SEDAR Procedural Workshop I
Indices Introduction
Why are we here?

Julie A. Neer
SEDAR Coordinator

Indices Procedural Workshop
Miami, FL
October 2008

SEDAR Procedural Workshops

Designed to address issues the have come up repeatedly in multiple SEDARs

- issues raised by both reviewers and participants

Designed to improve areas in the process that are lacking

Improve efficiency in preparation for workshops

- knowing what is expected

Increase quality of the product & amount of feedback at DW

Summary of Issues

Selection Criteria

- Indices with conflicting trends supposedly tracking same stock or stock subset
- Little or no evaluation of indices with respect to their relationship to and ability to track overall abundance
- Discussion of correlations between indices

Weighting Schemes

- Selection

Documentation

- Maps of survey coverage
- Summary presentations

SEDAR is a Council process

- many steps past the Review Workshop
- need to build a "legally defensible record" of decisions
  - "excessive requirements" for Review but necessary for Council

My Role at this workshop:

- SEDAR representative
- Big picture

SEDAR Procedural Workshop – Indices

SEFSC, MIAMI, FL, Oct. 14-17, 2008

What makes a good index of abundance?

- For fishery-independent:
  - fishery-independent survey objectives
  - sampling design
  - species targeted
  - life stage of target species at time of sampling
  - time of year of survey
  - areas where surveys are conducted
  - length of time series
  - conflicting trends with other independent and dependent indices

What makes a good index of abundance?

- For fishery-dependent data:
  - species targeted (including data reduction techniques)
  - life stage of target species at time of fishery prosecution
  - effects of data reporting errors
  - time of year of fishery prosecution
  - areas where fishery is prosecuted
  - length of time series
  - regulation and closure effects

Objectives of the workshop and resulting document:

- address the above factors relative to numerous databases used in the SEDAR process
- provide minimum requirements and an expected format for submission of SEDAR data workshop documents concerning development of abundance indices
- determine desired criteria for selecting indices for inclusion in the assessment model
- provide generalized and standardized computer code for developing abundance indices.
- The major deliverable of this workshop will be a document providing guidelines for indices development and documentation and criteria for assessing the usefulness of individual indices for stock assessment purposes.

Tuesday, October 14th

1300 Introduction (Julie Neer and Walter Ingram)

1320 Overview of Large Scale Fishery Independent Surveys (Walter Ingram)

1350 Overview of Small Scale Fishery Independent Surveys (Cami McCandless and John Carlson)

1420 Discussion and Determination of Main Issues of Fishery Independent Surveys (everyone)

1450 Break

1500 Fisheries dependent commercial data and its use in constructing indices of abundance (Kevin McCarthy)

1530 Standardization of Recreational CPUE: data sources and issues (Craig Brown)

1600 Discussion and Determination of Main Issues of Fishery Dependent Surveys (everyone)

A Brief Overview of Large-Scale, Fishery-Independent Surveys of NOAA Fisheries, MS Labs, in Relation to Development of Indices of Abundance, Problems and Solutions

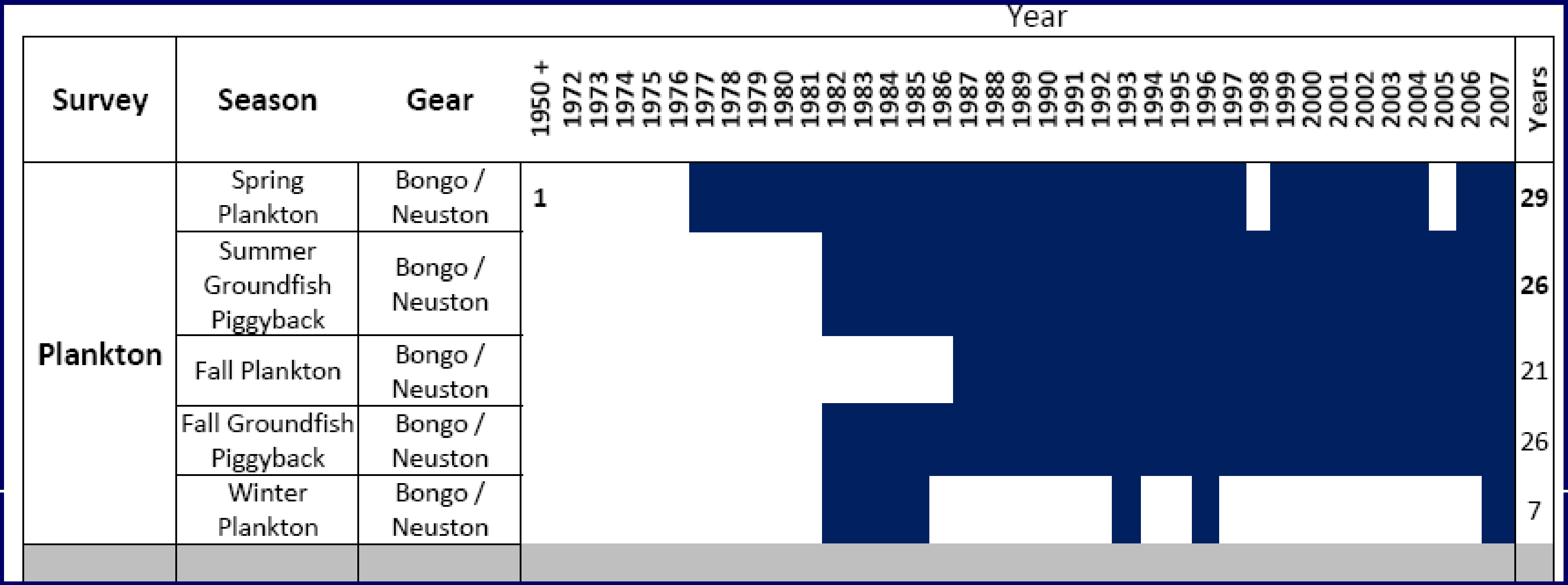
Walter Ingram

Resource Surveys

- Plankton Surveys
- Trawl Surveys
- Reef Fish Surveys
- Longline Surveys

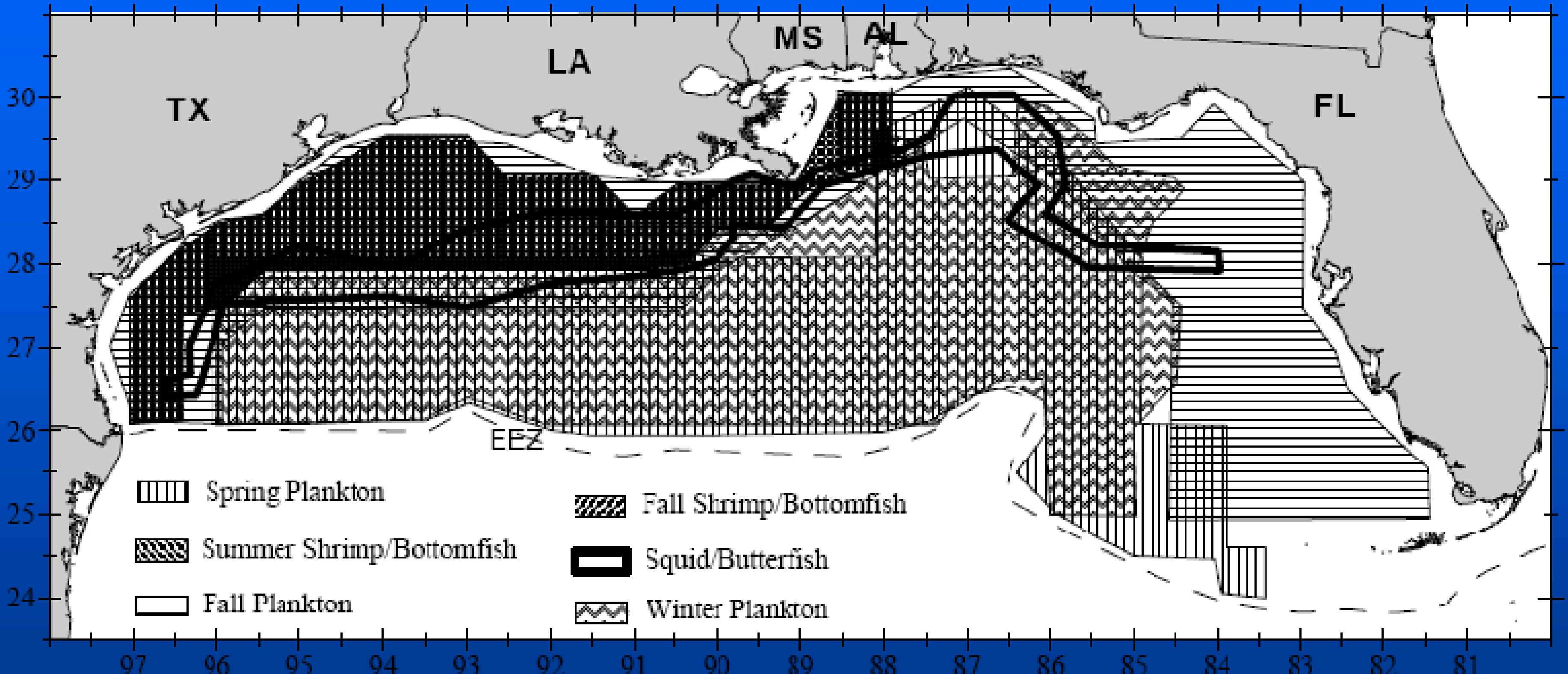
Plankton Surveys

- SEAMAP spring plankton survey
- SEAMAP fall plankton survey
- SEAMAP winter plankton survey
- SEAMAP piggyback plankton surveys (on groundfish surveys)



Comparative coverage of plankton sampling during SEAMAP resource surveys

(prior to the 2007 winter survey in the eastern Gulf)



Plankton Surveys (FSSI Stocks)

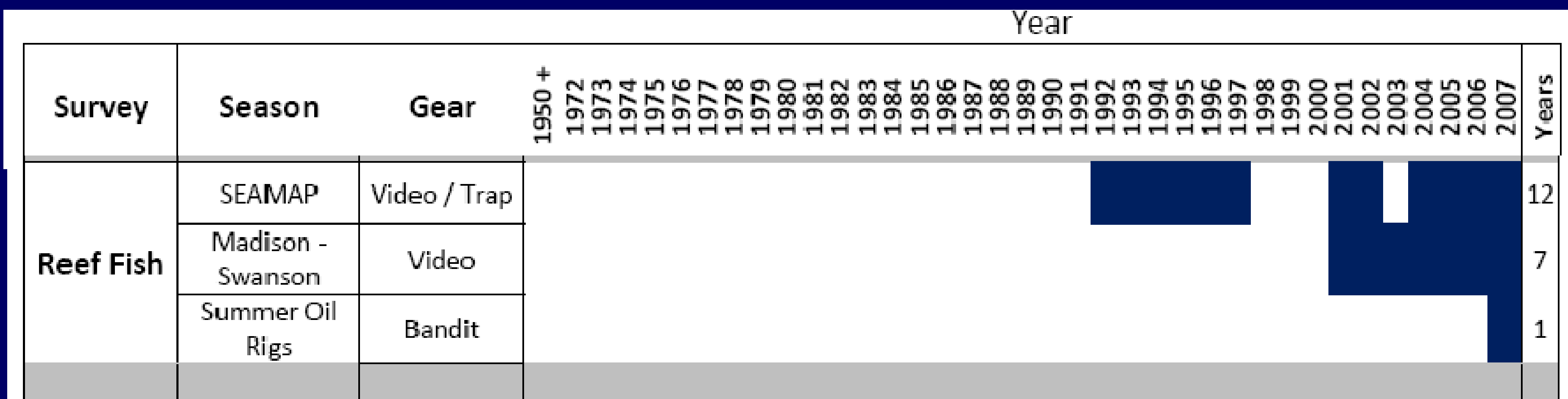
- SEAMAP spring plankton survey
  - Brown shrimp, Red grouper, Greater amberjack, Gag, Yellowedge grouper, Snowy grouper, Black grouper, Nassau grouper
- SEAMAP fall plankton survey
  - Brown shrimp, Pink shrimp, White shrimp, Royal red shrimp, Red snapper, Red grouper, Vermilion snapper, Gray triggerfish, Hogfish, Red drum
- SEAMAP winter plankton survey
  - Royal red shrimp, Gag, Yellowedge grouper, Snowy grouper, Black grouper, Hogfish, Nassau grouper
- SEAMAP piggyback plankton surveys (on groundfish surveys)
  - Brown shrimp, Pink shrimp, White shrimp, Royal red shrimp, Red snapper, Greater amberjack, Gray triggerfish,

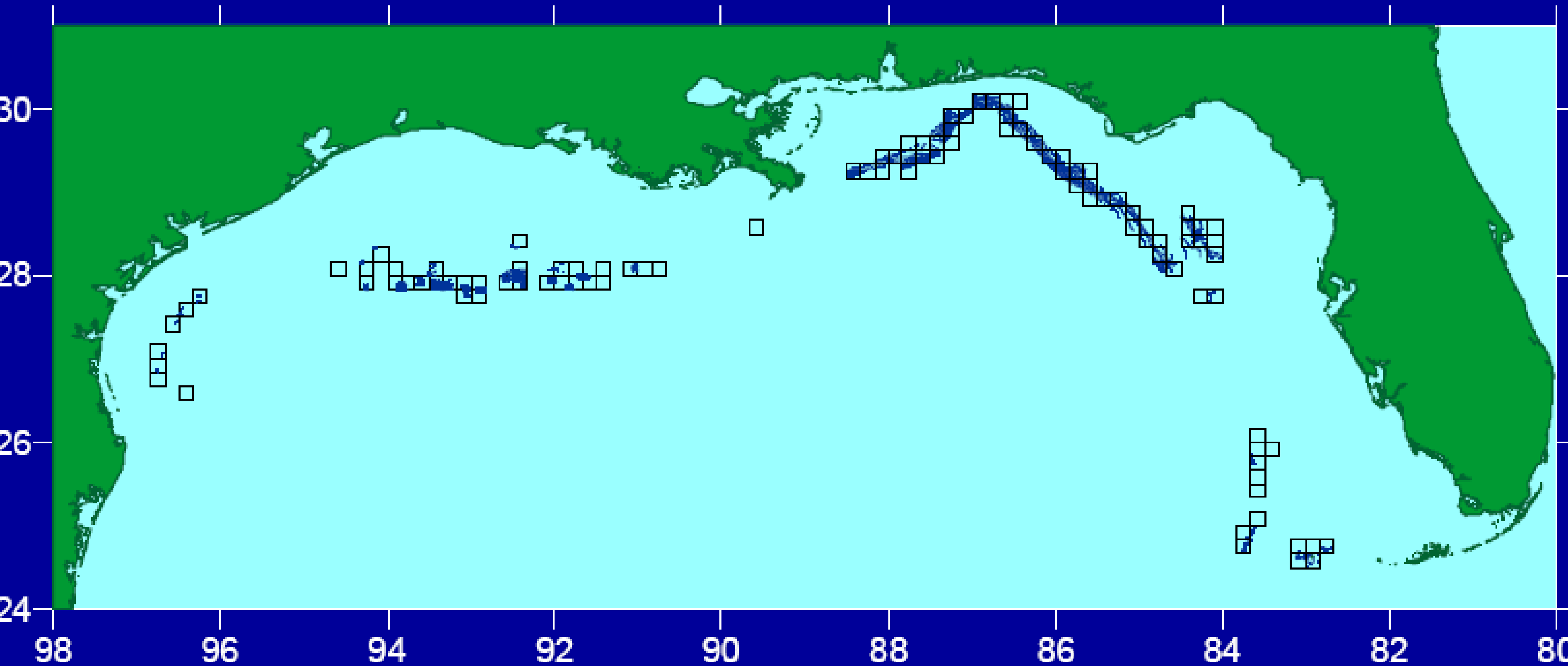
Plankton Surveys Concerns

- Systematic Sampling Design
  - Stations in 30-nmi grid
- Winter plankton surveys intermittent
- Indices typically have large CVs

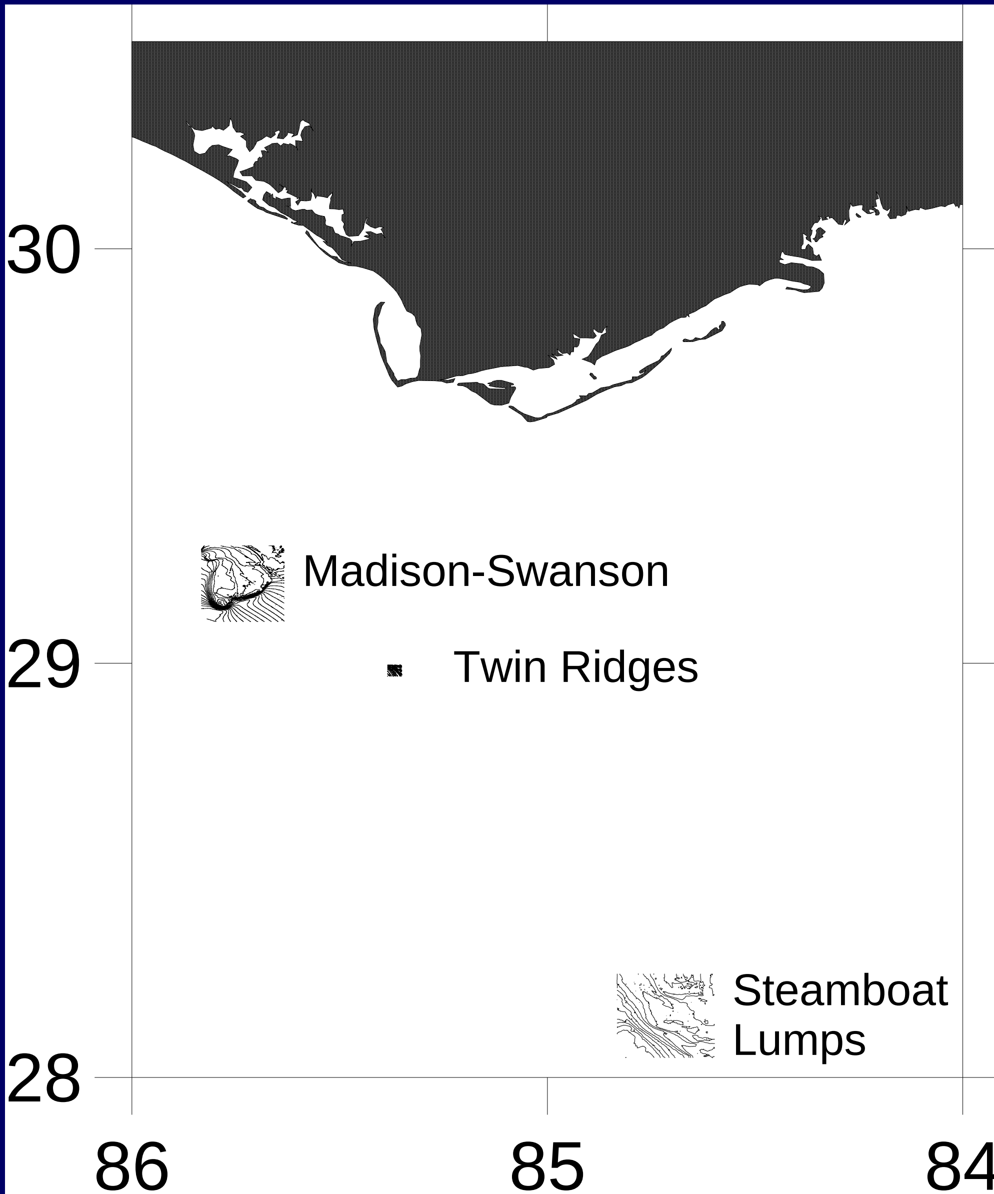
Reef Fish Surveys

- SEAMAP Trap/video survey
- Madison-Swanson Monitoring
- Oil Rig Monitoring





- Targets groupers, snappers, other Reef Fish FMP species.
- Two stage sampling. Primary Units are 10' Blocks of latitude and longitude. Ultimate sample units are reef sites.
- 1992-1997; 2001-2002, 2004-2007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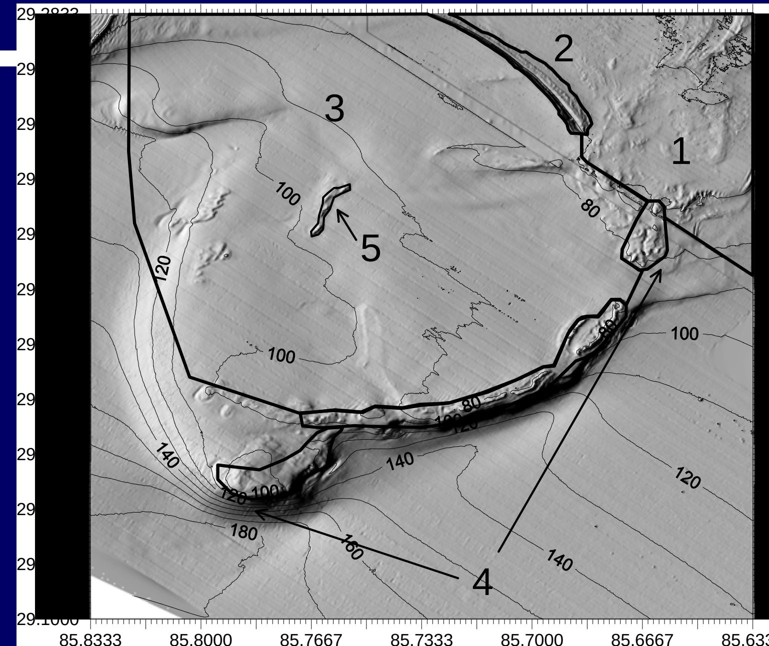
Madison-Swanson
Twin Ridges
Steamboat
Lumps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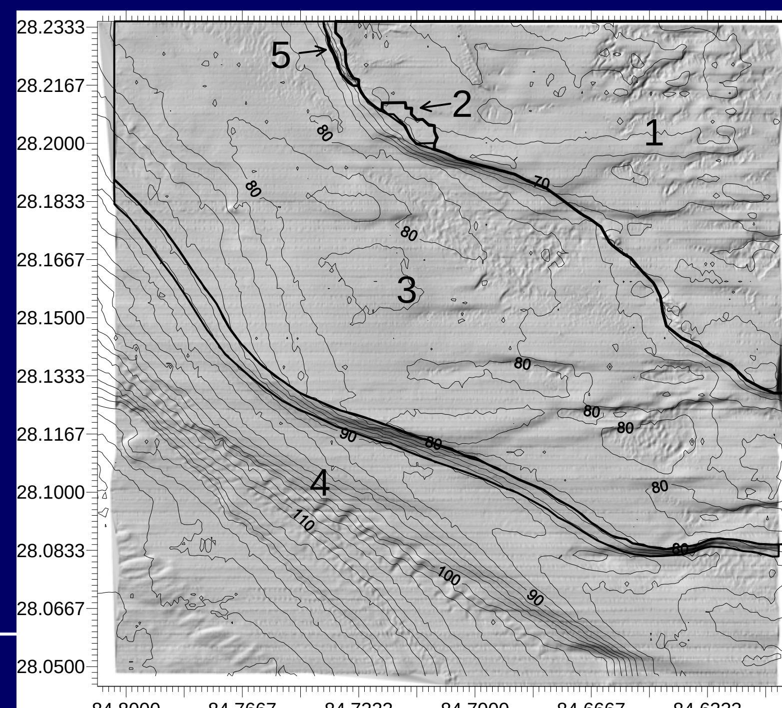
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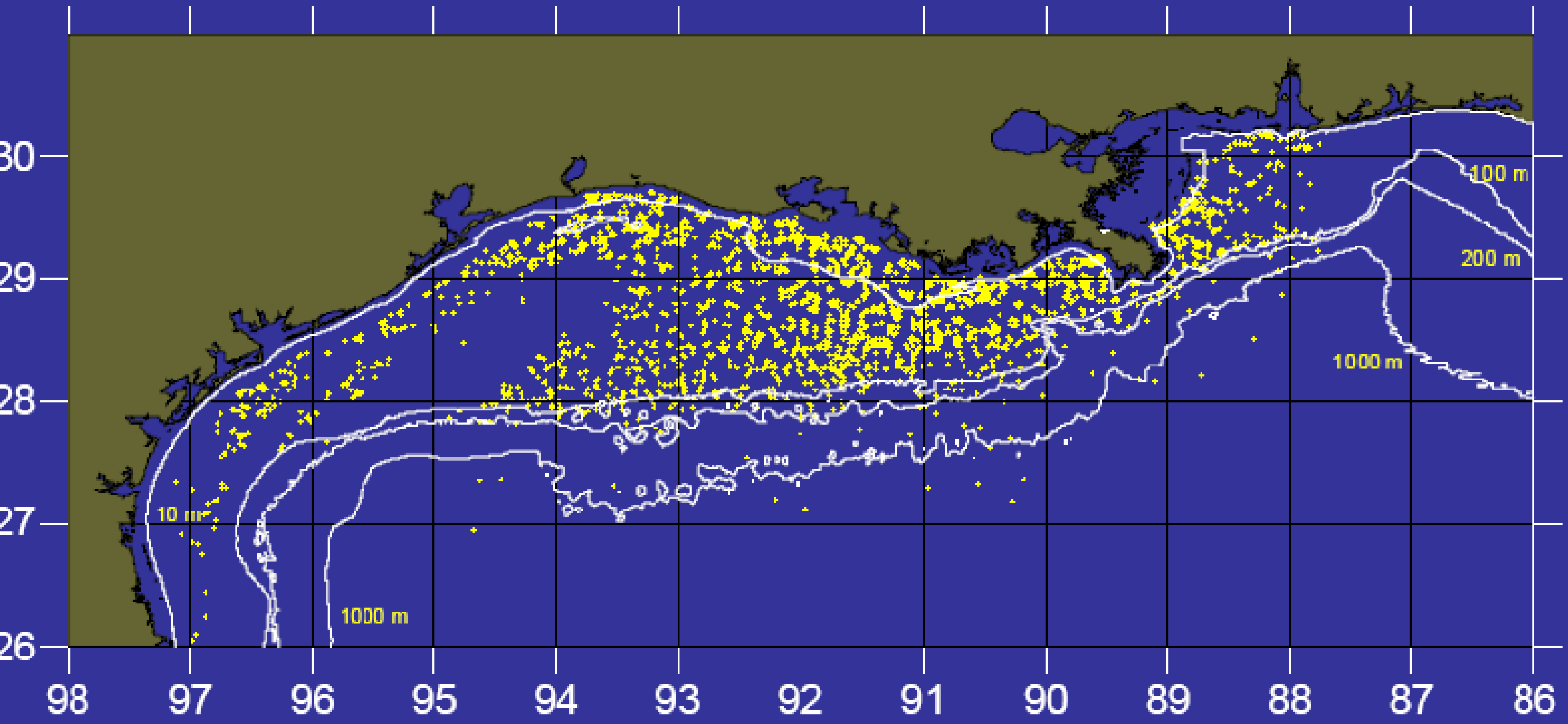
Oil/Gas Platform Survey



Reef Fish Surveys (FSSI Stocks)

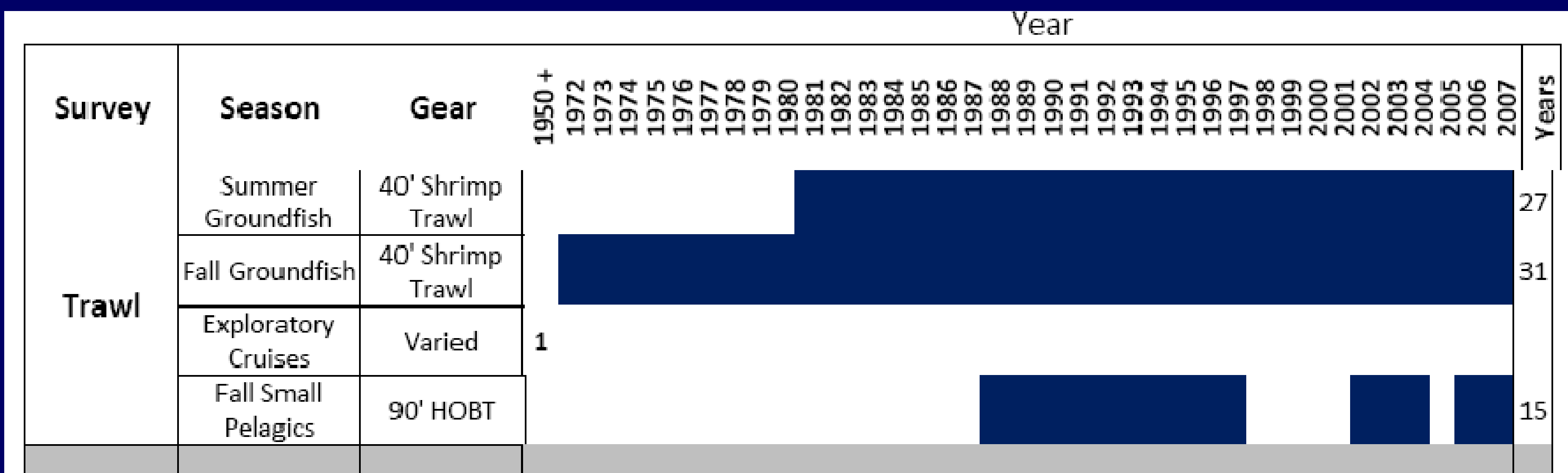
- SEAMAP Trap/video survey
  - Red snapper, Red grouper, Greater amberjack, Vermilion snapper, Gag, Gray triggerfish, Yellowedge grouper, Snowy grouper, Black grouper, Hogfish, Nassau grouper
- Madison-Swanson Monitoring
  - Same as above
- Oil Rig Monitoring
  - Red snapper

