



**A new integrated approach to  
establish fish health as an indicator  
of ecological stressors  
Part 2**

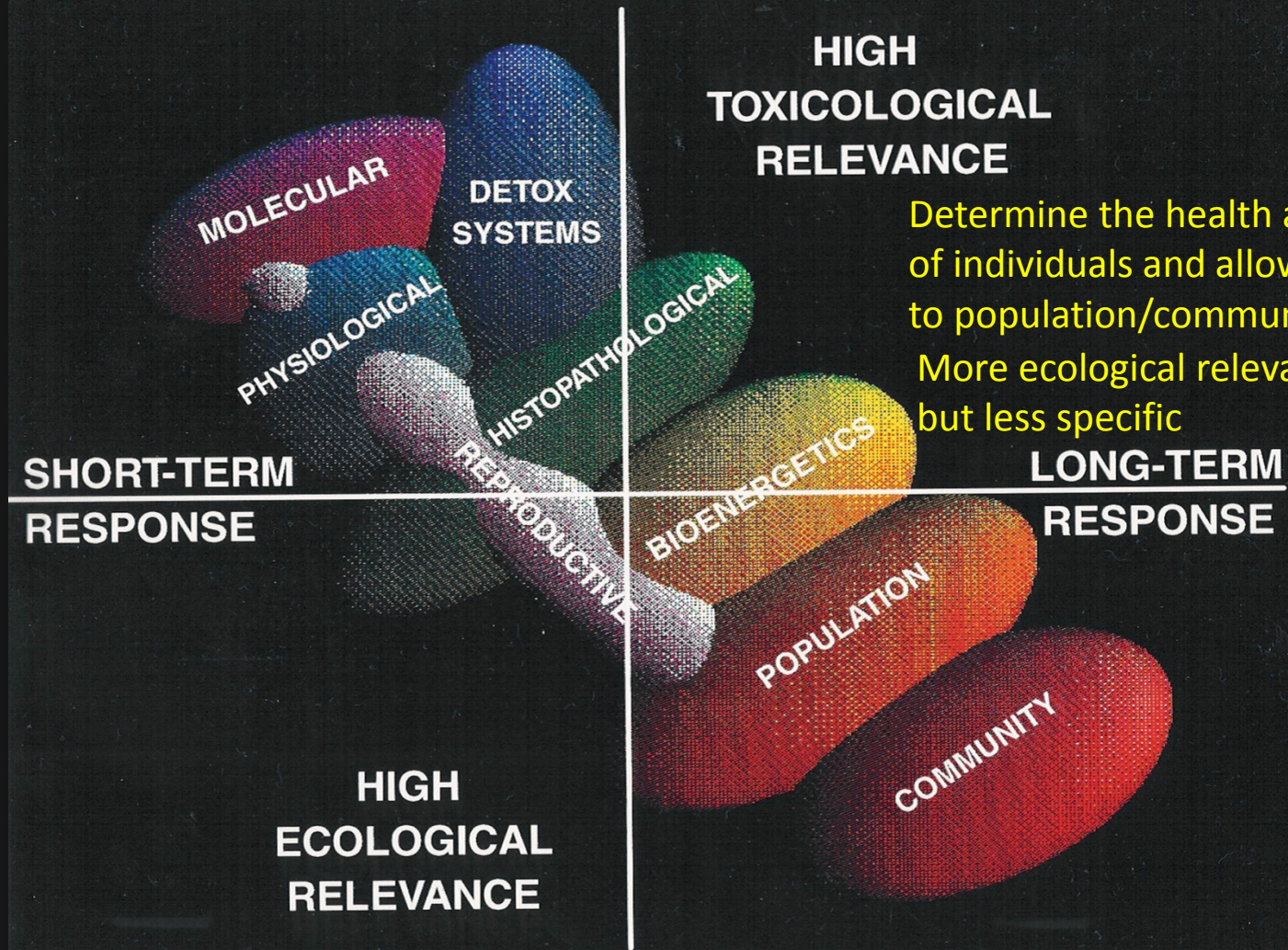
**Swee Teh,**

**Javidmehr A, Gandhi S, Baxa DV, Kurobe T, Acuna SC, Hobbs, J, and Baxter, R**

# Overview

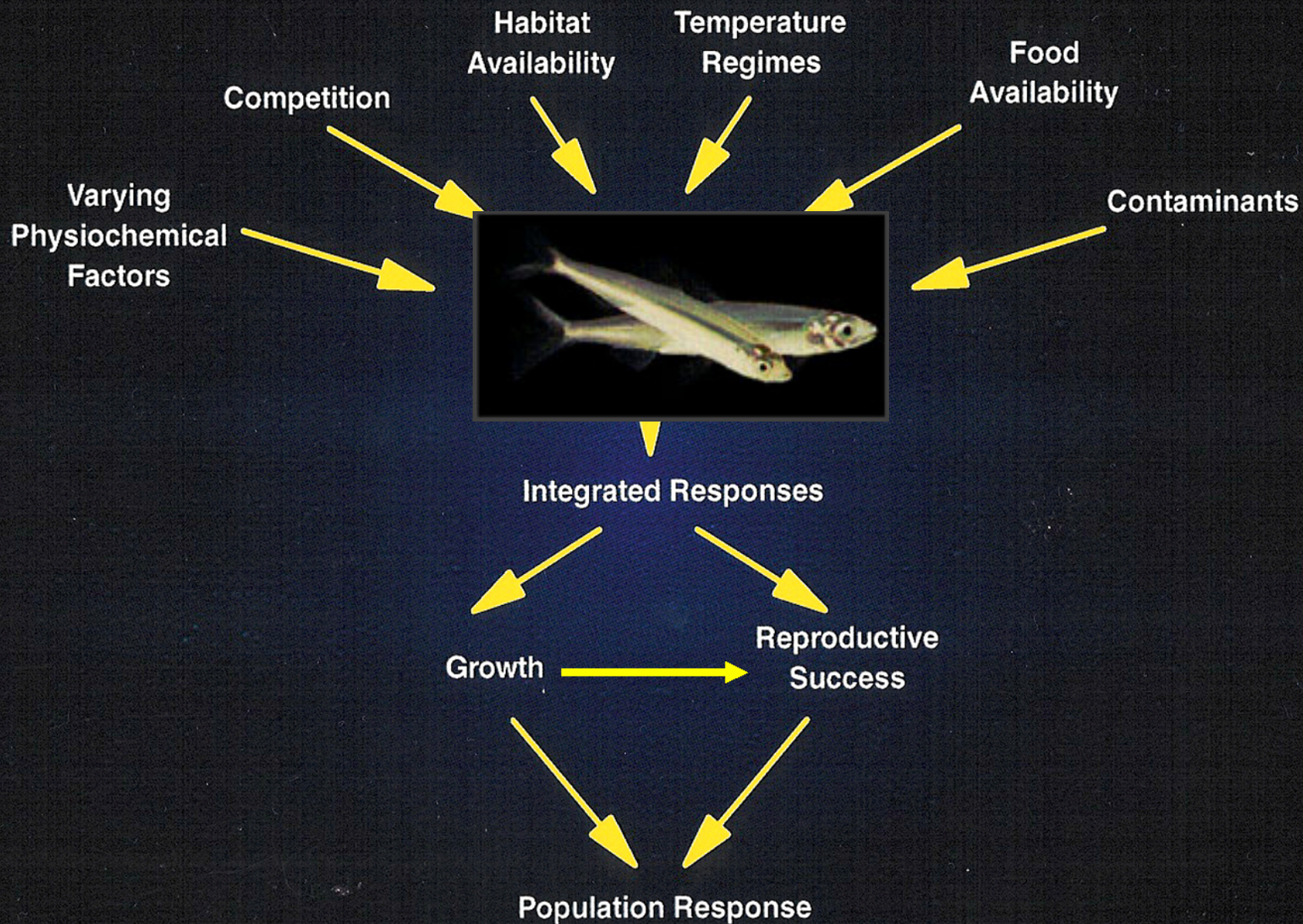
- Delta smelt as a biomonitoring tool for assessing the San Francisco estuarine ecosystem health
- Creating baseline Fish Health Index (FHI) for assessing delta smelt health
- Biomodeling of delta smelt population health
- Using FHI to evaluate and identify multiple stressors
- Future Approach

More specific, sensitive, and reproducible  
But more difficult to relate to ecological changes and generally unrealistic



