92	0.89	0.92	0.86	0.97			
T	0.97	0.95	0.99	0.93	0.92	0.92		
V	0.97	0.94	0.98	0.93	0.94	0.94	0.99	
W	0.92	0.86	0.89	0.87	0.97	0.98	0.89	0.90

Condition Categories

Southern California Euhaline Bays

#	C	D	M	N	O	R	T	V	W
21	A	M	M	A	M	M	A	A	M
22	M	M	M	M	M	M	M	M	A
23	R	R	R	R	R	R	R	R	M
24	M	M	M	A	M	M	M	M	M
25	R	R	R	R	R	R	R	R	M
26	S	S	S	S	S	S	A	S	S
27	R	R	R	R	R	M	R	R	A
28	S	S	S	A	S	A	S	S	S
29	M	R	R	M	M	M	M	R	M
30	A	M	M	M	A	A	A	A	A
31	A	A	A	M	A	A	A	A	A
32	A	A	M	A	M	A	M	M	A
33	A	M	A	A	A	A	A	A	A
34	S	S	S	S	S	S	A	S	S
35	M	A	M	M	M	M	M	M	A
36	S	S	S	S	S	A	S	S	A
37	R	R	R	R	R	R	M	R	R
38	S	S	S	S	S	S	A	S	A
39	A	S	S	S	S	S	S	S	S
40	R	R	R	R	R	R	M	R	R
41	S	A	S	A	S	A	A	A	A
42	A	A	A	A	A	A	A	A	A
43	M	R	M	M	A	M	R	M	M
44	R	R	R	R	M	R	M	R	R

Condition Categories

Polyhaline San Francisco Bay

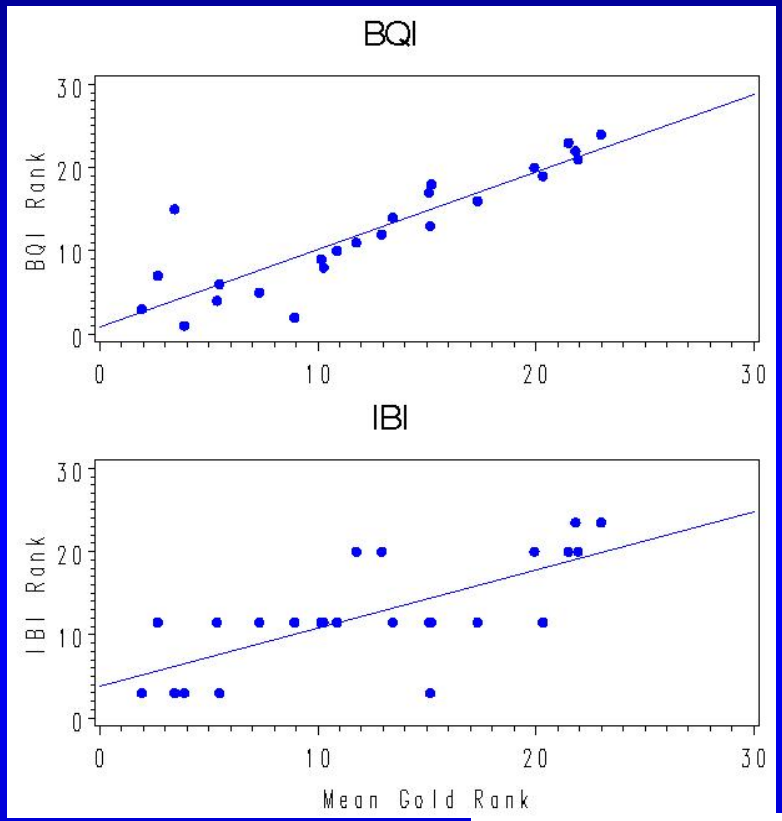
#	C	D	M	N	O	R	T	V	W
1	S	S	S	S	A	A	S	S	S
2	R	R	R	R	R	R	R	R	M
3	R	R	R	M	R	R	R	R	M
4	S	S	S	S	S	S	S	S	S
5	M	R	R	A	R	R	R	R	M
6	A	M	M	M	M	M	M	M	M
7	M	R	R	R	R	R	R	R	R
8	S	S	S	S	S	S	S	S	S
9	S	S	S	S	S	S	S	S	S
10	A	M	A	M	M	M	A	A	M
11	M	R	R	R	R	R	R	R	R
12	A	M	A	A	M	M	A	A	A