Reef Fish Surveys Concerns

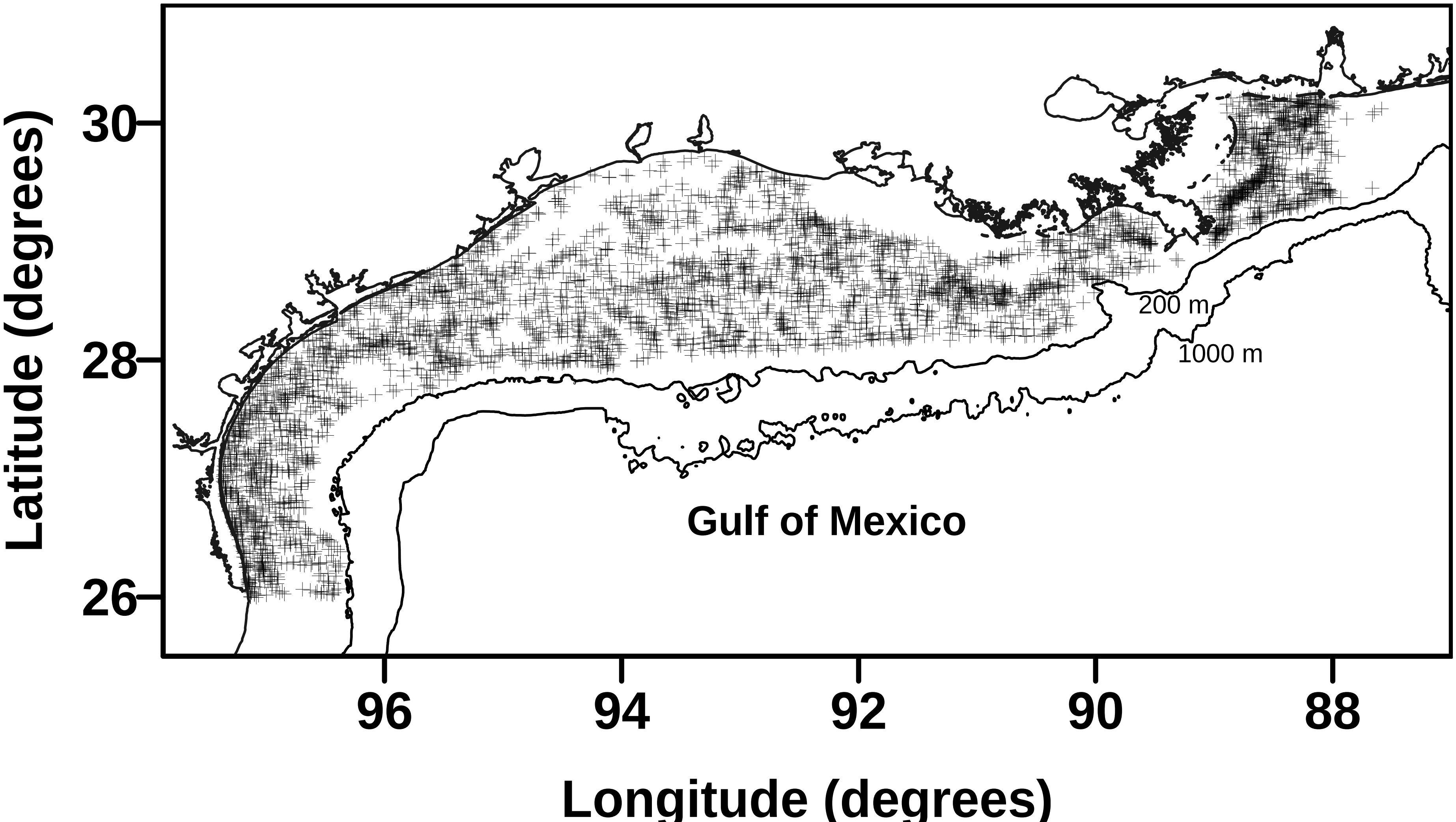
- SEAMAP Trap/video survey
  - Decent time series length but with data holidays
  - Limited Survey Area
  - Indices typically have large CVs
- Madison-Swanson Monitoring
  - Limited survey area
  - Relatively short time series
  - Indices typically have large CVs
- Oil Rig Monitoring
  - Just started

Trawl Surveys

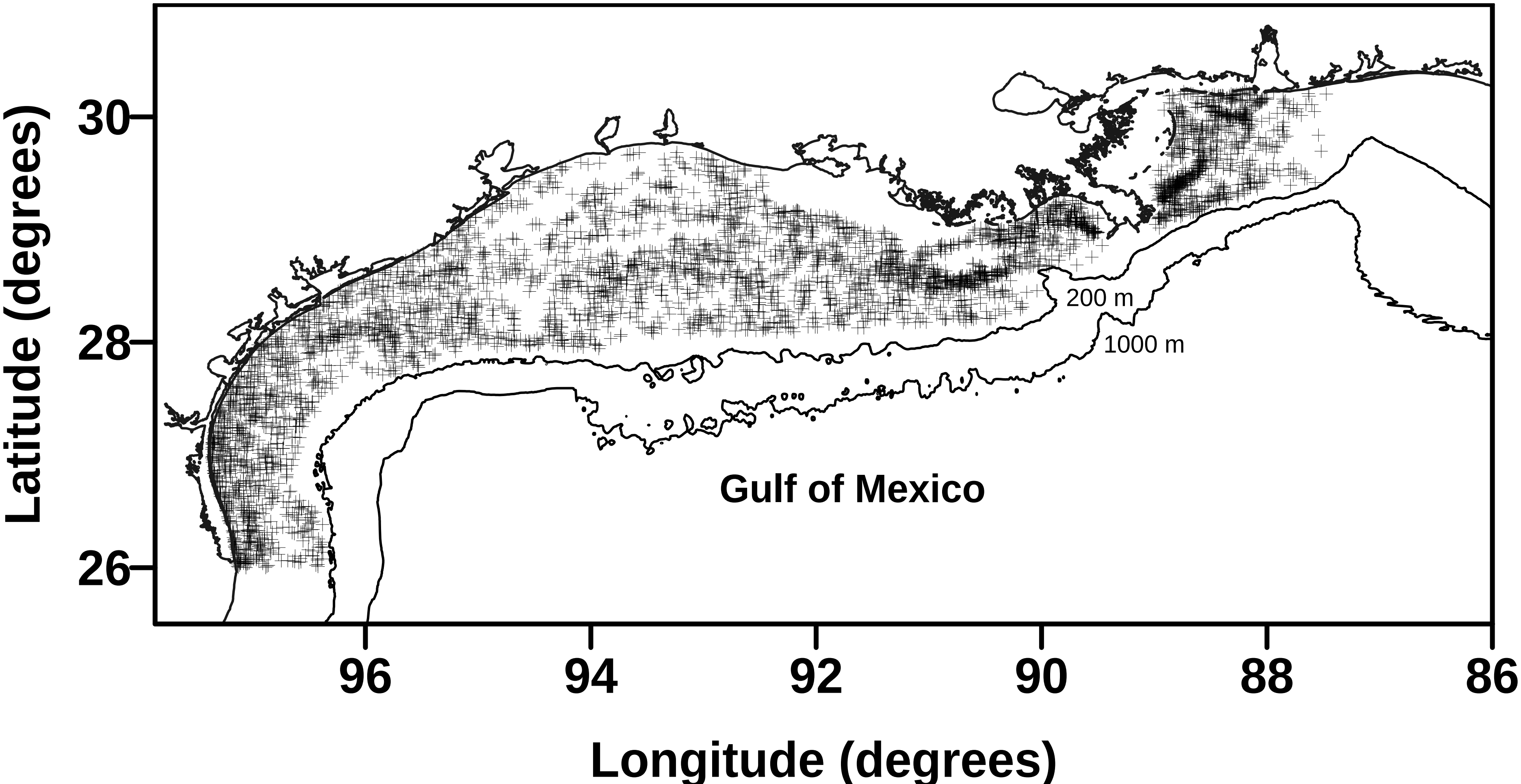
- SEAMAP Fall groundfish trawl survey
- SEAMAP Summer groundfish trawl survey
- Small Pelagic high opening bottom trawl (HOBT) survey



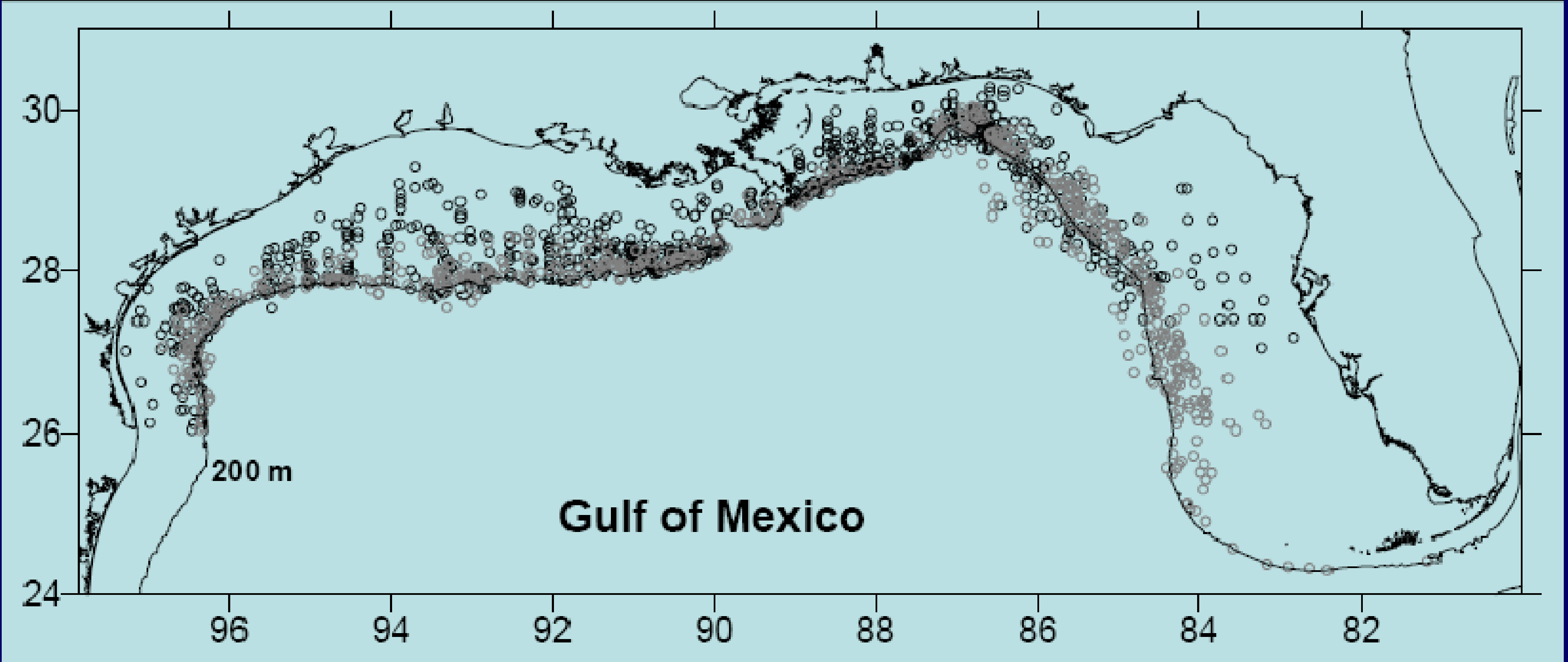
Fall Groundfish



Summer Groundfish



Effort during Historic and current Small Pelagics Trawl Surveys



Trawl Surveys (FSSI Stocks)

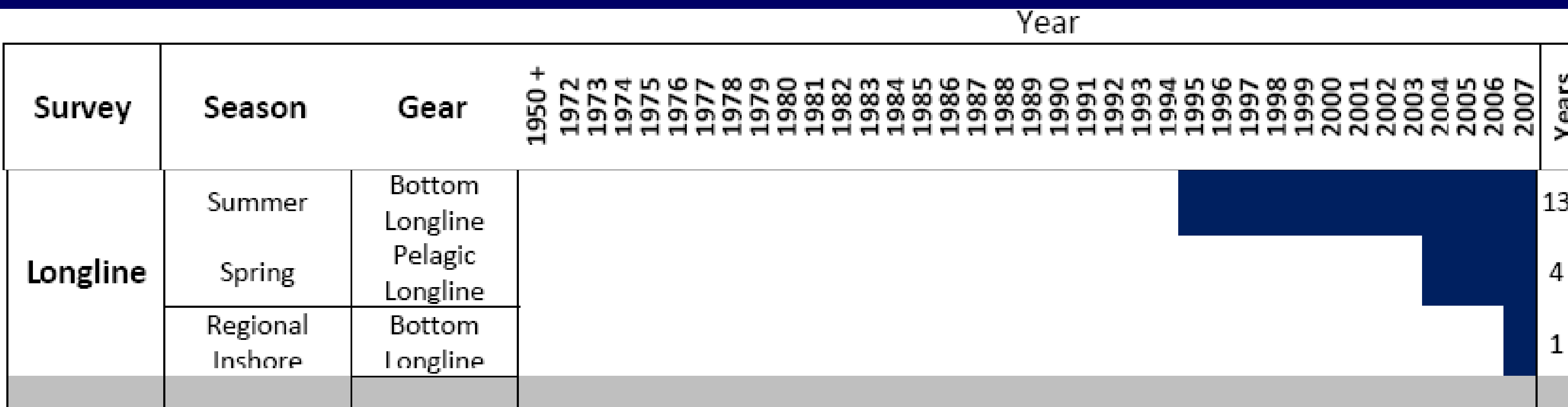
- SEAMAP Fall groundfish trawl survey
  - Brown shrimp, Pink shrimp, White shrimp, Red snapper, Greater amberjack, Vermilion snapper, Gray triggerfish
- SEAMAP Summer groundfish trawl survey
  - Brown shrimp, Pink shrimp, White shrimp, Red snapper, Greater amberjack, Vermilion snapper, Gray triggerfish
- Small Pelagic high opening bottom trawl (HOBT) survey
  - Brown shrimp, Pink shrimp, White shrimp, Royal red shrimp, Red snapper, Greater amberjack, Vermilion snapper, Gray triggerfish

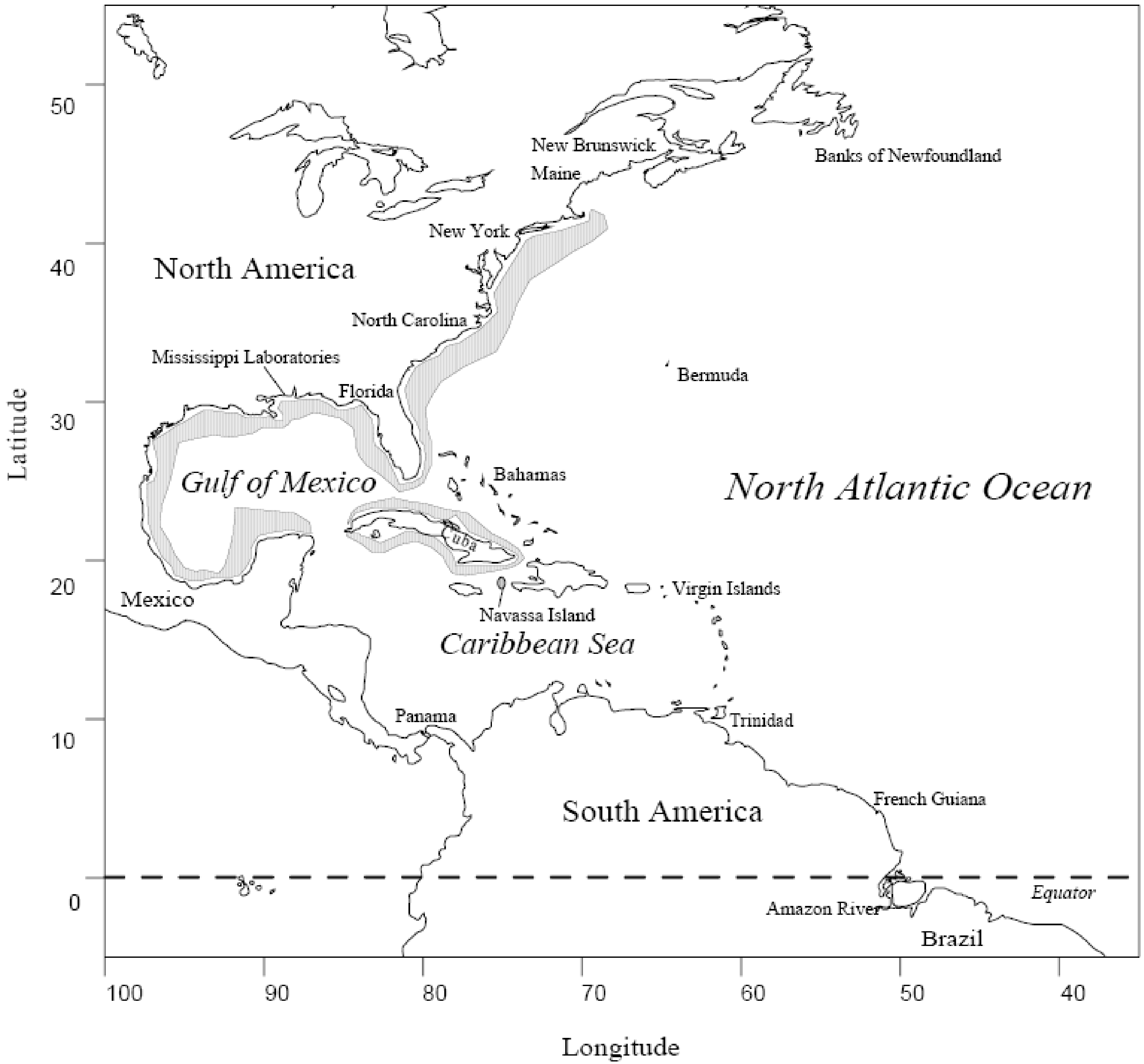
Trawl Surveys Concerns

- SEAMAP Fall and Summer groundfish trawl survey
  - Indices for certain species have large CVs
- Small Pelagic high opening bottom trawl (HOBT) survey
  - Decent time series length but with data holidays and changes in survey design
  - Indices typically have large CVs

Longline Surveys

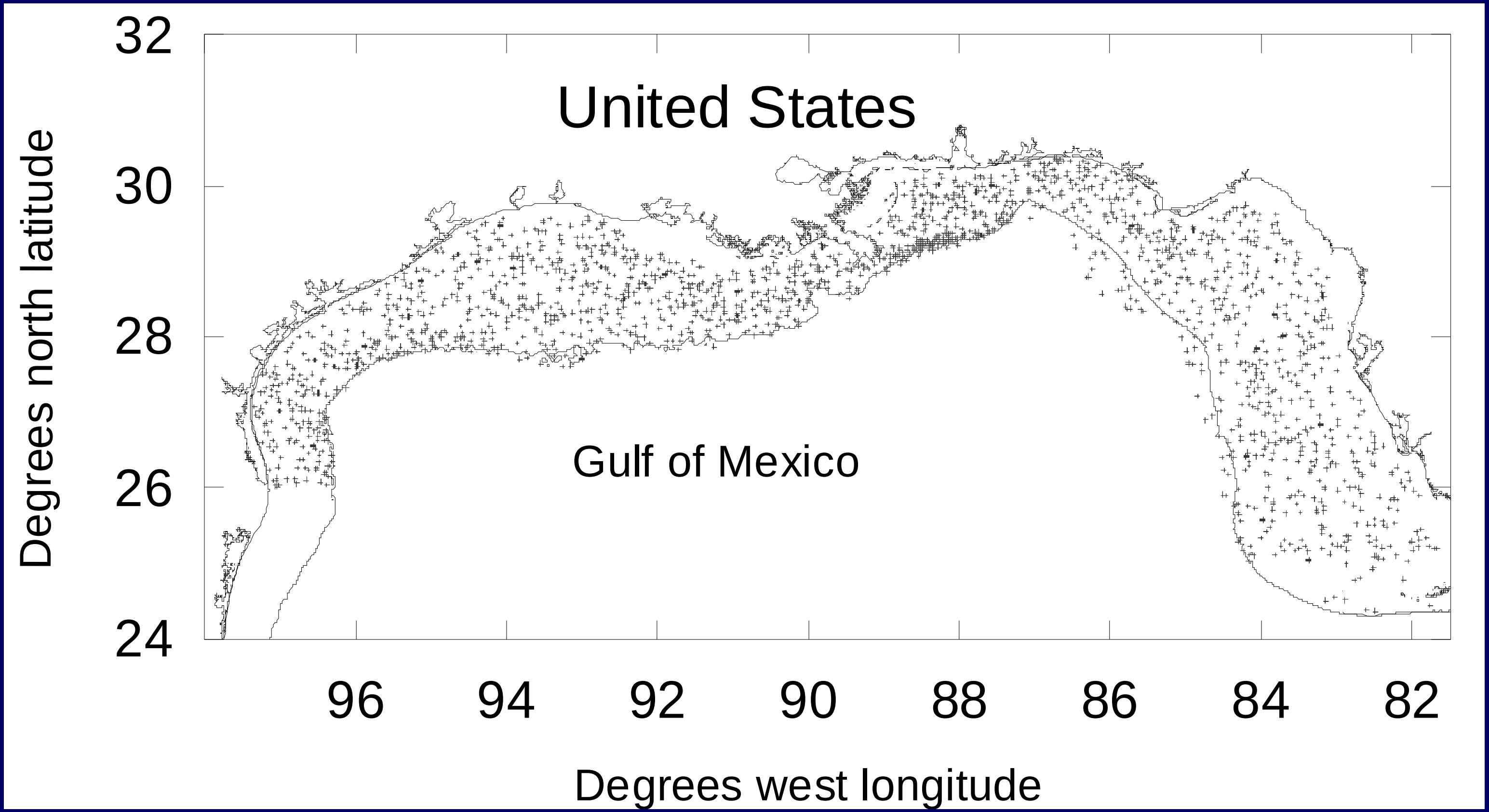
- Bottom Longline Survey
- Pelagic Longline Survey
- Regional, Coastal Longline Survey



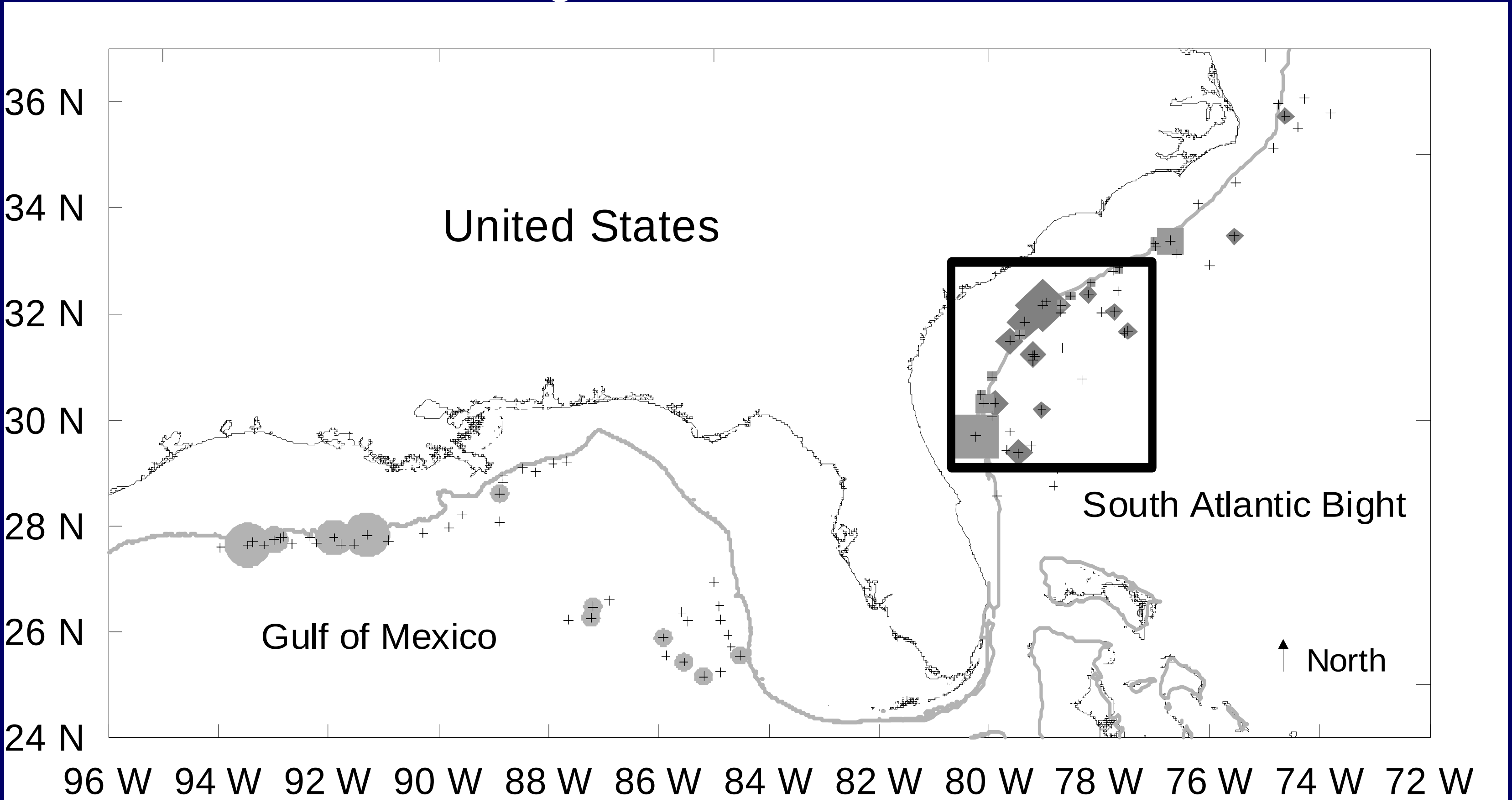


Survey areas for NMFS shark projects (1995 - 2008) in the western North Atlantic Ocean.

Survey area and sampling locations (indicated by crosses) in the Gulf of Mexico during National Marine Fisheries Service, Mississippi Laboratories fisheries-independent bottom longline surveys, 1995-2006



Sampling effort and catch-per-unit-effort (CPUE) of silky sharks collected during pelagic longline surveys conducted by NMFS/MSLABS. Sampling effort is indicated by crosses. CPUE of silky sharks collected during 2004, 2005 and 2006 is indicated squares, circles and diamonds, which are linearly related to the magnitude of the CPUE.