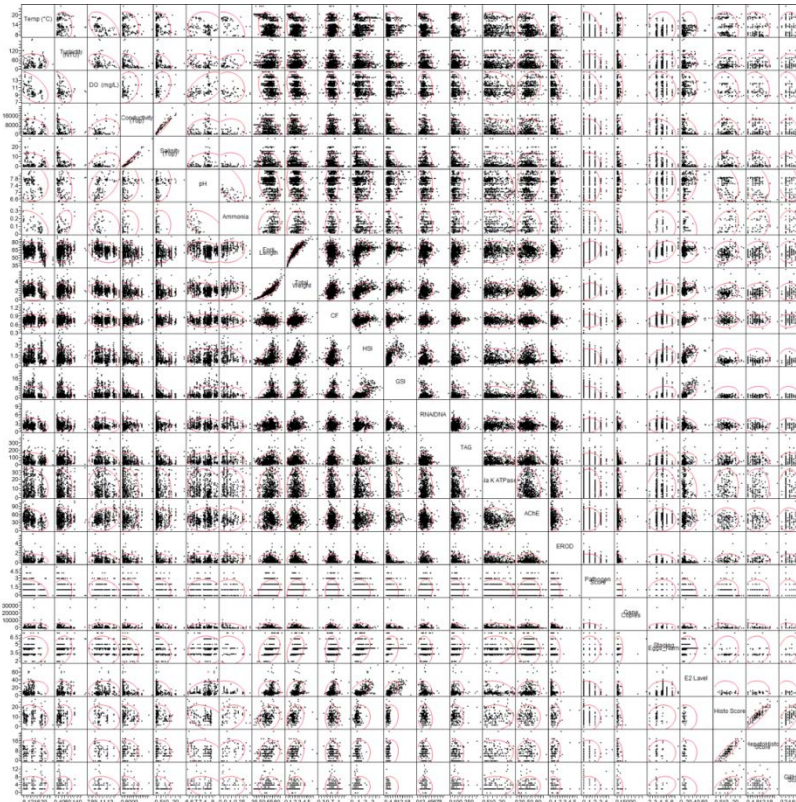
Determine the health and fitness of individuals and allow extrapolation to population/community effects  
More ecological relevance but less specific

Directly indicative of ecosystem health, more relevant to environmental management  
But difficult to determine, least specific, manifest when environmental damages have already occurred



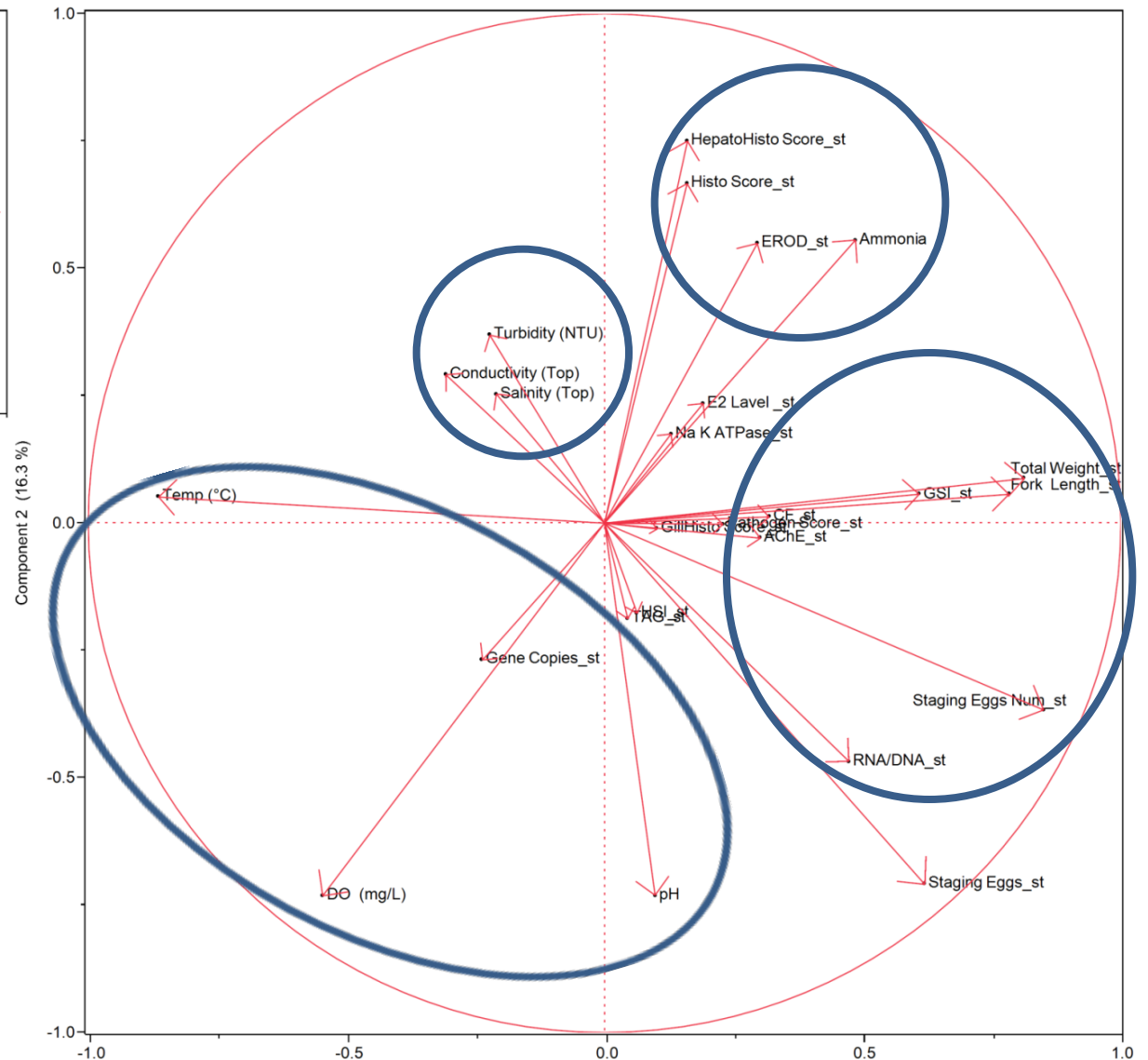
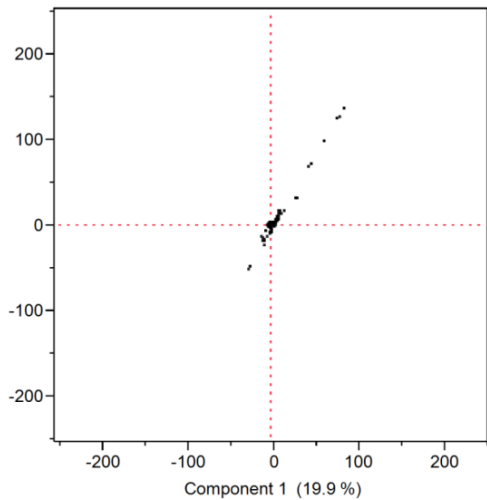
# Univariate Analysis

