An Ecosystem-Based Approach for Evaluating the Health of Estuarine Habitats

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Defining the Ecosystem

Classical Definition

"A biological community and the related nonliving environment interacting together as a whole"

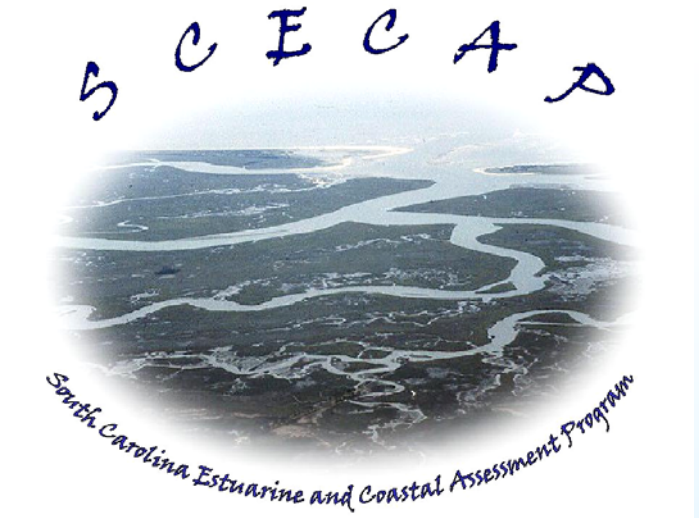
Management Issues:

- **Many managed fauna inhabit several different ecosystems that function very differently**
- **Some ecosystems more threatened than others**
- **Ecosystem health measures not applicable to all life stages**

Estuarine Ecosystem

- **Most threatened ecosystem due to coastal development**
- **Critical nursery habitat for many species**

The South Carolina Estuarine and Coastal Assessment Program



Objectives:

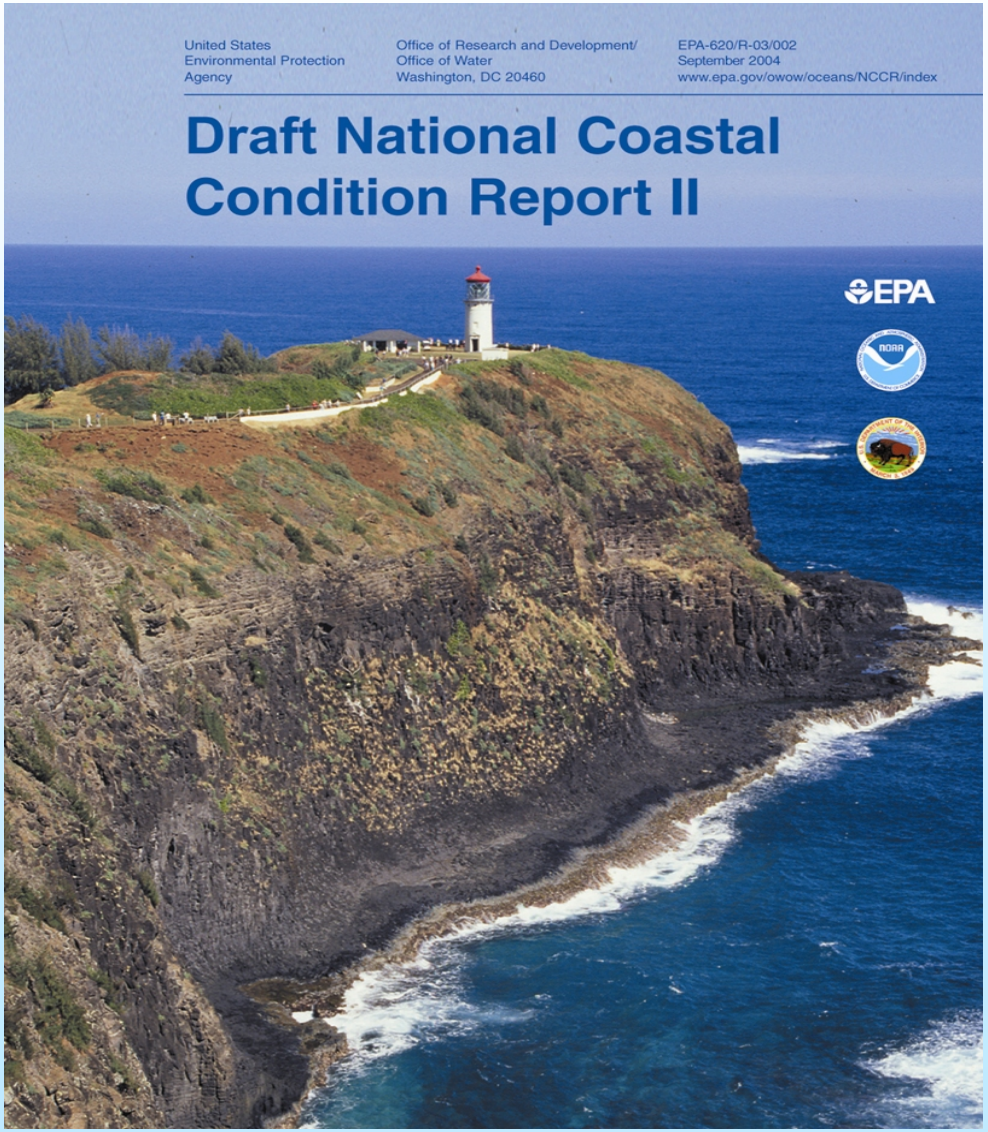
- ***Monitor the quality of all South Carolina estuaries***
  - **Water and Sediment Quality**
  - **Biological Condition**
- ***Develop integrated measures of habitat condition***
- ***Report findings to the public in understandable formats***
- ***Use the data for management / regulatory decisions***

DHEC
PROMOTE PROTECT PROSPER
South Carolina Department of Health and Environmental Control

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

National Coastal Assessment Program



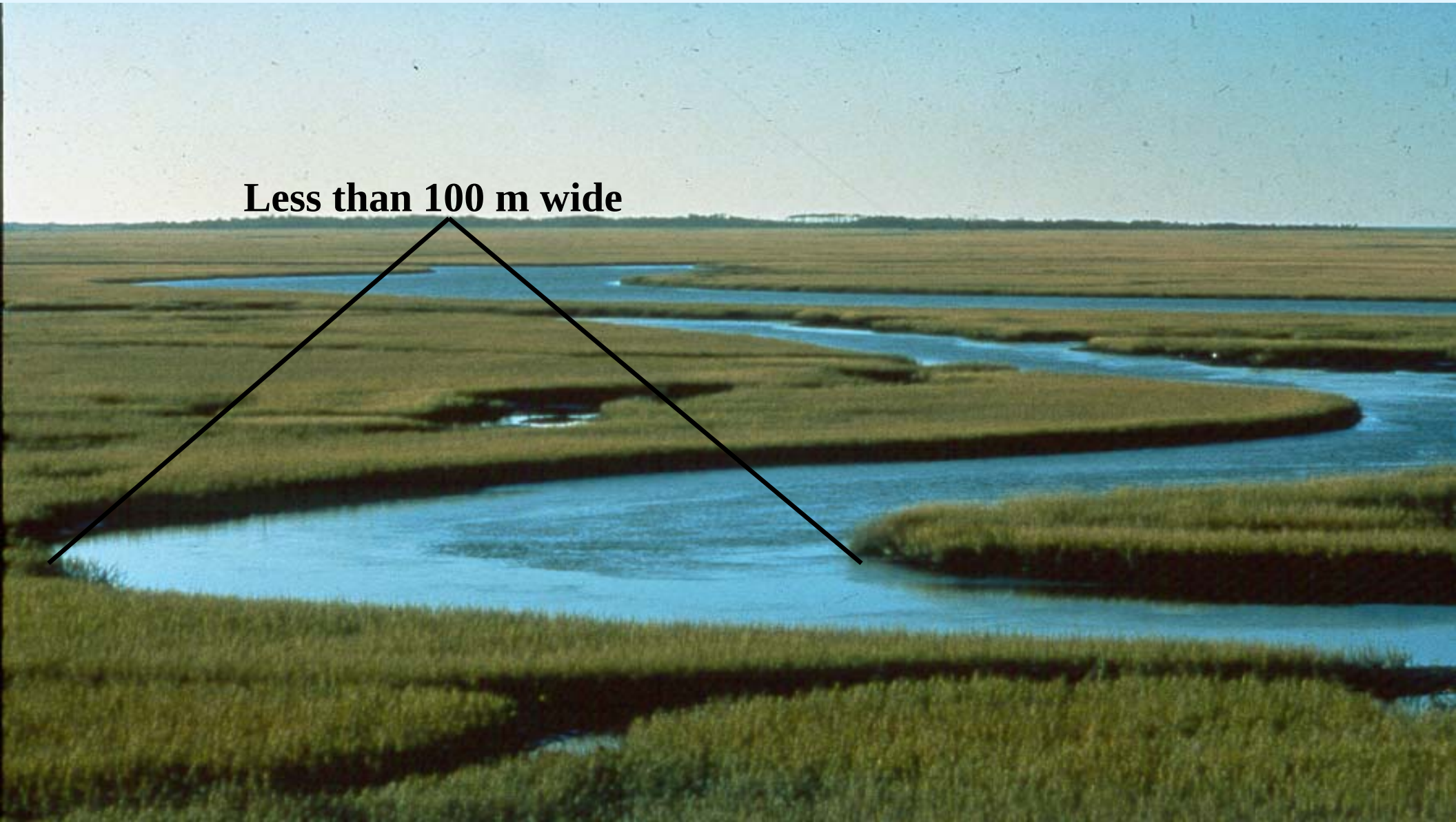
Program Approach / Advantages

- ***Uses an integrated approach** (water, sediment, biota)*
- ***Unbiased sampling design***
- ***Combines numerous measures into simplified indices of condition***
- ***Identifies percentage of impaired habitat with statistical confidence limits***
- ***Allows for trends analyses***
- ***Spatially extensive station array with many uses***

Monitoring Approach

- ***Targets two major habitat types***
  - ***Tidal creeks, larger open water bodies***
- ***Stations array random and density is proportional to size of the estuary***
- ***Sample 50-60 stations each year***
  - ***Summer sampling period***
  - ***Relocate stations every year***
  - ***Subset (30) sampled monthly***
    - *Water quality only*