Longline Surveys (FSSI Stocks)

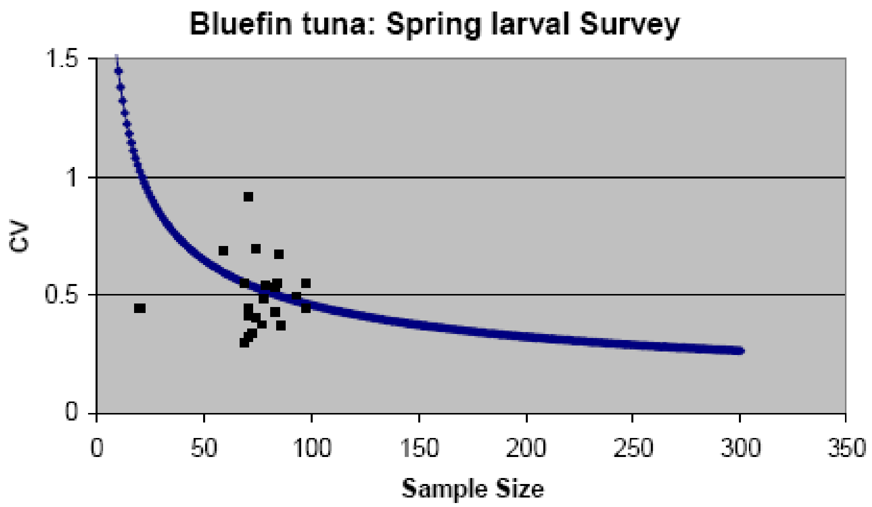
- Bottom Longline Survey
  - Red snapper, Red grouper, Greater amberjack, Vermilion snapper, Gag, Yellowedge grouper, Snowy grouper, Red drum
- Pelagic Longline Survey
  - King mackerel, Little tunny, Blue marlin, White marlin, Sailfish, Bigeye Tuna, Albacore, Bluefin tuna, Yellowfin tuna, Swordfish, Sandbar shark, blacktip shark, blacktip shark, Shortfin mako shark, Blue shark, Dusky shark
- Regional, Coastal Longline Survey
  - Red snapper, Greater amberjack, Red drum

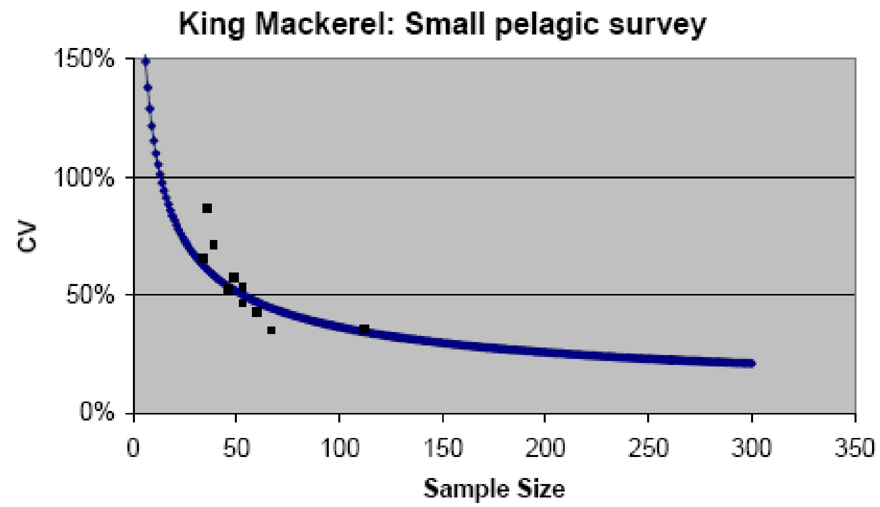
Longline Surveys Concerns

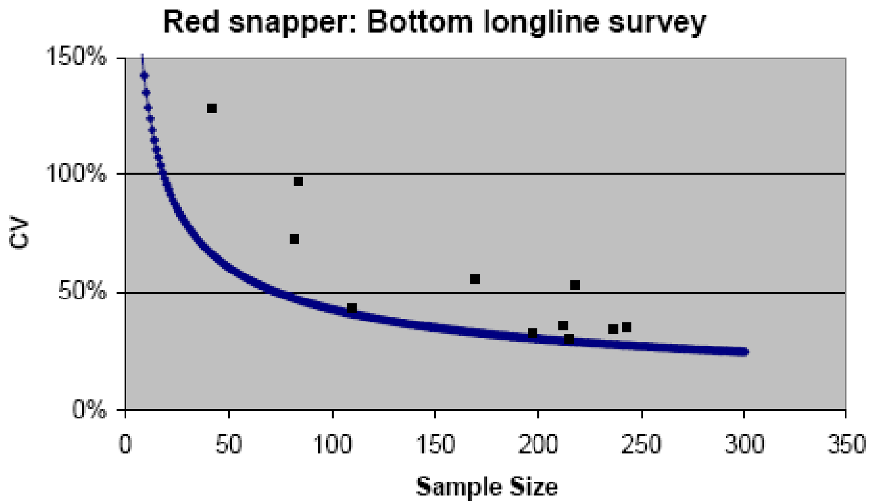
- Bottom Longline Survey
  - The time-series were considered short as of the most recent stock assessments
  - Indices typically have large CVs
- Pelagic Longline Survey and Regional, Coastal Longline Survey
  - Still in the developmental stages

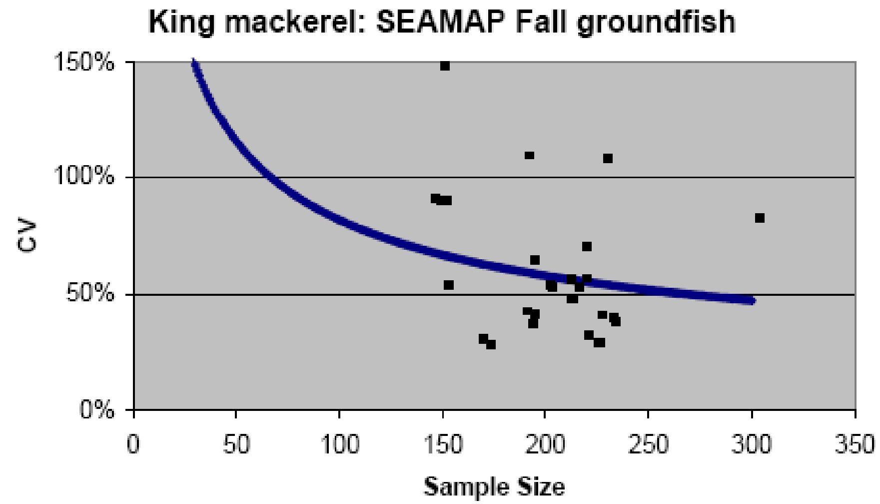
Overall Concerns of Large-Scale, Fishery-Independent Surveys

- Most prevalent concern – large CVs of the abundance indices









What’s it ultimately going to take?

$

Overview of Small Scale Fishery Independent Surveys

John Carlson
SEFSC-Panama City, FL

Cami McCandless
NEFSC-Narragansett, RI

Why small scale?

- Sampling in different spatial and temporal zones
  - Most larger NOAA vessels unable to get into shallow areas or restricted to certain times of the year
- Different life stages
  - Earlier life stages often found outside normal sampling areas
  - Recruitment indices
- At times, only available information is from small scale surveys

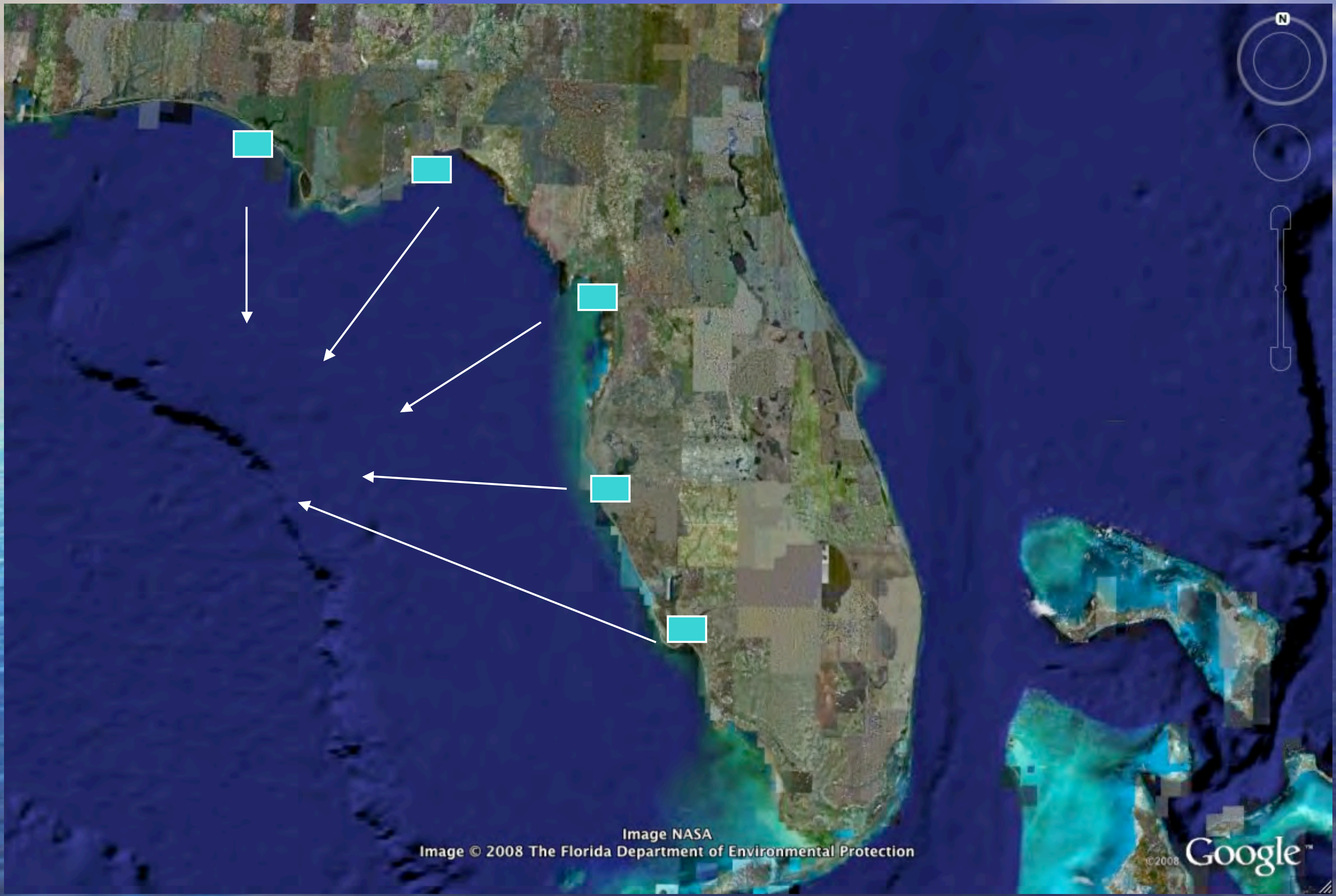
Survey design

- Standardized to fullest extent possible
  - Established stations
  - Randomly stratified by depth, grid, area, season
    - Study specific

Equal weight?

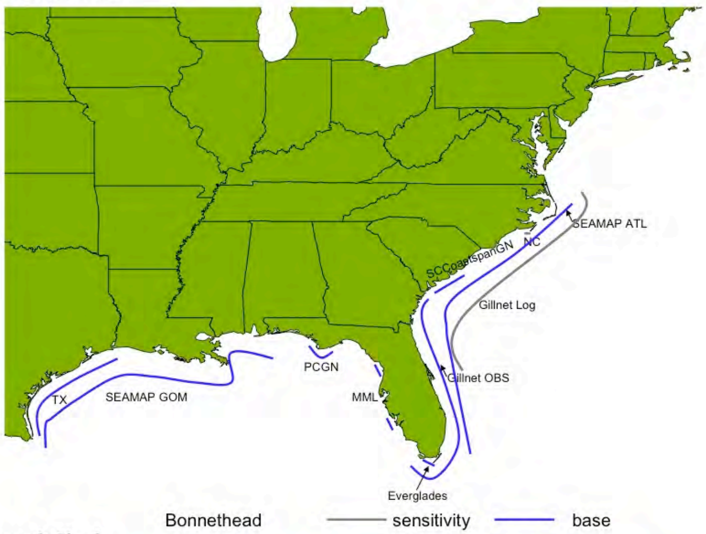
- Trawls, longlines, gillnets, traps, hook and line, and visual surveys
- Not stockwide but can be smaller segments of the species range
- Target species
  - Gag (Koenig and Coleman 1998; Heinisch and Fable 1999)
  - Sharks (Carlson and Brusher 1999, McCandless 2005, Drymon 2007)
  - Red porgy (Devries 2006)
  - Reef fish (Gomez 2000, Tobias et al. 2002, Mateo 2002)
  - State surveys
    - TX parks and Wildlife, SCDNR, FWC

Gag age-0 fishery independent index



Examples of Geographic Coverage

C. Bonnethead Shark



D. Finetooth Shark

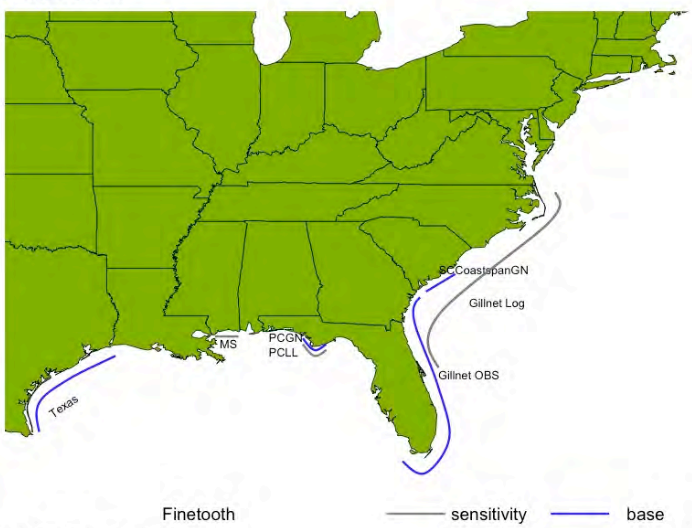
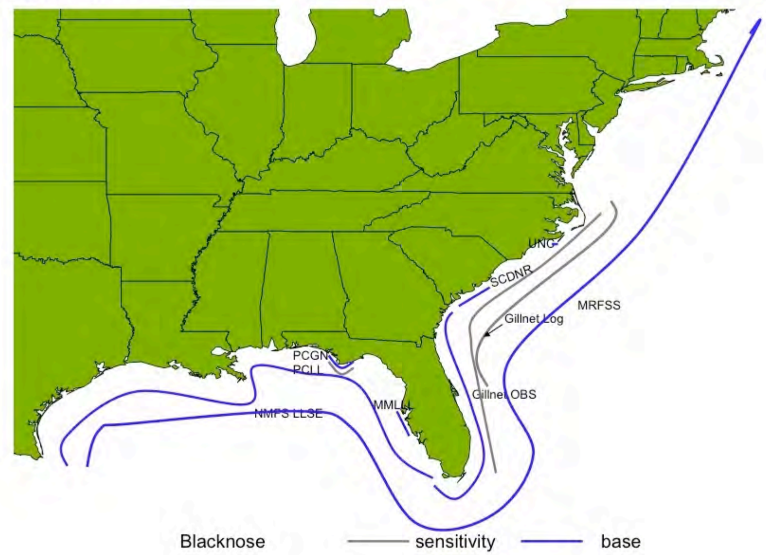


Figure 3.11. (continuted)

E. Blacknose Shark



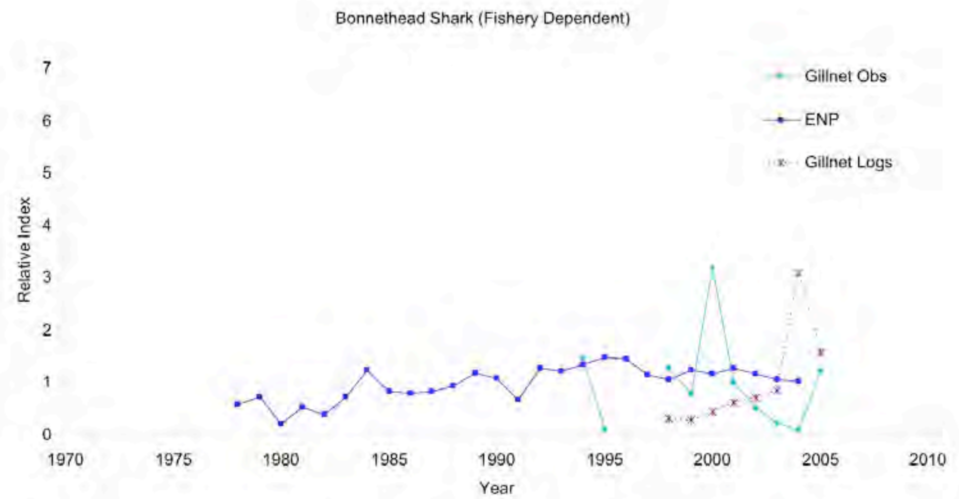


Figure 3.6. Fishery-dependent catch rate series for **bonnethead sharks**. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

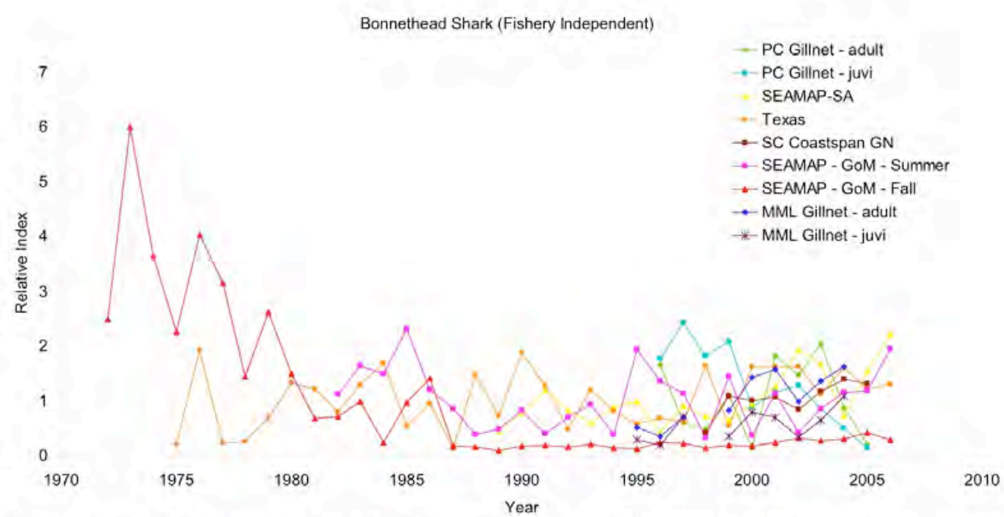


Figure 3.5. Fishery-independent catch rate series for **bonnethead sharks**. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

Issues with standardized surveys

- Gear changes
- Temporal and spatial coverage
- High proportion of zeros
- Gear selectivity
- Uncontrollable environmental factors
- Funding/logistical issues – discontinuous or short time series, variable effort

Need for GLM standardization

GLM Standardization

- Models used:
  - Log normal (cpue + x)
  - Poisson
  - Delta-lognormal
- Final model selected through stepwise elimination of factors

Results of the stepwise procedure for development of the catch rate model for juvenile age 1+ sandbar sharks captured by longline in Delaware Bay. %DIF is the percent difference in deviance/DF between each model and the null model. Delta% is the difference in deviance/DF between the newly included factor and the previous entered factor in the model. L is the log likelihood.

PROPORTION POSITIVE -BINOMIAL ERROR DISTRIBUTION

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQ	PR>CH I
NULL	279	384.4973	1.3781					
REGION	271	318.0197	1.1735	14.8465	14.8465	-159.0099	66.48	<.0001
YEAR	275	373.5627	1.3584	1.4295		-186.7813	10.93	0.0273
MONTH	278	379.7936	1.3662	0.8635		-189.8968	4.70	0.0301
DEPTH	246	381.0803	1.3807	-0.1887		-190.5 401	3.42	0.3317
REGION +								
YEAR	267	303.8540	1.1380	17.4225	2.5760	-151.9270	14.17	0.0068
MONTH	270	311.9419	1.1553	16.1672		-155.9710	6.08	0.0137
DEPTH	268	310.1205	1.1572	16.0293		-155.0603	7.90	0.0481
REGION + YEAR +								
MONTH	266	297.4271	1.1181	18.8666	1.4440	-148.7135	6.43	0.0112
DEPTH	264	295.4705	1.1192	18.7867		-147.7352	8.38	0.0387
REGION + YEAR + MONTH +								
DEPTH	263	288.8211	1.0982	20.3106	1.4440	-144.4106	8.61	0.0350

FINAL MODEL: REGION + YEAR + MONTH + DEPTH

Akaike's information criterion -656.9

Schwartz's Bayesian criterion -658.7

(-2) Res Log likelihood 1311.8

Type 3 Test of Fixed Effects

	REGION	YEAR	MONTH	DEPTH
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	0.0098	0.0132	0.0485
DF	8	4	1	3
CHI SQUARE	53.62	13.32	6.14	7.88

Positive catches-Poisson error distribution

FACTOR	DF	DEVIANCE	DEVIANCE/DF	%DIFF	DELTA%	L	CHISQUARE	PR>CHI
NULL	77	212.082	2.754			-63.525		
YEAR	69	95.374	1.382	49.816	49.816	-5.171	116.71	<.0001
SEASON	75	179.857	2.398	12.933		-47.413	32.22	<.0001
TIME	74	179.533	2.426	11.916		-47.251	32.55	<.0001
AREA	75	191.905	2.559	7.101		-53.437	20.18	<.0001
SETDEPTH	76	212.056	2.790	-1.304		-63.512	0.03	0.8724
YEAR +								
AREA	67	88.610	1.323	51.983	2.167	-1.789	6.76	0.0340
SEASON	67	89.972	1.343	51.245		-2.470	5.4	0.0671
TIME	66	94.311	1.429	48.119		-4.640	1.060	0.7861
YEAR + AREA +								
SEASON	65	81.941	1.261	54.230	2.248	1.545	6.67	0.0356
YEAR* AREA	57	75.686	1.328	51.791	-2.439	4.673	6.26	0.6186
YEAR* SEASON	57	78.585	1.379	49.944		3.223	3.36	0.9100

FINAL MODEL: YEAR + AREA + SEASON

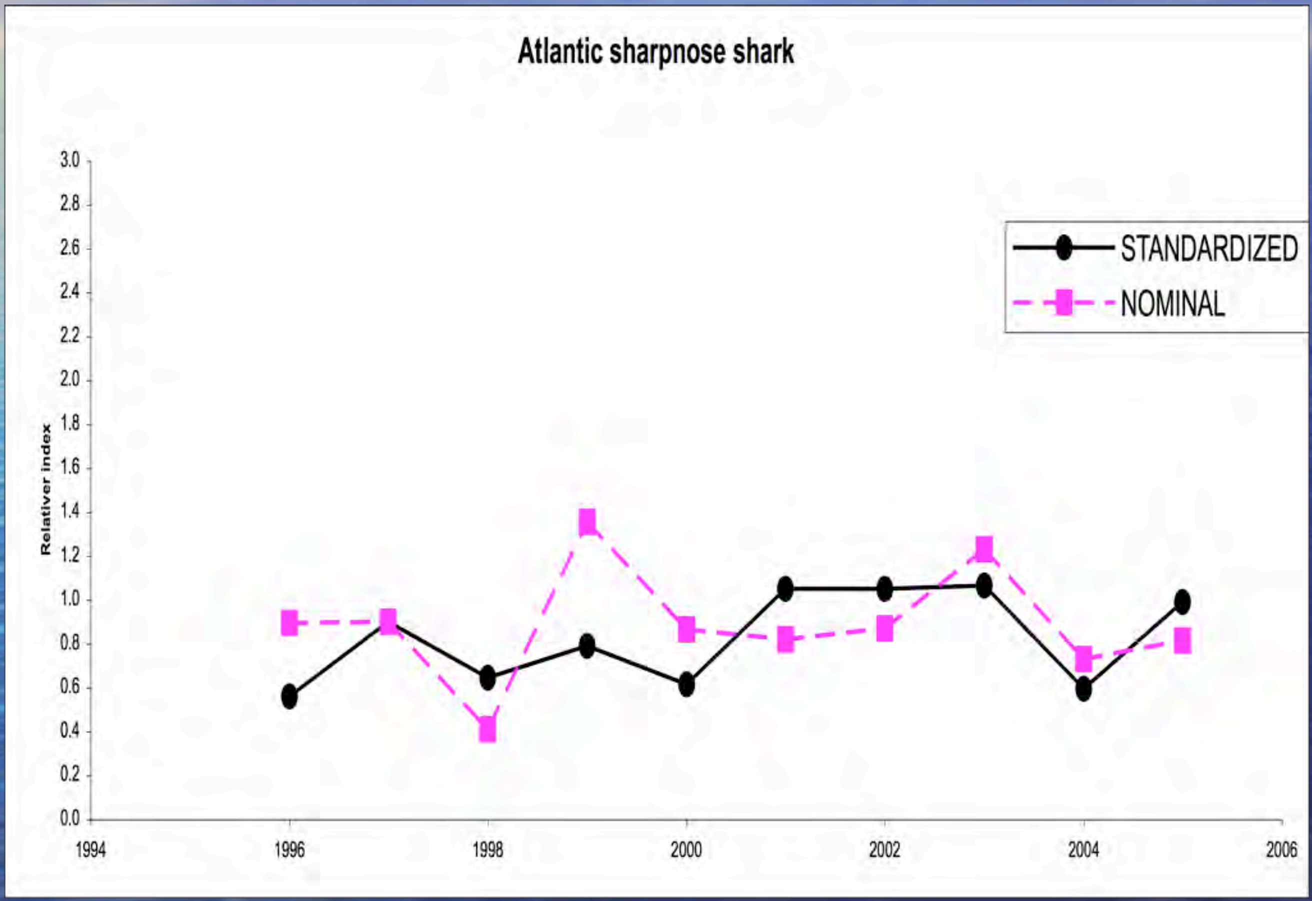
Akaike's information criterion	180.3
Schwartz's Bayesian criterion	182.5
(-2) Res Log Likelihood	178.3

	Type 3 Tests of Fixed Effects		
	YEAR	AREA	SEASON
Significance (Pr>Chi) of Type 3 test of fixed effects for each factor	<.0001	0.0180	0.0356
DF	8	2	2
CHI SQUARE	72.37	8.0300	0.04

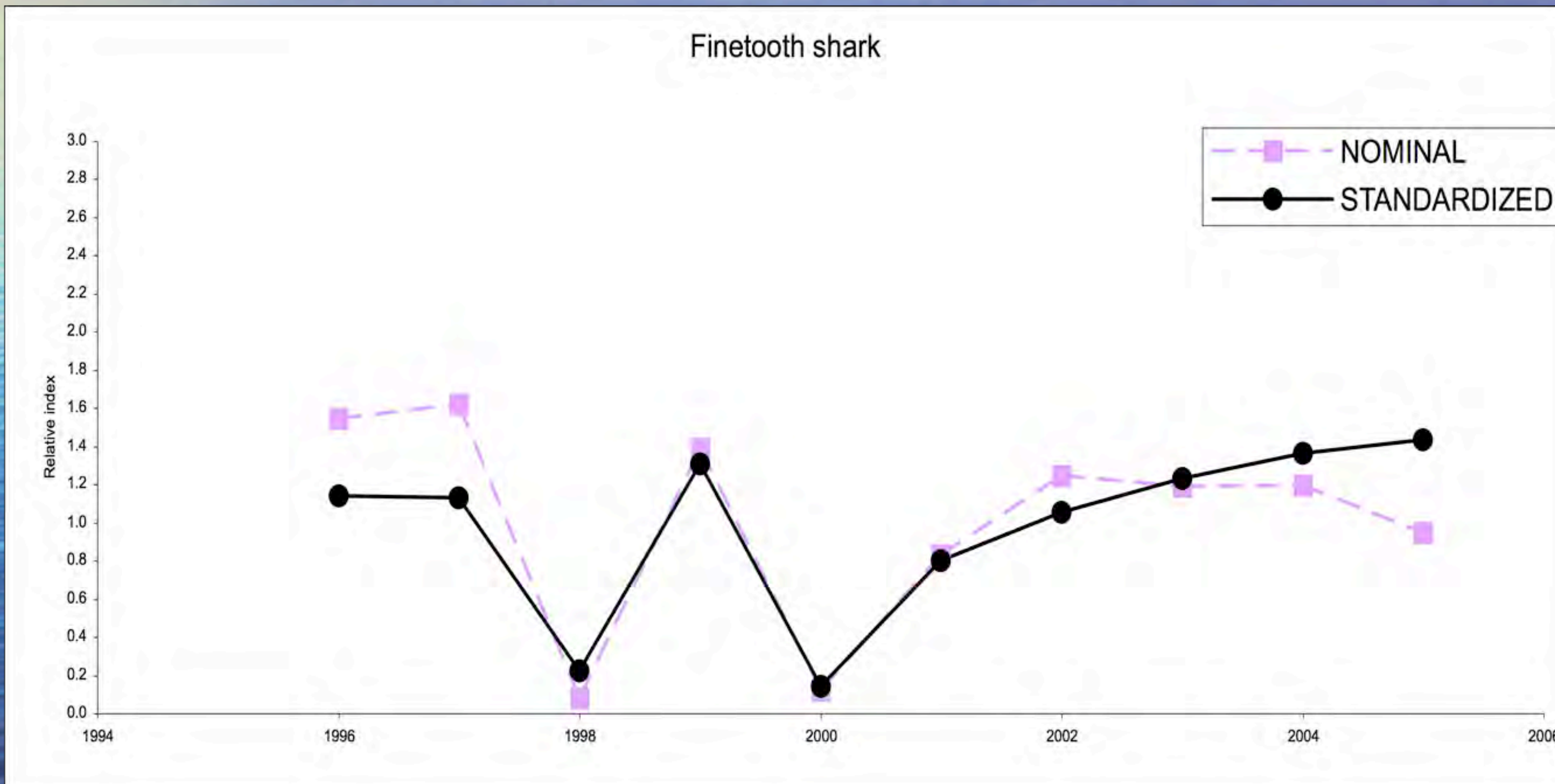
STANDARDIZATION

- **Factors generally explain 5-15% deviance in the final model**
- **Spatial factors and gear changes generally explain the greatest deviance from the null model from those factors examined**
  - Selection of factors may be important consideration