	Temp (°C)	Turbidity (NTU)	DO (mg/L)	Conductivity (Top)	Salinity (Top)	pH	Ammonia	Fork Length	Total Weight	CF	HSI	GSI	RNA/DNA	TAG	Na K ATPase	AChe	EROD	Pathogen Score	Gene Copies	Staging Eggs_Num	E2 Level	Histo Score	HepatoHisto Score	GillHisto Score
Temp (°C)	1.0000	0.0755	-0.5220	-0.0989	-0.1785	-0.0974	-0.3892	-0.2724	-0.1464	-0.0048	0.1947	0.1147	-0.2296	0.0010	-0.0424	-0.3608	-0.0301	-0.3096	0.1542	0.0816	0.1915	-0.1116	-0.1496	0.0549
Turbidity (NTU)	0.0755	1.0000	-0.4785	-0.1690	-0.2400	-0.3489	0.4697	0.1202	0.1777	0.0647	0.0891	0.0870	-0.1718	0.1665	0.0514	0.0458	0.1074	0.1030	0.0157	0.2368	0.0622	0.1946	0.1602	0.1469
DO (mg/L)	-0.5220	-0.4785	1.0000	0.2251	0.3046	0.4876	-0.1162	-0.2844	-0.3246	-0.1222	-0.1615	-0.1308	-0.0974	-0.1619	-0.1009	0.2514	-0.1729	-0.2355	-0.0591	-0.1365	0.0486	-0.1927	-0.1345	-0.2065
Conductivity (Top)	-0.0989	-0.1690	0.2251	1.0000	0.9806	0.0272	0.1175	-0.1717	-0.1636	-0.0486	-0.1543	-0.1780	-0.0381	-0.0238	0.0131	0.0571	0.0226	-0.0178	0.0282	-0.3058	-0.2523	0.0250	0.0799	-0.1076
Salinity (Top)	-0.1785	-0.2400	0.3046	0.9806	1.0000	0.1040	0.0716	-0.1482	-0.1607	-0.0454	-0.1557	-0.1709	-0.0322	-0.0423	0.0017	0.1011	0.0051	-0.0049	0.0295	-0.2882	-0.2264	-0.0034	0.0605	-0.1372
pH	-0.0974	-0.3489	0.4876	0.0272	0.1040	1.0000	-0.5649	-0.3136	-0.2918	0.0760	-0.0296	0.0609	-0.0808	-0.1779	-0.1738	0.1399	-0.2448	-0.1377	0.1139	-0.0132	0.2676	-0.3749	-0.3212	-0.2522
Ammonia	-0.3892	0.4697	-0.1162	0.0716	0.0716	-0.5649	1.0000	0.1633	0.1798	0.0673	-0.1264	-0.1219	-0.1273	0.0724	0.0312	0.0807	0.2412	0.0130	-0.2242	-0.0661	-0.3098	0.3186	-0.3322	0.0725
Fork Length	-0.2724	0.1202	-0.2844	-0.1717	-0.1482	-0.3136	0.1633	1.0000	0.9198	-0.0280	0.4147	0.3321	0.1034	0.1318	0.0846	0.0187	-0.0379	0.2742	-0.0405	0.4034	0.0938	0.2277	0.2411	0.0529
Total Weight	-0.1464	0.1777	-0.3246	-0.1636	-0.1607	-0.2918	0.1798	0.9198	1.0000	0.2744	0.4911	0.4062	0.1077	0.1850	0.0592	-0.0146	-0.0506	0.2341	-0.0728	0.3689	0.2049	0.2381	0.2455	0.0720
CF	-0.0048	0.0647	-0.1222	-0.0486	-0.0454	0.0760	0.0673	-0.0280	0.2744	1.0000	0.1756	0.2417	0.0765	0.1571	-0.0366	0.0107	-0.0613	0.0086	-0.0496	0.0490	0.2673	0.0229	0.0052	0.0491
HSI	0.1947	0.0891	-0.1615	-0.1543	-0.1557	-0.0296	-0.1264	0.4147	0.4911	0.1756	1.0000	0.6301	0.0345	0.1363	0.0252	0.0159	-0.2872	0.0018	0.0395	0.3433	0.5768	0.0659	0.0671	0.0188
GSI	0.1147	0.0870	-0.1308	-0.1780	-0.1709	0.0609	-0.1219	0.3321	0.4062	0.2417	0.6301	1.0000	-0.0923	0.0303	0.0074	0.0458	-0.2806	-0.0484	0.0101	0.2594	0.6368	0.1495	0.1905	-0.0413
RNA/DNA	-0.2296	-0.1718	-0.0974	-0.0381	-0.0322	-0.0808	-0.1273	0.1034	0.1077	0.0765	0.0345	-0.0923	1.0000	-0.0300	0.0034	-0.0234	-0.0251	0.1721	0.0219	-0.1167	-0.2096	-0.1438	-0.1259	-0.0927
TAG	0.0010	0.1665	-0.1619	-0.0238	-0.0423	-0.1779	0.0724	0.1318	0.1850	0.1571	0.1363	0.0303	-0.0300	1.0000	-0.0398	0.0466	0.0348	0.1074	-0.1090	0.0398	0.0614	0.0562	0.0345	0.0591
Na K ATPase	-0.0424	0.0514	-0.1009	0.0131	0.0017	-0.1738	0.0312	0.0846	0.0592	-0.0366	0.0107	0.0074	-0.0398	1.0000	1.0000	-0.1244	-0.0254	0.0348	-0.0391	-0.0189	-0.1643	0.1263	0.0660	0.0788
AChe	-0.3608	0.0458	0.2514	0.0571	0.1011	0.1399	0.0807	0.0187	-0.0146	0.0107	0.0159	0.0458	-0.0234	0.0466	-0.1244	1.0000	-0.0254	0.0795	-0.0271	-0.0189	0.1451	0.0274	0.0091	0.0487
EROD	-0.0301	0.1074	-0.1729	0.0228	0.0051	-0.2448	0.2412	-0.0379	-0.0506	-0.0613	-0.2872	-0.2806	-0.0251	0.0348	-0.0240	-0.0254	1.0000	0.0289	-0.0601	-0.1933	-0.1643	0.2432	0.2857	-0.0097
Pathogen Score	-0.3096	0.1030	-0.2355	-0.0178	-0.0049	-0.1377	0.0130	0.2742	0.2341	0.0086	0.0018	-0.0484	0.1721	0.1074	0.0348	0.0795	0.0289	1.0000	-0.0465	0.1162	-0.1311	0.0182	0.0245	-0.0112
Gene Copies	0.1542	0.0157	-0.0591	0.0282	0.0051	0.1139	-0.2242	-0.0405	-0.0728	-0.0496	0.0395	0.0101	-0.0219	-0.1090	-0.0391	-0.0271	-0.0601	-0.0465	1.0000	0.0761	-0.0087	-0.3034	-0.3038	-0.1095
Staging Eggs_Num	0.0816	0.2368	-0.1365	-0.3058	-0.2882	-0.0132	-0.0661	0.4034	0.3889	0.0490	0.3433	0.2594	-0.1167	0.0398	0.0630	-0.0189	-0.1933	0.1162	0.0761	1.0000	0.1427	0.1263	0.0383	0.2535
E2 Level	0.1915	0.0622	0.0486	-0.0178	-0.2523	-0.2264	0.2676	-0.3098	0.0938	0.2049	0.2673	0.5768	0.6368	-0.2096	-0.1696	0.1451	-0.1643	-0.1311	-0.0087	0.1427	1.0000	-0.0227	0.0660	-0.2179
Histo Score	-0.1116	0.1946	-0.1927	0.0250	-0.0034	-0.3749	0.3186	0.2277	0.2381	0.0229	0.0659	0.1495	-0.1438	0.0562	0.0805	0.0274	0.2432	0.0182	-0.3034	0.1263	-0.0227	1.0000	0.9190	0.5525
HepatoHisto Score	-0.1496	0.1602	-0.1345	0.0605	-0.3212	0.3332	0.2411	0.2455	0.0052	0.0671	0.1905	-0.1259	0.0345	0.0544	0.0091	0.2857	0.0245	-0.3038	0.0245	0.0363	0.0660	0.9190	1.0000	0.1792
GillHisto Score	0.0549	0.1469	-0.2065	-0.1076	-0.1372	-0.2522	0.0725	0.0529	0.0720	0.0491	0.0188	-0.0413	-0.0927	0.0591	0.0788	0.0487	-0.0097	-0.0112	-0.1095	0.2535	-0.2179	0.5525	0.1792	1.0000



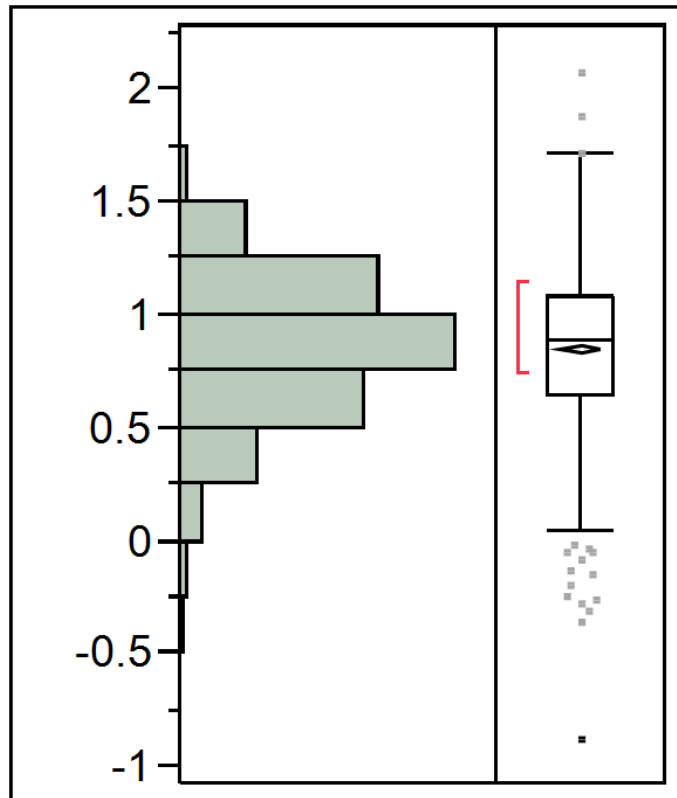
# Establishing Fish Health Index (FHI)