Habitat Designation Criteria



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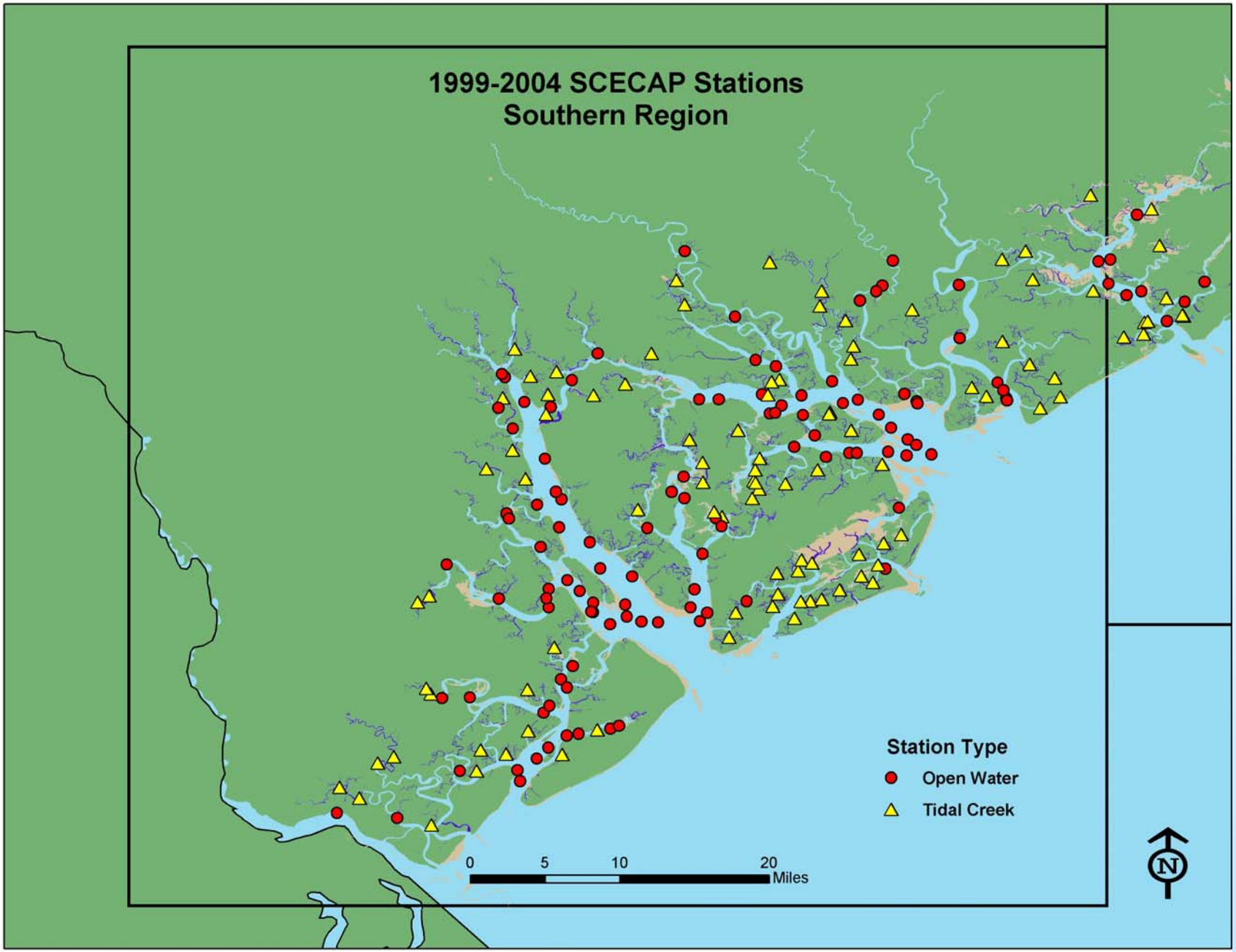
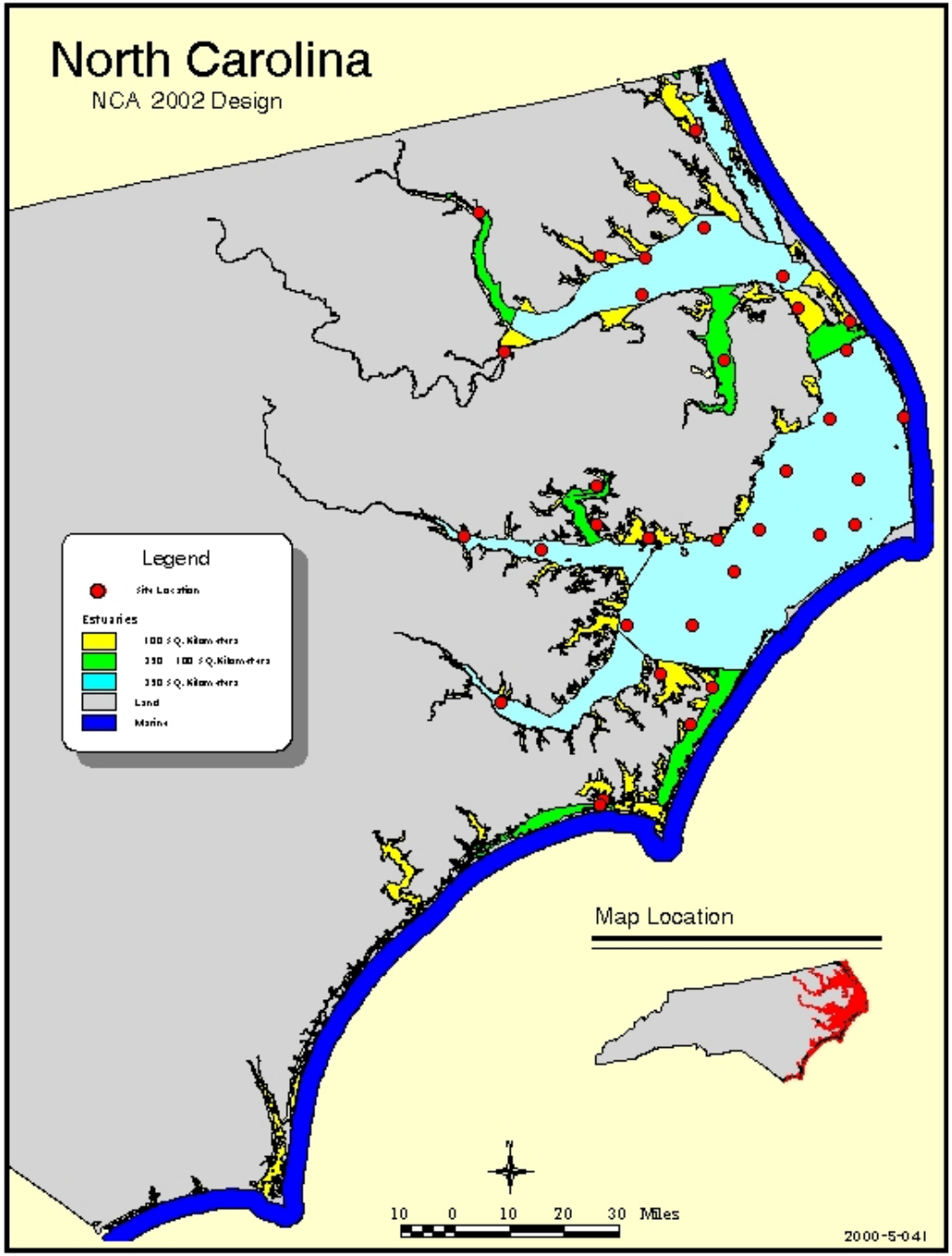
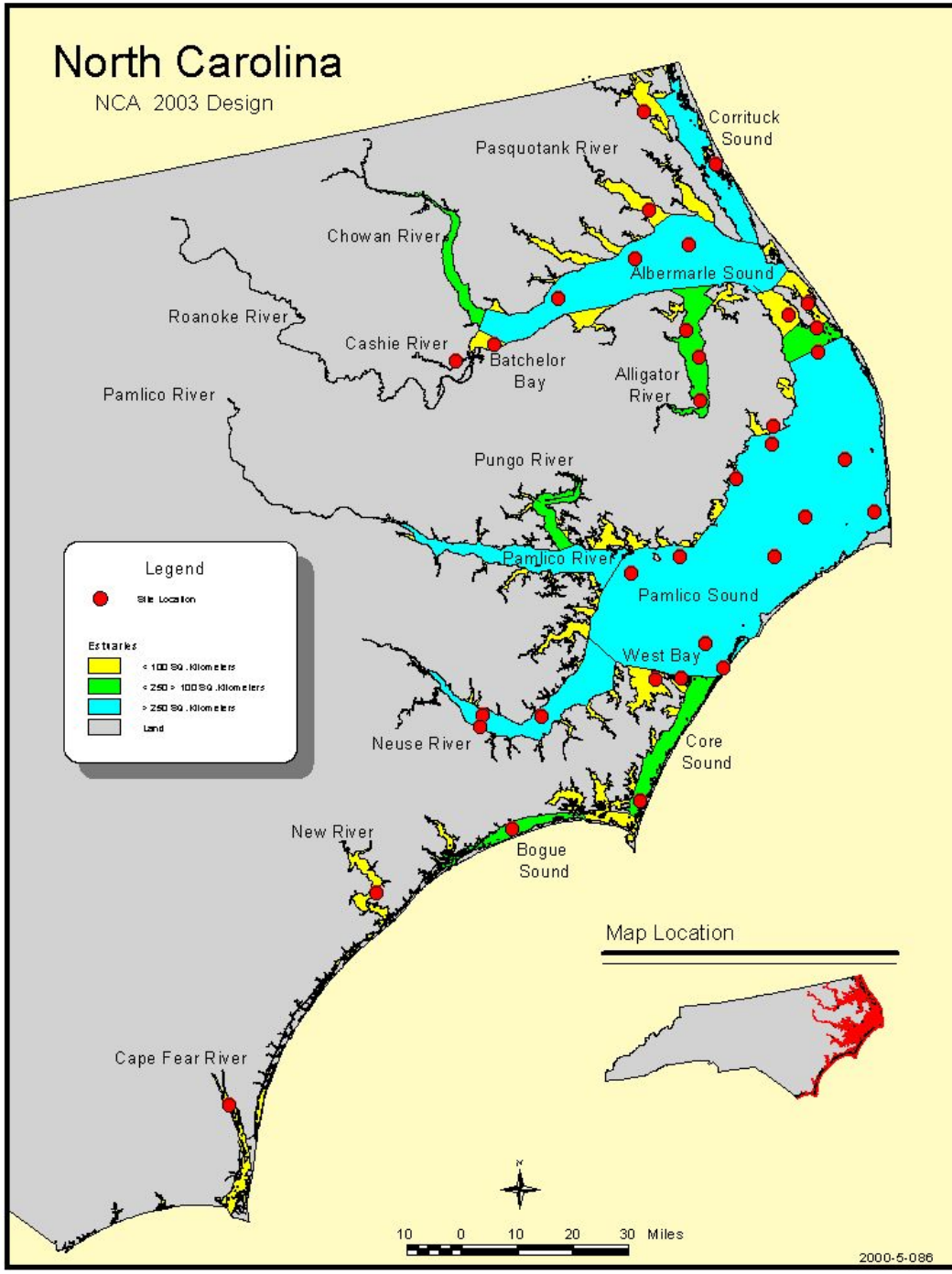
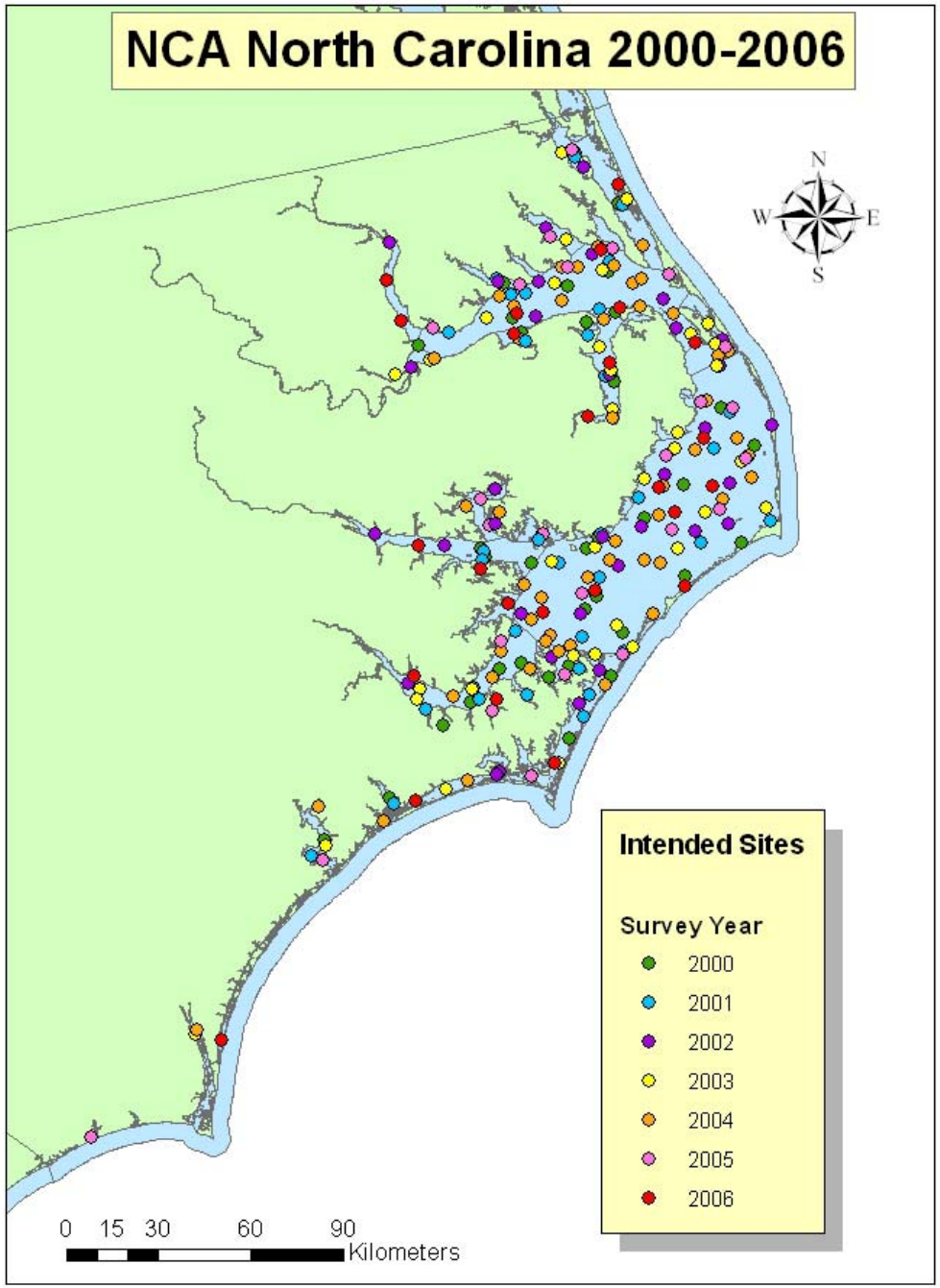

1999-2004 SCECAP Stations
Southern Region
Station Type
Open Water
Tidal Creek
0
5
10
20
Miles
N


North Carolina
NCA 2002 Design
Legend
Site Location
Estuaries
100 S Q. Kilometers
250 100 S Q. Kilometers
250 S Q. Kilometers
Land
Marine
Map Location
10 0 10 20 30 Miles
2000-5-041


North Carolina
NCA 2003 Design
Corrituck Sound
Pasquotank River
Chowan River
Albermarle Sound
Roanoke River
Cashie River
Batchelor Bay
Alligator River
Pamlico River
Pungo River
Pamlico River
Pamlico Sound
West Bay
Neuse River
Core Sound
New River
Bogue Sound
Cape Fear River
Legend
Site Location
Estuaries
< 100 SQ. Kilometers
< 250 > 100 SQ. Kilometers
> 250 SQ. Kilometers
Land
Map Location
10 0 10 20 30 Miles
2000-5-086


NCA North Carolina 2000-2006
N
W
E
S
Intended Sites
Survey Year
2000
2001
2002
2003
2004
2005
2006
0 15 30 60 90
Kilometers

Sampling Components

Water Quality

- Continuous monitoring for salinity, DO, pH, temp
- Turbidity, TOC
- Nutrients (total & dissolved nitrogen, phosphorus)
- BOD, fecal coliform bacteria, metals
- Phytoplankton (Chl-a)

Sediment Quality

- Contaminants (85 analytes)
- Toxicity (3 assays)

Biological Condition

- Benthos
- Phytoplankton composition
- Finfish and crustaceans

Sampling Components NCA

Water Quality

- ~~Continuous monitoring for~~ salinity, DO, pH, temp
- Light penetration
- Nutrients (~~total &~~ dissolved nitrogen, phosphorus)
- ~~BOD, fecal coliform bacteria, metals~~
- Phytoplankton (Chl-a)

Sediment Quality

- Contaminants (~~85 analytes~~ fewer)
- Toxicity (~~3 assays~~ one assay)