GLM HELPS TO REMOVE "NOISE" FROM SURVEY INDICES



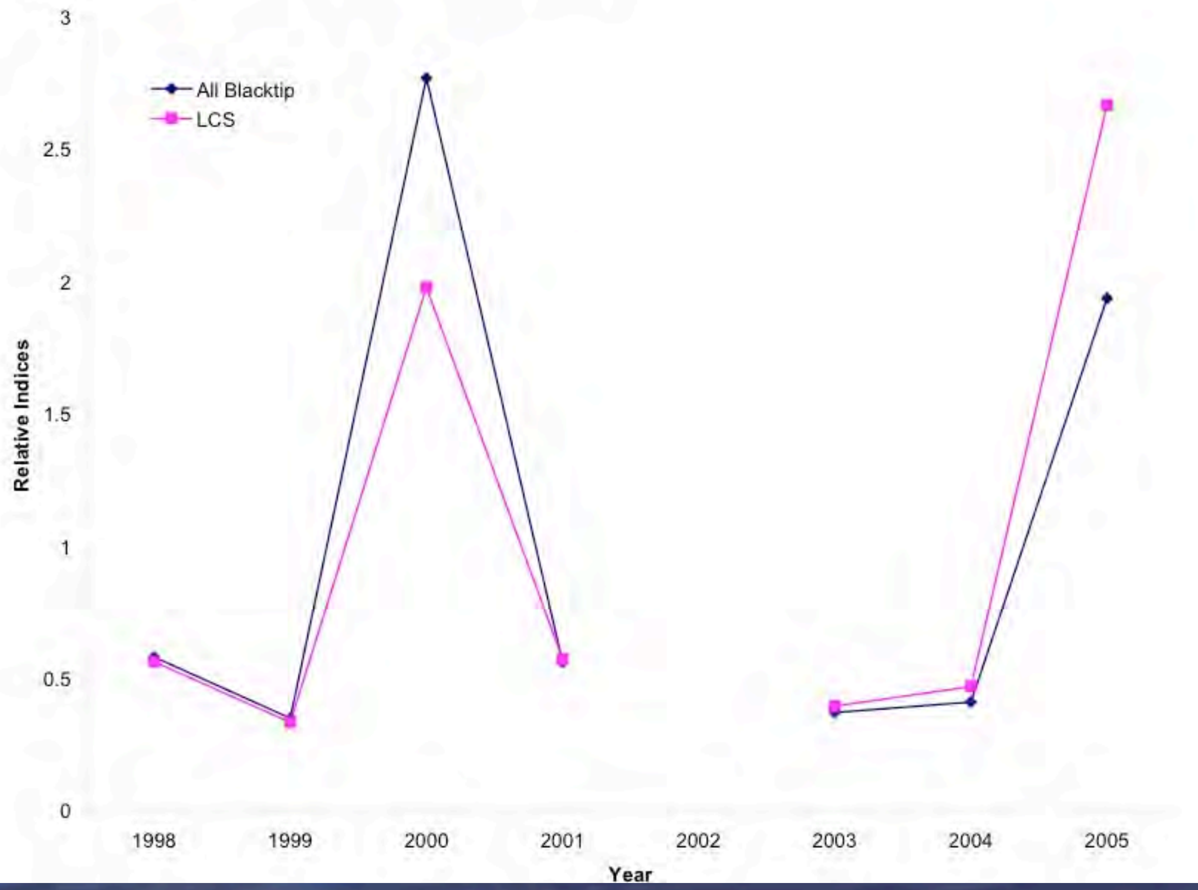
GLM CORRECTION FOR BIAS



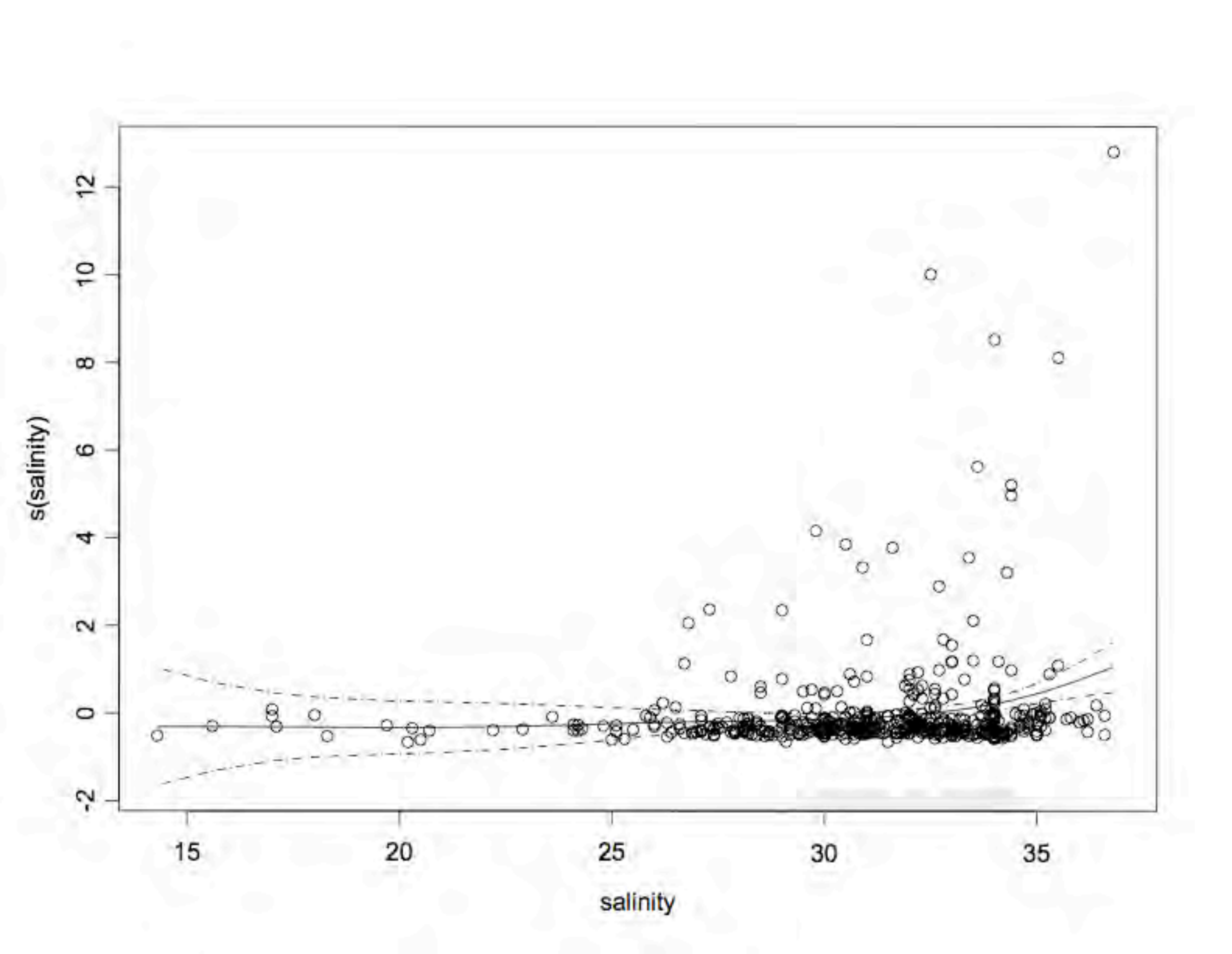
Environmental Factors

LCS05/06-DW-24

Figure 1. Relative indices of abundance for all blacktip and LCS sharks from Mississippi coastal water, 1998-2005.

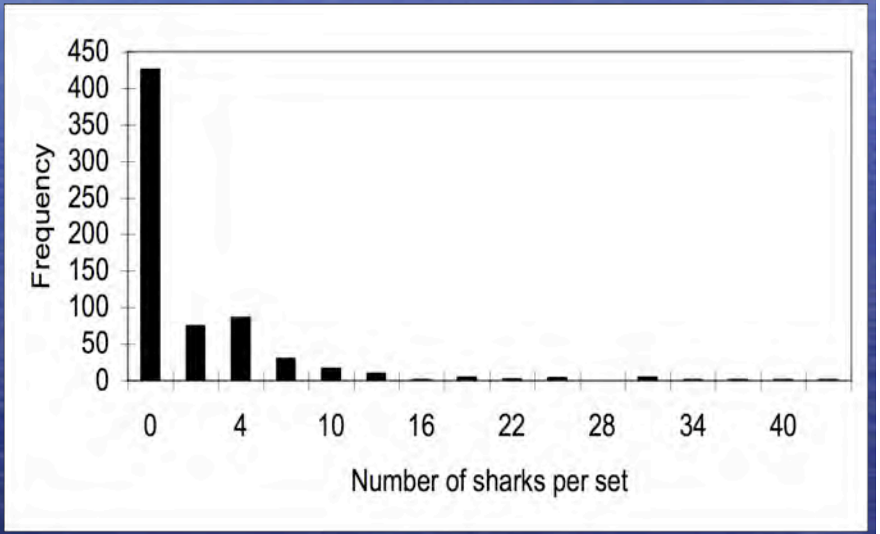


More exploration of environmental factors (GAMS)



OTHER ISSUES

- Highly skewed survey data containing a large portion of zeros
  - Ignore
    - Negative binomial
    - Poisson
  - Accommodate
    - Delta-lognormal
  - Model
    - Zero-inflated negative binomial



- Lack of examination of diagnostic plots to test assumptions for an acceptable model fit
- Conflicting signals

Science, Service, Stewardship

Fisheries dependent commercial data for constructing indices of abundance

NOAA FISHERIES SERVICE

Available commercial data sets: interview/observer

Trip interview program (TIP)

Observer data

—Pelagic longline

—Shark bottom longline – Gulf and South Atlantic

—Shark gillnet observer

—Gulf reef fish

—Shrimp observer

Available commercial data sets: self-reported

Trip ticket

Coastal logbook

Pelagic logbook – all US flagged vessels (HMS)

Puerto Rico sales tickets

USVI landings reports

Others:

- —Golden crab logbook
- —Wreckfish logbook
- —Gulf shrimp statistics
- —Atlantic shrimp

NOAA
FISHERIES
SERVICE

Available Data

Trained observer/sampler

- —Accurate species identification
- —Size information
- —Other details of fishing behavior/conditions, e.g. fished at night, weather conditions, etc.
- —Fine scale spatial information (observers)
- —Total catch (observers)
- —Discard information (observers)
- —Accurate, detailed effort information (observers)
- —Detailed gear configuration information
- —Data are set-based (all longline observers, gillnets) or trip-based (TIP and gear other than longlines)

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Available Data

Self reported

- —Honest, few errors, reporting as instructed?
- —Potential species misidentification (e.g. gag/black grouper)
- —Species identified by species category (e.g. groupers) or worse
- —Broad scale spatial information (except pelagic logbook)
- —Landings (pounds) not total catch
- —Some discard information (coastal & pelagic logbooks)
- —Effort information may be problematic (e.g. traps, bottom longlines)
- —Data are trip based, set based in pelagic logbook
- —Individual size information for some species in pelagic logbook

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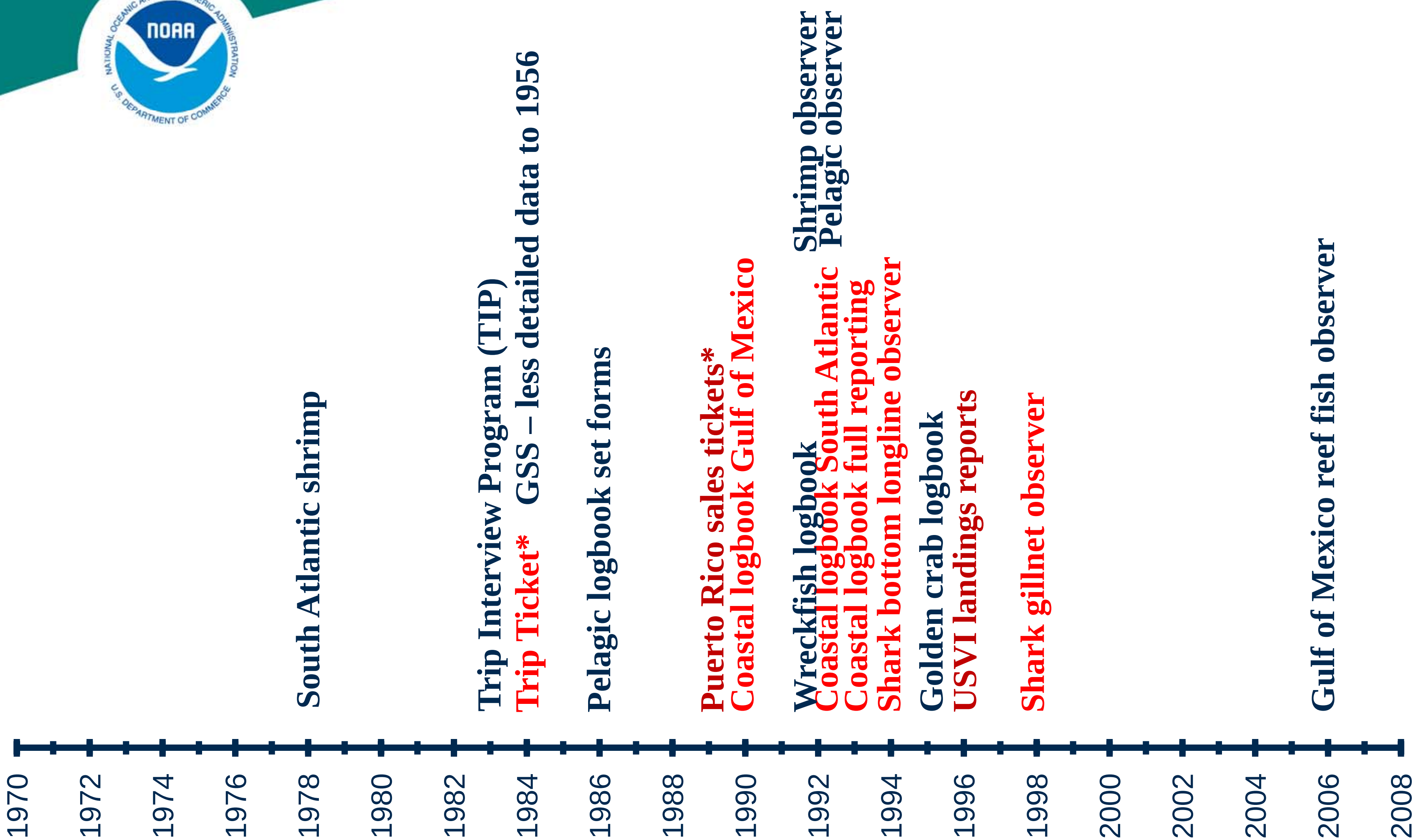
Commercial data sets timeline



Spatial extent of commercial fishing data

- Federal waters
- States may have commercial data available (e.g. trip tickets)
- Some gears restricted from certain areas (e.g. longline >20/50 fathoms, traps banned from Gulf)
- Pelagic logbook – all US flagged vessels regardless of areas fished
- Closed areas in some fisheries, including year-round and seasonal closures

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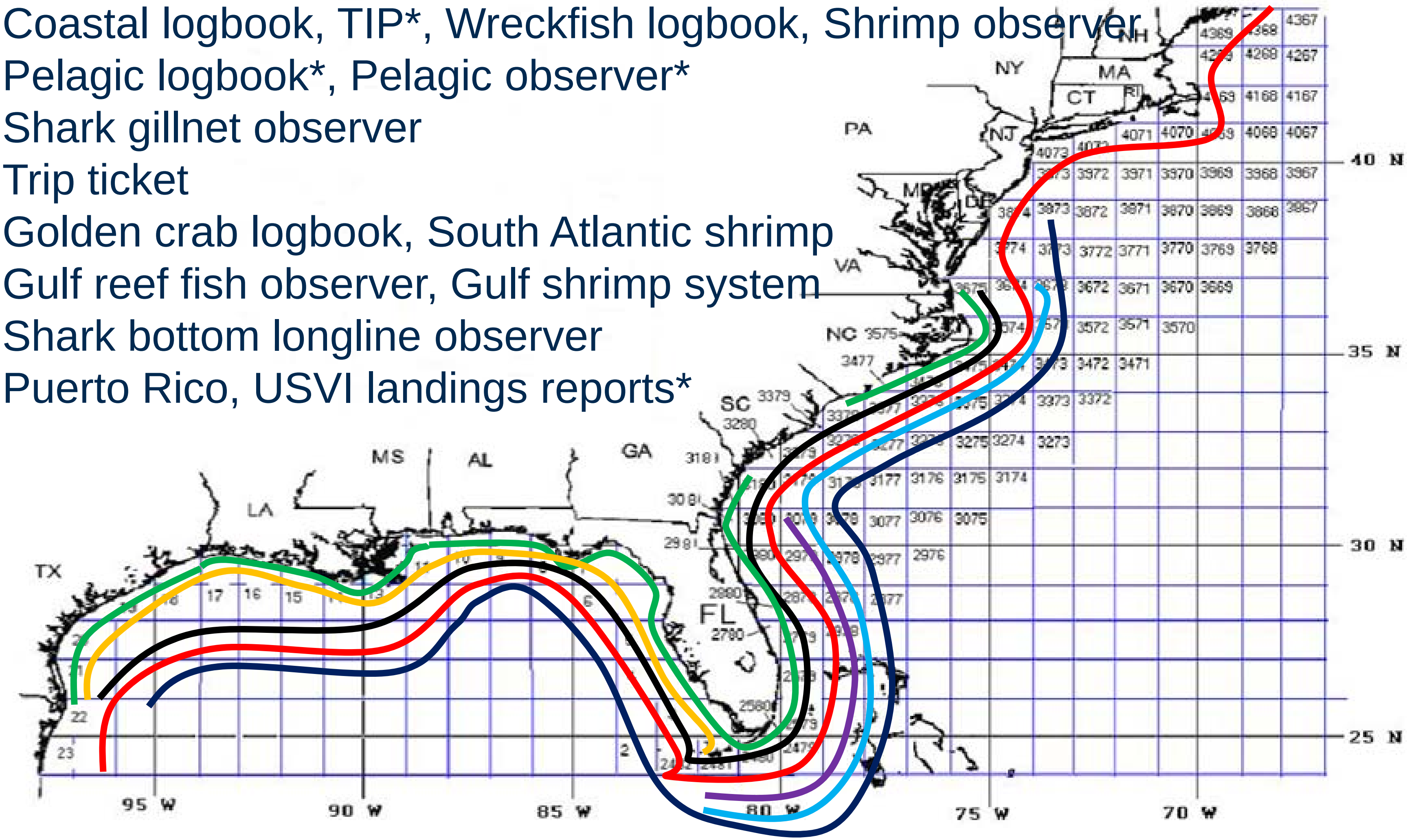
Data set spatial coverage

- Coastal logbook, TIP*, Wreckfish logbook, Shrimp observer
- Pelagic logbook*, Pelagic observer*
- Shark gillnet observer
- Trip ticket
- Golden crab logbook, South Atlantic shrimp
- Gulf reef fish observer, Gulf shrimp system
- Shark bottom longline observer

Puerto Rico, USVI landings reports*



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Spatial scale of reporting

- All observer data at fine spatial scale (e.g. lat/lon at beginning and end of longline set)
- Pelagic logbook at fine spatial scale
- Coastal, wreckfish, golden crab logbooks; USVI landings; coarse spatial reporting
- Trip ticket, Puerto Rico area fished not reported – port/county landed reported
- Depth information reported for observer data, logbooks, TIP, Puerto Rico, GSS
- No depth information for trip tickets, USVI (distance from shore)

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Gears reported

May be a single gear, e.g. pelagic longlines – pelagic longline observer data

May include many gears, e.g. 11 gears (plus 4 “other” categories) may be reported on the coastal logbook

Multiple gears = multiple indices from a data set

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Effort

Hook hour or other fine scale effort measure

- —Pelagic logbook
- —All observer data
- —TIP
- —Caribbean landings (in some cases)
- —Coastal logbook (handline/bandit rig, gill nets)
- —Golden crab and wreckfish logbooks
- —Shrimp landings/effort

Day at sea or per trip

- —Trip ticket
- —Caribbean landings?

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Size range of individuals in commercial data sets

- Limited by gear – e.g. traps may catch greater range of sizes than longline or they may merely be different size ranges
- Observer data likely to include greater size range (catch) and will often have size information
- TIP will have sizes of landed fish
- Logbook data reports landings (for the most part) and will include only legal size fish, but size of individual fish not available – pelagic logbook does have lengths/weights of individuals

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Commercial data advantages

Large sample size – coastal logbook >2.3 x 10^6 records

Data for multiple gears – multiple indices that reflect broader size/age/spatial range of the stock

Spatially extensive – often much more so than fisheries independent data, data are from where the fish are abundant

Relatively long time series

Many species are reported – these data sets may be useful for many, if not all, assessments of exploited species (not much use for protected species, e.g. goliath grouper)

Commercial Data Issues/Limitations

Size distribution of caught/landed animals

Limited number of variables in the data sets

Discards, i.e. landings not catch

Individual data set caveats

Species misidentification/non-reporting

CPUE correlated with abundance?

Changing catchability

Defining targeting

Fishing regulations

Size distribution of catch/landings

Commercial fishing gear not a good sampling method for all size classes

At best the total catch is sampled and that likely will not include the smallest individuals

For many data sets (e.g. logbooks) the size structure of the landings is completely unknown other than the assumption that all animals (or nearly all) were legal size or larger

Limited number of variables in the data sets

- Ability to characterize gears, vessels, areas fished, fishing behavior, etc. are all highly variable among data sets
- Observer data typically contains more detailed information
- Self-reported data includes less detailed gear configuration information – this varies from no information (e.g. trip ticket) to fairly detailed (e.g. pelagic logbook includes hook size/type/offset, bait type)
- Self-reported data usually includes only coarse spatial detail or none (trip ticket, PR); exception is pelagic logbook with reporting at finer scale
- Captain information (e.g. experience) often lacking

Total catch vs. landings

Total catch

- —Observer data, may also include size of individual animals
- —Coastal logbook trips that report discards, but landings are in pounds and discards are counted
- —Pelagic logbook reports may include discards

Landings

- —TIP
- —Trip ticket
- —All logbooks (except pelagic when discards reported)

Individual data set caveats

Some are more caveat rich than others, but all have their issues

Know your data, it will save time, potential embarrassment, and thousands of dollars in therapy

Species misidentification/non-reporting

- Should only be an issue with self-reported data, including self-reported discards
- May be systematic or limited to individual fishers
- Major issue with gag and black grouper
- Unknown problem until SEDAR data workshop
- Used TIP data to develop conversion factors that were applied to both landings and coastal logbook data

CPUE correlated with abundance?

- Especially problematic for commercial data, fishermen know how and where to catch fish
- Most commercial data sets have poor measures of search time, if it can be estimated at all from the available data, so entire effort not included in most analyses
- Changing spatial extent of the fishery may indicate changes in stock size even if CPUE is flat or increasing
- This issue drove the queen conch assessment, or lack of one, in the Caribbean – short answer, it wasn't

Changing catchability

Poorly understood, topic for the next workshop

May vary with improvements in technology (e.g. GPS), gear changes (e.g. hook design), environmental conditions (e.g. red tides), and fisher experience (affects individual vessels as well as fisheries as a whole)

Observer data most likely to have some measures of potential causes of catchability change in available data

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Targeting

Targeting may be reported for:

- —Observer data (ask the captain)
- —Pelagic logbook?
- —TIP?
- —Golden crab and wreckfish logbooks
- —Shrimp landings and effort

Targeting information not directly available for:

- —Trip ticket
- —Caribbean landings/sales ticket
- —Coastal logbook

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Targeting not reported, now what?

Gear configuration based approach

- Characterize gear configuration(s) of positive trips
- Include all trips with appropriate gear configuration
- May have limited information for gear configuration
- Ad hoc and subjective

Stephens-MacCall

Possible effects of regulations on the construction of indices of abundance

Indices potentially affected: all constructed from fishery dependent data

Regulatory measures of concern:

- —Regulatory boundaries – spatial and temporal
- —Minimum size limits
- —Fishery closures
- —Bag/trip limits

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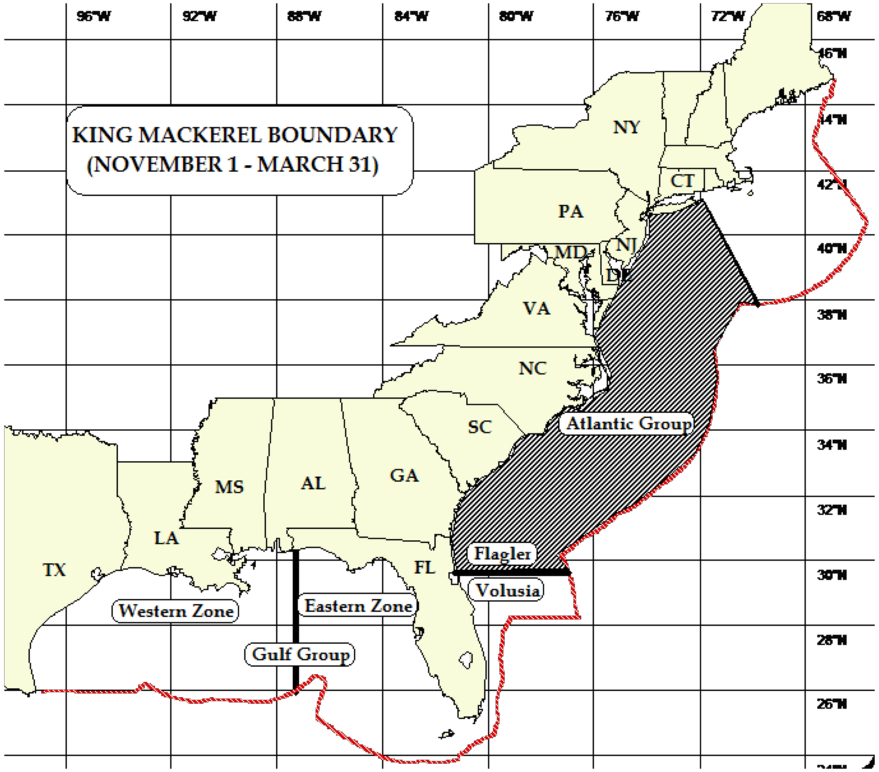
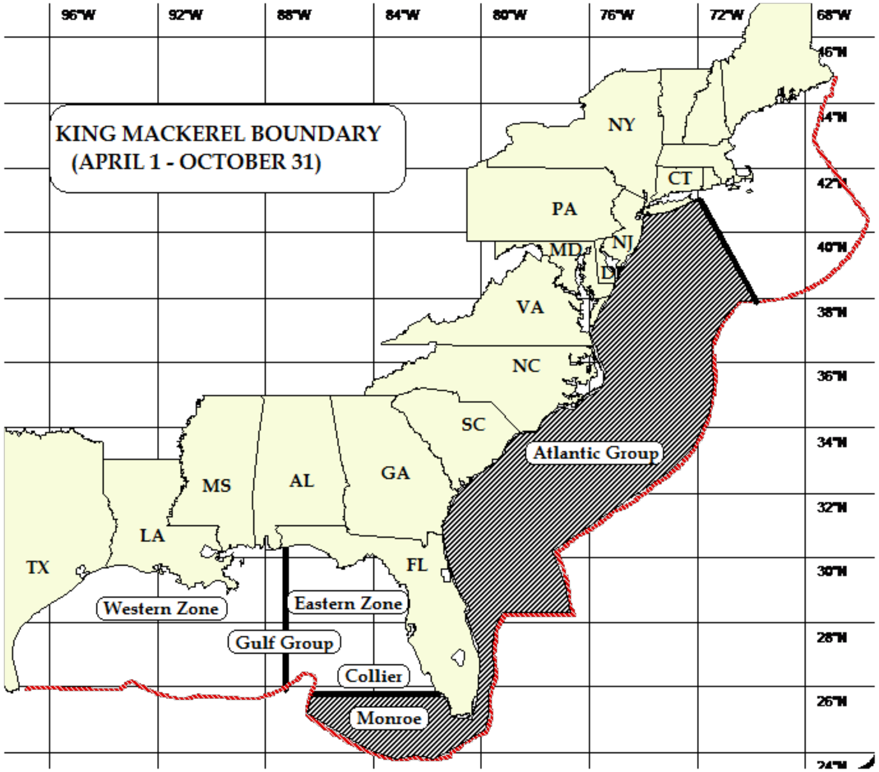
Regulatory boundaries