## Principal Component Analysis (PCA)

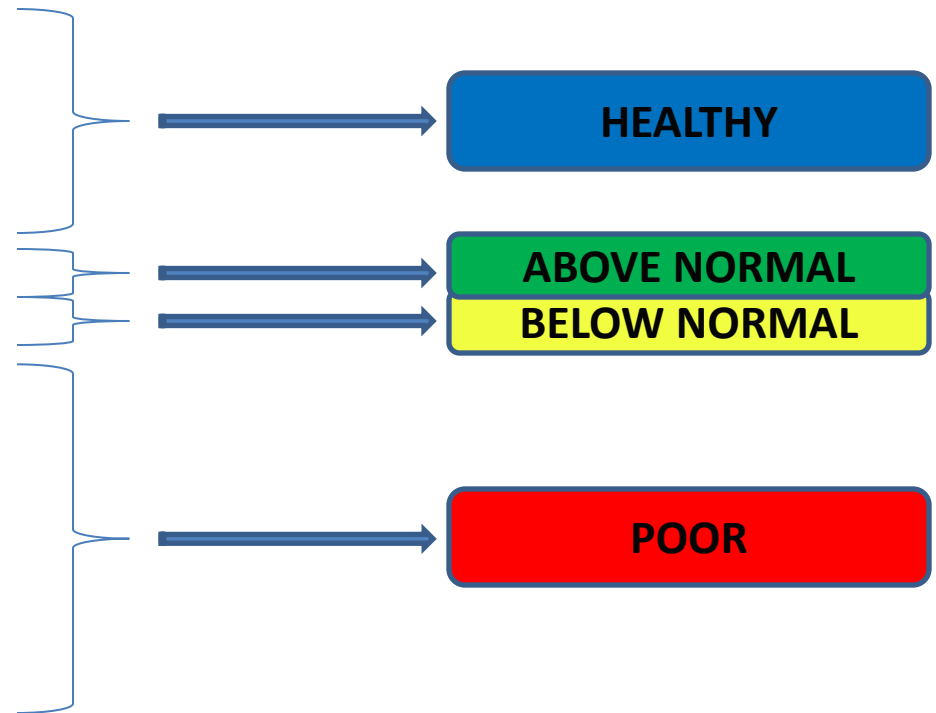


# Establishing Fish Health Index (FHI)

## FHI Distribution Study

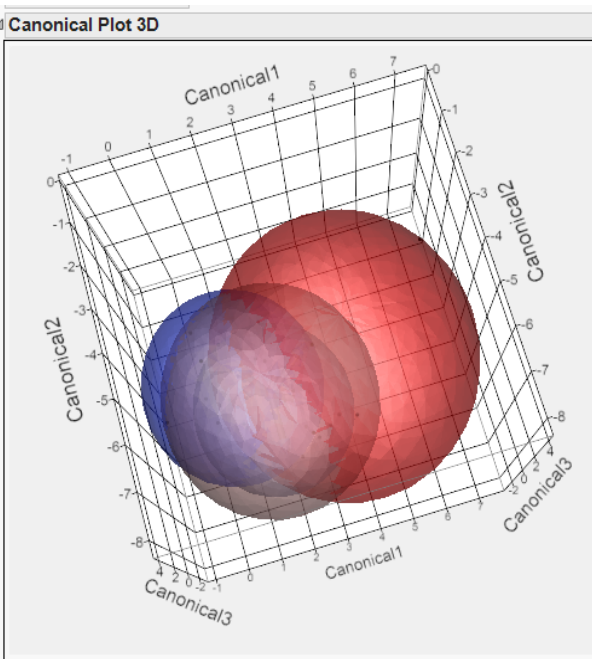


2011 Cohort

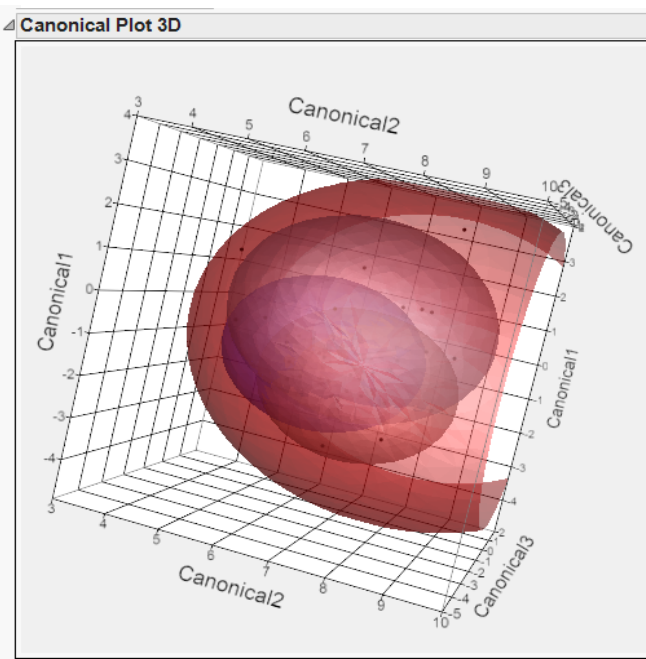


# FHI Canonical Analysis

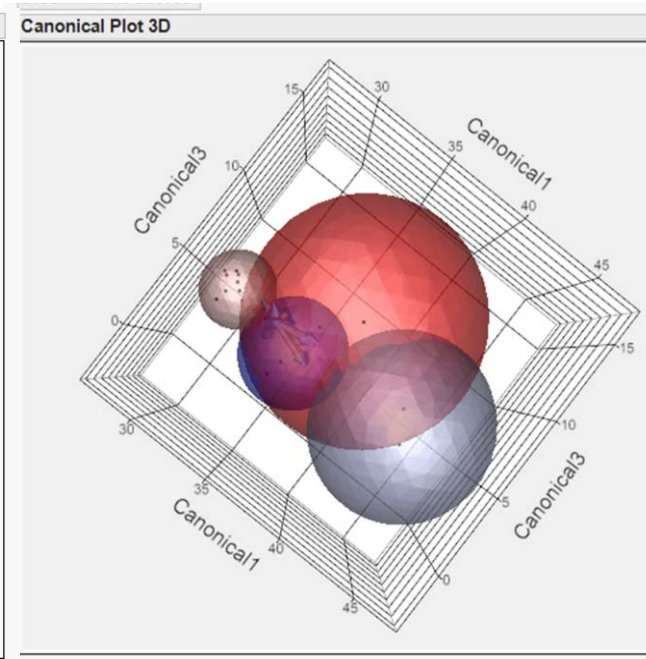