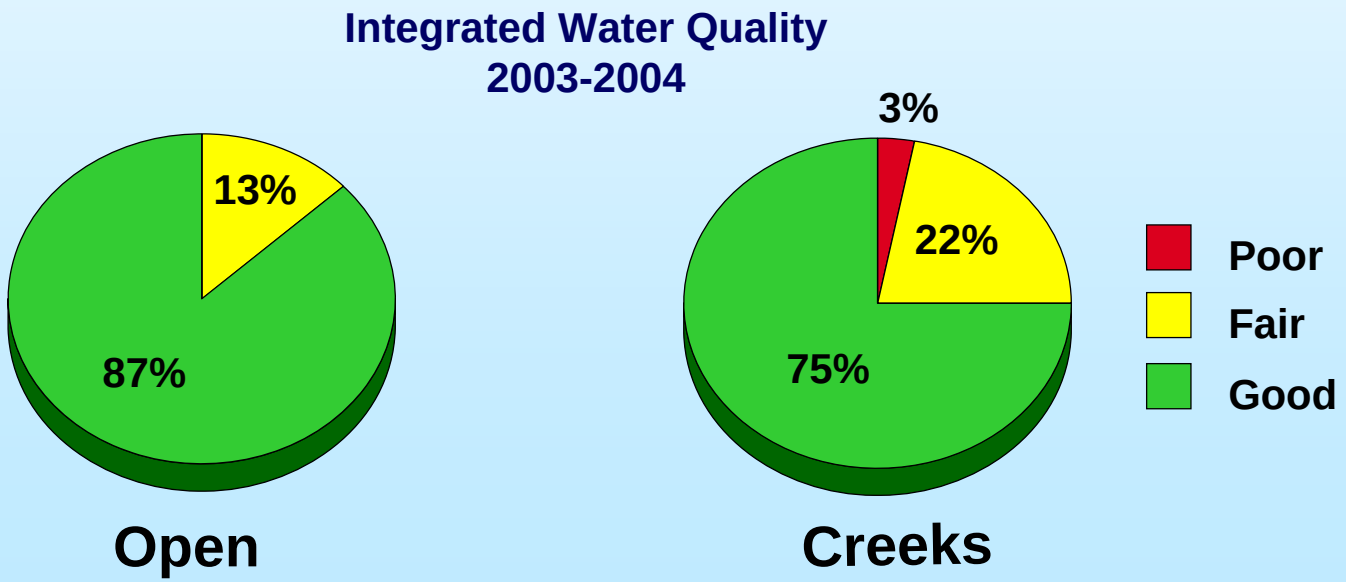
Biological Condition

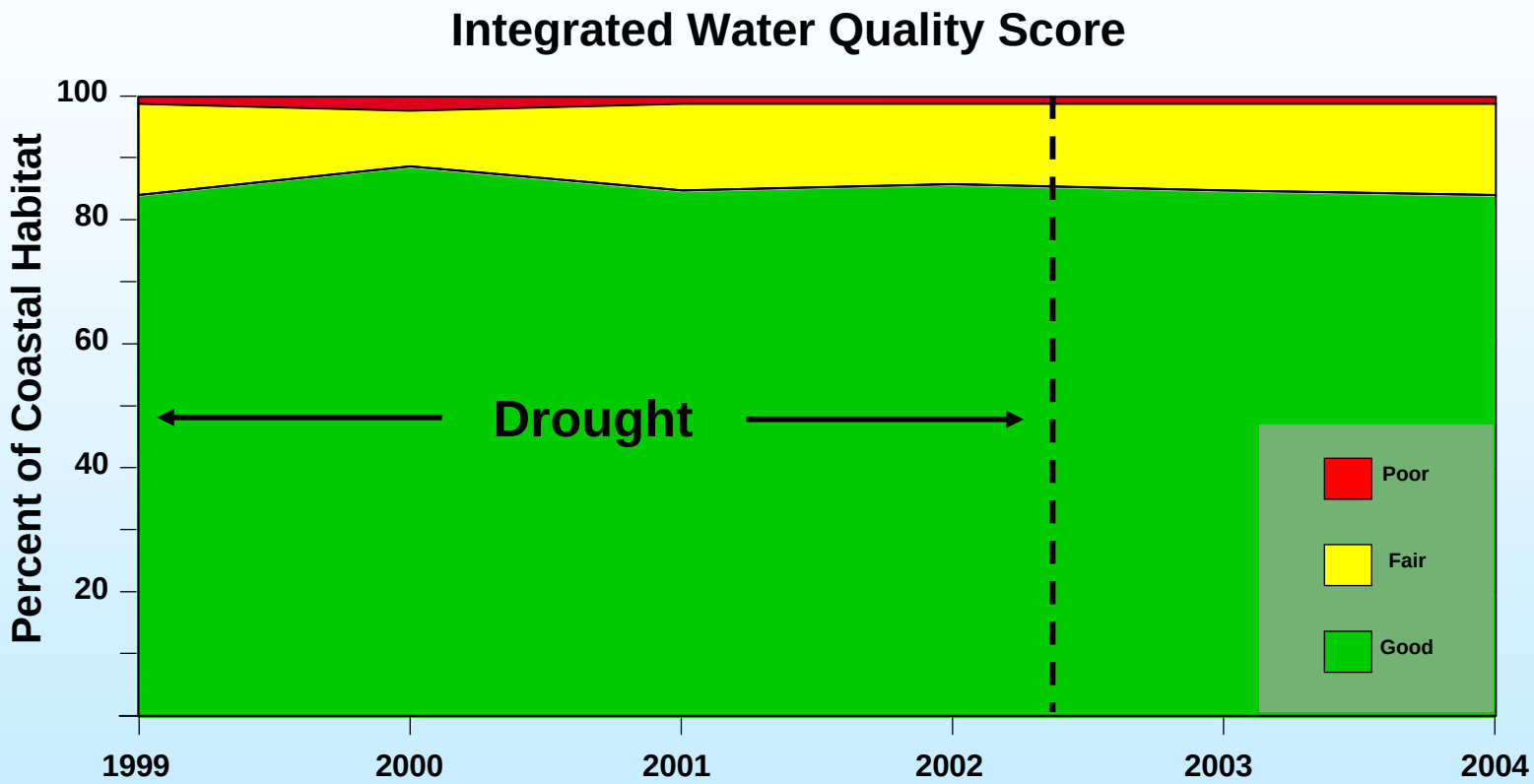
- Benthos (limited)
- ~~Phytoplankton composition~~
- Finfish and crustaceans

Developed Integrated Measures

Water Quality

- **Six primary measures (DO, pH, TN,TP, Chla, fecal coliform bacteria)**
- **Each measure scored based on water quality criteria or historical data** (thresholds 75th and 90th percentiles)
- **Scores averaged for integrated water quality measure**

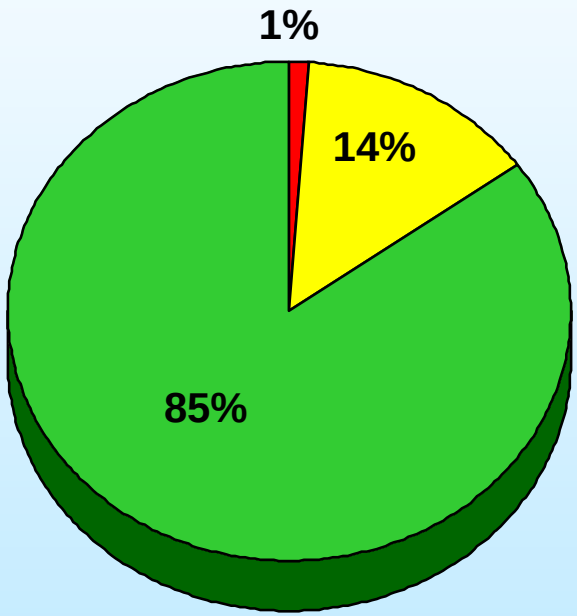



Integrated Water Quality Score
Percent of Coastal Habitat
100
80
60
40
20
Drought
Poor
Fair
Good
1999
2000
2001
2002
2003
2004