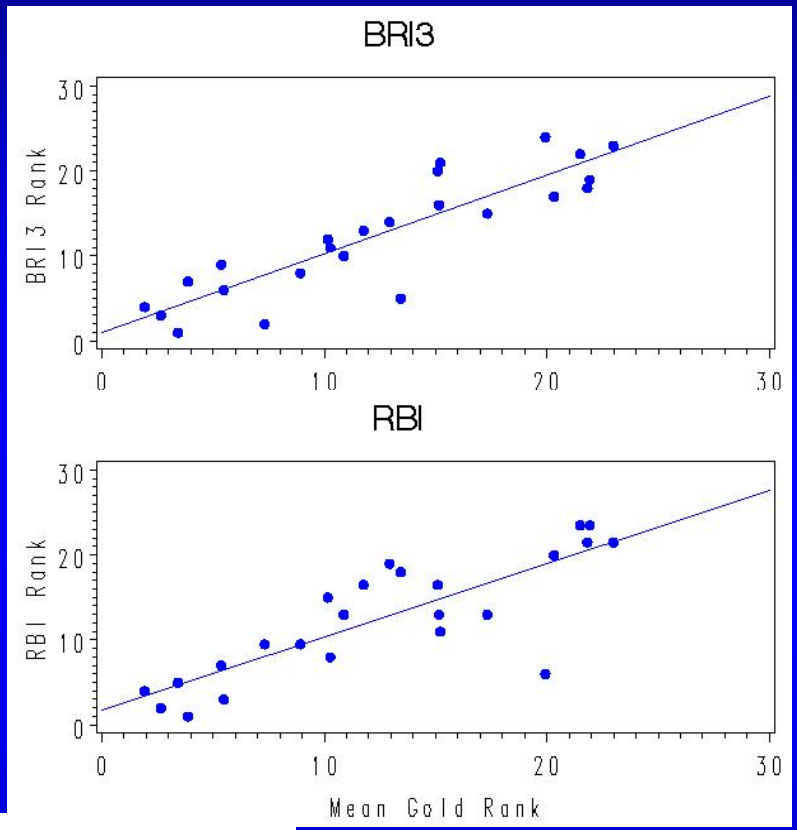
Index Evaluation

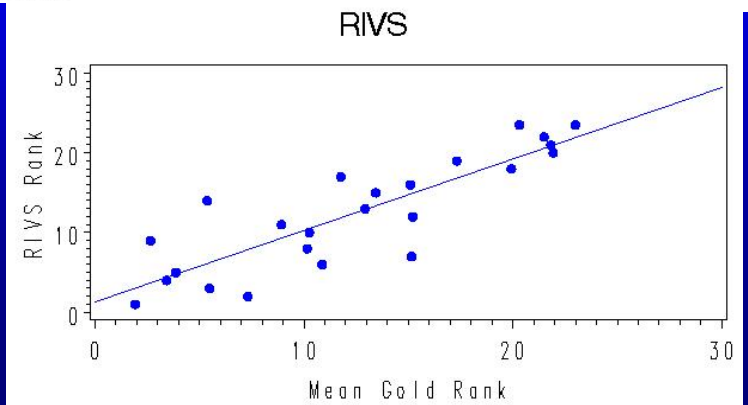
Correlation of Candidate Index Rank with Mean Rater Rank

Index	Euhaline SoCal Bays	Polyhaline San Francisco Bay
BQI	0.89	0.92
BRI	0.88	0.83
IBI	0.70	0.85
RBI	0.82	0.90
RIVPACs	0.84	0.86
Mean Rater Correlation (n=9)	0.95	0.96