2011 FMWT



2012 FMWT



2011-12 FMWT



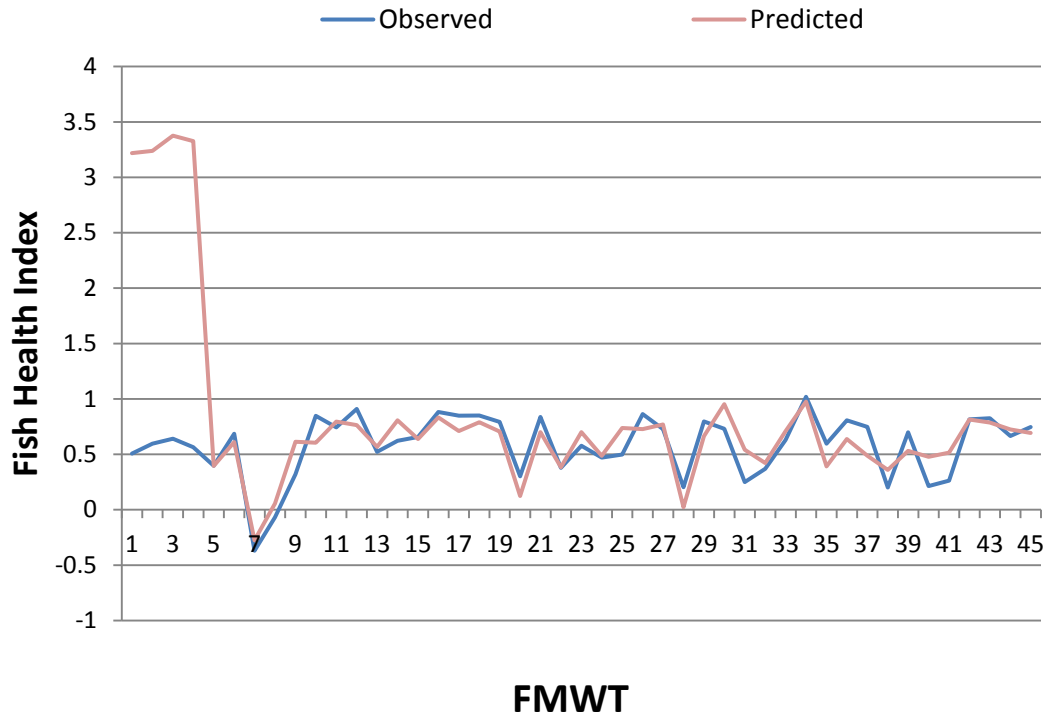
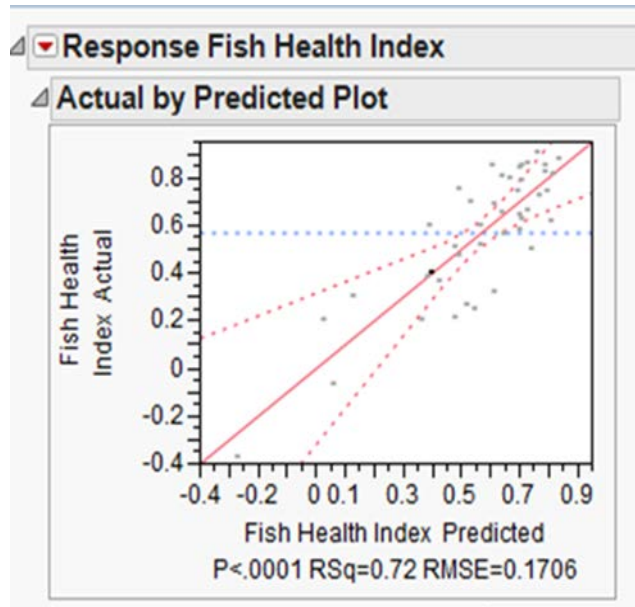
**Poor** ; **Below Normal** ; **Above Normal** ; **Healthy**

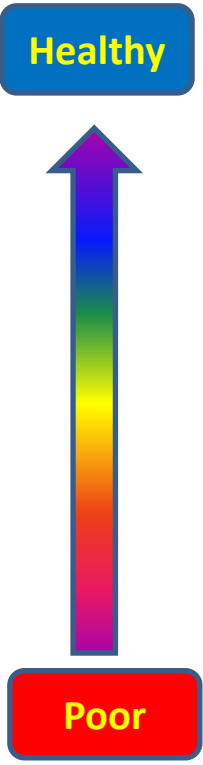
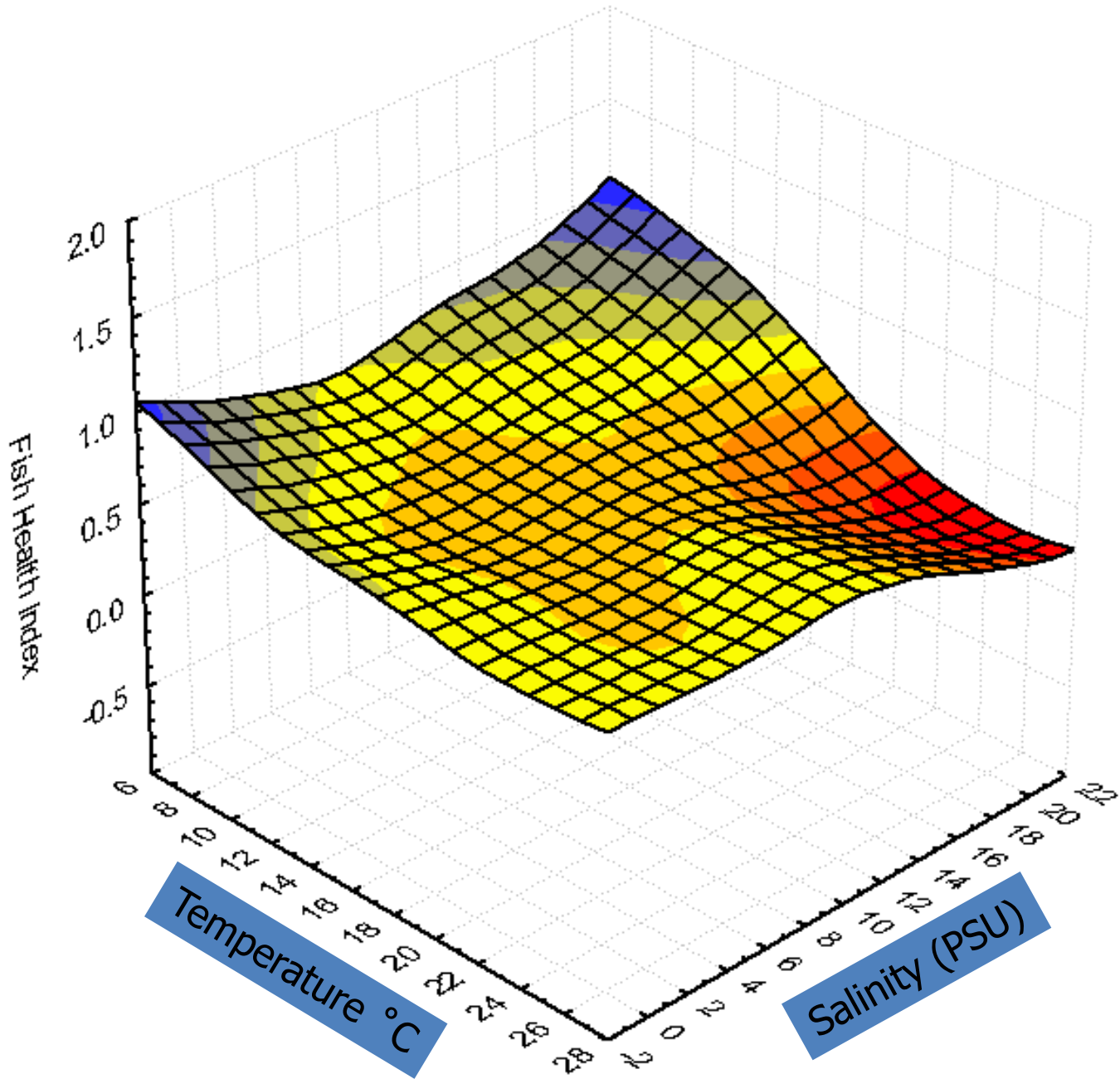
Indices in Canonical Discriminant Analysis:

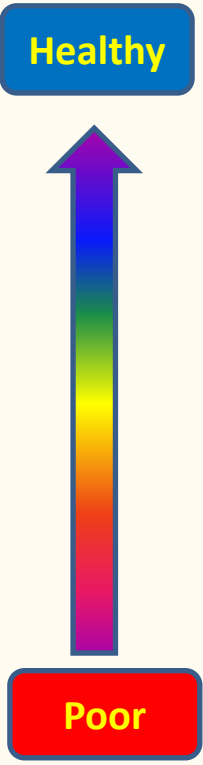
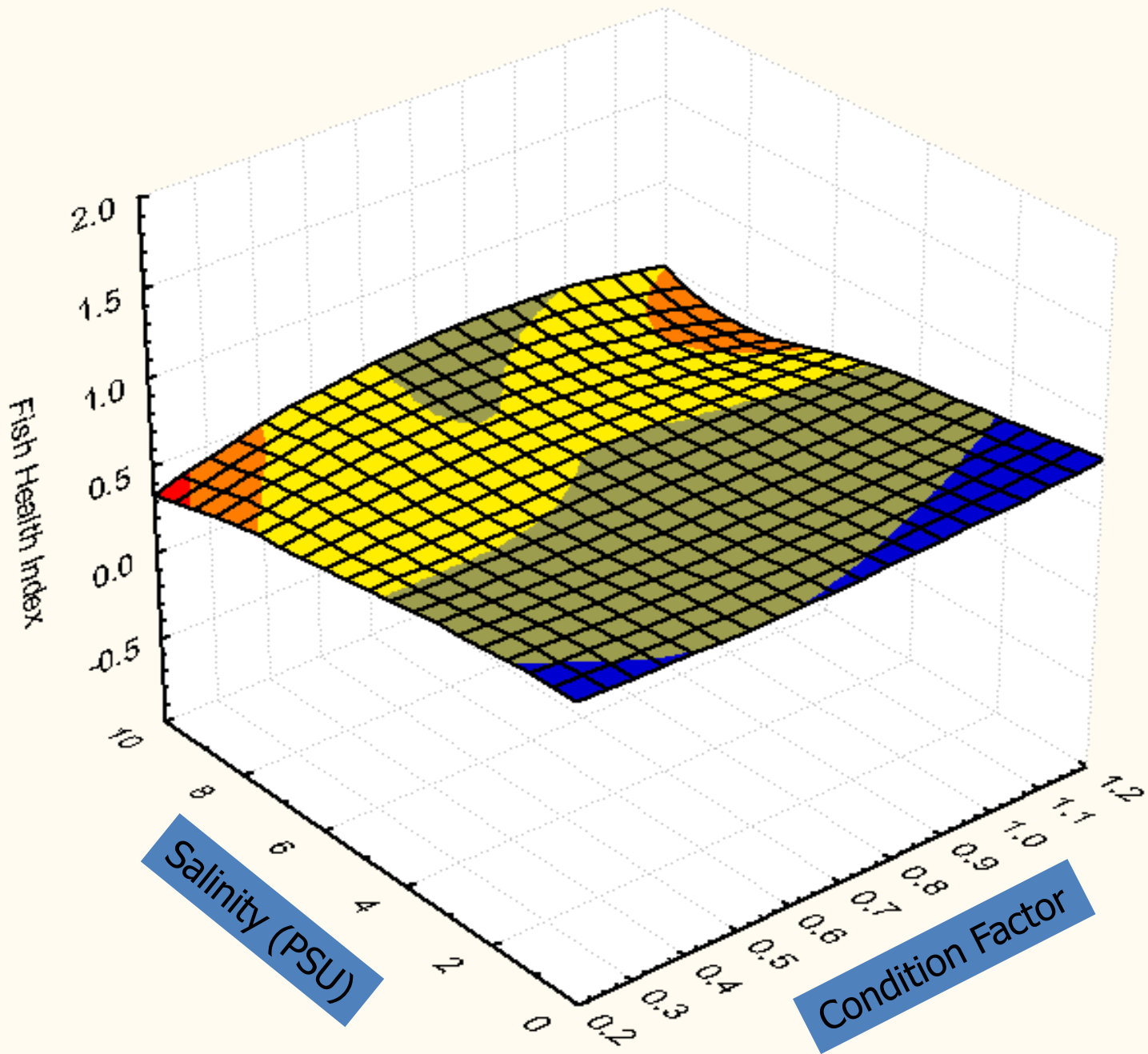
Body Weight and Length; Condition Factor; Hepatosomatic Index; Gonadosomatic index; RNA/DNA; Triglyceride; NA/K ATPase; EROD; AChE; Liver Histopathology Score; Gill Histopathology Score

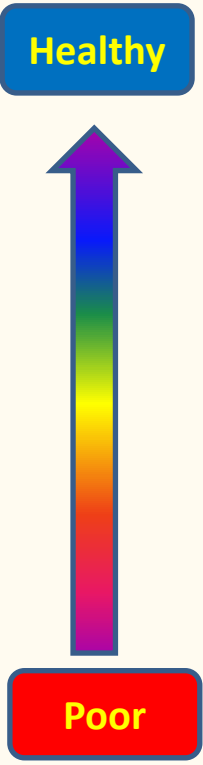
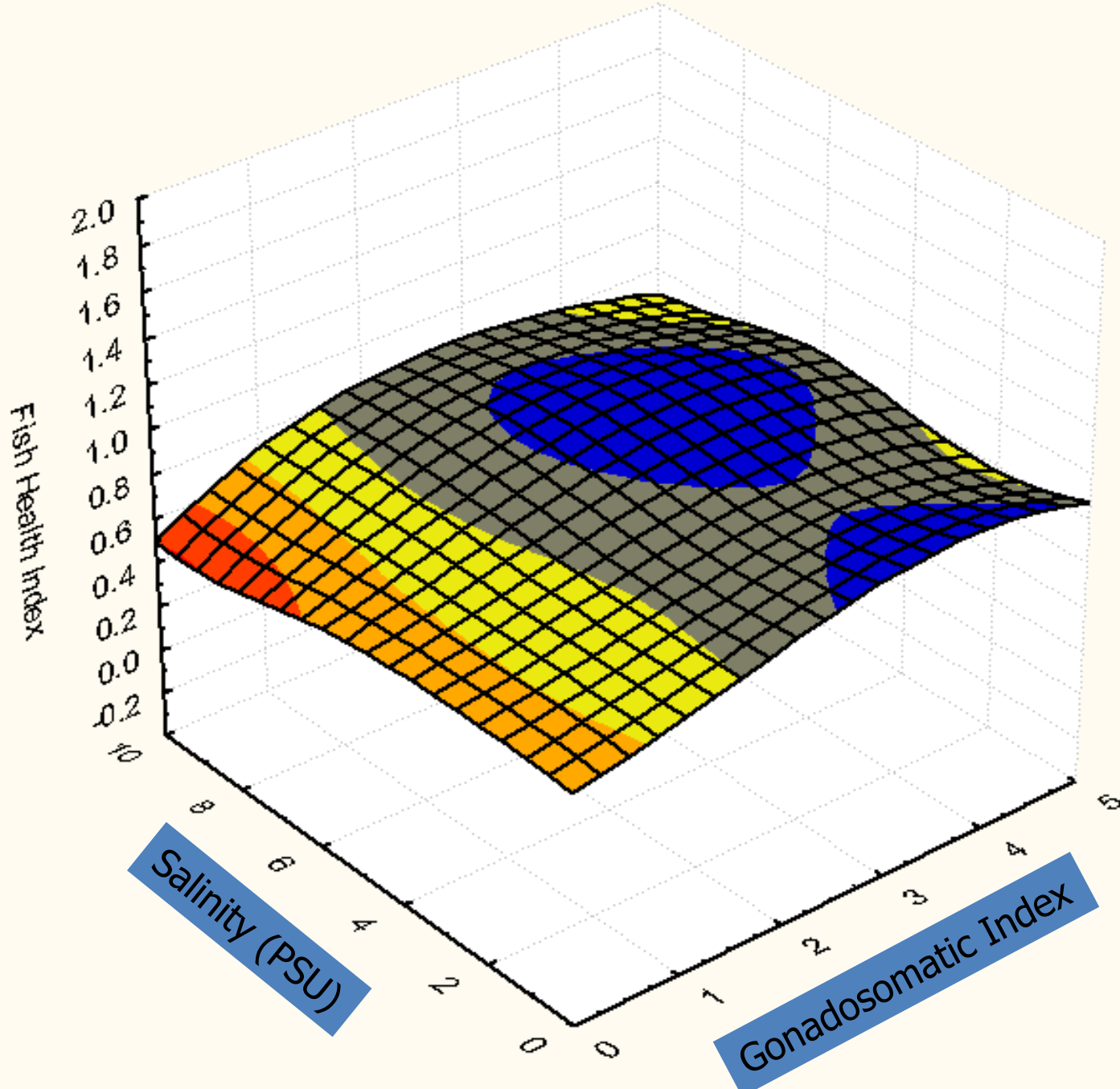