Water Quality – Habitats Combined

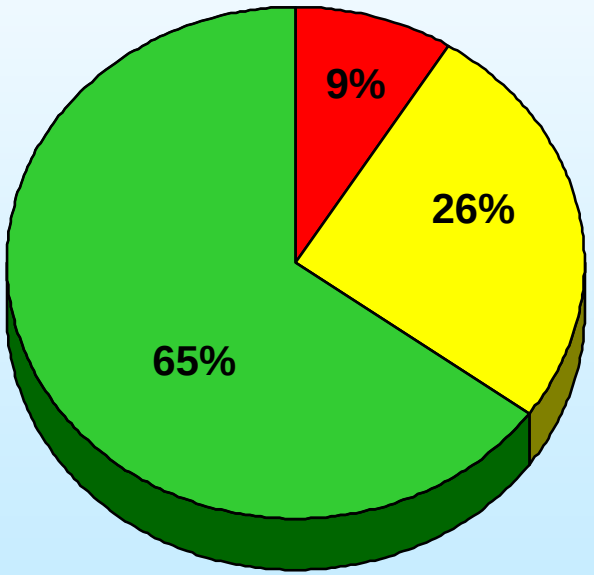
SCECAP Criteria Summer Only

2003-2004



SCECAP Criteria Monthly

2003-2004

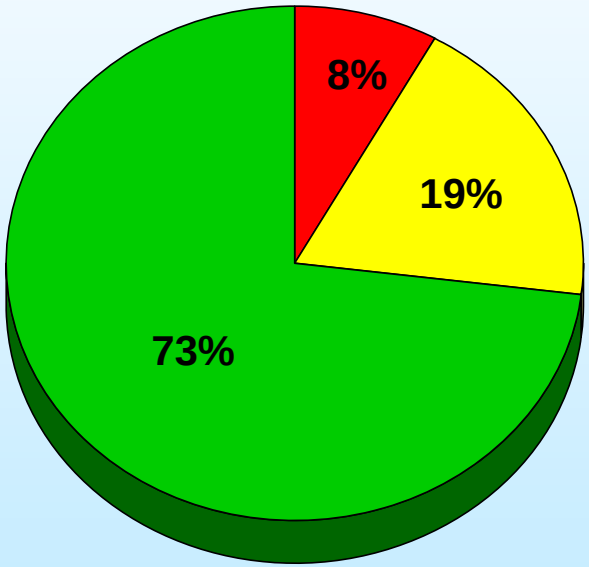


Good Fair Poor

Water Quality – Habitats Combined

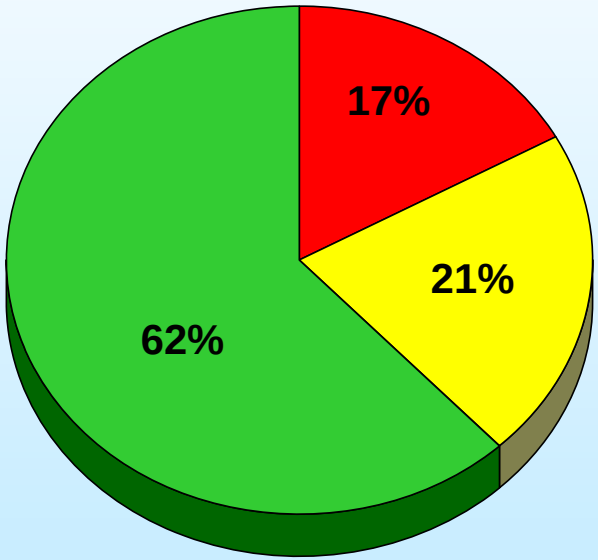
DO, pH, Fecals Summer Only

2003-2004



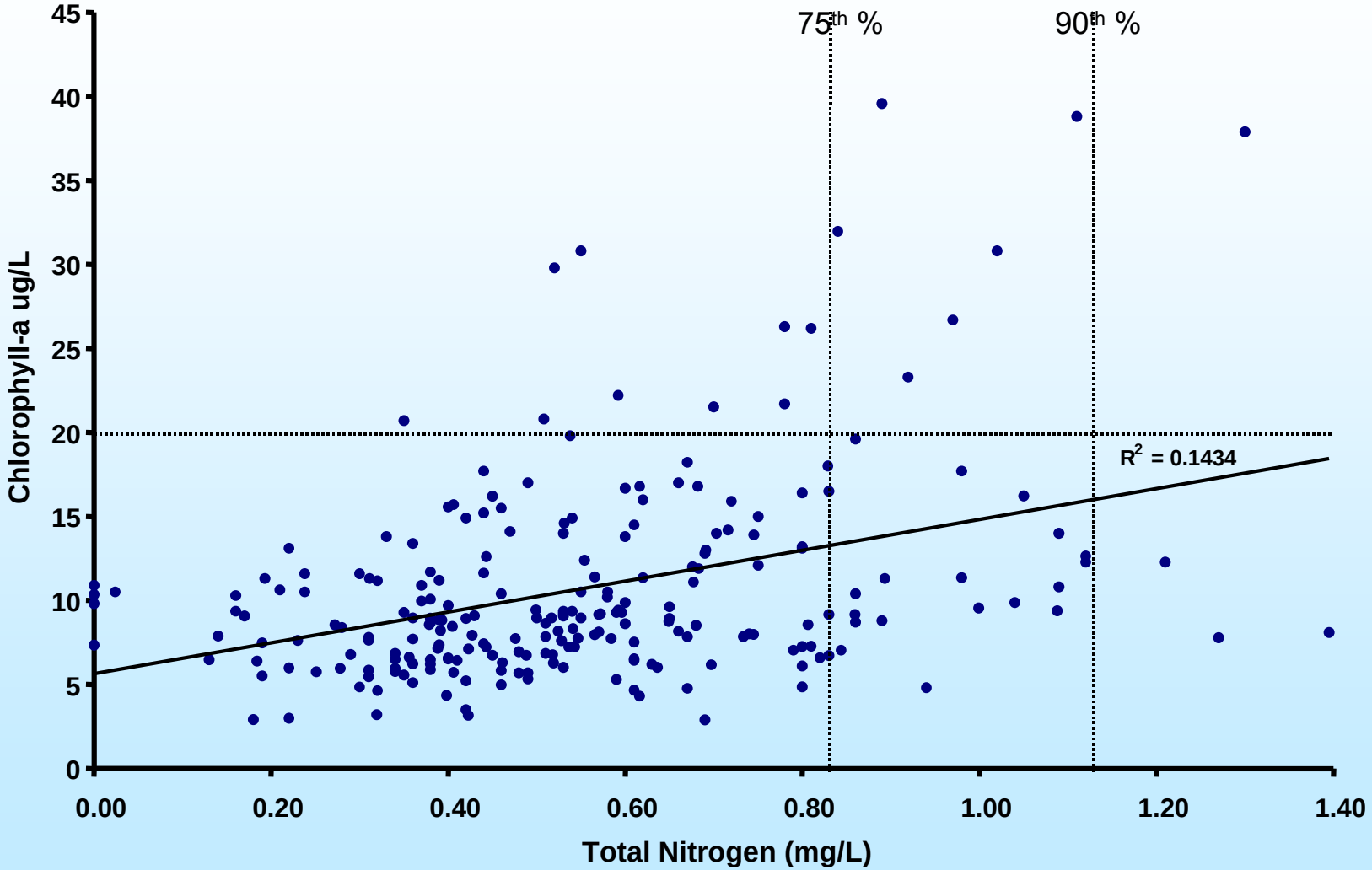
DO, pH, Fecals Monthly – One Year

2003-2004

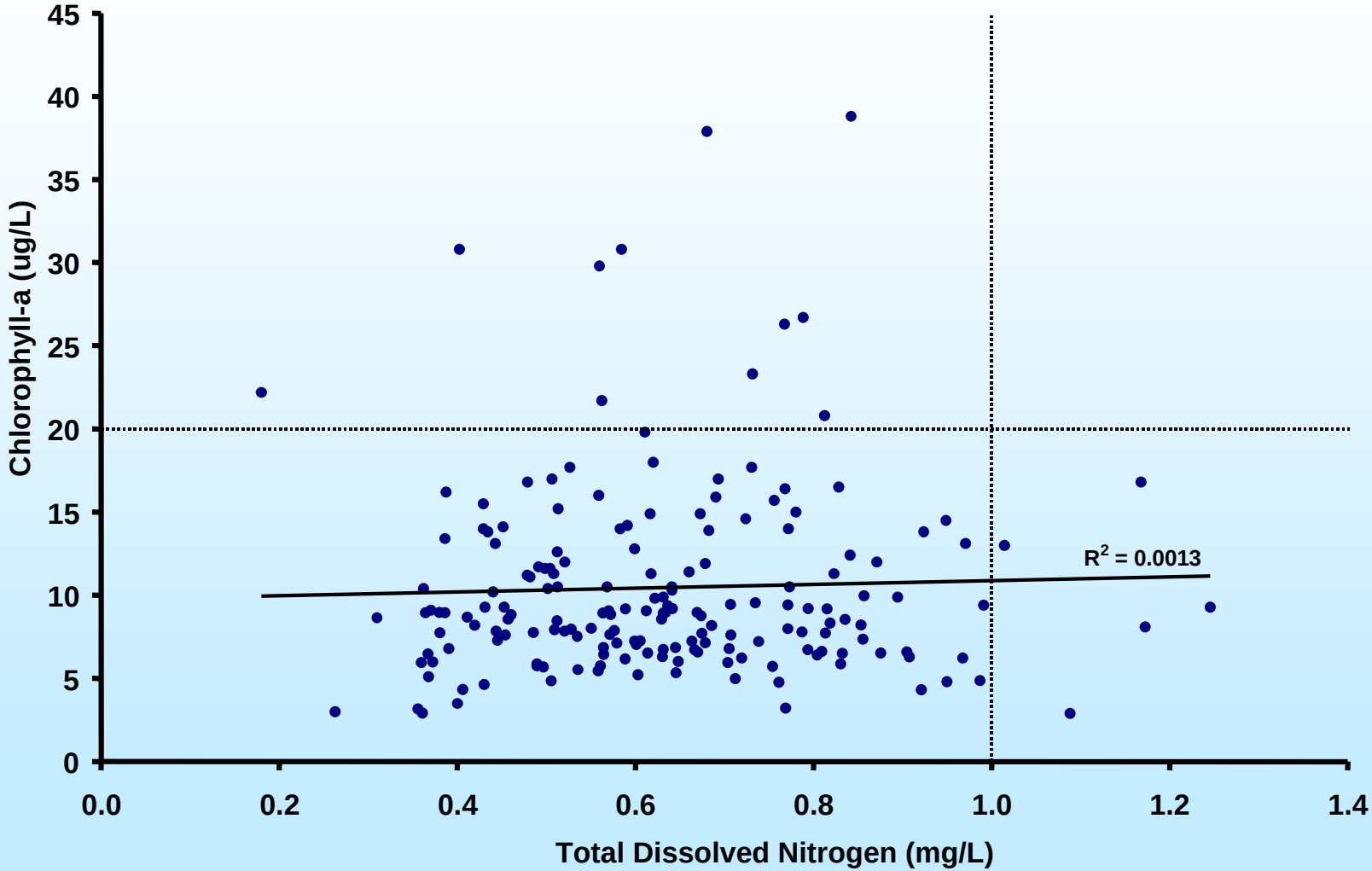


Good Fair Poor

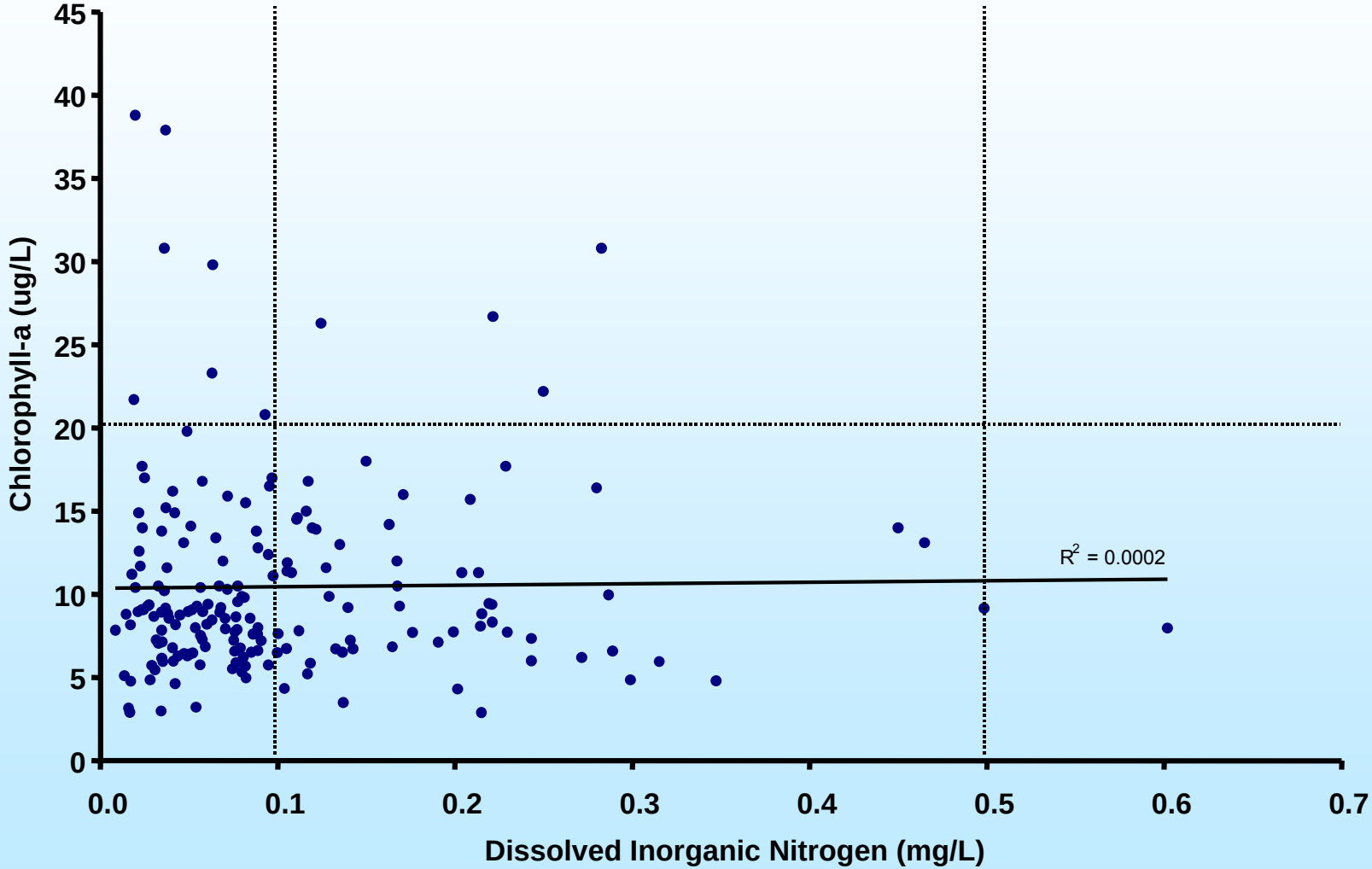
Total Nitrogen vs. Chlorophyll-a



Total Dissolved Nitrogen vs. Chlorophyll-a



Dissolved Inorganic Nitrogen vs. Chlorophyll-a



Integrated Measures

Sediment Quality

- Selected 24 priority pollutants with known bioeffects data
- Developed Effects Range Median Quotient (ERM-Q)
- Scored ERM-Q by published benthic effects ranges

Contaminant Measures

ERM = Effects Range Median (Long et al. 1998)

ERM-Q = Effects Range Median - Quotient

Calculated as:

$$\text{ERM-Q} = \frac{\sum \left(\frac{\text{Actual Conc}}{\text{As ERM}} + \frac{\text{Actual Conc}}{\text{Pb ERM}} + \ldots + \frac{\text{Actual Conc}}{\text{PCB ERM}} + \frac{\text{Actual Conc}}{\text{Pest ERM}} \ldots \frac{\text{Actual Conc}}{\text{PAH ERM}} \right)}{\text{24 Analytes}}$$

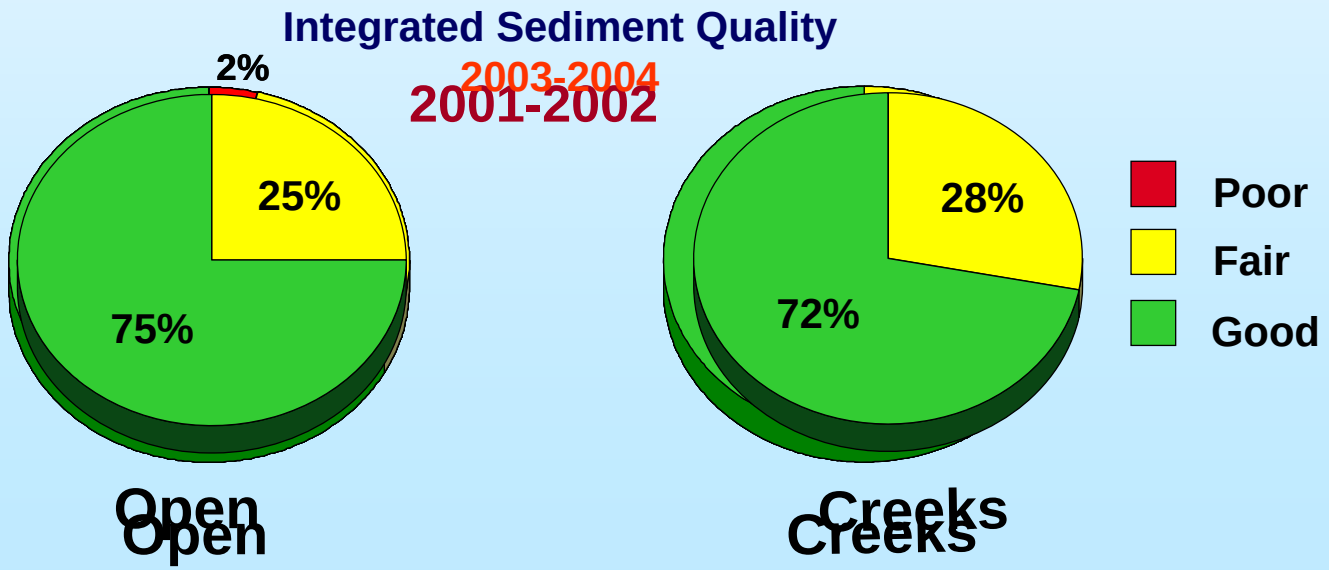
Low Risk < 0.02
Moderate Risk 0.02 – 0.058
High Risk > 0.058

Hyland *et al.* 1999. Predicting stress in benthic communities of southeastern U.S. estuaries in relation to chemical contamination of sediments. Environmental Toxicology and Chemistry 18: 2557-2564

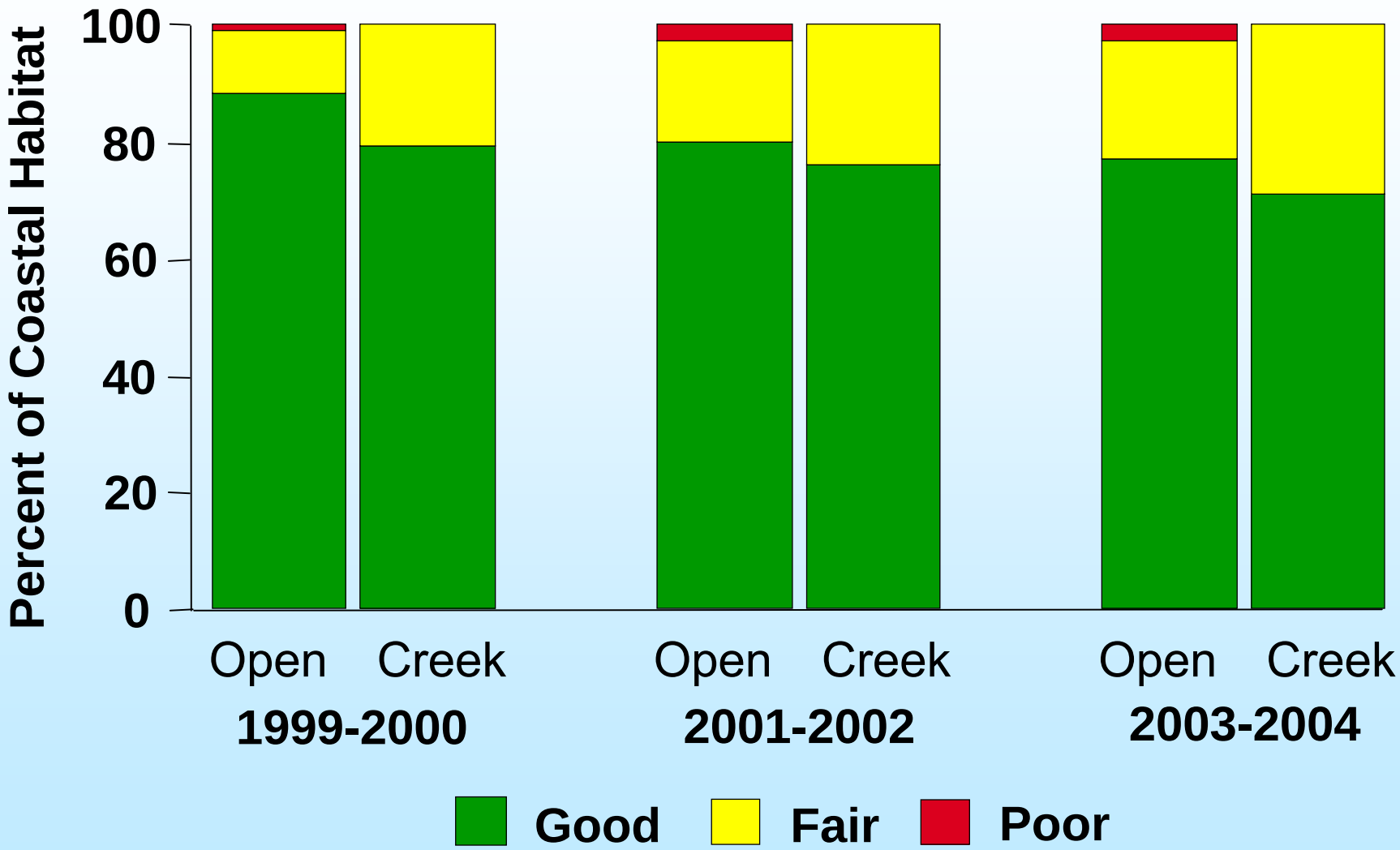
Integrated Measures

Sediment Quality

- Selected 24 priority pollutants with known bioeffects data
- Developed Effects Range Median Quotient (ERM-Q)
- Scored ERM-Q by published benthic effects ranges
- **Scored toxicity assays by number of assays with “hits”**
- **Averaged contaminants and toxicity score**



Sediment Contamination (ERM-Q)



Integrated Measures

Biological Condition

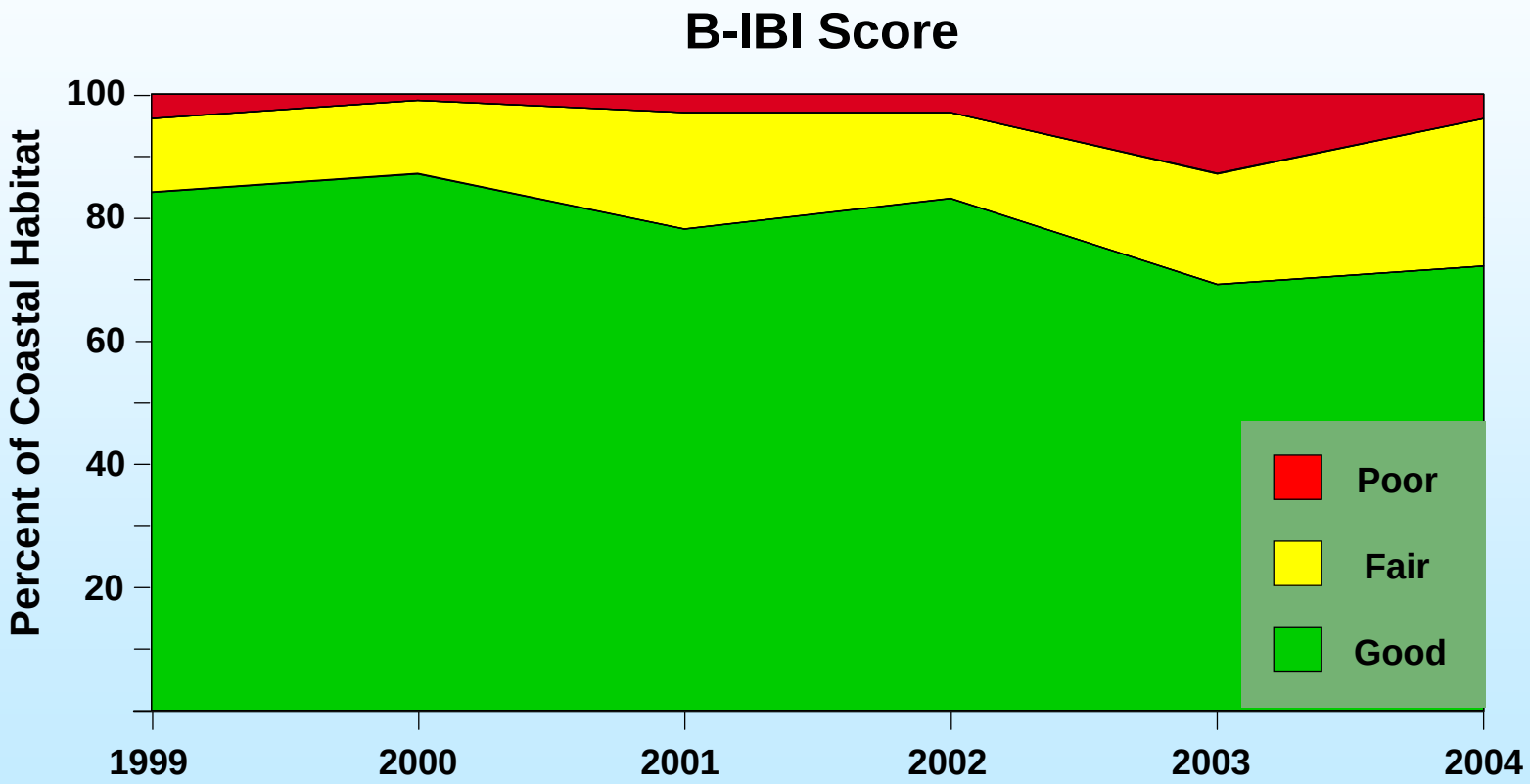
- **Benthic Index of Biotic Integrity (B-IBI) for biological response**
  - ***Described by Van Dolah et al. (1999) for use in Southeast region***