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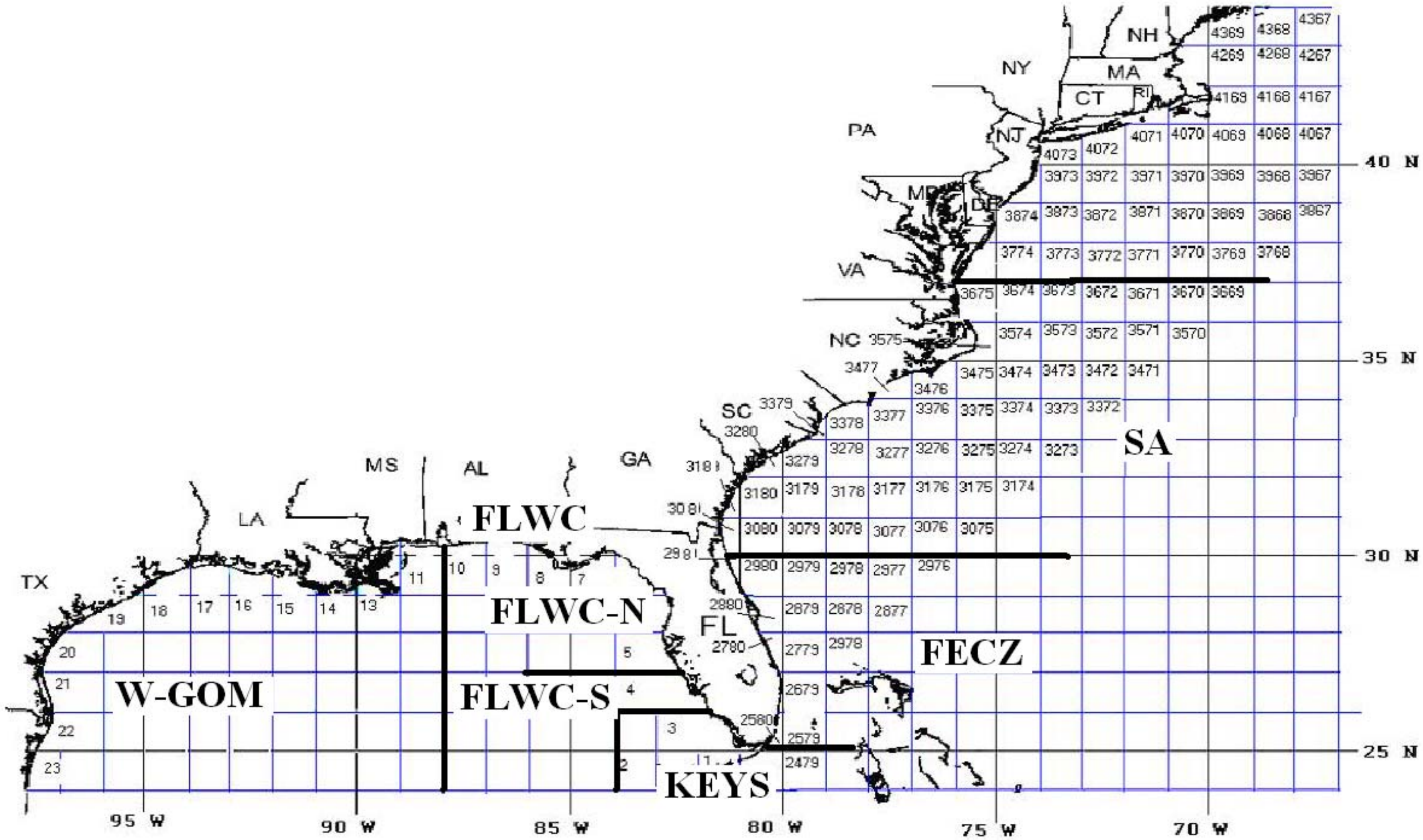
Zones used in commercial indices



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King mackerel commercial fishing regulations: effective dates of minimum size limits

Size Limit	W-GOM	FLWC	FLWC-N	FLWC-S	KEYS	FECZ	SA
12"	7/1/1990	7/1/1990	n/a	n/a	4/1/1990	4/1/1990	4/1/1990
20"	7/1/1992	7/1/1992	n/a	n/a	4/1/1992	4/1/1992	4/1/1992
24"	7/1/1999	7/1/1999	4/27/2000	4/27/2000	4/1/1999	4/1/1999	4/1/1999

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Minimum size limits

Split the index when size limit implemented or changed

- —May result in indices with short time series
- —Multiple size limit changes = multiple short time series indices

Determine if size limit change had an effect on size of landed animals

- —Use TIP or observer data pre- and post-regulation
- —“Informed judgment” (fisher observation) approach

King mackerel commercial fishing regulations: effective dates of regional fishery closures

W-GOM		FLWC		FECZ		KEYS		SA	
open	close	open	close	open	close	open	close	open	close
	5/6/1983		3/12/1986		3/12/1986		3/12/1986		11/23/1988
7/1/1983	3/12/1986	7/1/1986	2/4/1987	4/1/1986	2/4/1987	4/1/1986	2/4/1987	4/1/1989	3/29/1998
7/1/1986	2/4/1987	7/1/1987	1/27/1994	4/1/1987	12/29/1987	4/1/1987	1/27/1994	4/1/1998	
7/1/1987	11/2/1987	7/1/1994	12/20/1994	4/1/1988	12/31/1988	4/1/1994	12/20/1994		
7/1/1988	12/3/1988	2/7/1995	2/22/1995	4/1/1989	1/9/1990	2/7/1995	2/22/1995		
7/1/1989	10/25/1989	7/1/1995	2/22/1996	4/1/1990	1/4/1991	4/1/1995	2/22/1996		
7/1/1990	10/18/1990	7/1/1996	1/22/1997	4/1/1991	1/31/1992	4/1/1996	1/22/1997		
7/1/1991	9/29/1991	7/1/1997	1/7/1998	4/1/1992	1/13/1993	4/1/1997	1/7/1998		
7/1/1992	10/18/1992	2/20/1998	3/5/1998	2/18/1993	3/27/1993	2/20/1998	3/5/1998		
7/1/1993	10/1/1993	7/1/1998	3/16/1999	4/1/1993	3/29/1998	4/1/1998	3/16/1999		
7/1/1994	9/24/1994	7/1/1999	3/6/2000	4/1/1998	3/13/1999	4/1/1999	3/6/2000		
7/1/1995	9/5/1995	FLWC-S		4/1/1999		4/1/2000	3/2/2001		
7/1/1996	8/26/1996		4/27/2000			4/1/2001	3/23/2002		
7/1/1997	8/2/1997	7/1/2000	3/2/2001			4/1/2002	3/12/2006		
2/20/1998	3/29/1998	7/1/2001	3/23/2002			4/1/2006			
7/1/1998	8/25/1998	7/1/2002	4/9/2004						
7/1/1999	8/25/1999	7/1/2004	3/12/2006						
7/1/2000	8/26/2000	7/1/2006							
7/1/2001	11/20/2001	FLWC-N							
7/1/2002	10/26/2002		4/27/2000						
7/1/2003	9/25/2003	7/1/2000	11/19/2000						
7/1/2004	10/21/2004	7/1/2001	11/11/2001						
7/1/2005	11/18/2005	7/1/2002	12/6/2002						
7/1/2006	10/7/2006	7/1/2003	11/14/2003						
		7/1/2004							

Regulatory Closures

Exclude data from periods of fishery closures to avoid erroneously lowering yearly mean CPUE

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King mackerel commercial fishing regulations: effective dates of regional trip limit changes

W-GOM

limit	start	end
none		6/30/2000
3,000 lbs	7/1/2000	

FLWC

limit	start	end
none		12/28/1993
50 fish	12/29/1993	6/30/1994
none	7/1/1994	2/6/1995
125 fish	2/7/1995	2/21/1995
125 fish	7/1/1995	1/23/1996
50 fish	1/24/1996	2/21/1996
1250 lbs	7/1/1996	12/31/1996
500 lbs	1/1/1997	1/21/1997
1250 lbs	7/1/1997	11/27/1997
500 lbs	11/28/1997	1/6/1998
500 lbs	2/20/1998	3/4/1998
1250 lbs	7/1/1998	1/29/1999
500 lbs	1/30/1999	3/15/1999
1250 lbs	7/1/1999	1/23/2000
500 lbs	1/24/2000	3/5/2000

SA

limit	start	end
none		3/31/1995
3,500 lbs	4/1/1995	

FLWC-S

limit	start	end
1250 lbs	7/1/2000	2/19/2001
500 lbs	2/20/2001	3/1/2001
1250 lbs	7/1/2001	3/10/2002
500 lbs	3/11/2002	3/22/2002
1250 lbs	7/1/2003	3/4/2003
500 lbs	3/5/2003	6/30/2003
1250 lbs	7/1/2003	3/19/2004
500 lbs	3/20/2004	4/8/2004
1250 lbs	7/1/2004	2/24/2005
500 lbs	2/25/2005	6/30/2005
1250 lbs	7/1/2005	2/24/2006
500 lbs	2/25/2006	3/11/2006
1250 lbs	7/1/2006	

FLWC-N

limit	start	end
1250 lbs	7/1/2000	11/11/2000
500 lbs	11/12/2000	11/18/2000
1250 lbs	7/1/2001	11/10/2001
1250 lbs	7/1/2002	11/29/2002
500 lbs	11/30/2002	12/5/2002
1250 lbs	7/1/2003	10/29/2003
500 lbs	10/30/2003	11/13/2003
1250 lbs	7/1/2004	11/26/2006
500 lbs	11/27/2006	

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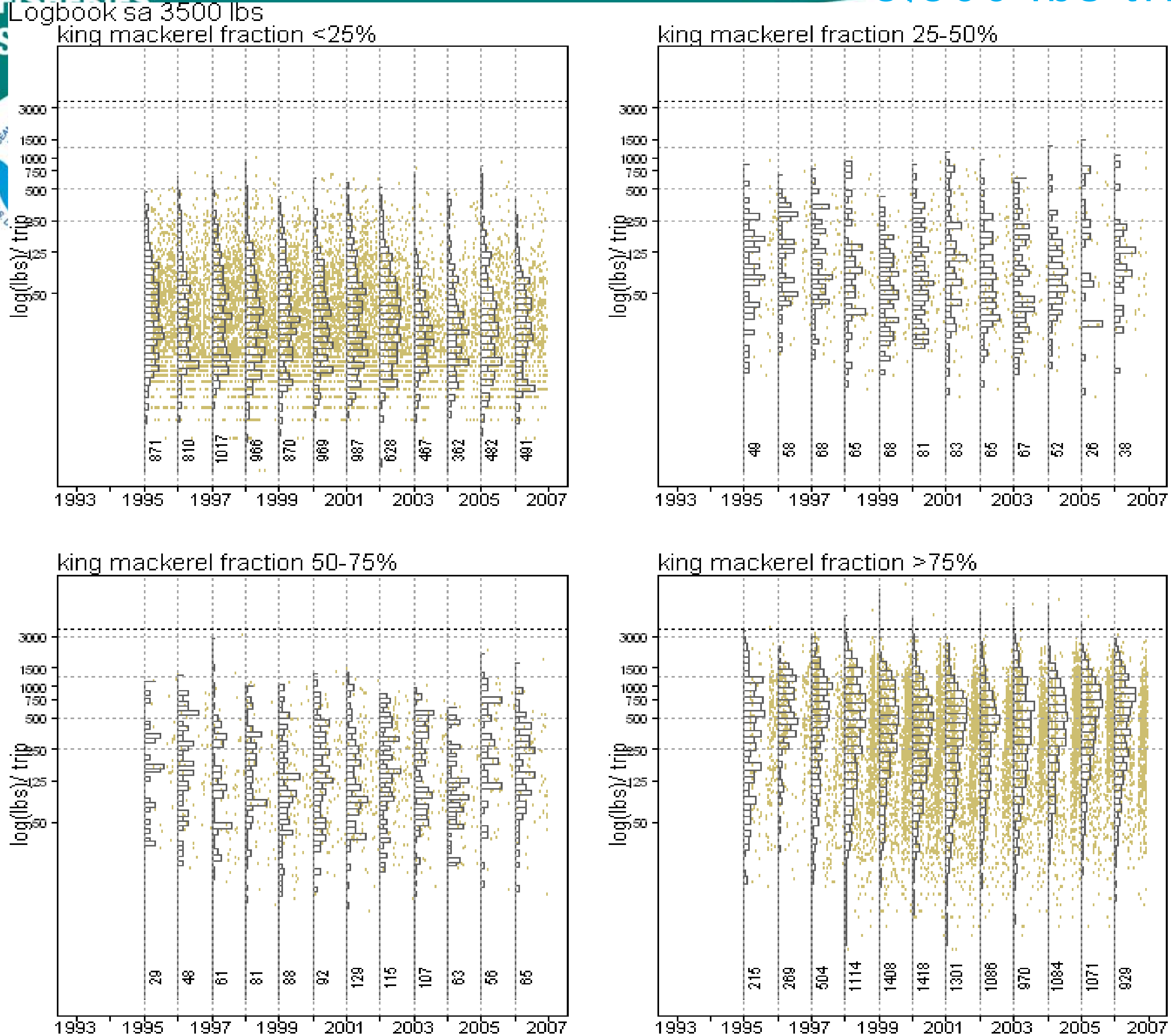
King mackerel commercial fishing regulations: effective dates of regional trip limit changes, continued

KEYS			FECZ		
limit	start	end	limit	start	end
none		12/28/1993	none		1/12/1993
50 fish	12/29/1993	1/26/1994	25 fish	2/18/1993	3/26/1993
none	4/1/1994	12/19/1994	none	4/1/1993	10/31/1993
125 fish	2/7/1995	2/21/1995	50 fish	11/1/1993	3/31/1994
50 fish	4/1/1995	10/31/1995	none	4/1/1994	10/31/1994
125 fish	11/1/1995	1/23/1996	50 fish	11/1/1994	3/14/1996
50 fish	1/24/1996	2/21/1996	25 fish	3/15/1996	3/31/1996
50 fish	4/1/1996	10/31/1996	50 fish	4/1/1996	10/31/1996
1250 lbs	11/1/1996	12/31/1996	750 lbs	11/1/1996	2/28/1997
500 lbs	1/1/1997	1/21/1997	500 lbs	3/1/1997	3/31/1997
1250 lbs	4/1/1997	11/27/1997	50 fish	4/1/1997	3/28/1998
500 lbs	11/28/1997	1/6/1998	50 fish	4/1/1998	3/12/1999
500 lbs	2/20/1998	3/4/1998	50 fish	4/1/1999	3/31/2000
1250 lbs	4/1/1998	1/29/1999	75 fish	4/1/2000	10/31/2000
500 lbs	1/30/1999	3/15/1999	50 fish	11/1/2000	3/31/2001
1250 lbs	4/1/1999	1/23/2000	75 fish	4/1/2001	10/31/2001
500 lbs	1/24/2000	3/5/2000	50 fish	11/1/2001	1/31/2002
1250 lbs	4/1/2000	2/19/2001	75 fish	2/1/2002	10/31/2002
500 lbs	2/20/2001	3/1/2001	50 fish	11/1/2002	1/31/2003
1250 lbs	4/1/2001	3/10/2002	75 fish	2/1/2003	10/31/2003
500 lbs	3/11/2002	3/22/2002	50 fish	11/1/2003	1/31/2004
1250 lbs	4/1/2002	3/4/2003	75 fish	2/1/2004	10/31/2004
500 lbs	3/5/2003	3/31/2003	50 fish	11/1/2004	1/31/2005
1250 lbs	4/1/2003	3/19/2004	75 fish	2/1/2005	10/31/2005
500 lbs	3/20/2004	3/31/2004	50 fish	11/1/2005	1/31/2006
1250 lbs	4/1/2004	2/24/2005	75 fish	2/1/2006	10/31/2006
500 lbs	2/25/2005	3/31/2005	50 fish	11/1/2006	
1250 lbs	4/1/2005	2/24/2006			
500 lbs	2/25/2006	3/11/2006			
1250 lbs	4/1/2006				

Coastal Logbook Data, South Atlantic 3,500 lbs trip limit



Coastal Logbook Data, Keys 500 lbs trip limit

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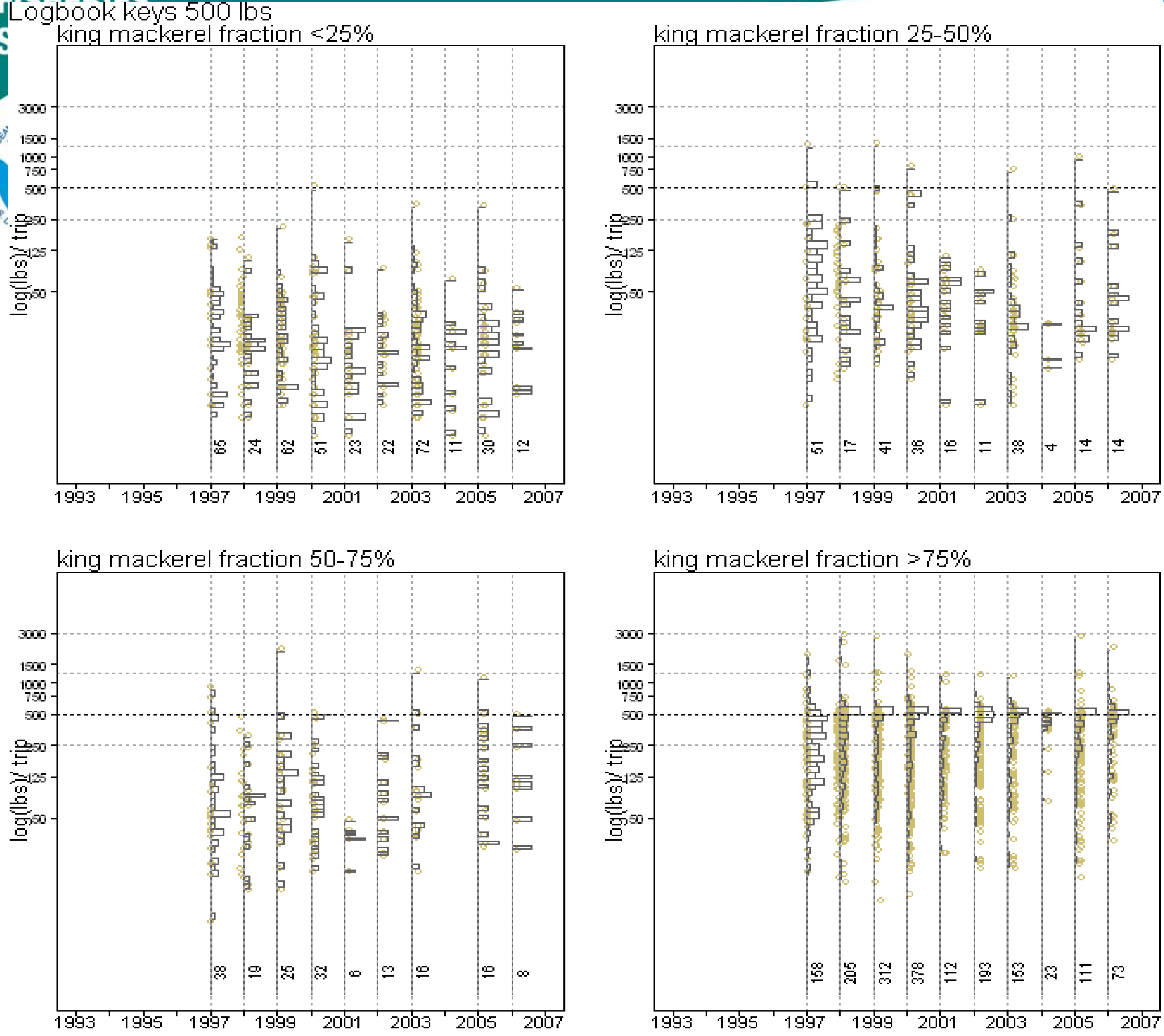

Trip limits

Determine the extent to which trip limits may have effected fishing effort

- —If no effect (few or no trips reach limit), then ignore
- —If effect (many trips limit, how many is “many”), can’t ignore

If many trips limit

- —Exclude data from periods/regions when trip limit was in effect
- —Use censored data approach

Elements to include in SEDAR documents

Identify the data set

Temporal and spatial range of the data

Identify the measure of effort

Describe how targeted trips (or sets, trawls, etc.) were identified

Describe size structure of the catch – if known

Are the data landings or total catch, in pounds or individuals

Table of factors/variables considered in the analysis

Methods of addressing fishing regulations

Science, Service, Stewardship

Fishery Dependent Indices:

Standardization of Recreational CPUE - Data and Issues

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Data reported through surveys/logbooks

Basic info:

- **Effort Measures (*e.g.* trips, hours fishing, hooks, lines, anglers)**
- **Catch (species, numbers or weight)**
- **Date (year, month or quarter)**
- **General location (fishing area)**

Preferred detail:

- **Effort Qualifiers (*e.g.* fishing method, bait, gear configuration, fishing depth, time of day, TARGET SPECIES)**
- **Catch Status (kept, release dead or alive, reason for release)**
- **Date (day)**
- **Detailed Location (lat/lon, fishing spot)**
- **Environmental Info (*e.g.* SST, depth, weather, sea state)**

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Available Recreational CPUE Data

Marine Recreational Fishery Statistics Survey:

- **Catch and effort statistics collected on intercepted angler-trips by fishing mode (shore, private or rental boats, charter boats and/or headboats) since 1981 for Louisiana through Maine. Texas was partially sampled by the MRFSS in 1981-1985, but has not participated in the survey since 1985.**
- **Sampling unit is angler-trip, but these are clustered within a vessel-trip)**
- **Catch (numbers by species, whether observed by sampler or not, disposition)**
- **General location only (state/sub-region, offshore/near-shore)**

HEADBOAT Survey:

- **Total landed catch by species is reported by trip in logbooks provided to all headboat crews from TX-NC.**
- **Only kept fish recorded for most of survey history. Field for released fish added in 2004, but reporting may be incomplete.**
- **The HBS has had full coverage in the S. Atlantic since 1981 and in the Gulf of Mexico since 1986.**
- **Detailed Location (lat/lon, 10 min square)**

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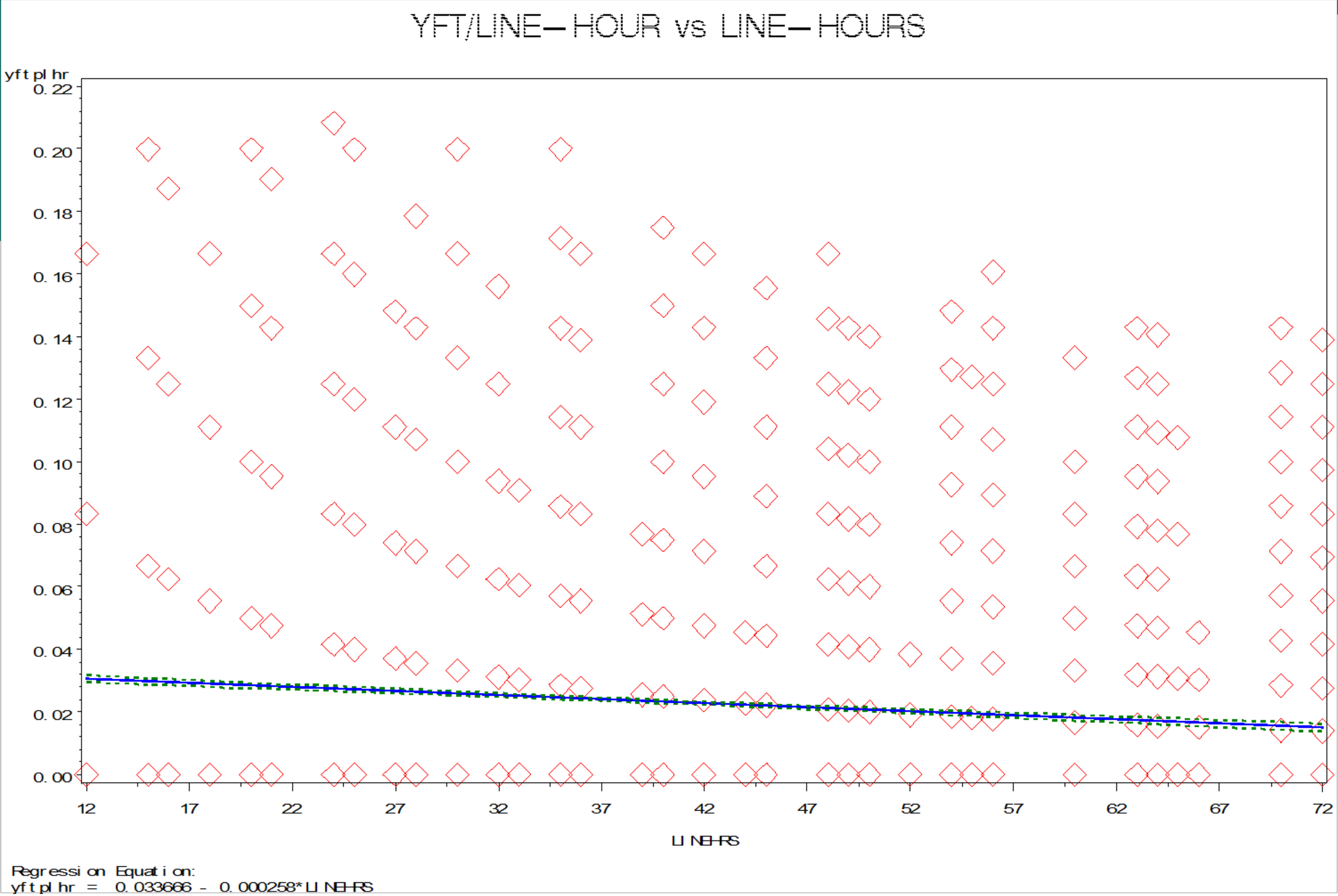
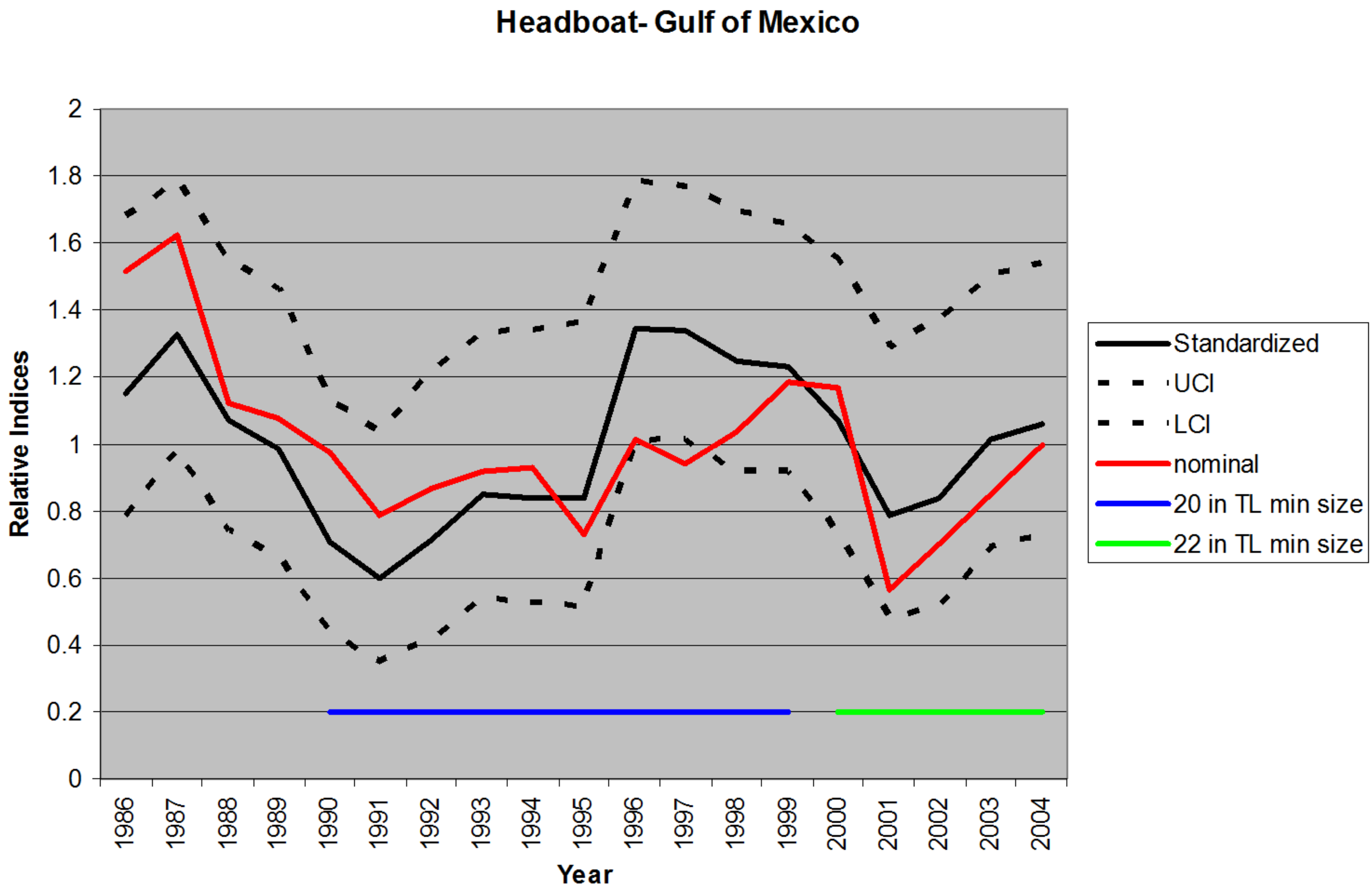
Available Recreational CPUE Data

Large Pelagics Intercept Survey:

- **Catch and effort statistics collected on intercepted vessels returning from offshore trips targetting large pelagic species (tunas, billfish, sharks, etc.) since 1982 for Virginia through Massachusetts (in recent years, extended through Maine).**
- **Vessel captain interviewed (sampling unit is vessel-trip)**
- **Catch (numbers by species, whether observed by sampler or not, disposition)**
- **Detailed Location (lat/lon, fishing spot)**
- **Detailed fishing method (chum/troll/chunk, bait-live/dead/artificial)**
- **Limited environmental data (SST, water depth)**
- **Target Species (as reported by vessel captain)**


YFT/LINE-HOUR vs LINE-HOURS
yftplhr
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
12
17
22
27
32
37
42
47
52
57
62
67
72
LINEHRS
Regression Equation:
yftplhr = 0.033666 - 0.000258*LINEHRS


Headboat- Gulf of Mexico
Relative Indices
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Year
Standardized
UCI
LCI
nominal
20 in TL min size
22 in TL min size

A few common problems. . .