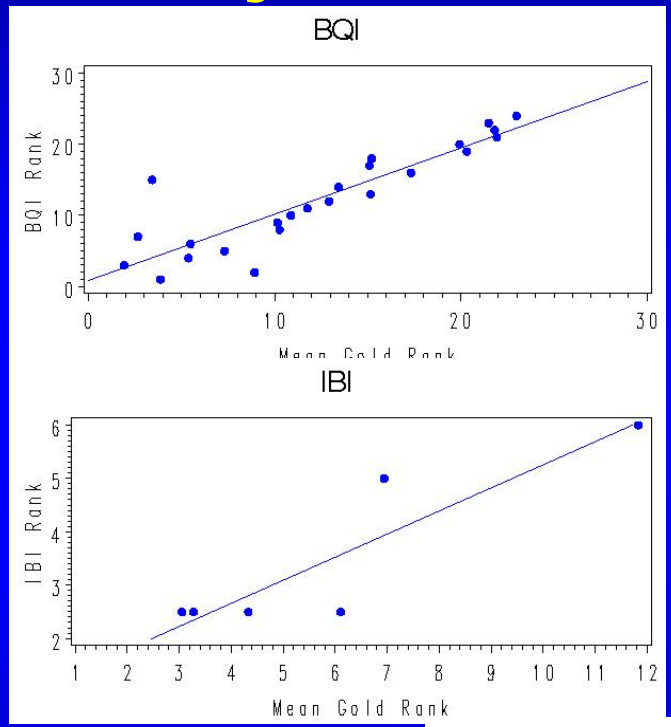
Southern California Euhaline Bays

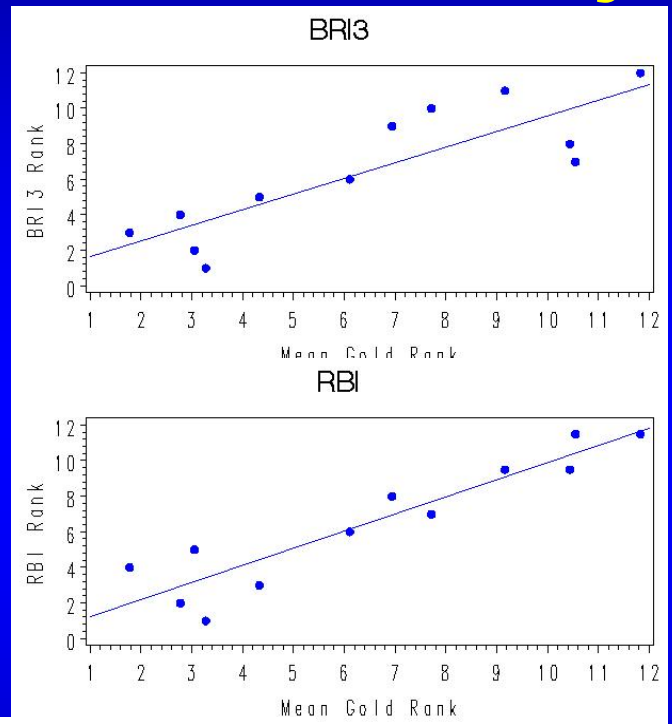


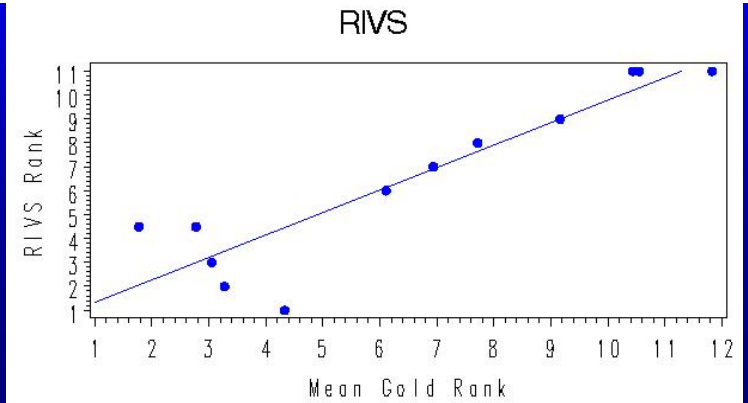




Polyhaline San Francisco Bay







Classification Accuracy

- How well do candidate indices evaluate condition category?
- Assessed at two levels
  - Status (Good or Bad)
  - Four-category scale
    - Reference, Marginal, Affected, Severely affected

Index Classification Accuracy

Status: Good or Bad

Index	Southern California Euhaline Bays (n=24)	Polyhaline San Francisco Bay (n=11)
BQI	79.2	100.0
BRI	87.5	100.0
IBI	70.8	100.0
RBI	75.0	100.0
RIVPACs	91.7	100.0
Raters	91.2	94.9

Index Classification Accuracy

Four-Category Classification

Index	Southern California Euhaline Bays (n=24)	Polyhaline San Francisco Bay (n=11)
BQI	62.5	90.9
BRI	58.3	72.7
IBI	50.0	80.0
RBI	50.0	72.7
RIVPACs	62.5	81.8
Raters	80.1	85.9

Overview

- Previous accomplishments
  - Select a “benthic index” approach
  - Identify habitats and develop candidate indices
    - Developed five benthic indices in two habitats
- Subsequent activities
  - Evaluate indices
  - Select benthic index(es)
  - Develop index application strategy

Select Benthic Indices

- We tried combining indices to improve classification accuracy
  - Tested many different permutations and combinations
- Index combinations improved results
  - Several different combinations yielded similar results
- We selected three indices previously published, applied and accepted in California
  - BRI, IBI, and RBI
  - Combined as the median condition category
  - Classification accuracy was similar to several other combinations

Classification Accuracy
BRI-IBI-RBI Combination

Measure	Southern California Euhaline Bays (n=24)		Polyhaline San Francisco Bay (n=11)	
	Good-Bad	Four-Category	Good-Bad	Four-Category
BRI-IBI-RBI Combination	87.5	70.8	100.0	72.7
Index Range	70.8-87.5	50.0-58.3	100.0	72.7-80.0
Experts	91.2	80.1	94.9	85.9

Conclusion

- Experts did well
  - Index combinations did almost as well
- Many index combinations worked equally well
  - Not as well as the average expert
  - But better than the weakest expert
- We selected a combination of three indices previously accepted and used in California