Other Indices of Interest

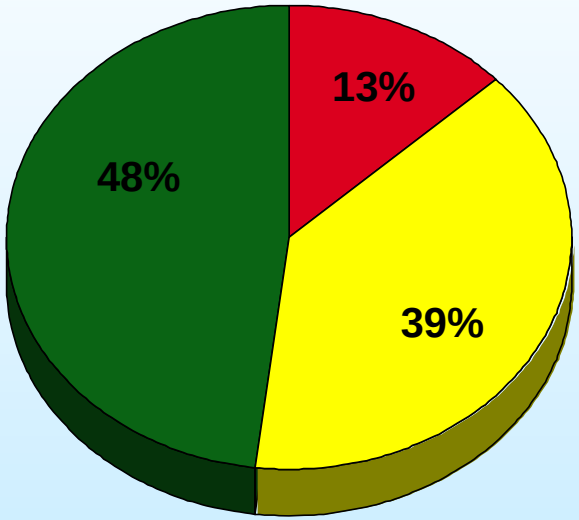
- **Demersal Finfish / Crustacean IBI**

- **Phytoplankton Composition Index (HABs)**

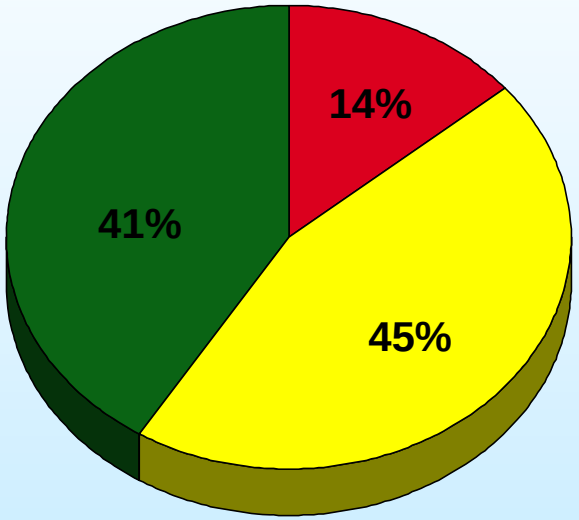
Trend in Benthic Condition Measure



Phytoplankton Composition by Stratum



Open



Creeks

Harmful taxa

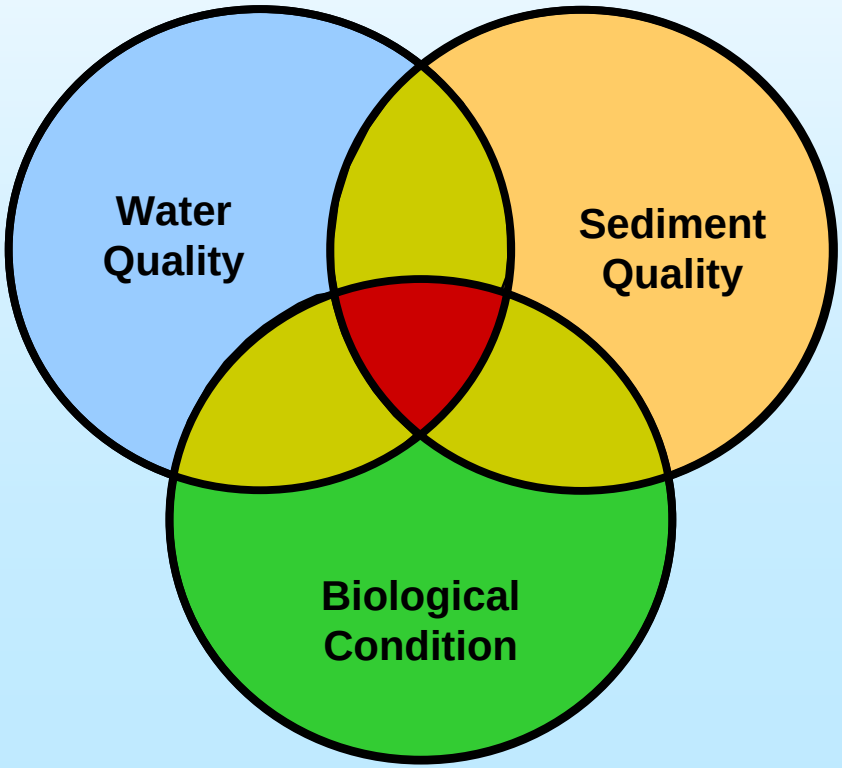
Mixed flagellates

Diatoms

Integrated Measures

Overall habitat quality

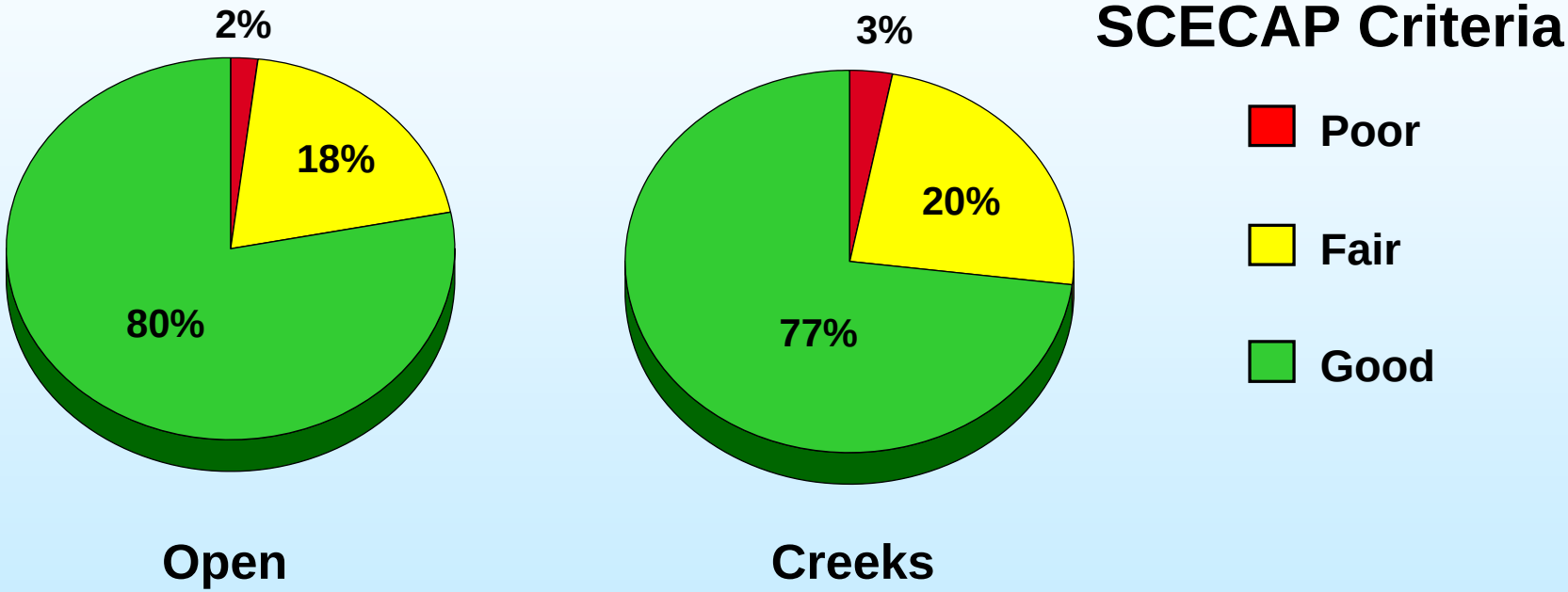
- **Averaged scores of each subcomponent into an integrated score for overall habitat quality**
- **Each component weighted equally**