Defining target using Stephens and MacCall (2004) approach:

- **Uses a multispecies logistic regression approach to predict the likelihood of catching the species of interest based upon its association with other species in the catch. Defines a threshold probability value to accept trip/interview records.**
- **The Stephens and MacCall method is most appropriately applied to fishing trips that typically land a number of species on a single trip. This is generally not the case in the MRFSS dataset, and this can confound the estimation of the threshold required for the procedure. The approach appears to be more suitable in the case of the HBS.**
- **One difficulty in the application if this approach is how to handle trips that ONLY catch the species of interest. Since no associated species are caught on such trips, by default these trips might not be included. This is an obvious bias. However, forcing such trips into the analysis data set might also result in a bias if the trip factors would normally have made a catch unlikely. This is particularly a problem with MRFSS data.**

Science, Service, Stewardship

Spatial considerations for CPUE indices

John Walter
SEFSC
October 15 2008

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Terms of Reference:

1. Definition of the problem

   - CPUE is function only of the fished area

   - Space-time interactions make CPUE difficult to interpret

2. Brief examination of possible issues, particularly for GLMs

3. Provision of some basic recommendations

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Problem 1: Aggregate CPUE $\not\sim$ qN

RAPID COMMUNICATION / COMMUNICATION RAPIDE

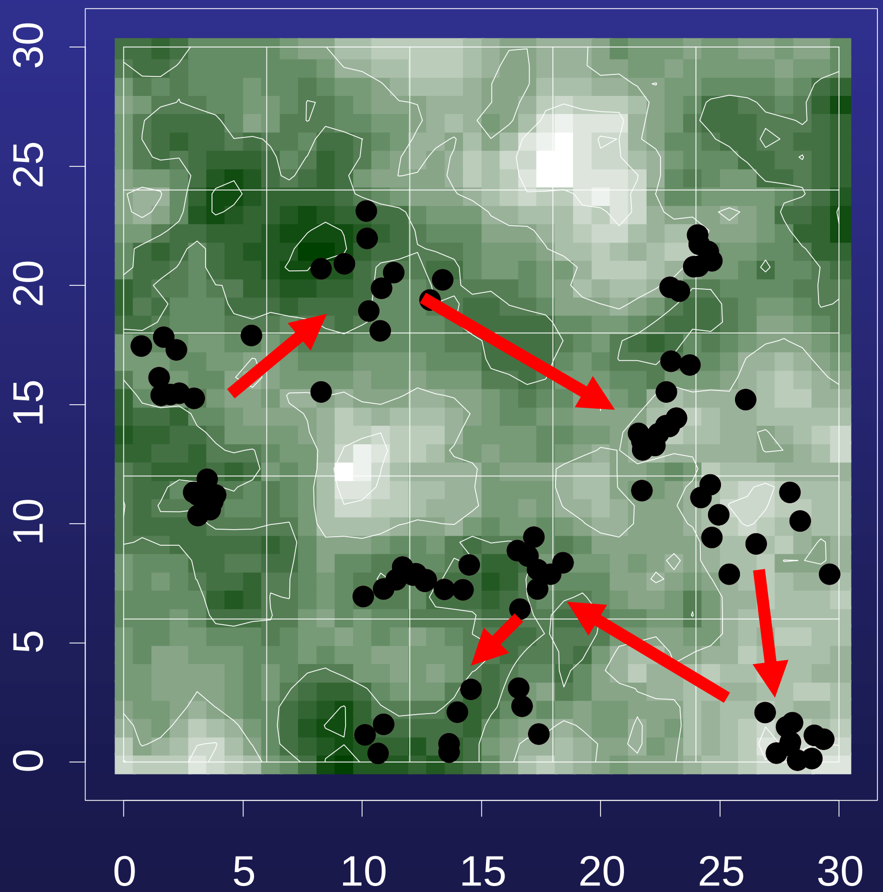
Folly and fantasy in the analysis of spatial catch rate data

Carl Walters

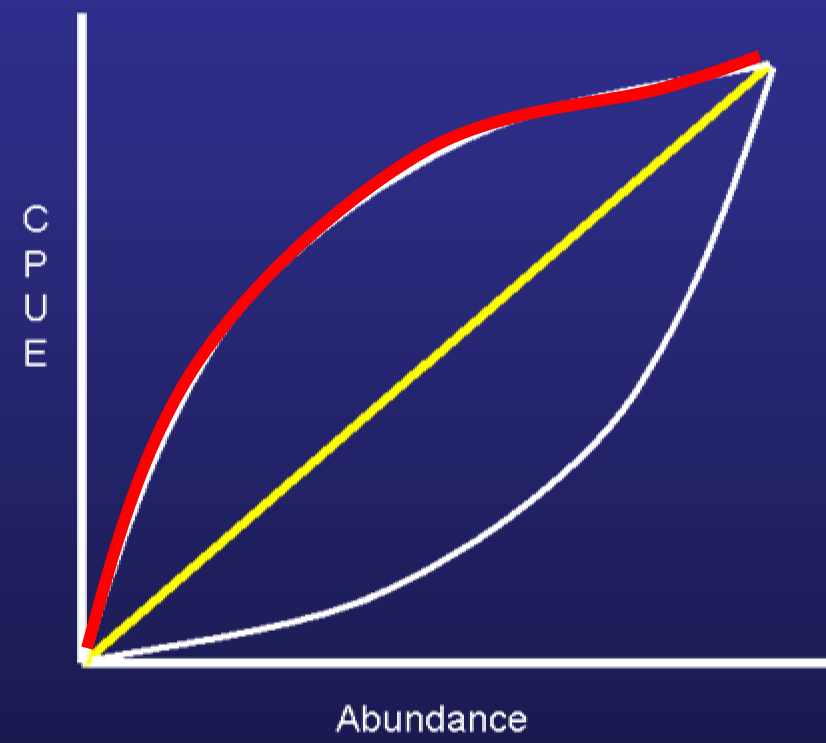
Can. J. Fish. Aquat. Sci. 60: 1433–1436 (2003)

CPUE $\not\sim$ q $\bar{N}$: Hyperstability

Mobile fishery, stationary resource- Fishery moves before catch rates decline

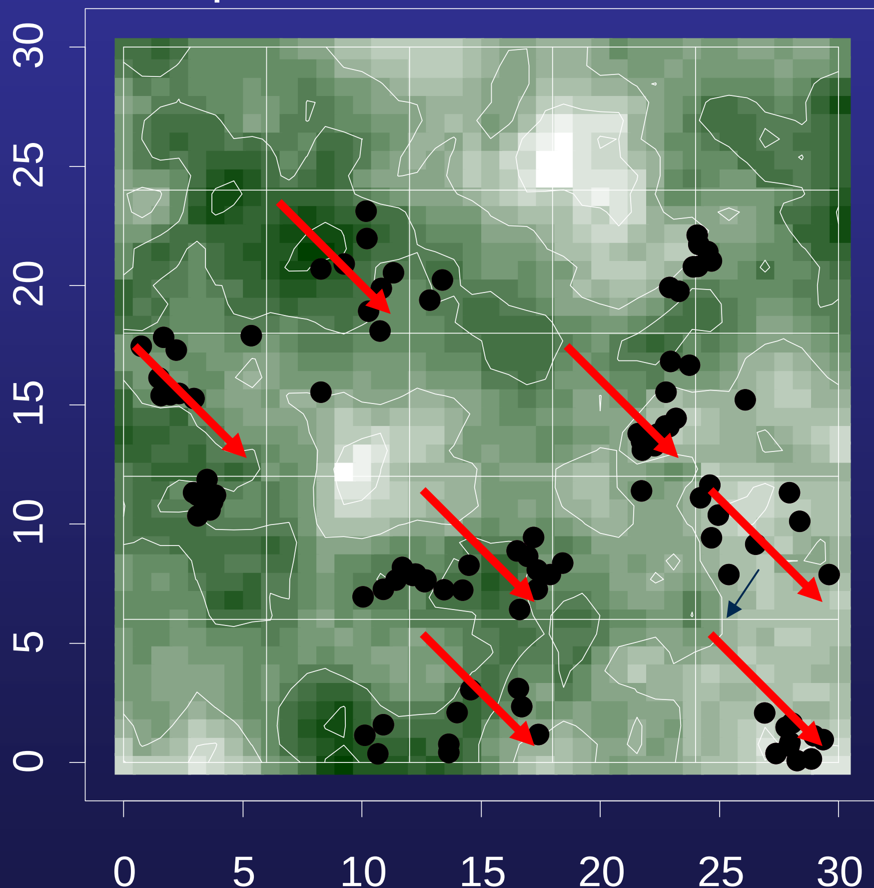


Hyperinflation: index remains high as overall A drops

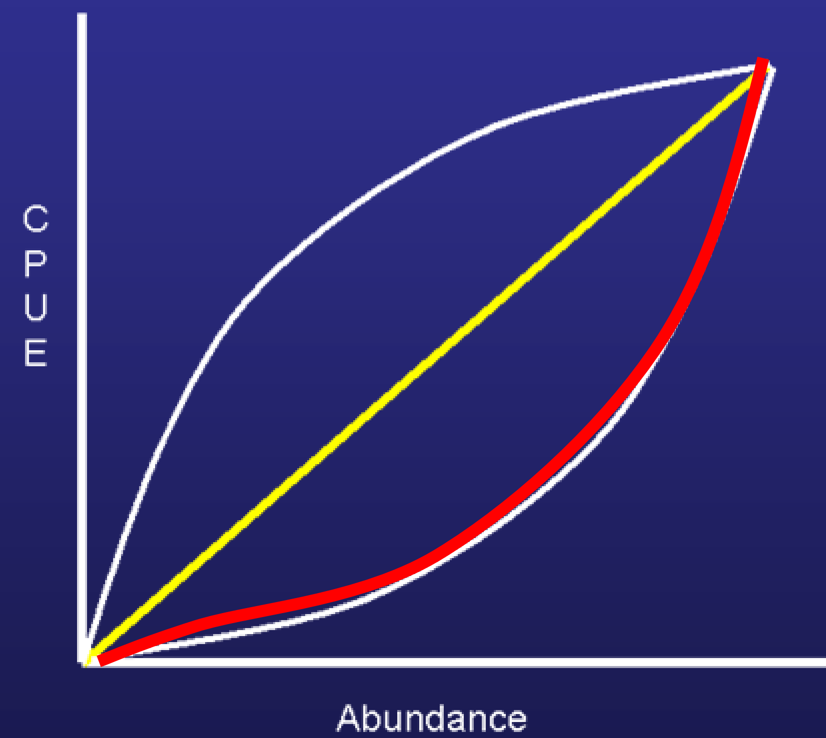


CPUE $\not\sim q\,\overline{N}$: Hyperdepletion

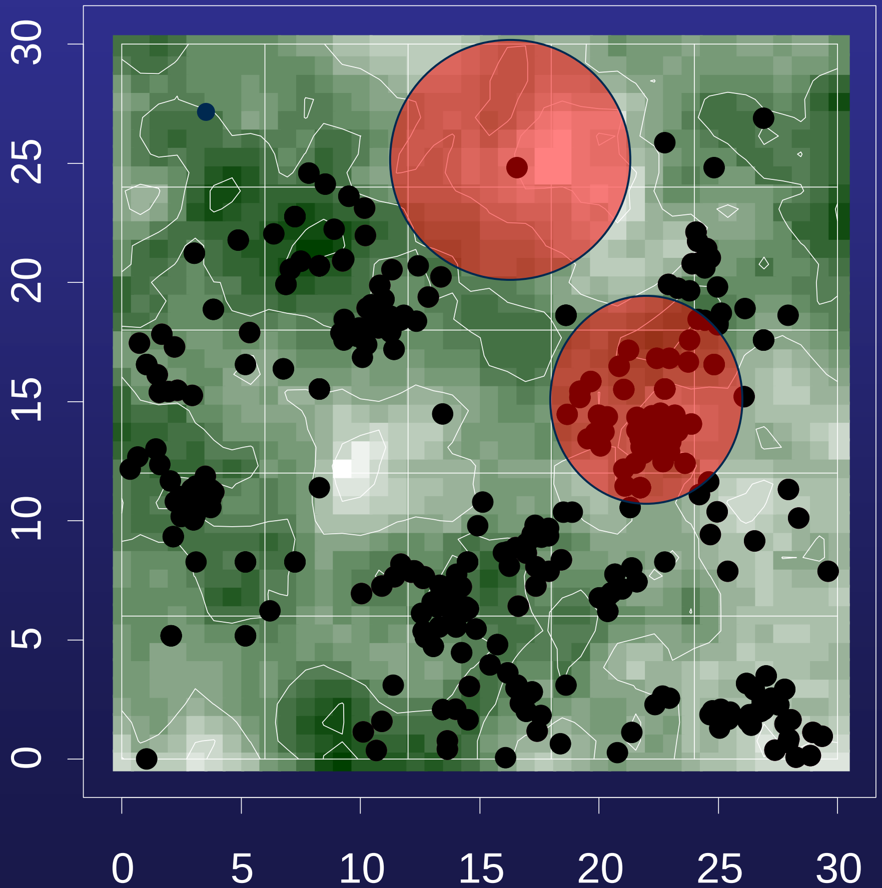
Catches concentrated in a few cells, depletes these, and moves to less productive areas



Hyperdepletion: index declines faster than overall A



Need to predict in unfished areas
Downweight clusters of high catches



Perhaps some method that weights sample values according to the space they “represent”

Requires some rather dodgy assumption regarding abundance in unfished areas

Interpolation, geostatistics, spatial GLMs, GAMs, etc

Problem 2: YEAR*AREA INTERACTIONS

1. Ignore the interaction

2. Obtain weighted average of year effect for each area

3. Treat the interaction as a random effect

4. Model separate populations

http://www.fisheriesstockassessment.com/TikiWiki/tiki-index.php?page=IATTC+October+Stock+Assessment+Methodology+Workshops

Mark Maunder, pers comm, 2008

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1. Ignore the interaction

Interaction often an artifact of unbalanced sample design…but that imbalance may not be ignorable

May lead to bias when significant interactions exist

We may not be able to separate changes in abundance from changes in the fishery

We will likely not achieve ‘legally defensible science’

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2. Weight the year effects for each area

Define some type of spatial weighting factor, this could be a priori or within the model (geostatistical?)

Habitat area, area fished, etc.

Punt et al. (2000) used habitat area to weight gummy shark CPUE (*Mustelus antarcticus*) off southern Australia.

ICCAT(2008) Skipjack tuna assessment group weighted individual CPUE by number of 1^{o} squares fished by each fishery in each year

Punt, A.E., Pribac, F.,Walker, T.I., Taylor, B.L., Prince, J.D., 2000. Stock assessment of school shark Galeorhinus galeus based on a spatially-explicit population dynamics model. Mar. Freshw. Res. 51, 205–220.

ICCAT 2008 Skipjack tuna assessment

3. Treat as random effect

Model year interactions as random effects rather than as fixed effects.

Assumes that year×area interactions are due to random changes in the distribution of the population (Cooke 1997)

Why not fixed effect? - If year*area interactions are included in a fixed-effects GLM, the resulting estimates of annual CPUE are no longer unique, and may not converge with severe imbalance

BUT fixed effects may actually be the reality- we may not be able to separate changes in abundance over time from changes in location over time.

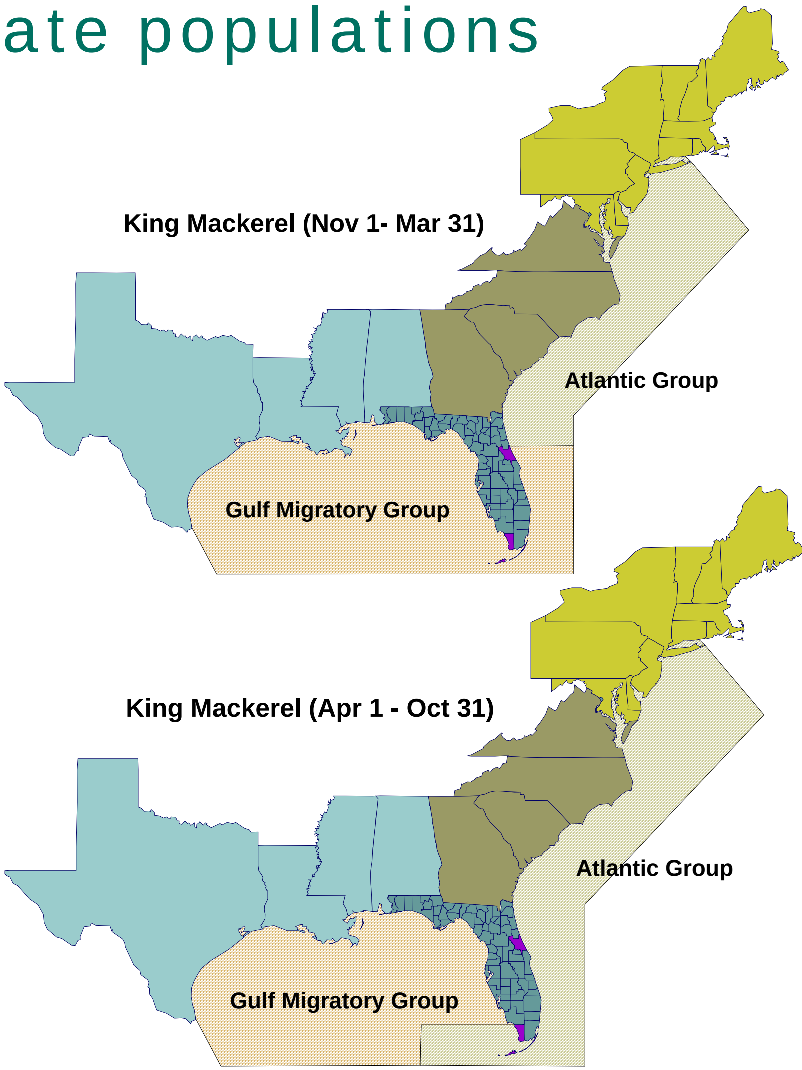
Cooke, J.G. 1997. A procedure for using catch-effort indices in bluefin tuna assessments. Col.Vol.Sci.Pap. ICCAT: 46 (2) : 228-232

4. Model as separate populations

Split indices, split assessment models

How do we deal with movement?

How much of a particular index 'applies' to a given segment of the stock?



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General Recommendations

1. Tables of sample sizes/percent positive by area [simple]
2. Maps of catch observations for each year [simple]
3. Plot your data [very time consuming of analyst]
4. Evaluate how representative the index is of population of interest [subjective]

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1. Table of observations, catch, effort, percent positive

Table of sample observations by area over time from Pelagic logbook

Is there a change in location over time

(highly dependent upon areal partitioning)

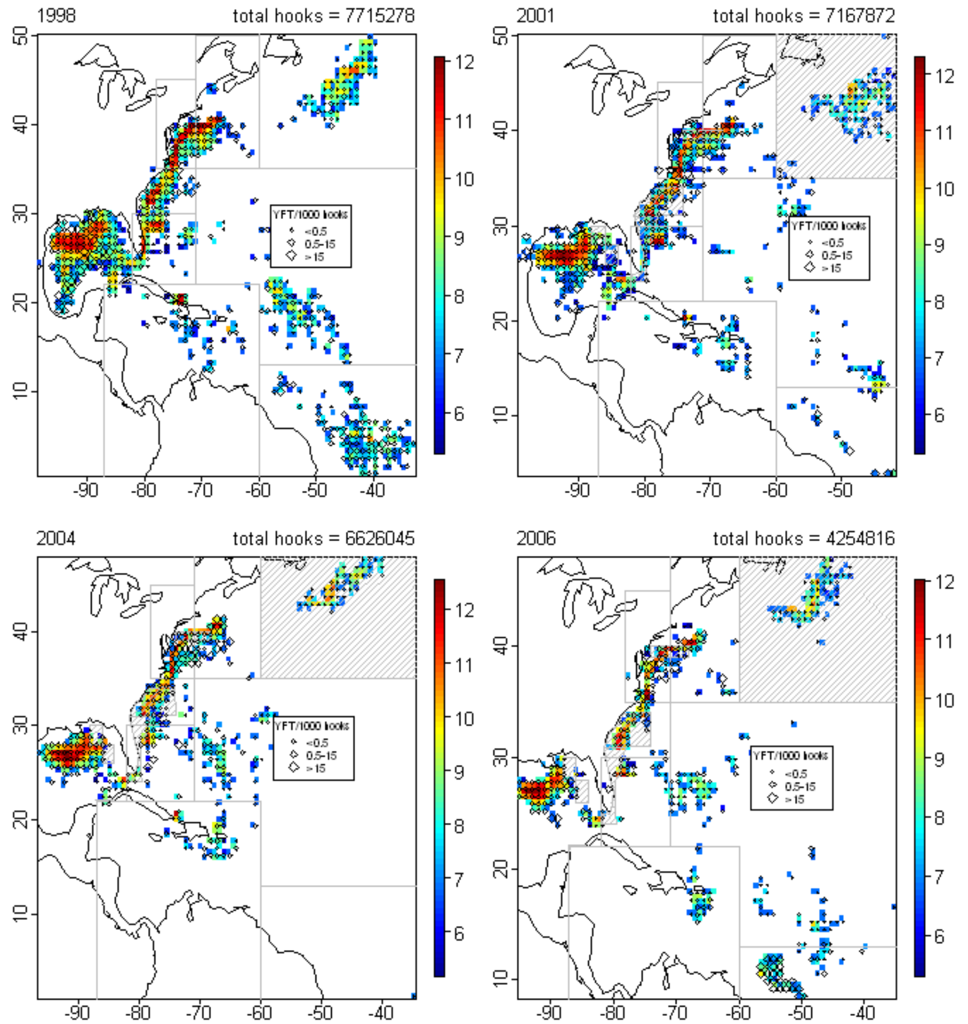
	Caribbean	Florida East	Gulf of Mexico	Mid-Atl. Bight	NE Coast	NE Distant	Sargasso Sea	South Atl. Bight
1986	76	379	448	239	209	51	2	93
1987	1605	3141	3003	1429	946	760	41	414
1988	2081	3340	2215	1282	957	1464	27	820
1989	1519	4142	2703	2069	1026	1577	186	970
1990	1391	3299	2672	2147	1617	1072	210	1386
1991	1043	2922	3145	2302	1794	1062	232	1152
1992	912	2539	3888	2456	1410	1189	385	1068
1993	1128	1962	3345	2476	1217	1067	606	1630
1994	1414	2108	3333	2821	1027	1007	642	1788
1995	1336	1963	3689	3061	1270	927	1191	1544
1996	1219	1830	4929	1429	1320	688	690	2729
1997	878	2254	5005	1719	1464	728	378	1706
1998	559	1785	3799	1741	1058	619	335	1411
1999	294	2097	4521	1814	757	430	194	1486
2000	420	1982	4432	1545	752	602	118	1325
2001	314	991	4459	1506	1003	332	172	1301
2002	288	934	4461	1283	681	493	206	834
2003	242	898	4425	903	556	534	297	948
2004	352	598	4542	958	547	456	156	1054
2005	201	569	3250	956	421	463	189	722
2006	84	578	2685	1088	456	383	209	760
2007	41	719	3078	1175	361	348	148	983
2008	51	156	285	17	NA	NA	44	123

2. Maps of catch/effort

Maps of catch and effort for each year

Examine for:

- contraction/ expansion of effort
- area*time interactions



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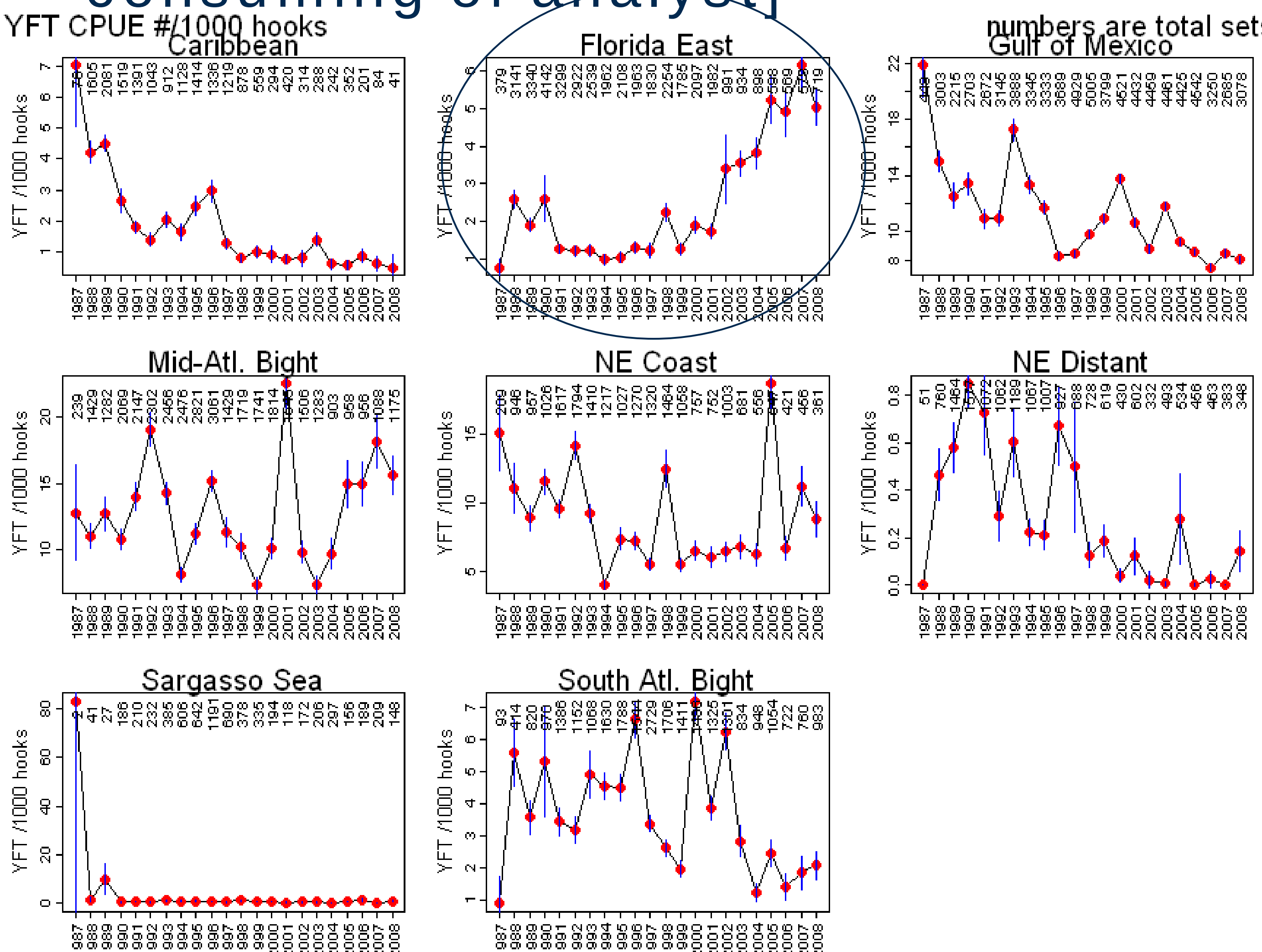
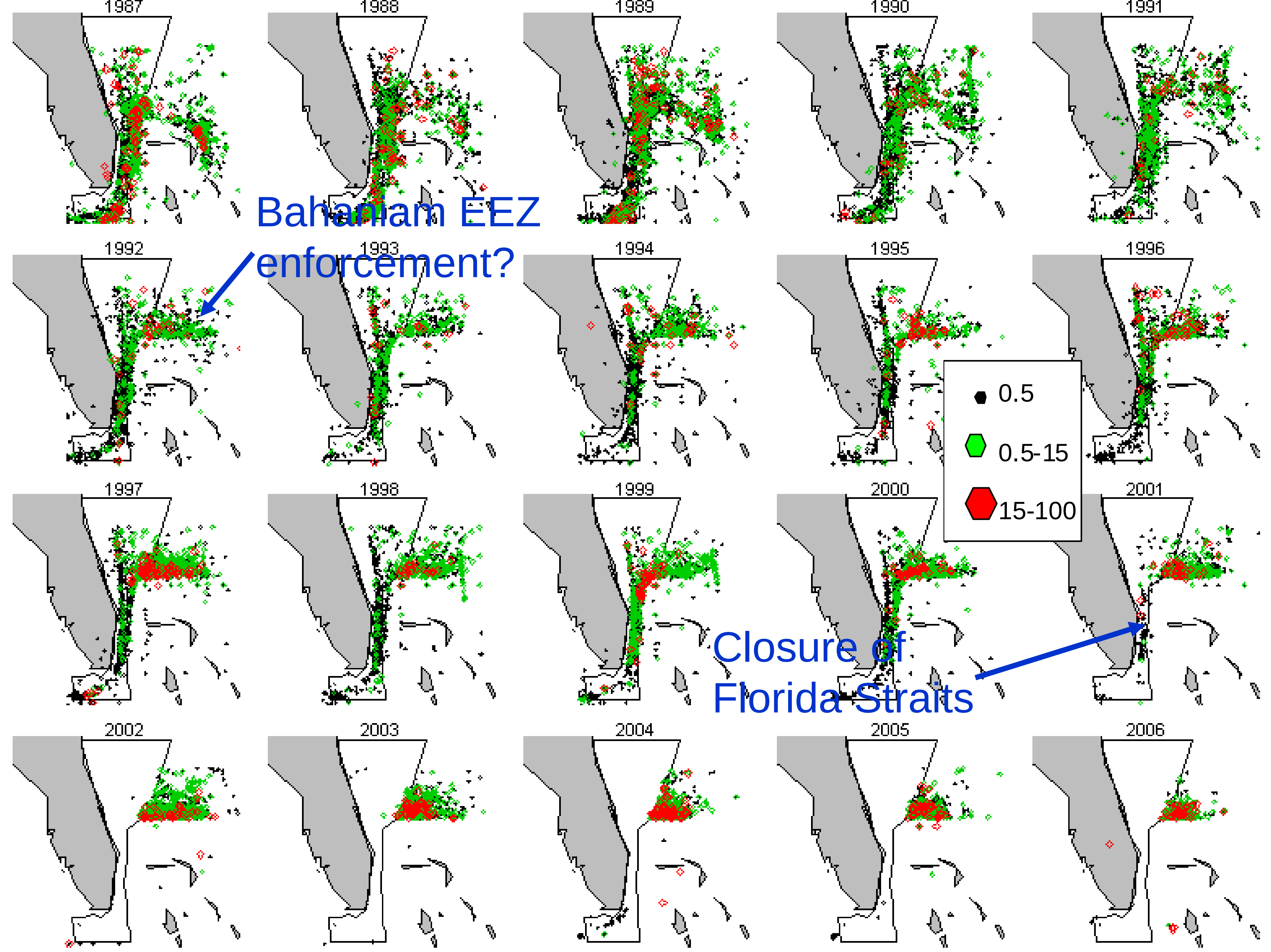
3. Plot your data [very time consuming of analyst]