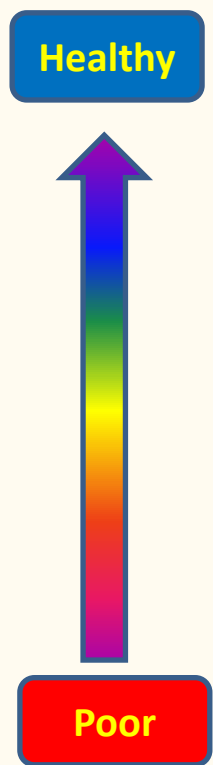
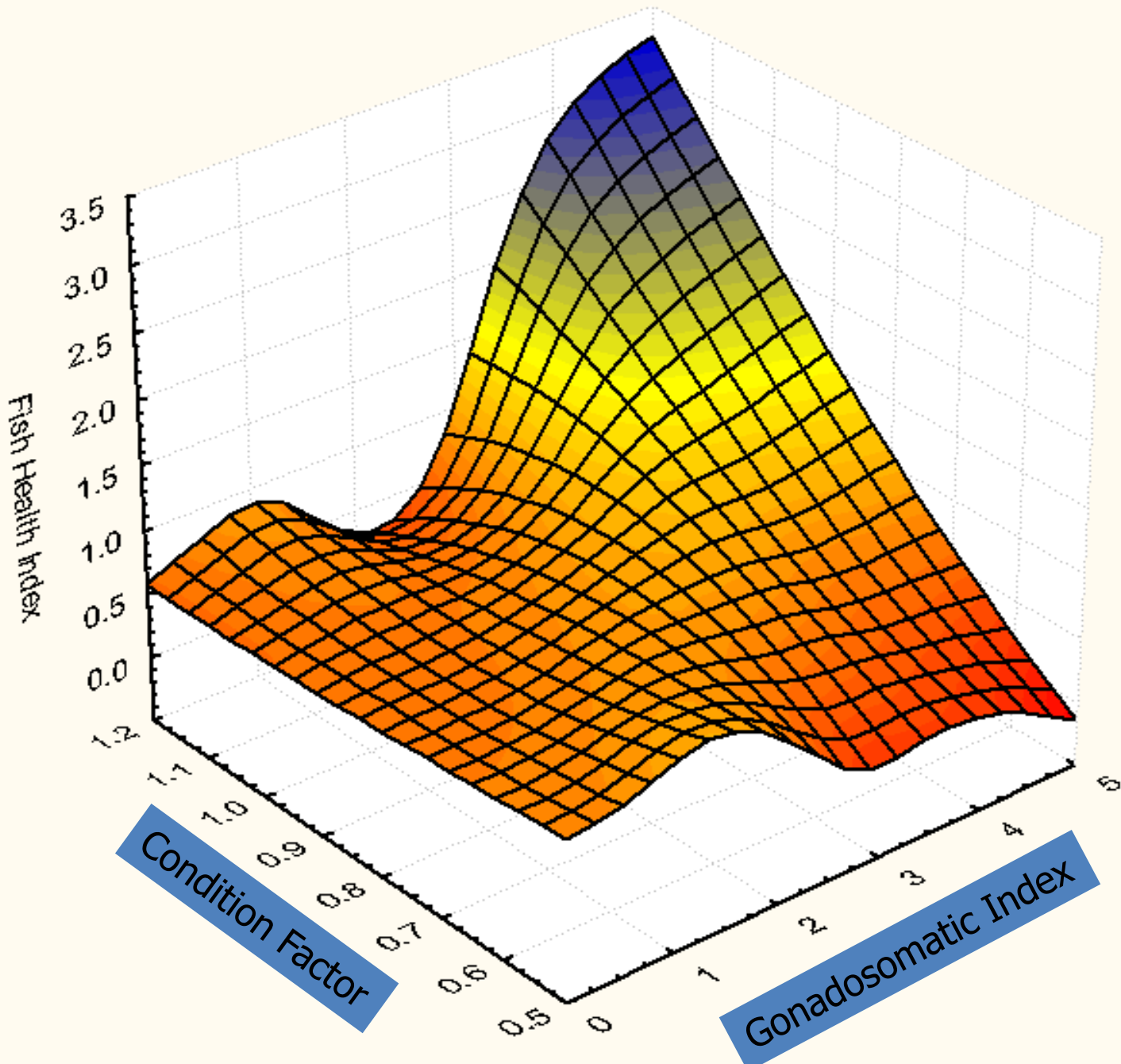
# FHI Biomodeling