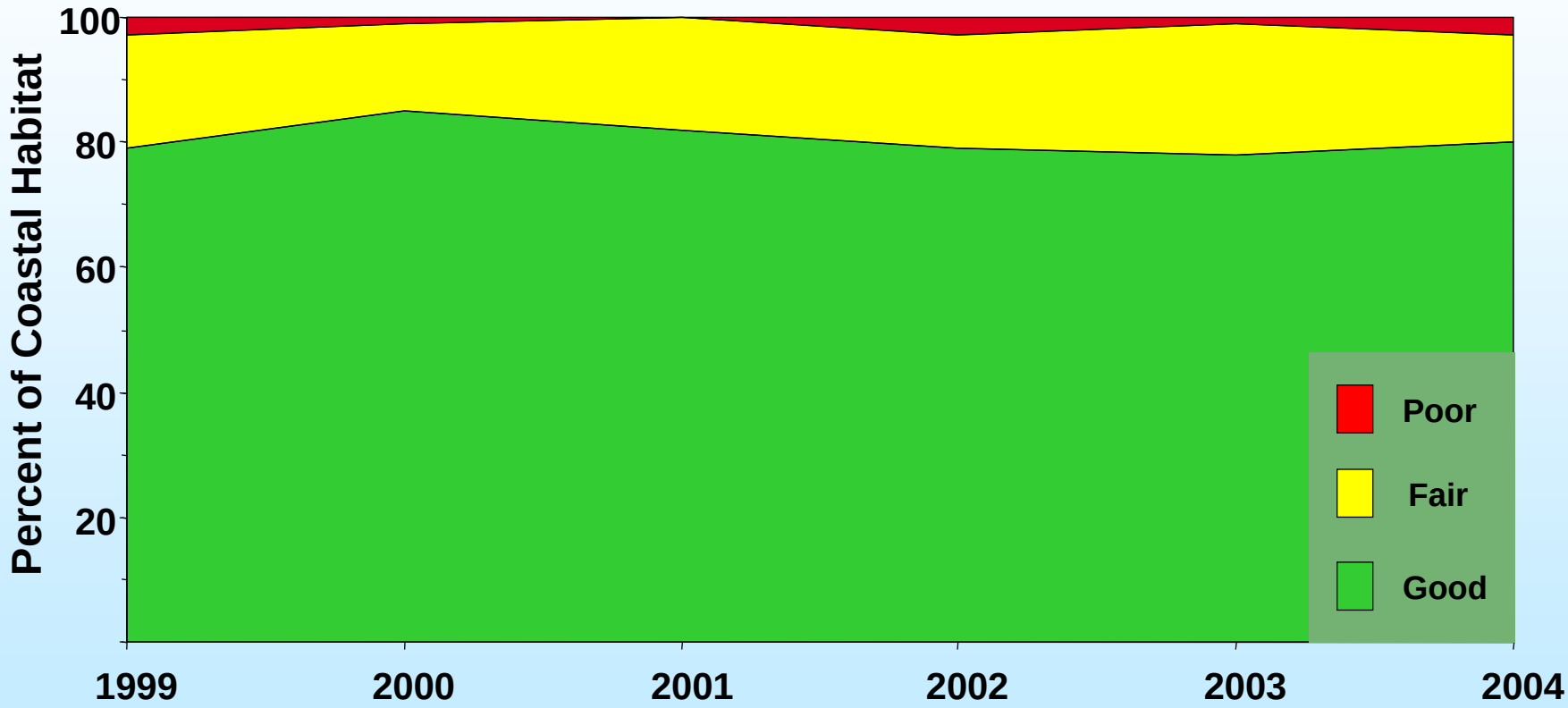
For more information: Google SCECAP

Integrated Habitat Quality Score

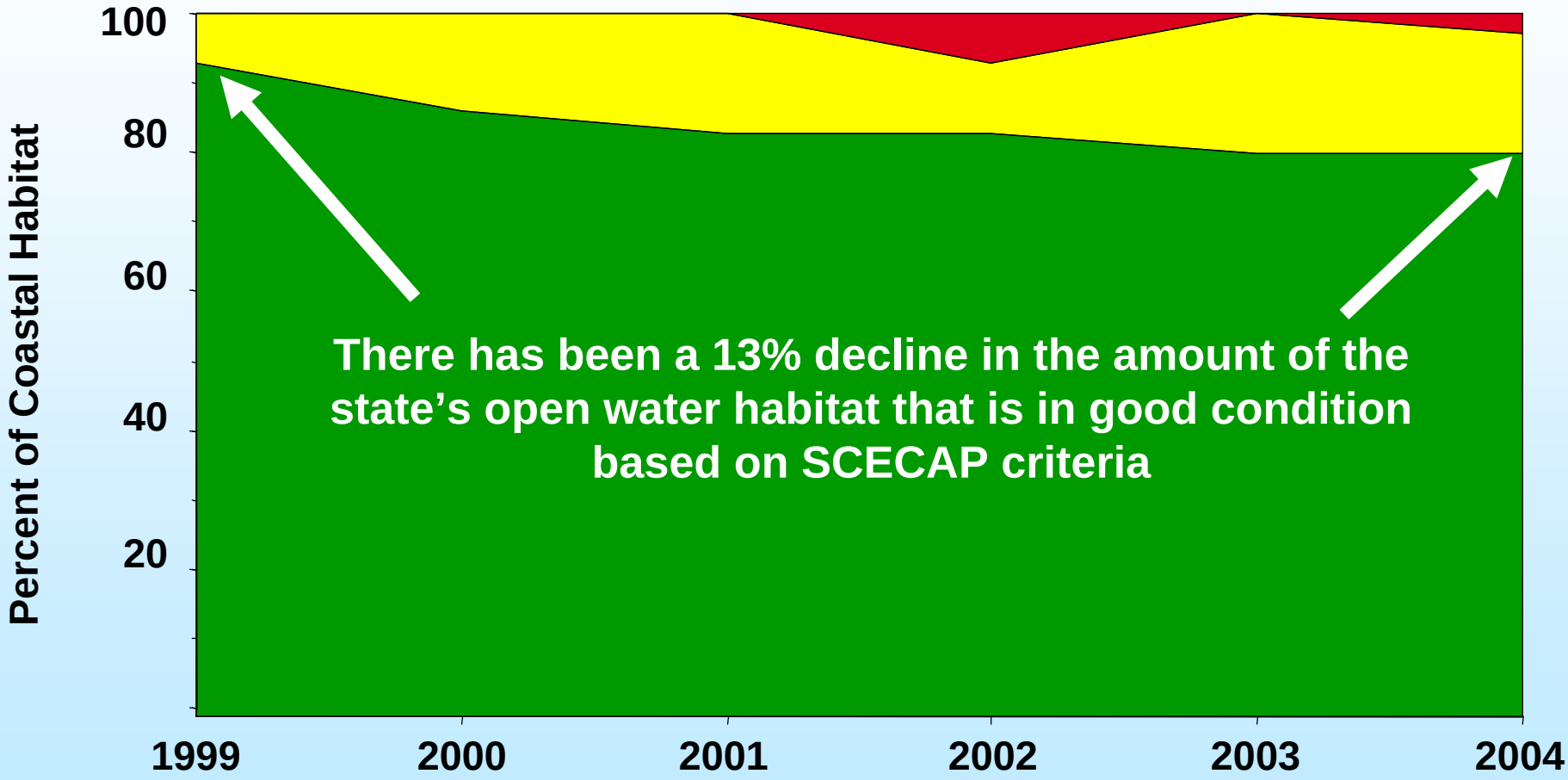
2003 - 2004

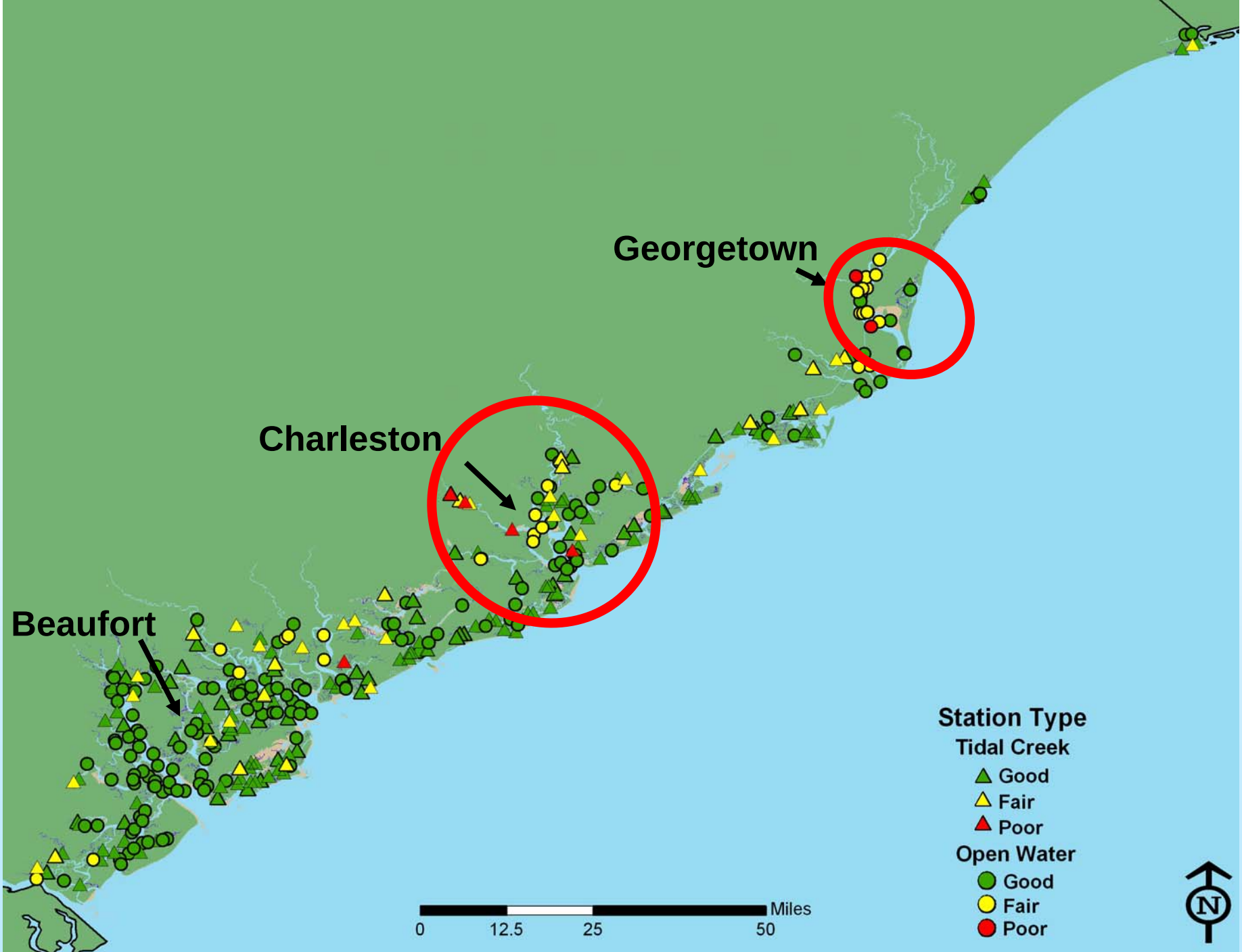


Temporal Change in Overall Habitat Quality Score



Integrated Habitat Quality Score
(Open Water Habitat)




Georgetown
Charleston
Beaufort
Station Type
Tidal Creek
Good
Fair
Poor
Open Water
Good
Fair
Poor
Miles
0
12.5
25
50
N

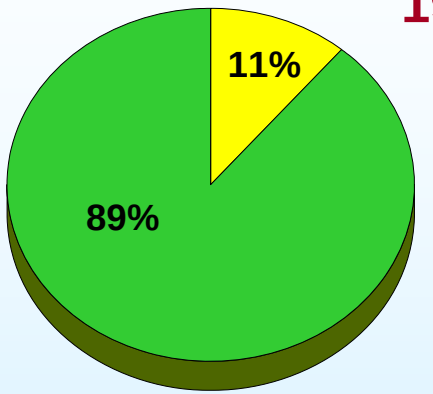
Approach Useful at Several Levels

- **State Wide Assessment**
  - Approach used for 305(b), 303(d) reporting
  - Better than index sites
  - Unbiased random sample
  - Represents entire resource
  - Known confidence of estimates
- **Specific watersheds**

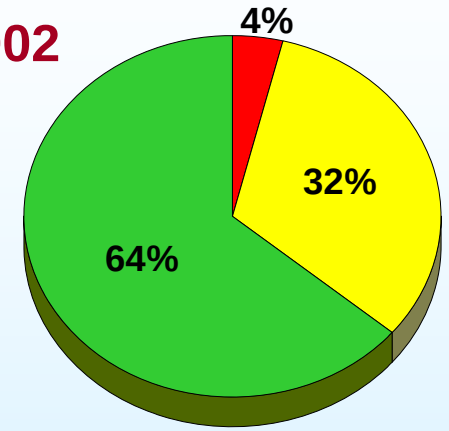
ACE Basin Condition (99-02)

Overall Quality ACE

1999-2002



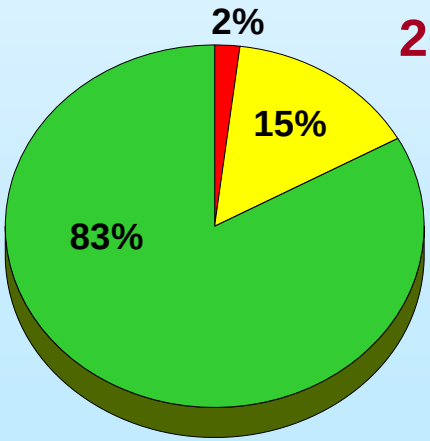
Open

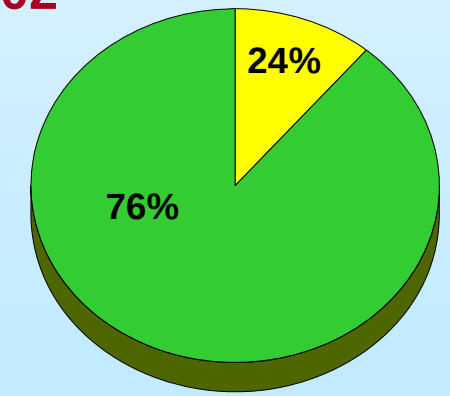


Creeks

Overall Quality Entire State

2001-2002

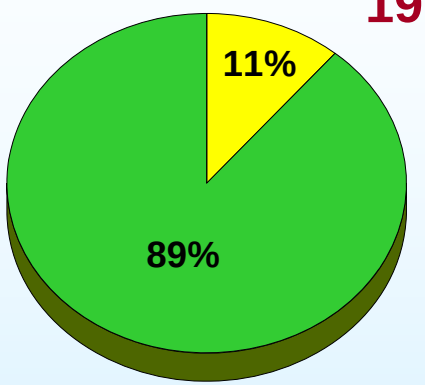




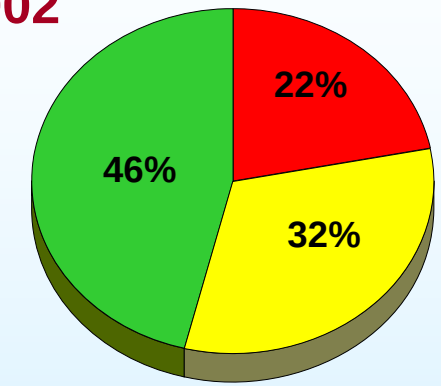
ACE Basin Condition (99-02)