- Plot data on various spatial scales
- Examine CPUE for time*area interactions
- Examine CPUE before and after management actions





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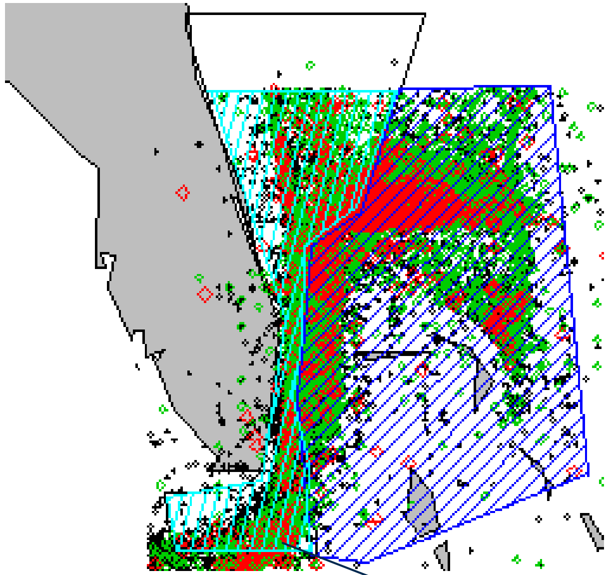
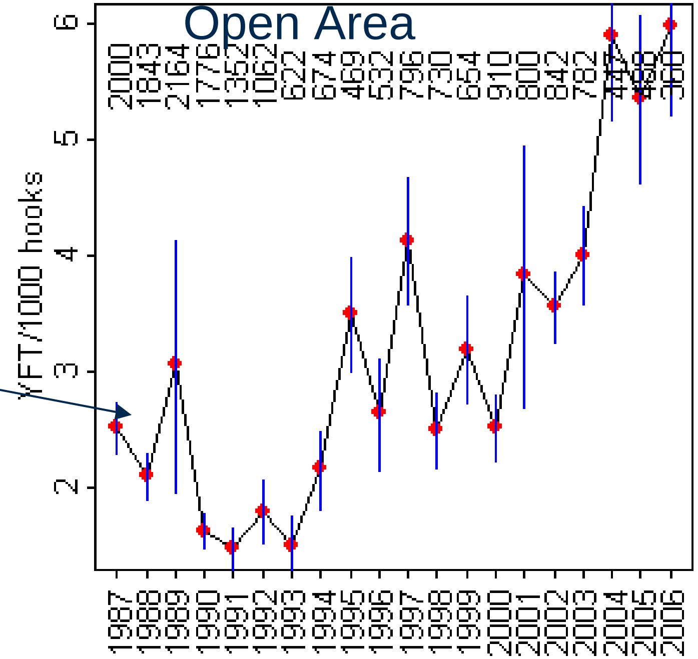
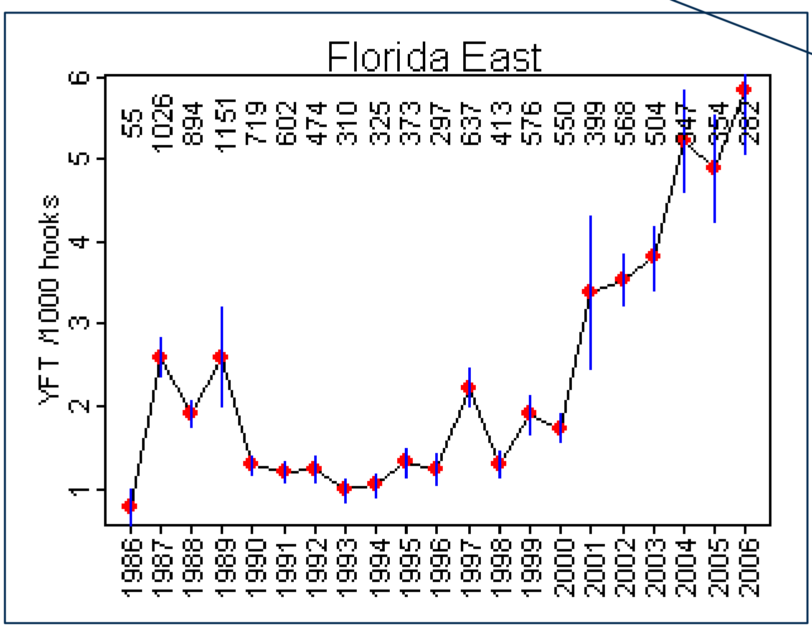
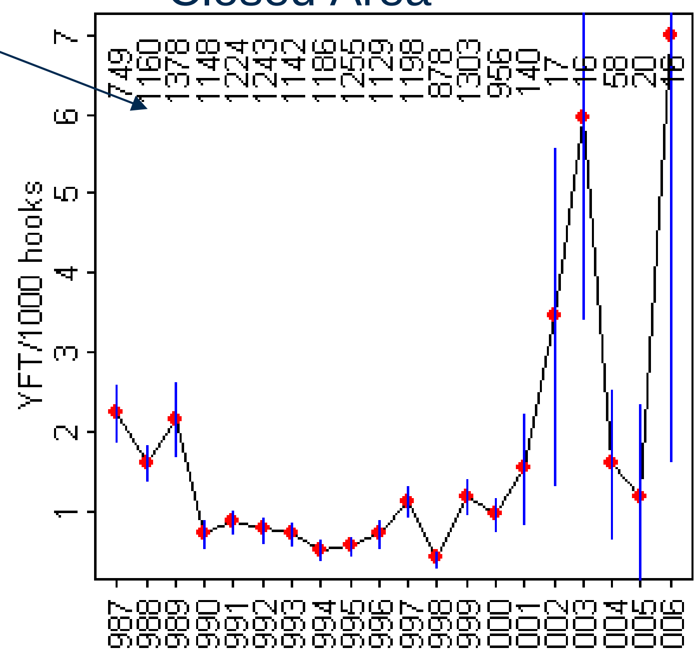
2006
Bahaniam EEZ enforcement?
Closure of Florida Straits
0.5
0.5-15
15-100




Open Area
YFT/1000 hooks


Florida East
YFT /1000 hooks

Closed Area


YFT/1000 hooks

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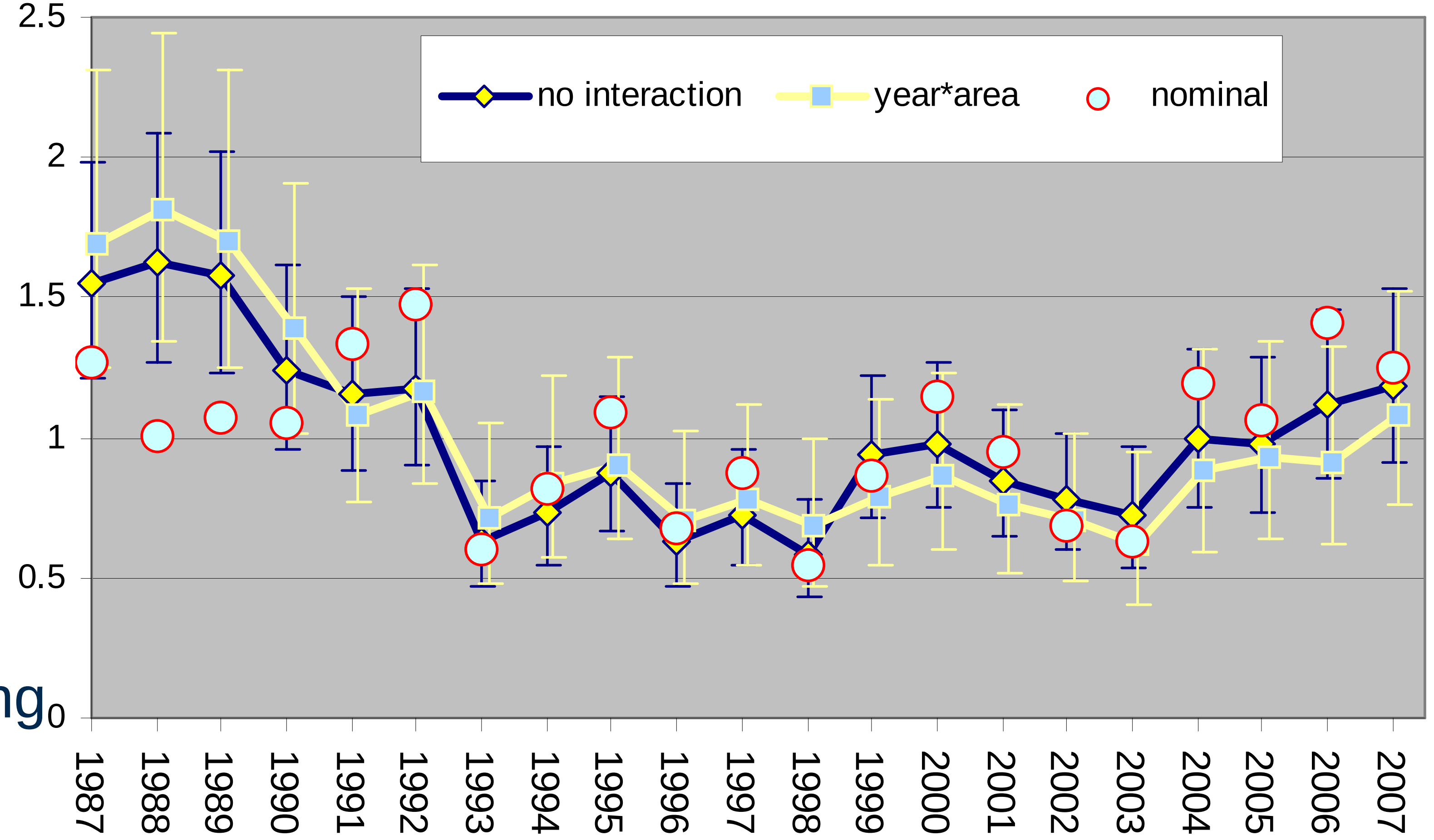
Including year*area random interaction#



and excluding GOM

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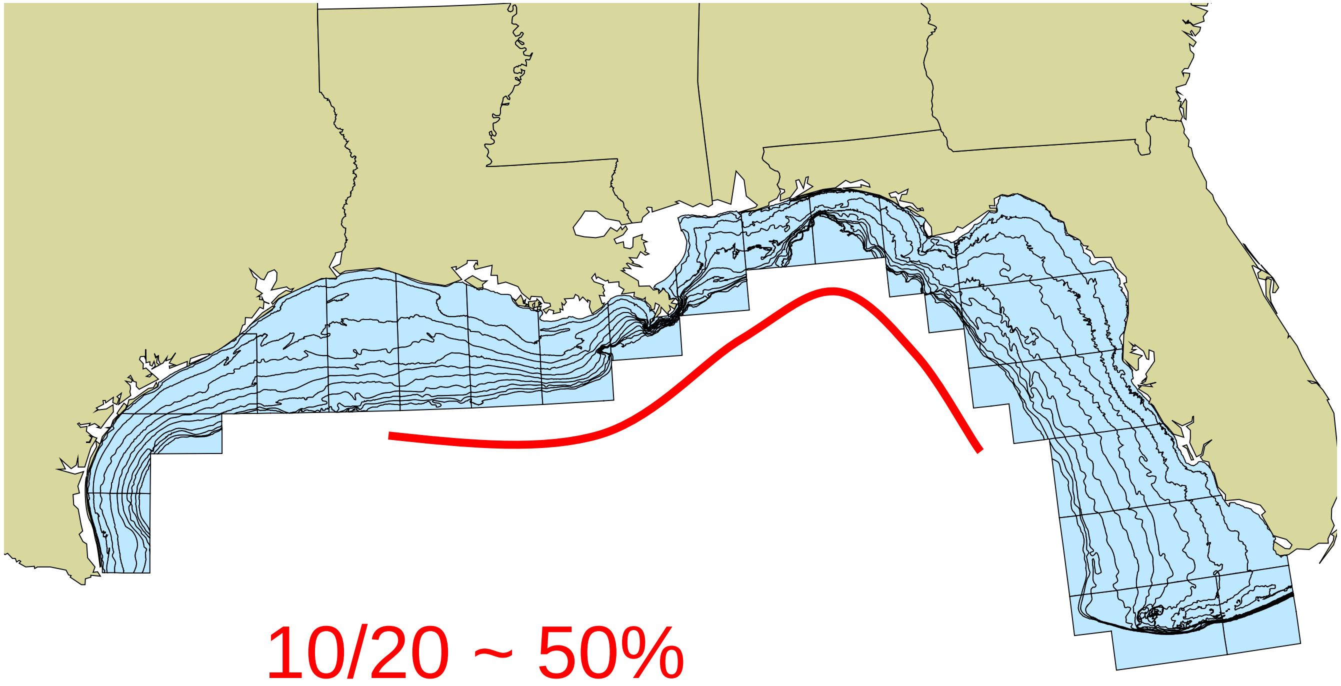
4. Evaluate how representative the index is of the population of interest

Perhaps as simple as some guess as to how much of the stock area the index ‘covers’

How many shrimp grids, or other spatial cells?



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Other recommendations

1. Tables of sample sizes/percent positive by area [simple]
2. Maps of catch observations for each year [simple]
3. Plot your data [very time consuming of analyst]
4. Evaluate how representative the index is of population of interest [subjective]
5. How to deal with space-time interactions in GLM

Science, Service, Stewardship

Combined inference from multiple noisy CPUE Indices

Paul Conn, NMFS Beaufort

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Motivation

In data poor fisheries (all of them?), there are often a number of CPUE indices to choose from. The situation (esp. in SE U.S.) is often the following:

1) There are multiple CPUE indices, but little-moderate correlation between them
2) Not clear which one is "best"
3) Numerical difficulties / poor fits when trying to fit them all

Motivation

Since each index is ostensibly attempting to measure the same quantity (relative abundance), it is often evident that differences among indices cannot be explained by estimated level of sampling error (i.e., variation attributable to sample size)

There must be some residual, unexplained source of variation

Sources of additional variance

In an age structured population, residual variation in index values can be explained in a number of ways:

- Selectivity differences between indices
- Departure from index assumptions (e.g., departures from IID sampling, model structure)
- Variation in catchability over time and space

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Joint inference approach

Problem statement: Assuming selectivities are similar for different indices, can we come up with a single, *most probable* index conditional on observed index values and estimates of sampling variance?

Intuition: We'll probably need some way of estimating the additional variance not explained by sampling variance (hereafter, "process variance")

Intuition: The degree of agreement/disagreement between indices gives us some idea of how well they are measuring relative abundance.

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Joint inference approach

- Assume that each index is subject to process errors in addition to sampling errors
- The most “likely” value an index can take on is related directly to actual changes in abundance and/or biomass
- Easier to describe problem in terms of relative change in an index than absolute value (scale invariant)

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Model

U_{it} Index *i* in year *t* (data)

$\Delta_{it} = U_{i,t+1}/U_{it}$ "Gradient" for index *i* in year *t*

σ_i^p Process error in index *i* gradient

σ_{it}^s Sampling error for index *i* gradient in year *t*

L_{it} "Latent" gradient for index *i* in year *t*

λ_t Finite rate of pop change, year *t*

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Joint inference approach

Why relative change in indices?

→ Can't resolve differences in scaling with raw indices. But…

$$\mathrm{E}(\Delta_{it}) = \mathrm{E}\left(\frac{U_{i,t+1}}{U_{it}}\right)$$

$$= \mathrm{E}\left(\frac{q_{i,t+1}}{q_{it}}\right)\frac{N_{i,t+1}}{N_{it}} = \mathrm{E}\left(\frac{q_{i,t+1}}{q_{it}}\right)\lambda_t \quad \approx \lambda_t$$

or biomass

(assuming no long term trend in catchability or adjusting for assumed trend beforehand)

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Joint inference approach

Step 1: Calculate $\Delta_{it} = U_{i,t+1}/U_{it}$

Step 2: Calculate sampling error σ_{it}^{s}
for each index *i* , using delta method:

$$\hat{Var}(U_{i,t+1}/U_{it}) = \frac{\hat{Var}(U_{i,t+1})}{U_{it}^2} + \frac{U_{i,t+1}^2}{U_{it}^4}\hat{Var}(U_{it})$$

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Model

Step 3: Apply hierarchical model, e.g.

$$[\Delta_{it}|\lambda_t, \sigma_i^p, \sigma_{it}^s] = [\Delta_{it}|L_{it}, \sigma_{it}^s]$$

$$[L_{it}|\sigma_i^p, \lambda_t][\lambda_t][\sigma_i^p]$$

$$[\Delta_{it}|L_{it}, \sigma_{it}^s] \qquad \text{Normal}(\Delta_{it}; L_{it}, 1/\tau_{it}^s)$$

$$[L_{it}|\sigma_i^p, \lambda_t] \qquad \text{Normal}(L_{it}; \lambda_t, 1/\tau_t^p)$$

$$[\tau_i^p]: \qquad \text{Gamma}(\tau_i^p; \alpha, \beta)$$

$$[\lambda_t]: \qquad \text{Uniform}(a, b)$$

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Model

So, inference focuses on λ_t
but a derived index can be calculated as

$$\hat{\boldsymbol{\mu}} = [1, \lambda_1, \lambda_1\lambda_2, \ldots, \prod_t \lambda_t]$$

with an arbitrary value of 1 in the first year to scale the index

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Spanish mackerel example

Nine indices were constructed for Spanish mackerel, with the following correlation structure

	FL trip ticket, gillnet series 1	FL trip ticket, gillnet series 2	FL trip ticket, castnet	FL trip ticket, hand lines	MRFSS	Commercial logbook, GA-NY, gillnet	Commercial logbook, GA-NY, hand lines	SEAMAP YOY	SEAMAP YOY (1 yr. lag)	SEAMAP 1-yr-olds
FL trip ticket, gillnet series 1	1	NA	NA	-0.37	-0.16	NA	NA	-0.79	-0.73	-0.12
FL trip ticket, gillnet series 2	NA	1	-0.63	-0.19	-0.28	-0.64	-0.29	0.22	0.03	0.27
FL trip ticket, castnet	NA	-0.63	1	0.44	0.19	0.28	-0.11	-0.67	-0.25	-0.51
FL trip ticket, hand lines	-0.37	-0.19	0.44	1	0.08	0.27	-0.08	0.22	-0.1	-0.18
MRFSS	-0.16	-0.28	0.19	0.08	1	0.14	0.21	-0.22	-0.03	-0.06
Commercial logbook, GA-NY, gillnet	NA	-0.64	0.28	0.27	0.14	1	0.15	0.19	0.68	-0.55
Commercial logbook, GA-NY, hand lines	NA	-0.29	-0.11	-0.08	0.21	0.15	1	0.06	0.38	-0.11
SEAMAP YOY	-0.79	0.22	-0.67	0.22	-0.22	0.19	0.06	1	0.44	-0.11
SEAMAP YOY (1 yr. lag)	-0.73	0.03	-0.25	-0.1	-0.03	0.68	0.38	0.44	1	-0.26
SEAMAP 1-yr-olds	-0.12	0.27	-0.51	-0.18	-0.06	-0.55	-0.11	-0.11	-0.26	1

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Spanish mackerel example

- No a priori reason why one index best
- Commercial fishermen indicated there were shifts in wintering distributions that would affect different fisheries in a different manner
- Basing inference on a few indices would ignore information about catch-effort trends in other fisheries/regions

Decision: Apply joint inference procedure before running stock assessment analyses

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Spanish mackerel example

Concentrated on 7 fishery dependent indices (6 commercial, 1 general recreational) where selectivity was “similar” over the most highly abundant/harvested age classes. Delta-GLMs used to construct each index.

(Two SEAMAP indices not considered because they reflected indices of young-of-year and 1-year-olds only)

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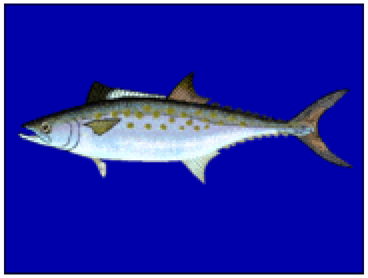
Spanish mackerel example

A hybrid Gibbs/Metropolis-Hastings sampler (programmed in R) was used to sample from posterior distribution of the parameters given the data (110,000 MCMC iterations with a 10,000 iteration burn-in

Inference focused on changes in relative abundance (λ_t), but a posterior predictive distribution for a "standardized" index calculated as

,

$$\hat{\boldsymbol{\mu}} = [1, \lambda_1, \lambda_1\lambda_2, \ldots, \prod_t \lambda_t]$$



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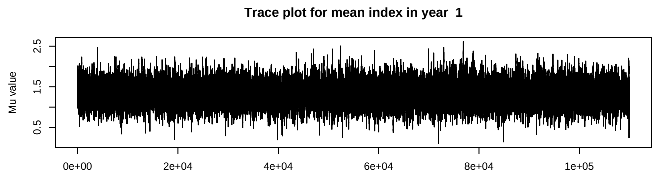
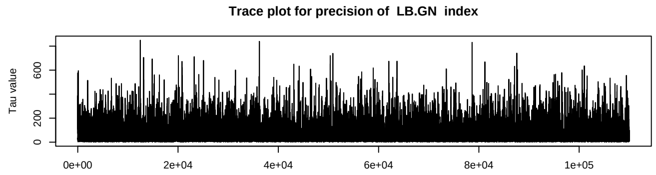
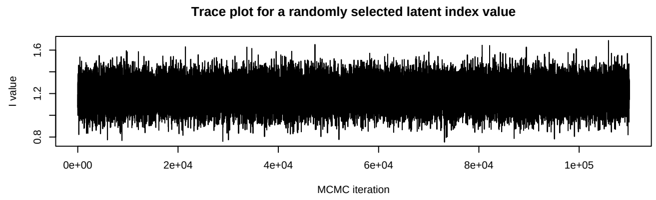
Spanish mackerel example

Standard MCMC diagnostics indicated convergence to the posterior







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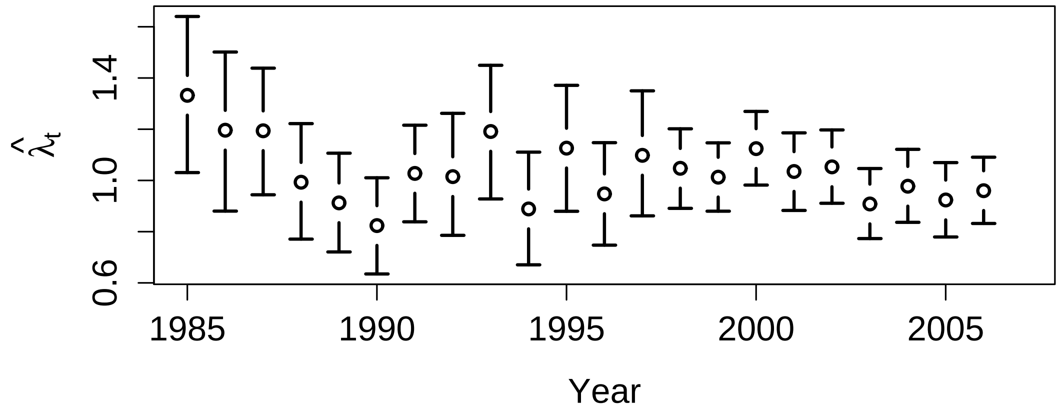
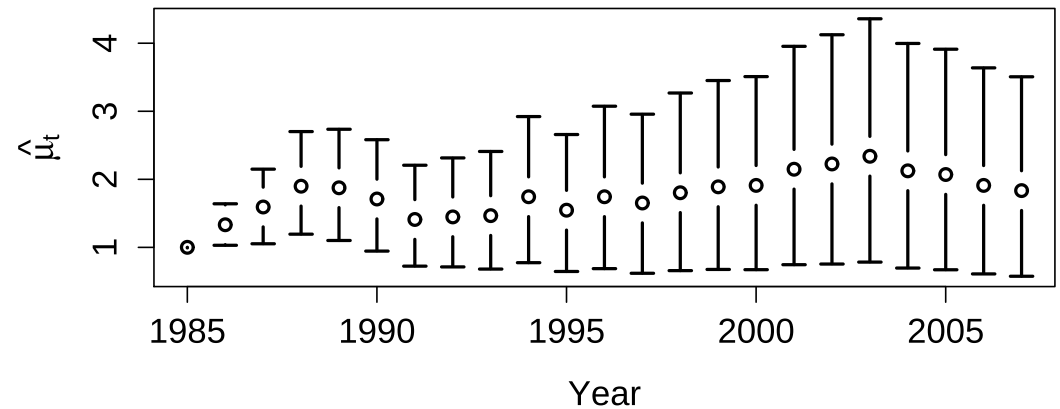
Spanish mackerel example

Posterior means (w/ 90% CIs)





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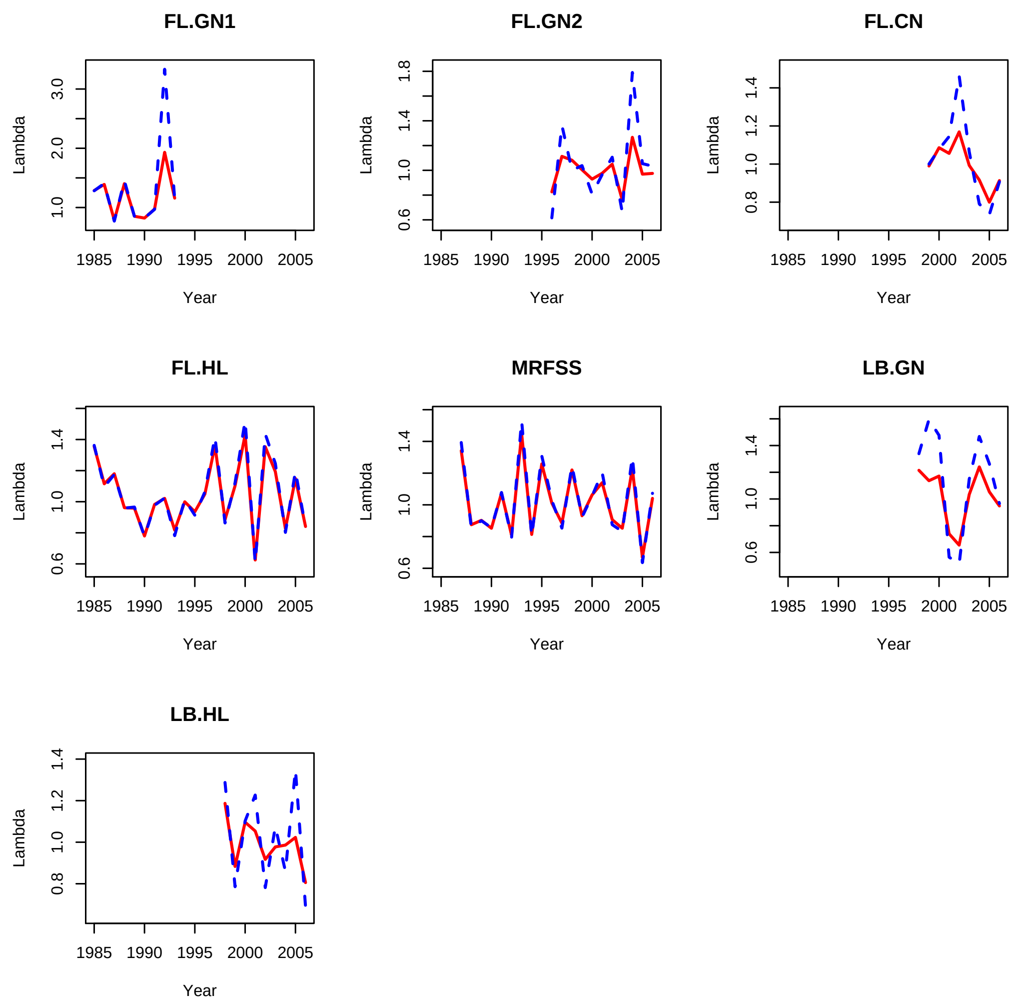
Spanish mackerel example