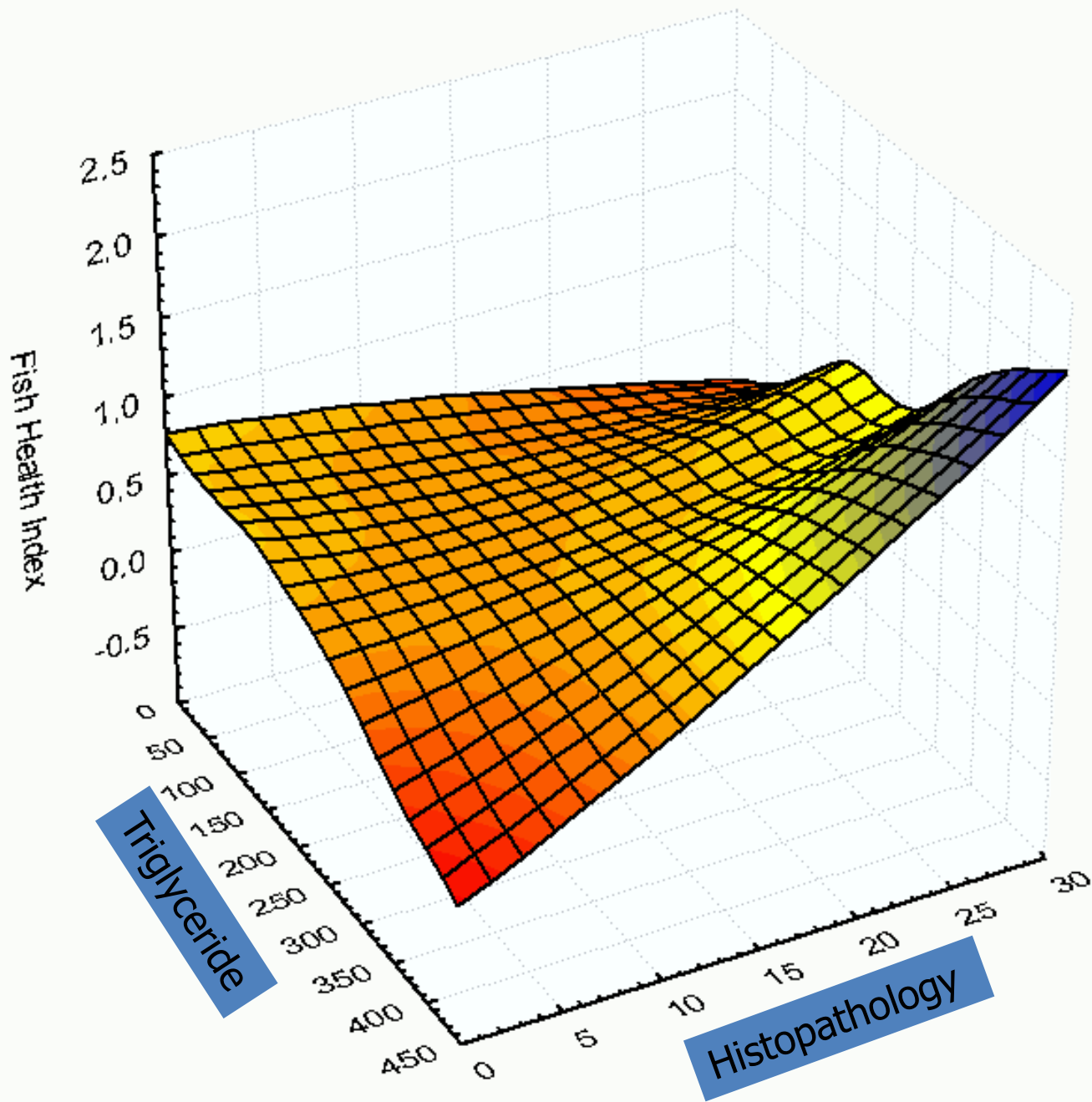




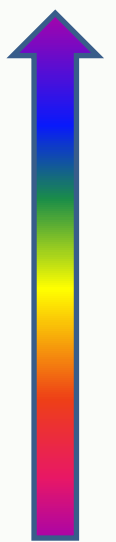




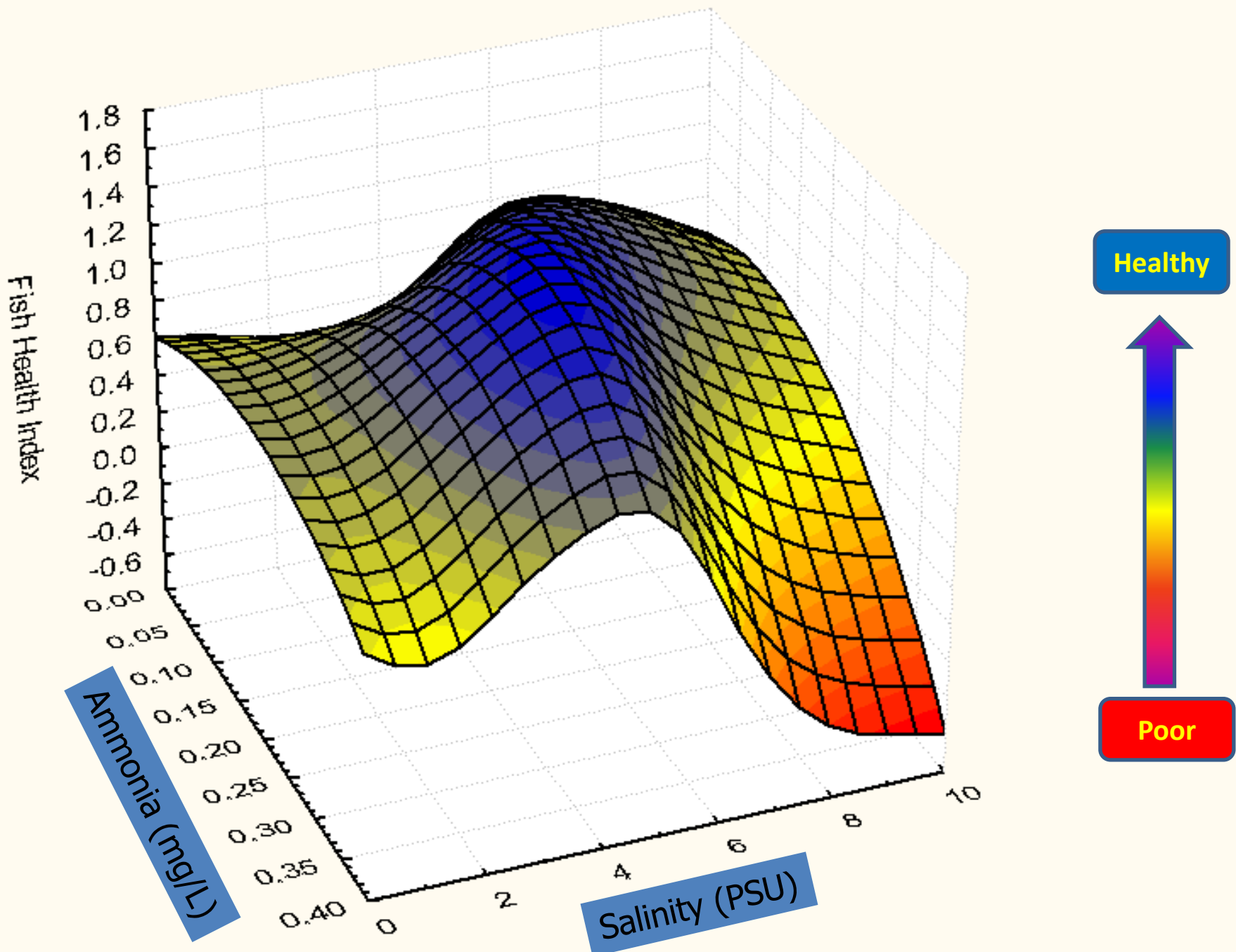




Healthy



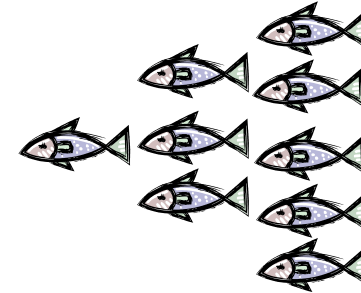
Poor



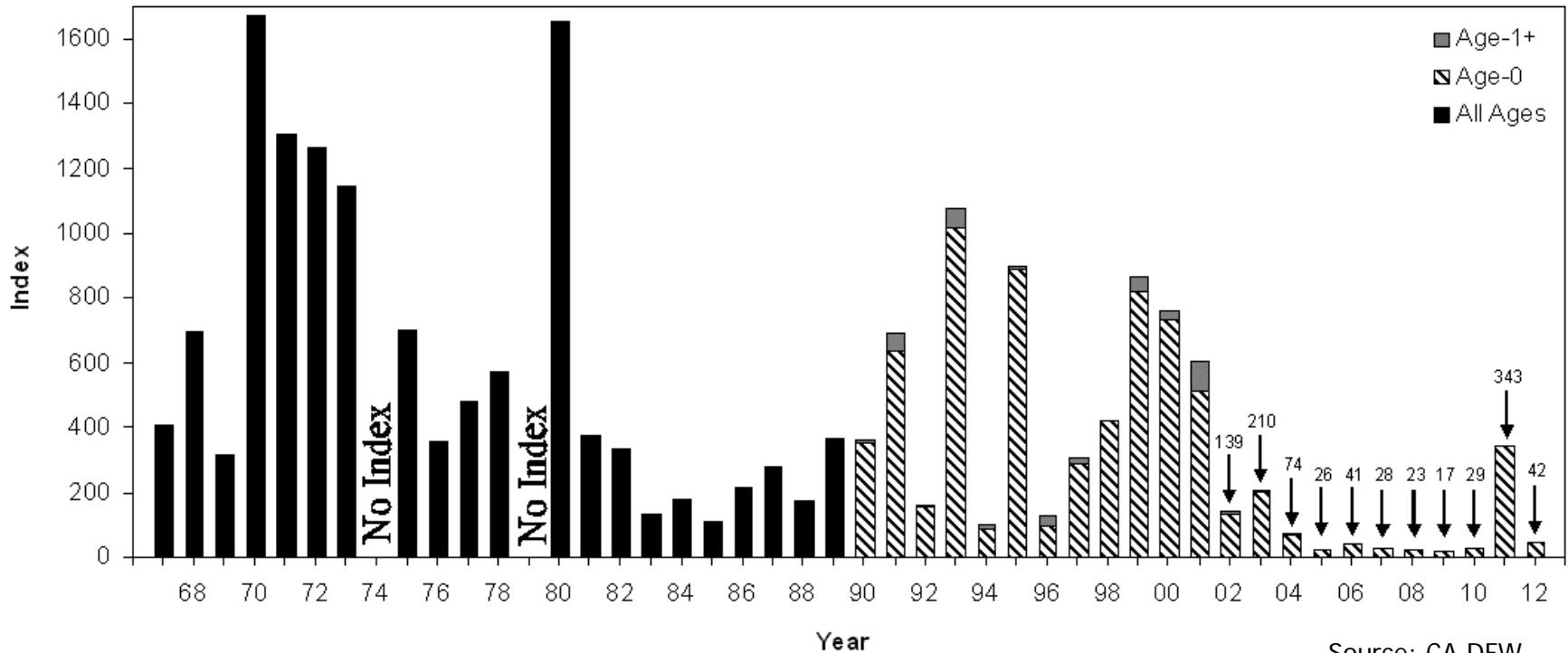
Individual



Population



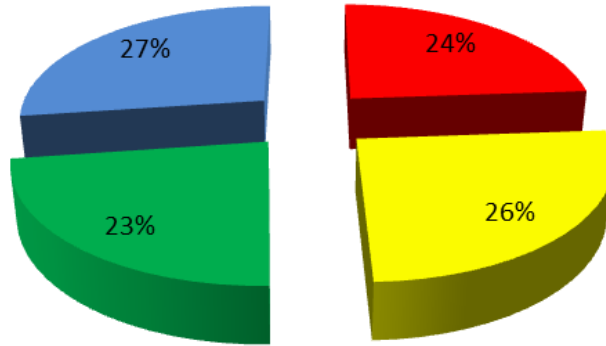
Delta Smelt Indices From 1967-2012



Source: CA DFW

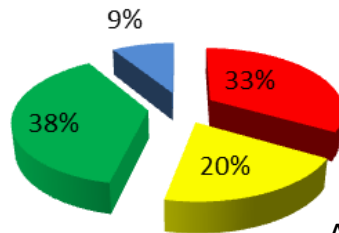


## 2011 Cohort



Abundance Index: 343

## 2012 Cohort



Abundance Index: 42

HEALTHY

ABOVE NORMAL

BELOW NORMAL

POOR

# Fish Health Index and Biomodel Development – Summary

- 1) Used PCA to discriminate inter-related indices
- 2) Targeted biologically relevant biomarkers from each group differentiated by PCA
- 3) Established **Fish Health Index** as a new composite health status indicator
- 4) Applied Canonical analysis to verify causal relationship between FHI and indices
- 5) Developed predictive Biomodel using biomarkers, stressors and multiple regression
- 6) Extrapolated FHI and Biomodel data from individual to population level

# **Future Approach: Refining the Biomodeling of Fish Health Index**

- 1) Develop biomodel for Spring Kodiak Trawl and Summer Townet survey
- 2) Link FMWT to SKT in a predictive biomodel
- 3) Compare FHI of delta smelt: wet vs. dry years
- 4) Evaluate interaction of multiple biomarkers in the model
- 5) Analyze larger data sets by collecting biomarker data for multiple years
- 6) Validate FHI biomodel precision by collecting multi-year samples



California Department of Fish & Wildlife  
National Oceanic & Atmospheric Administration  
US Fish & Wildlife Service



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