Water Quality
ACE

1999-2002



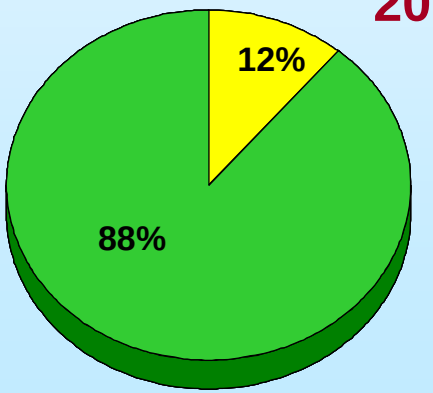
Open

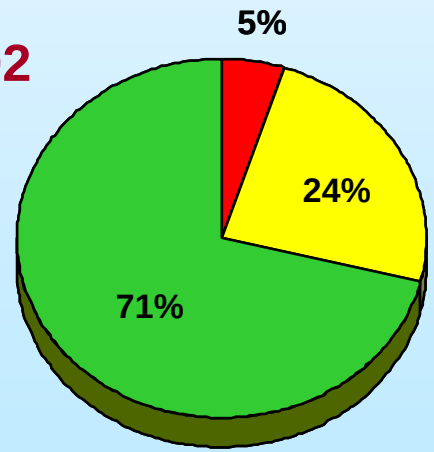


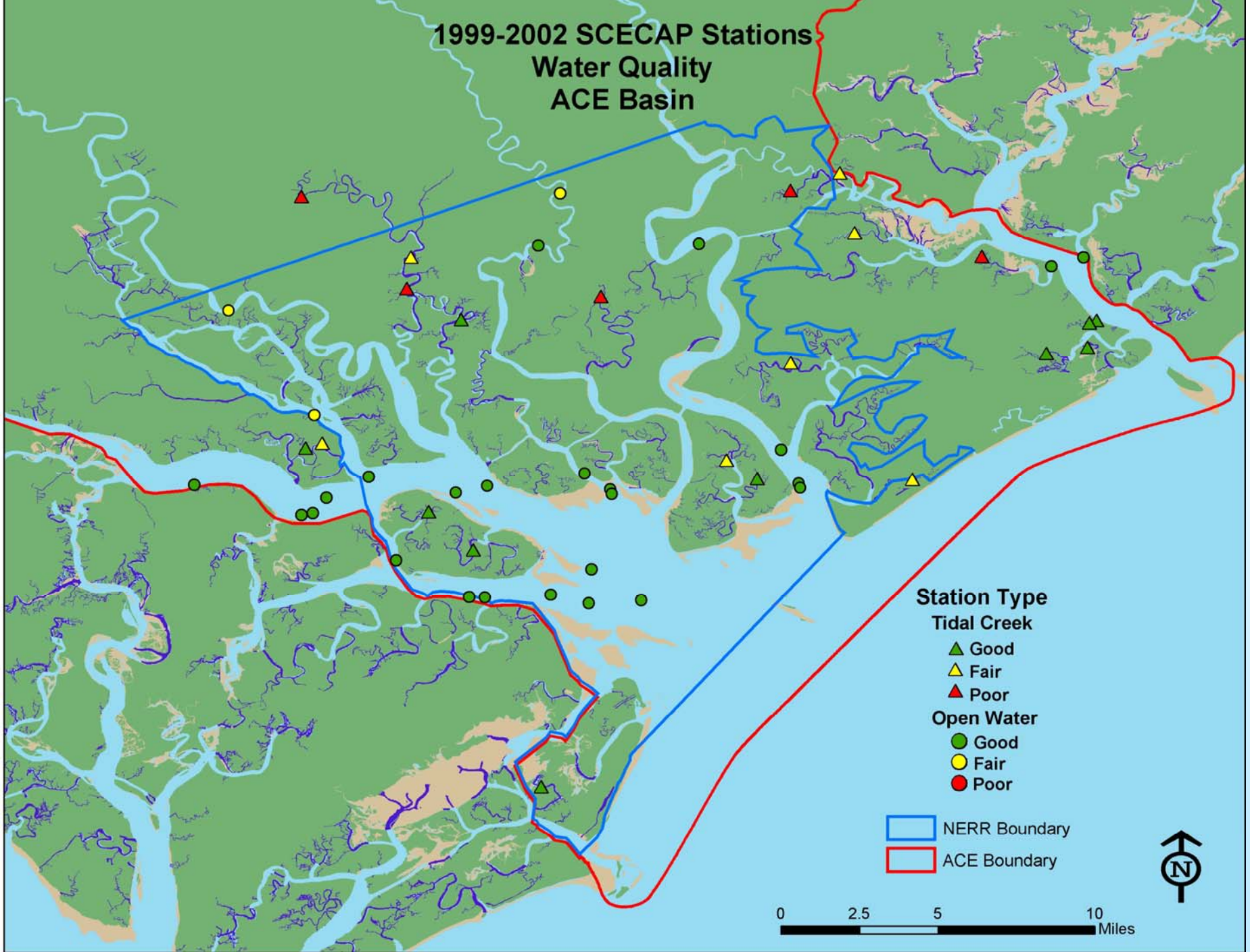
Creeks

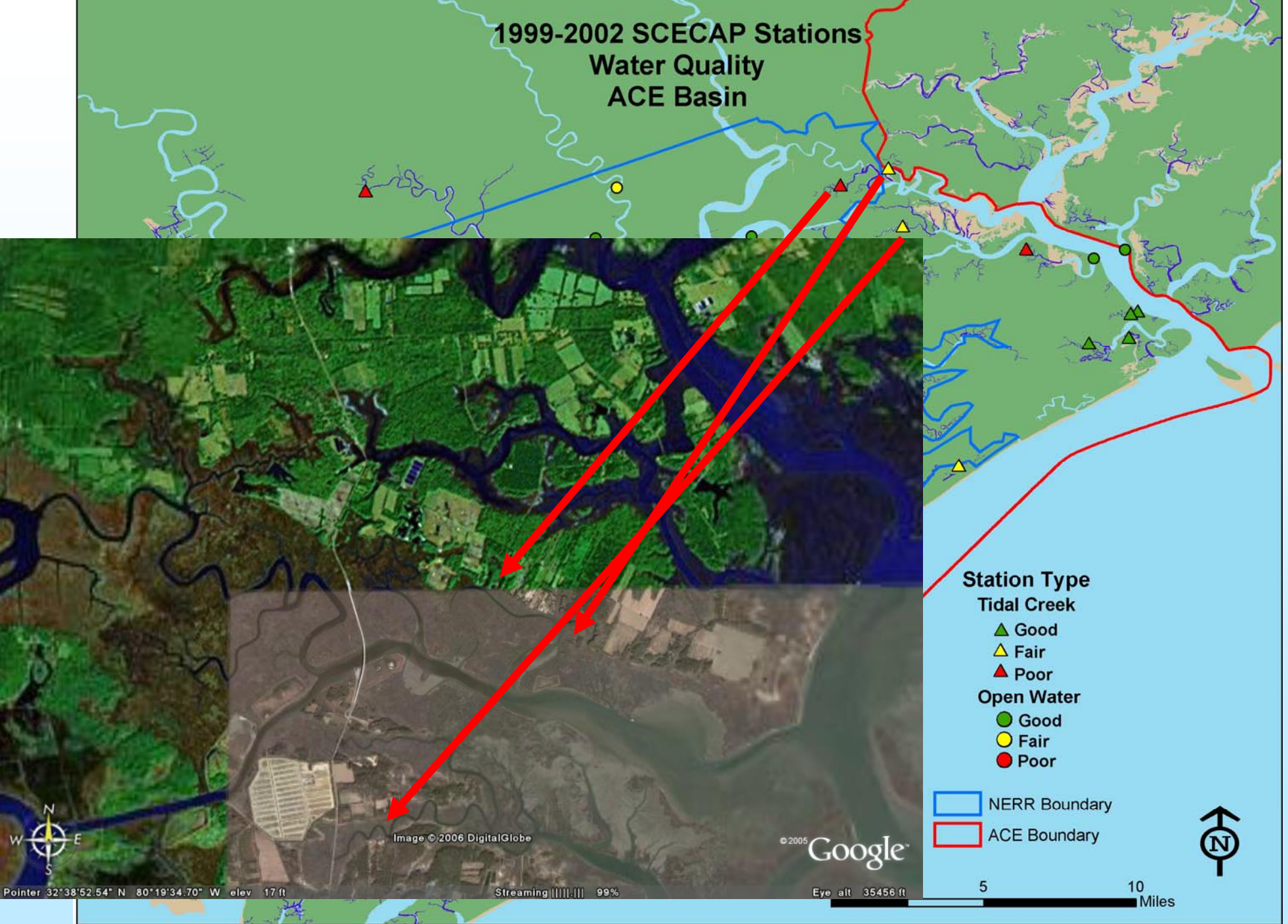
Water Quality
Entire State

2001-2002






1999-2002 SCECAP Stations
Water Quality
ACE Basin
Station Type
Tidal Creek
Good
Fair
Poor
Open Water
Good
Fair
Poor
NERR Boundary
ACE Boundary
N
0
2.5
5
10
Miles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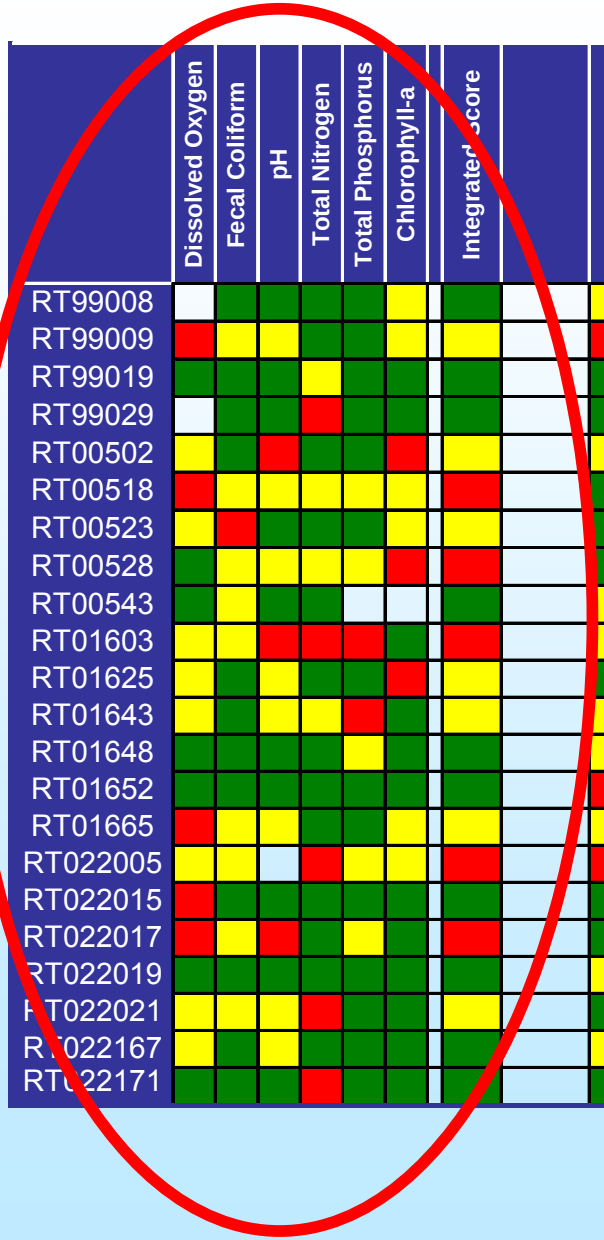
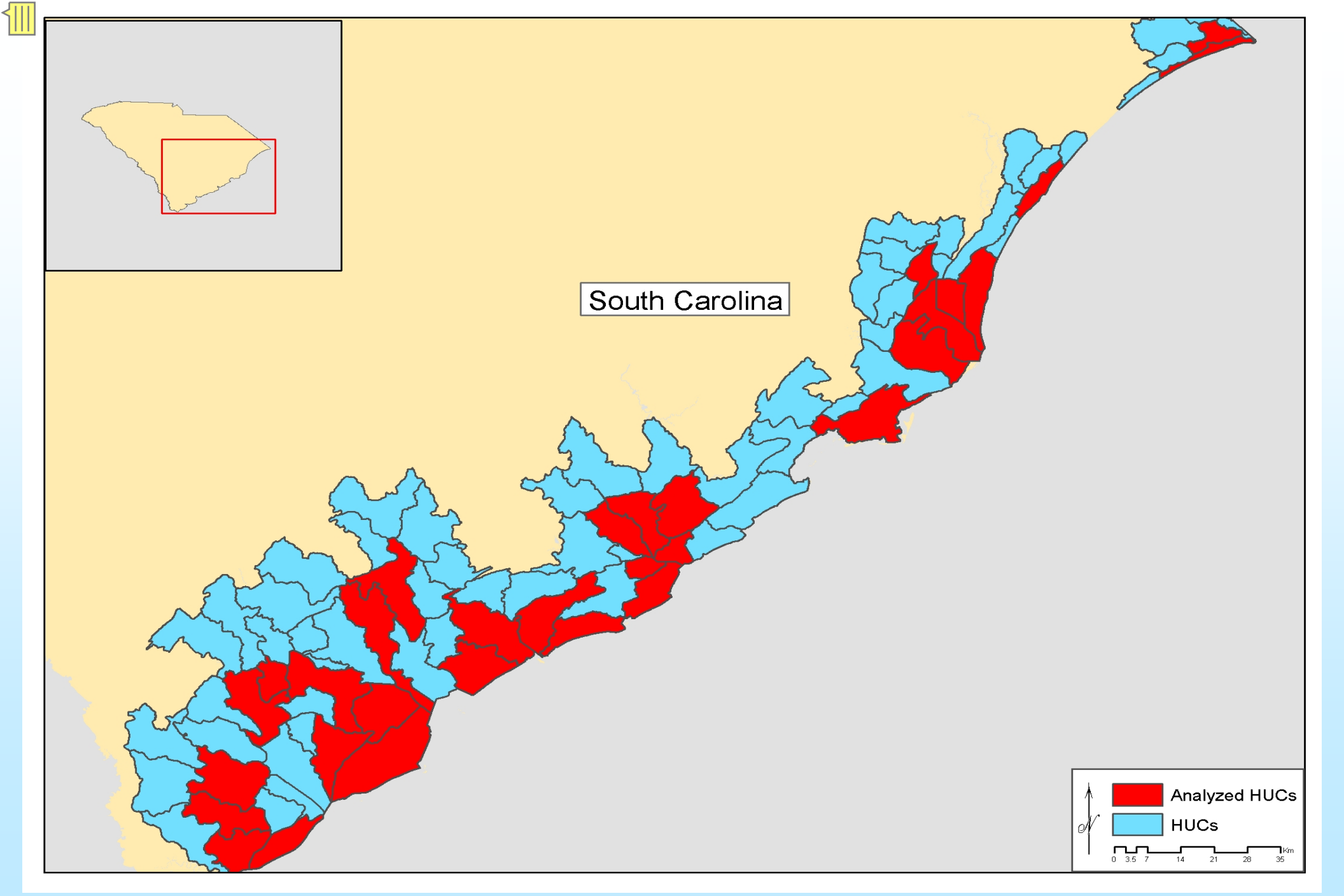
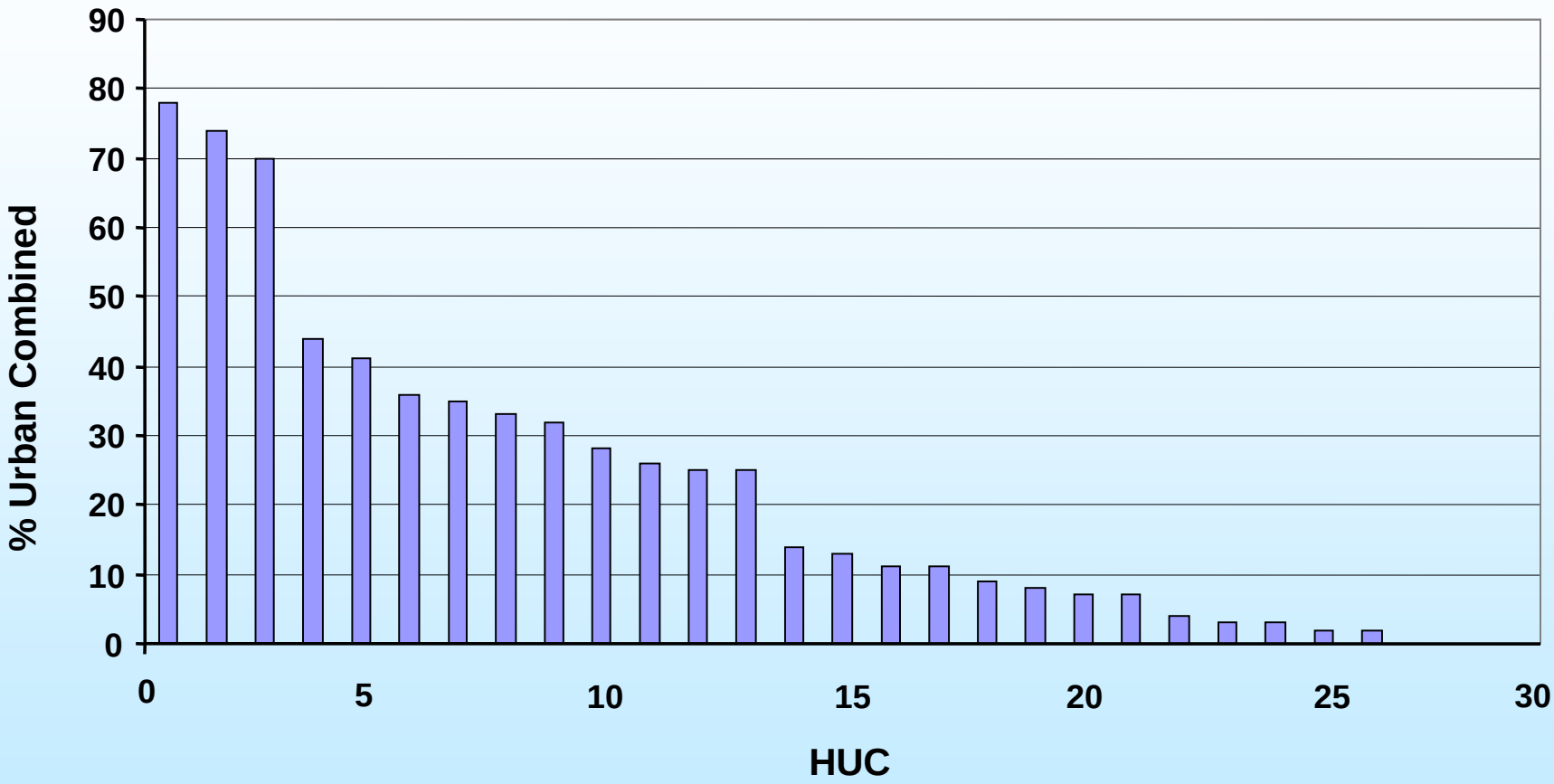
NERR Boundary
ACE Boundary
N
5
10
Miles
Image © 2006 DigitalGlobe
© 2005 Google
Pointer 32°38'52.54" N 80°19'34.70" W elev 17 ft
Streaming 99%
Eye alt 35456 ft



	Dissolved Oxygen	Fecal Coliform	pH	Total Nitrogen	Total Phosphorus	Chlorophyll-a	Integrated Score		Toxicity	Contaminants	Integrated Score		Benthic IBI			Integrated Score			
RT99008																5.0		Beaufort	Small creek on Hunting Island
RT99009																2.3		Charleston	Bailey Creek in South Edisto River
RT99019																5.0		Charleston	Ocella Creek in North Edisto River
RT99029																5.0		Charleston	Small creek in lower North Edisto
RT00502																4.3		Colleton	Old Chehaw River below Social Hall Creek
RT00518																3.0		Charleston	North Edisto River in Westbank Creek
RT00523																4.3		Colleton	Edisto Island in creek behind island
RT00528																3.7		Colleton	Ashepoo River in Mosquito Creek
RT00543																5.0		Beaufort	MorganRiver in center of Morgan Island
RT01603																3.0		Colleton	Old Chehaw River
RT01625																4.3		Colleton	Fish Creek between Otter and Pine Is.
RT01643																4.3		Beaufort	Creek off Bull River above St. Helena Sound
RT01648																3.7		Beaufort	Morgan Island
RT01652																4.3		Charleston	tributary off Ocella Creek, Near Botany Bay Island
RT01665																3.0		Charleston	Dawhoo River
RT022005																3.0		Charleston	Fishing Creek off Dawhoo Cut
RT022015																5.0		Beaufort	Oak Island Creek near Bull River
RT022017																3.0		Colleton	Old Chehaw River near Hwy 162
RT022019																5.0		Colleton	Fish Creek near Otter Island
RT022021																4.3		Charleston	Sand Creek off of Steamboat Creek
RT022167																4.3		Colleton	New Chehaw River NE of Boulder Island
RT022171																5.0		Charleston	Creek at Point of Pines on North Edisto


South Carolina
Analyzed HUCs
HUCs
0 3.5 7 14 21 28 35
Km

Percent Urban Cover for Analyzed HUCs



Approx.600 Stations with Water and/or Sediment Quality Data

Land Cover vs. Estuarine Sediment Quality

Pearson Correlation Coefficients for HUCs with Three or More Stations (Habitats Combined)

Land Cover Category	TOC*	ERM-Q*	PAHs*	PCBs*	Pesticides**	Metals (8)*
Scrub shrub & forested wetlands	0.0207	0.0519	-0.0849	-0.0902	-0.28	0.129
Bare land	-0.238	-0.544	-0.464	-0.292	-0.207	-0.471
Grassland & pasture & scrub shrub	-0.421	-0.267	-0.374	-0.26	-0.179	-0.247
Deciduous & mixed forest	-0.296	-0.194	-0.194	-0.277	-0.215	-0.241
Evergreen forest	-0.0401	-0.305	-0.36	-0.342	-0.343	-0.221
Cutlivated land	-0.134	-0.0744	-0.239	-0.0262	-0.103	-0.0783
Urban low density	-0.0347	0.23	0.319	0.186	0.35	0.141
Urban high density	0.25	0.468	0.551	0.503	0.402	0.401
Urban combined	0.0992	0.361	0.442	0.344	0.389	0.275
Percent impervious surface	0.0016	0.324	0.425	0.412	0.423	0.223

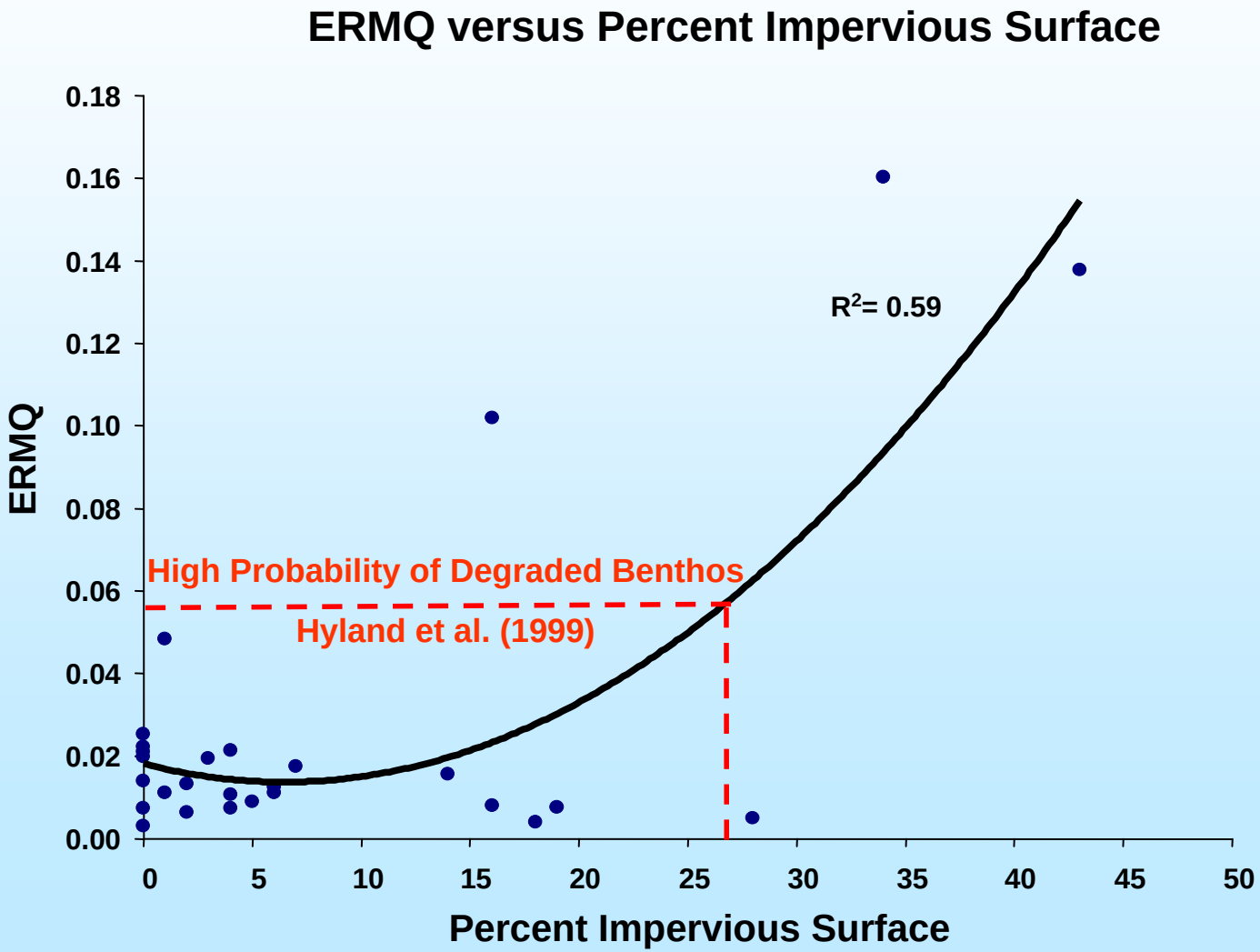
* data log transformed

** Spearman rank correlation

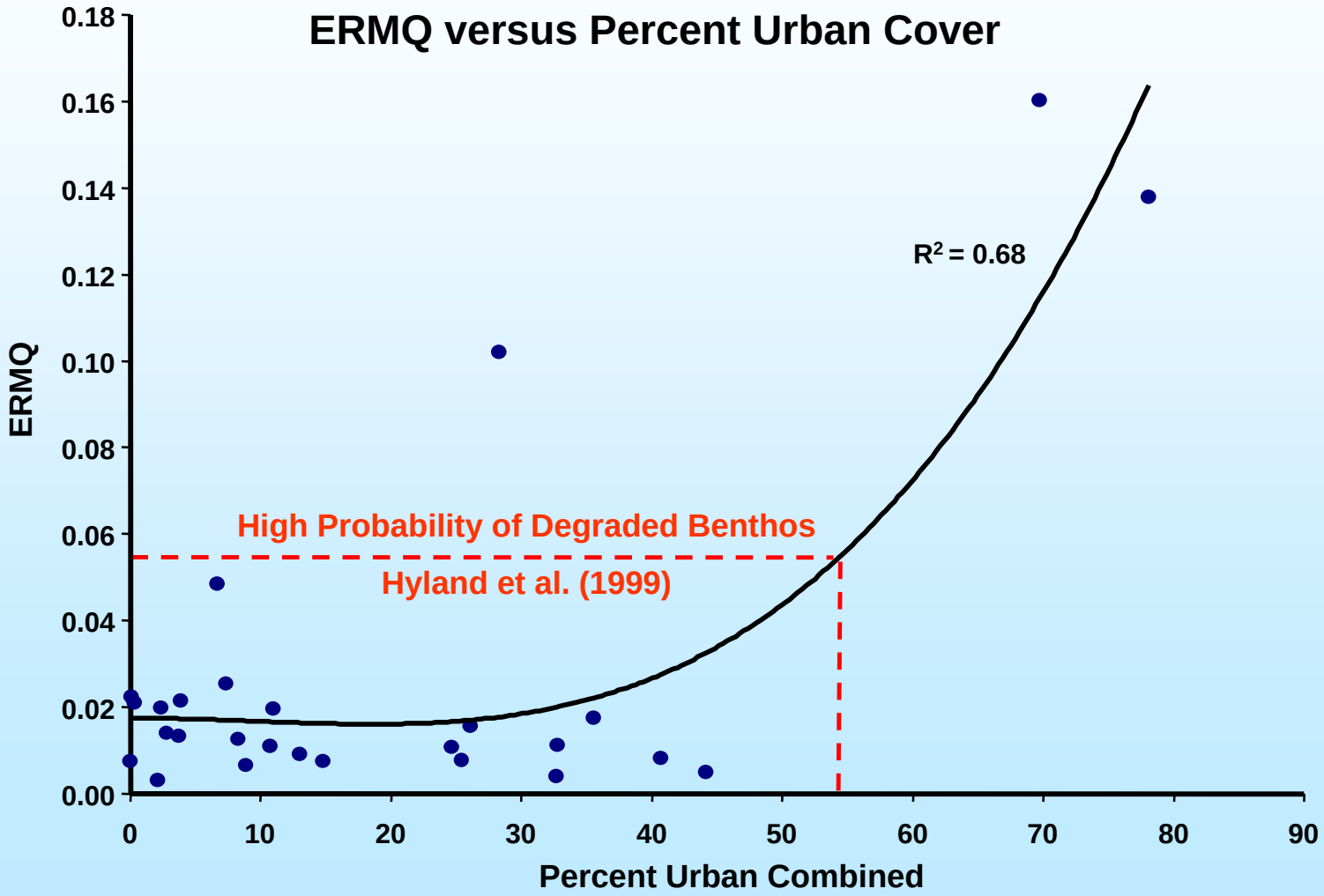
P < 0.05

P < 0.10

Land Cover vs. Estuarine Quality



Land Cover vs. Estuarine Quality



Land Cover vs. Estuarine Water Quality

Pearson Correlation Coefficients for HUCs with Three or More Stations (Habitats Combined)

Land Use Category	NO_2-NO_3	TKN*	Phos	Chl-a	TOC*	Fecals*	pH
Scrub shrub & forested wetlands	0.06	-0.31	-0.10	-0.01	-0.18	-0.50	-0.36
Bare land	-0.28	-0.35	-0.09	-0.26	-0.46	0.04	0.64
Deciduous & mixed forest	0.04	-0.33	0.09	-0.12	-0.12	-0.57	-0.30
Evergreen forest	0.25	-0.05	-0.17	0.18	0.07	-0.34	-0.35
Cutlivated land	0.13	-0.20	0.02	-0.14	-0.30	-0.26	-0.24
Urban low density	-0.24	0.11	0.12	-0.07	0.12	0.40	0.36
Urban high density	-0.03	0.29	0.06	-0.07	0.08	0.50	0.33
Urban combined	-0.19	0.18	0.11	-0.06	0.11	0.46	0.35
Percent impervious surface	-0.05	0.23	0.17	-0.05	0.11	0.48	0.36

* data log transformed

P < 0.05

P < 0.10

Other Agency Uses

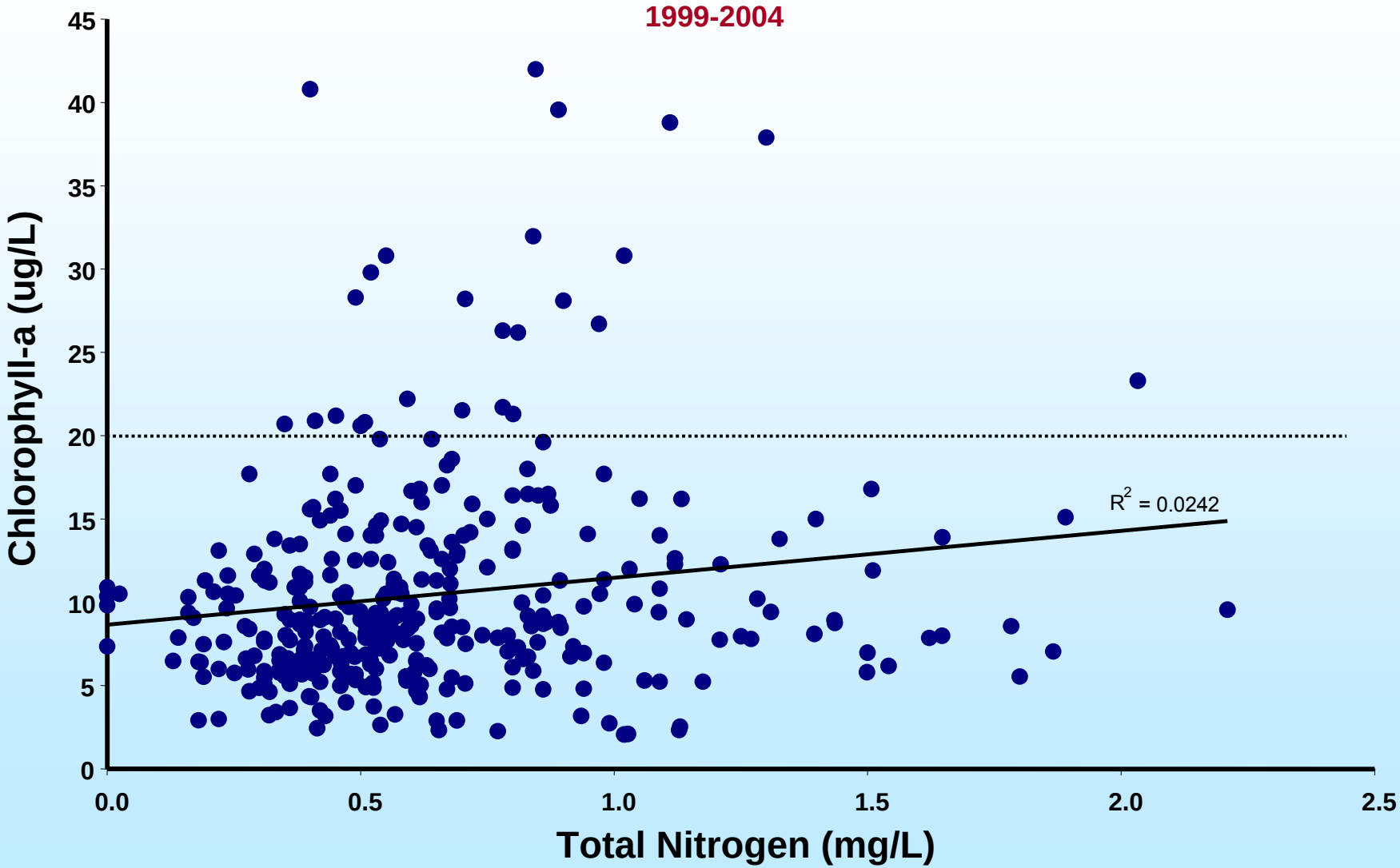
- ***DNR***
  - *Special basin assessments requested by towns, agencies*
  - *State Wildlife Grant information needs*
  - *Fishery monitoring data (spot, croaker, weakfish)*
- ***DHEC - OCRM***
  - *Assessment of effects of docks in tidal creeks*
- ***NOAA***
  - *Oceans and Human Health Initiative – Relating tidal creek order with land use effects*
  - *Dolphin Health Assessment*
  - *Grass Shrimp - Indices of Estuarine Health*

Summary

- ***SCECAP approach is useful to SCDNR and SCDHEC***
  - *Provides unbiased assessment of state's estuarine environmental quality and biotic condition*
  - *Integrated measures of ecosystem condition*
  - *Unique to most other state monitoring programs*
  - *Useful for evaluating change over time state-wide*
- ***Additional Program Values***
  - *Allows comparison between natural (unaltered) conditions and versus areas of concern*
  - *Aids in understanding relationships between environmental and biotic condition*

Summary

- ***Easily adaptable to North Carolina coastal zone***
  - *Already a database with >170 sites (220 when 2005-2006 included)*
  - *Pick your own parameters and thresholds*
  - *Can use existing benthic index, others available locally, or a mix*
    - *Polyhaline-euhaline - northern latitudes: 89% accuracy*
    - *Oligohaline- mesohaline – all latitudes: 82% accuracy*

- ***Try it – You might like it !!!***

Total Nitrogen vs. Chlorophyll-a