Also, get estimates of L_{it} (shrinkage estimates)

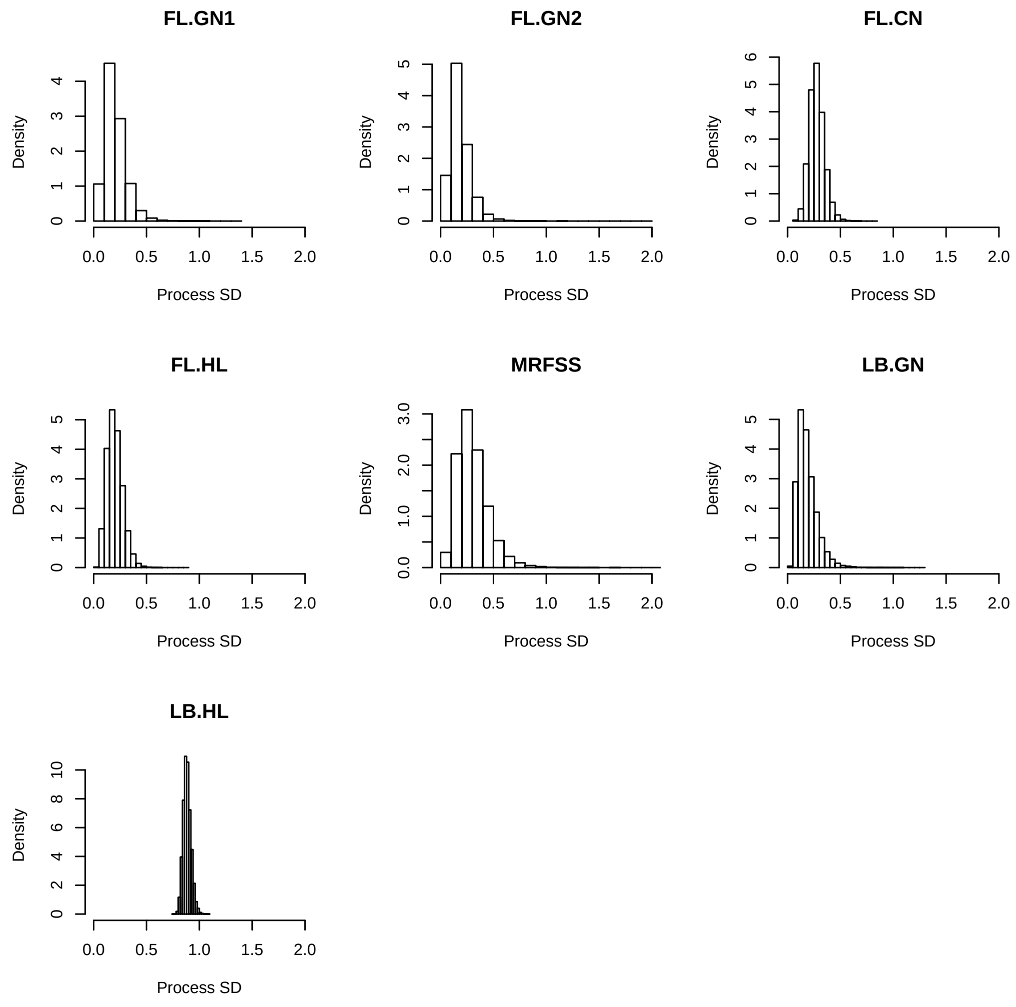
Shrinkage estimates

Nominal



Spanish mackerel example

Estimates of process error



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Summary

- Focusing on gradients allows combination of indices of different length (scale invariant)
- Calibration concerns possibly less of an issue
- Doesn’t require subjectivity – but if some is desired, it could take the form of informative prior distributions on process errors (e.g., if certain indices have better spatial coverage, etc.)

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Summary

But….. There are some caveats

- Somewhat sloppy of a method in that the “true” lambda may differ for each index if selectivity differs among indices – it’s not defined in an entirely consistent way
- May not be appropriate for metapopulations
- Precision of combined index increases over course of study because of compounded uncertainty in lambda
  - —Assume fixed variance
  - —Fit to lambda within assessment model
  - —Fit internally to assessment model itself (also could account for selectivity differences…but added computing time)

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Future research

Simulation study needed to examine

- Overall performance when assumptions met
- Effects of different selectivities
- Different patterns of process variance
- Different functional forms for model components (model selection/averaging ?)

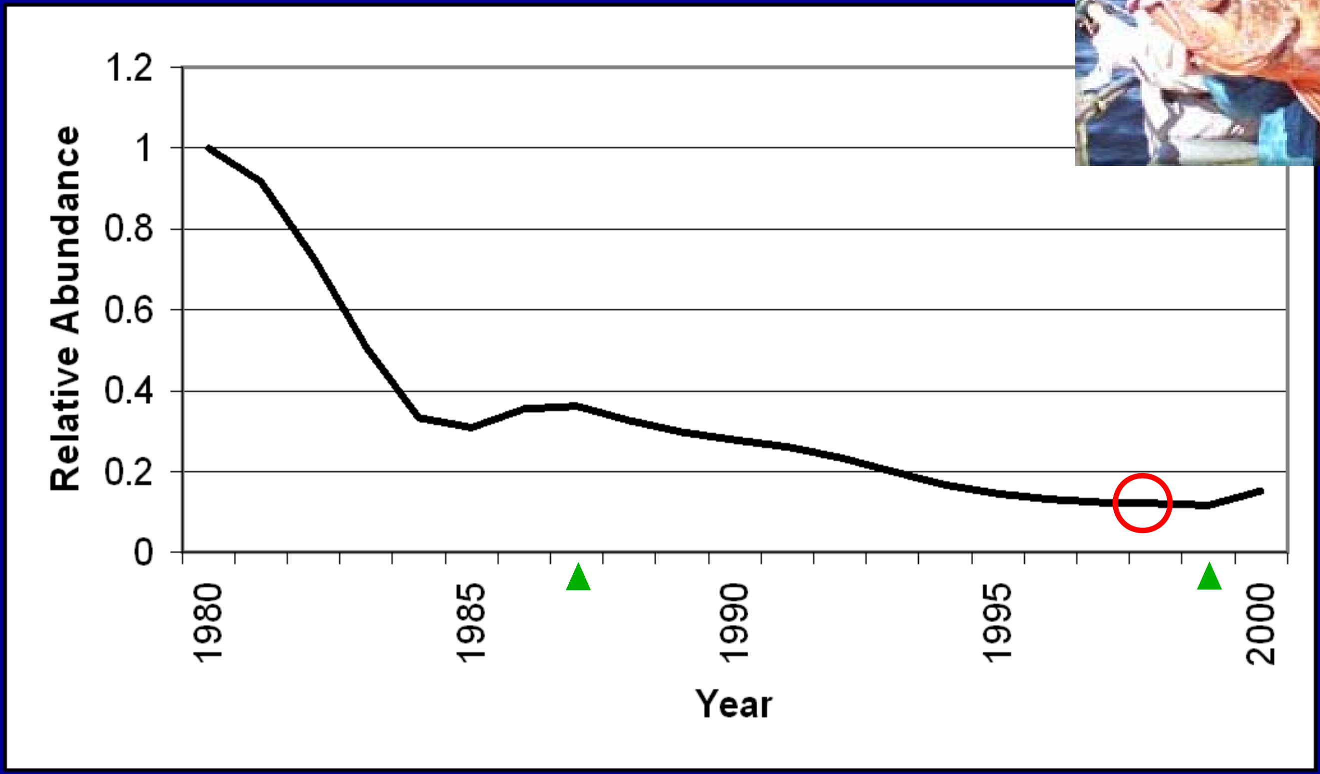
Current recommendation: Only use for indices with "similar" selectivities

BEYOND STEPHENS & MACCALL TO BETTER INTUITION AND DIAGNOSTICS

California Recreational Fishery

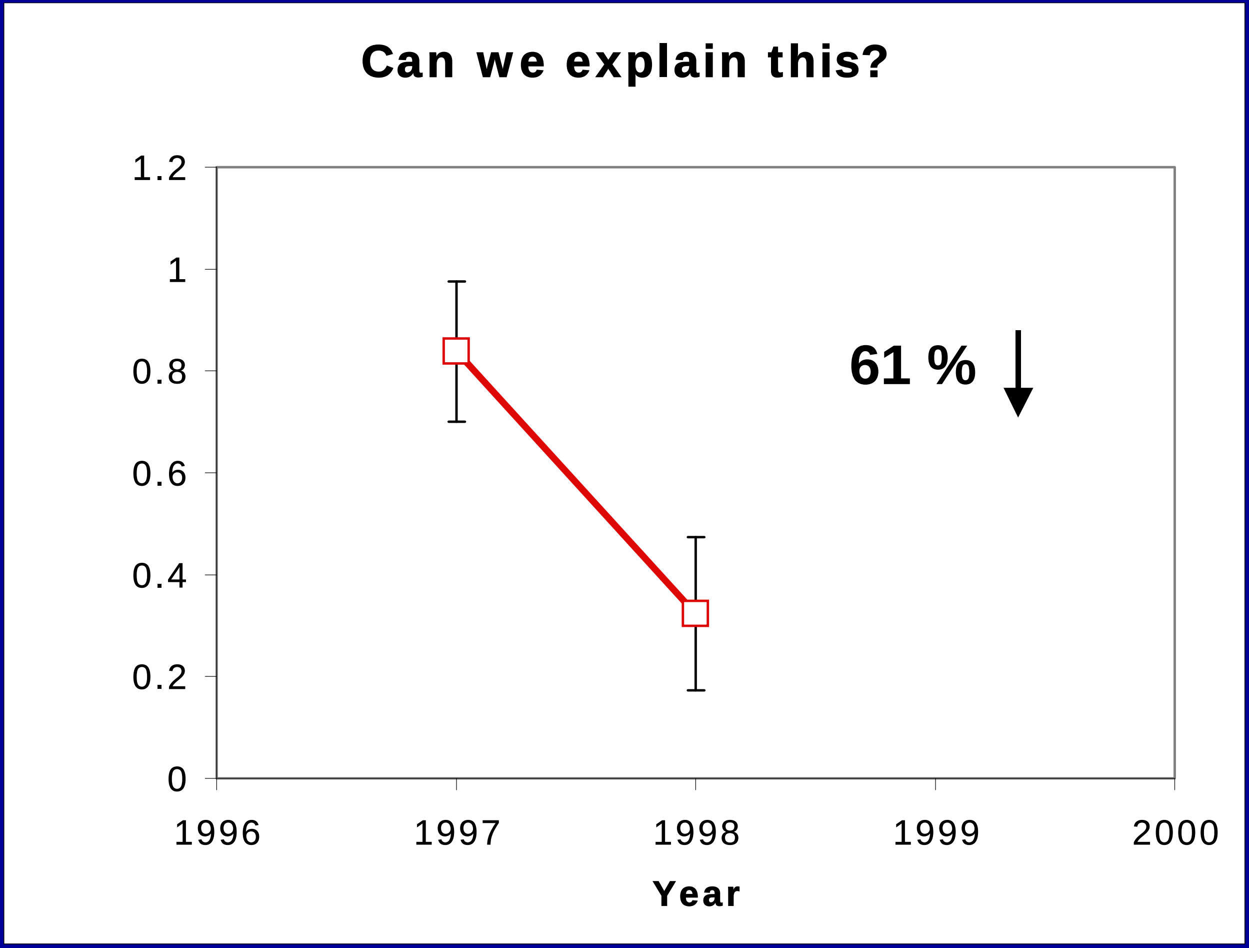
- Partyboats ~ 10 fishers
- Different targets: different habitat
- Targets: 120 spp.
    - Tuna
    - Salmon
    - Groundfish
- Visit 1-4 sites/day

Target: Bocaccio



NMFS Bocaccio Assessment (MacCall, 2003)

Confounding influences



CPUE estimation in a mixed fishery

- Calculate effort for bocaccio
- Remove the influence of tuna
- Eliminate influence of fishing trends
- Understand stock dynamics

Subsetting the data

- Explicit: species assemblage
- Implicit: habitat ⟷ species
- Presence/Absence
- Logistic regression:

Maximum likelihood

MRFSS Data

- Marine Recreational Fishery Statistics Survey
- 1980-1989, 1993-1999
- Dockside survey
- NO location information

CDFG Data

- California Department of Fish and Game
- 1986-1998
- Onboard sampling with locations
- “Trip Data” Multi-site trips

  Compare with MRFSS data
- “Site Data” Individual site visits

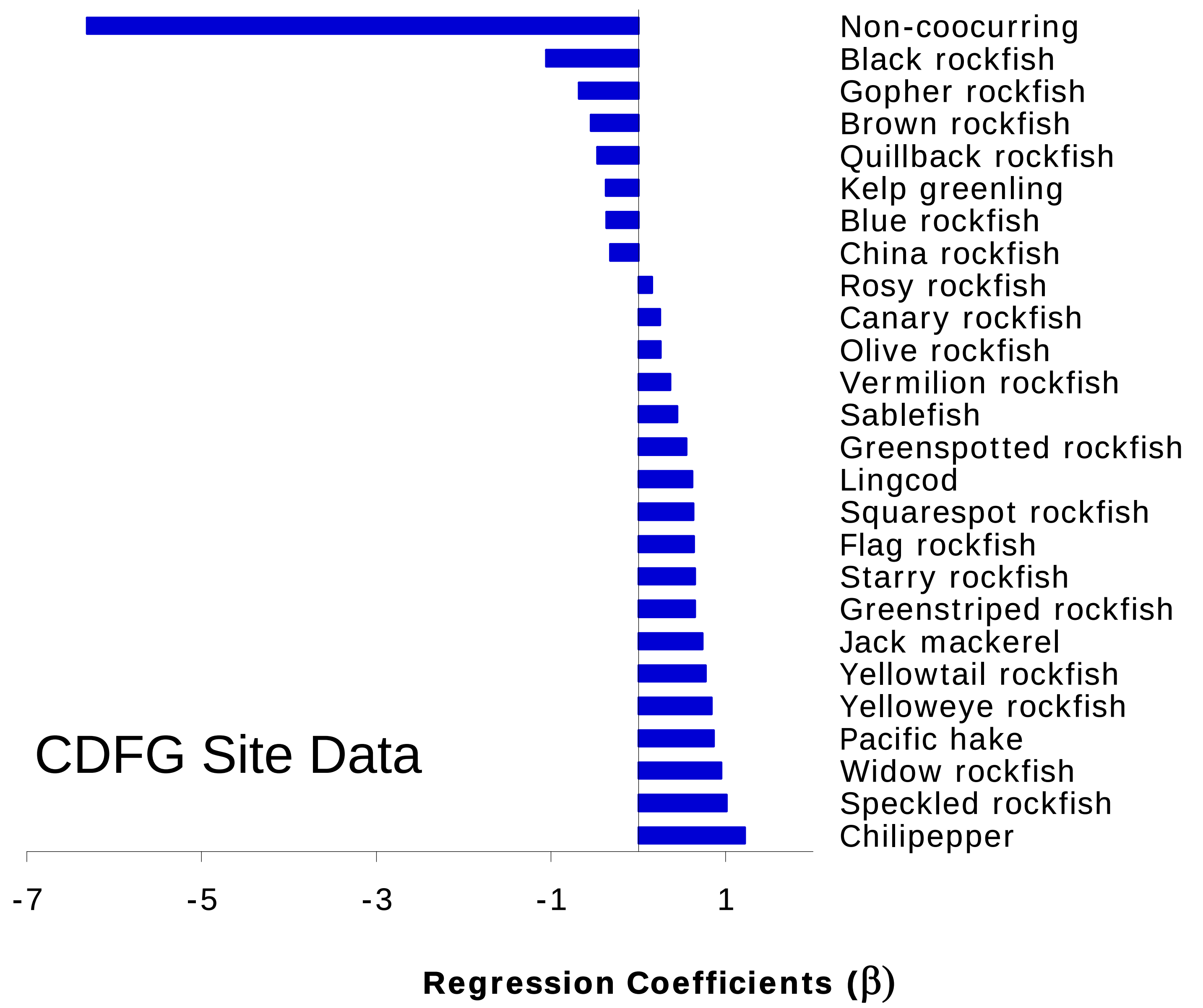
  Compare Species/Location Criteria

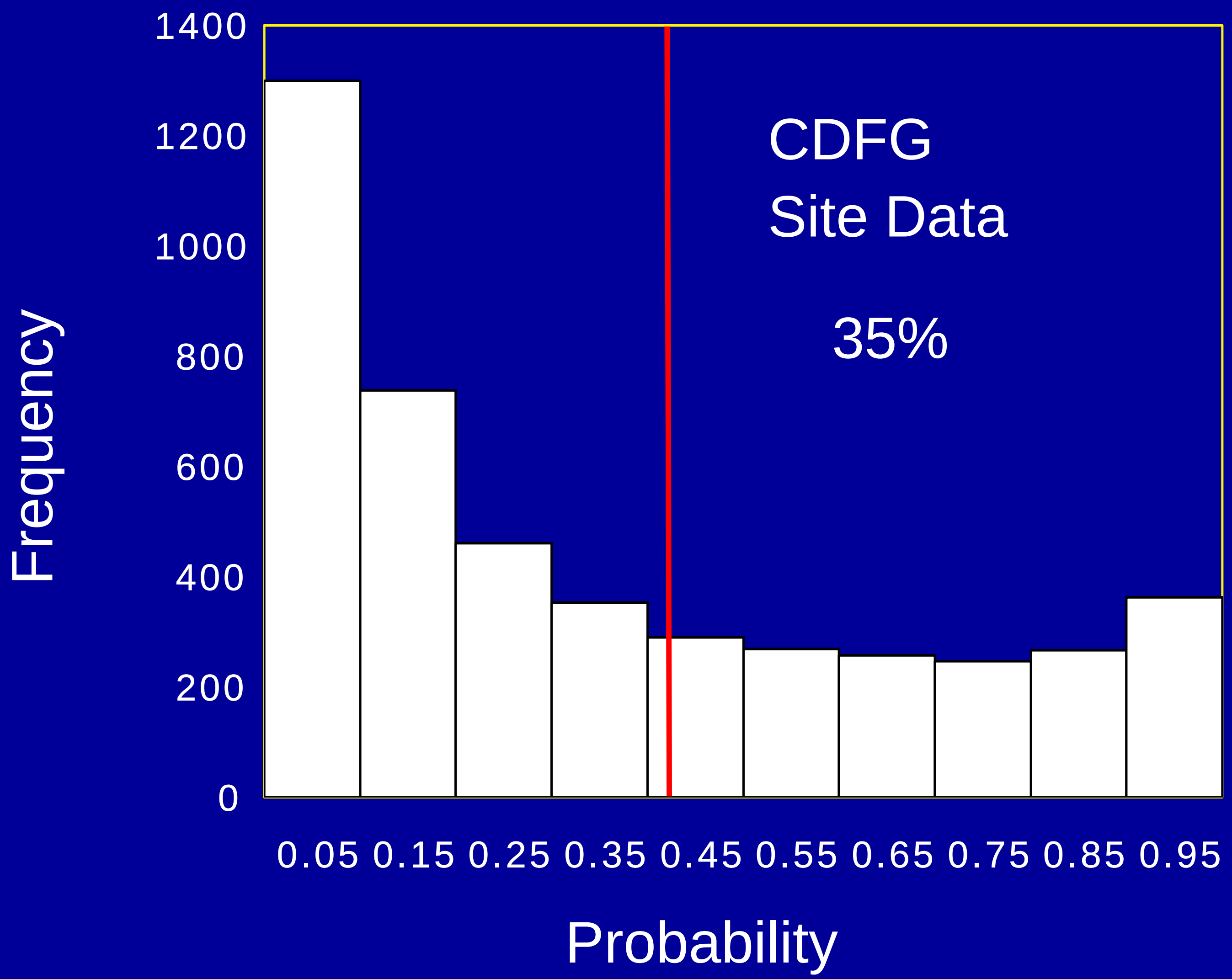
Evaluating the Regression

- Do the coefficients make sense biologically?
- Which trips do we accept?

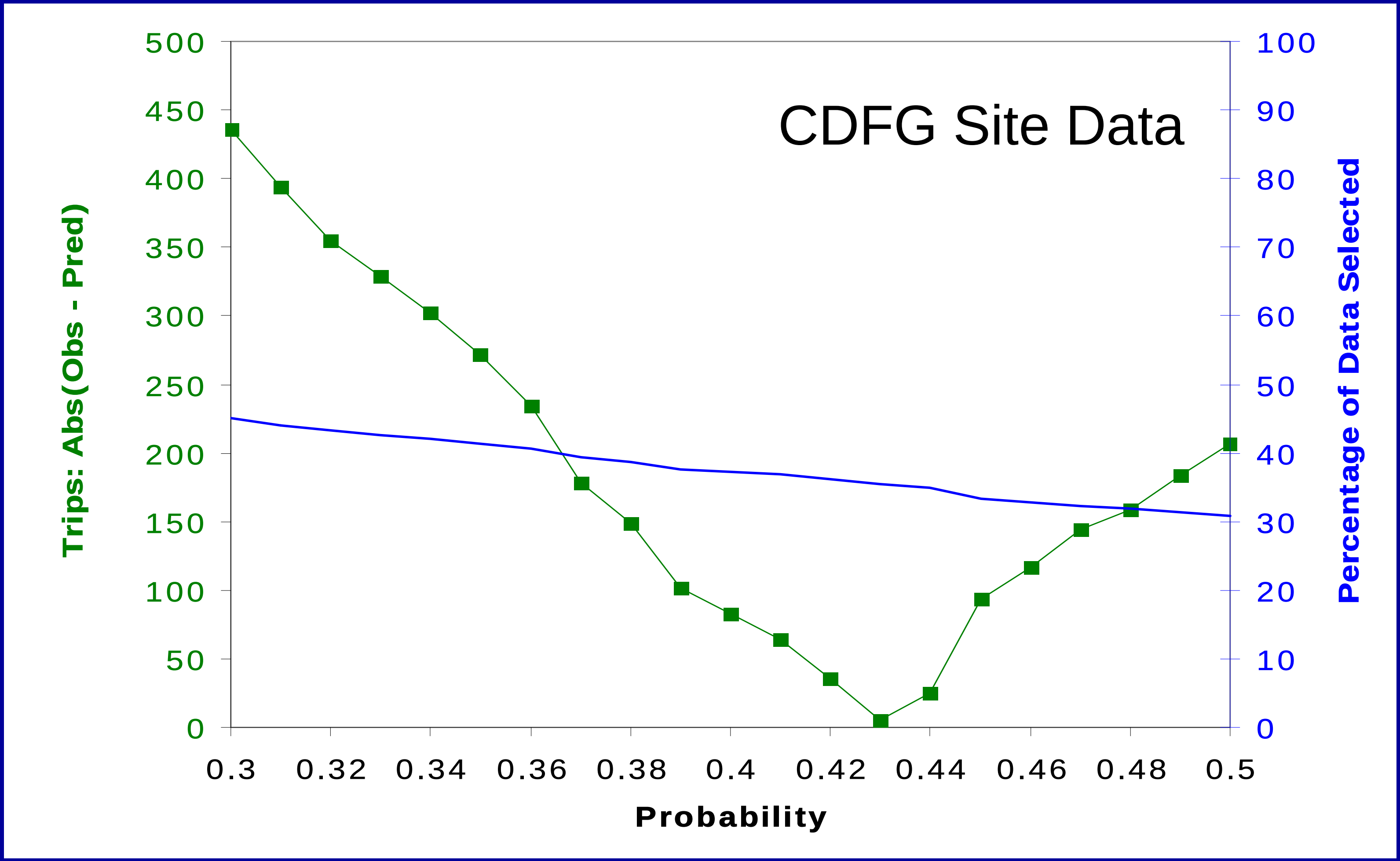
  Choose a probability threshold

- How many of our predictions are correct?

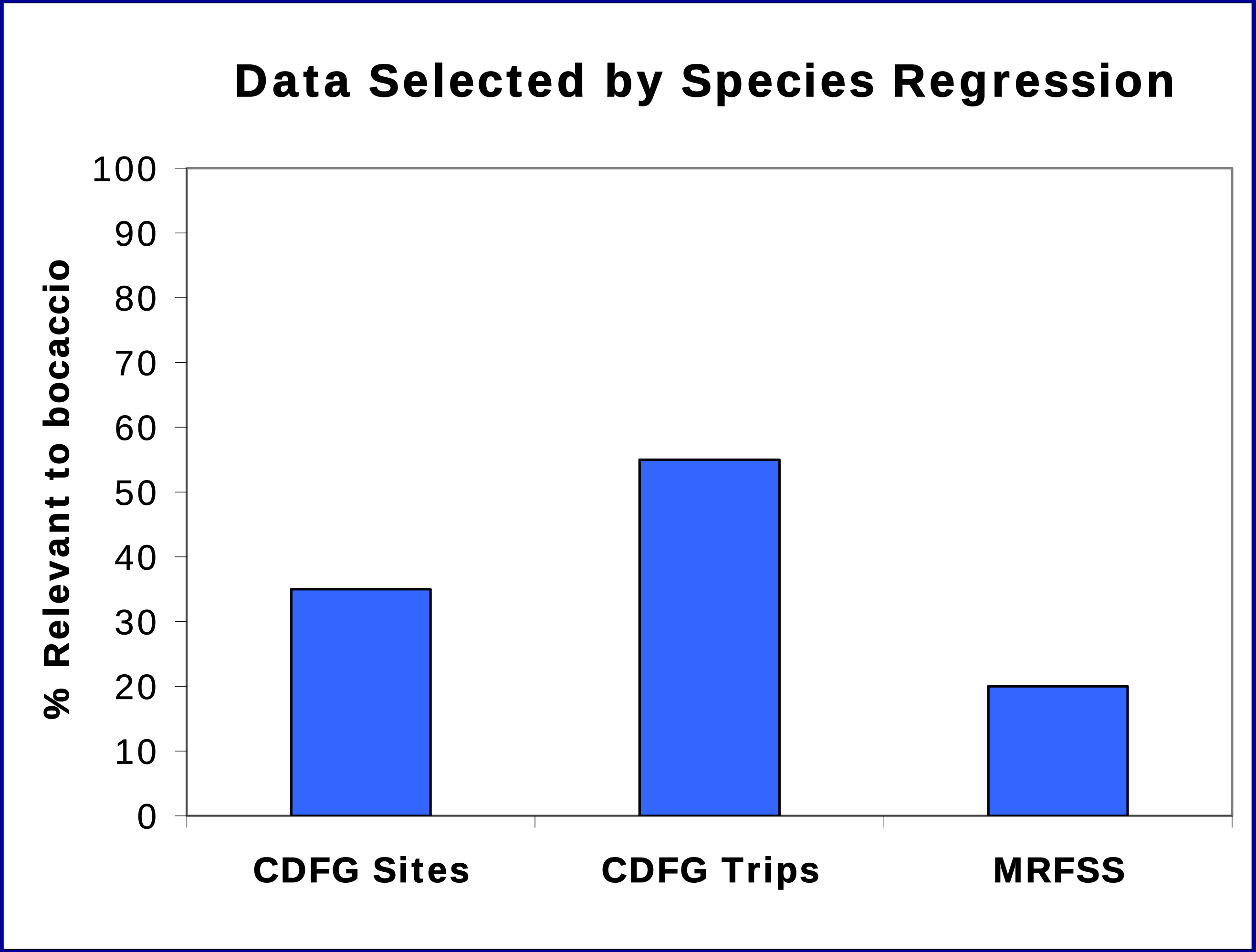

Non-coocurring
Black rockfish
Gopher rockfish
Brown rockfish
Quillback rockfish
Kelp greenling
Blue rockfish
China rockfish
Rosy rockfish
Canary rockfish
Olive rockfish
Vermilion rockfish
Sablefish
Greenspotted rockfish
Lingcod
Squarespot rockfish
Flag rockfish
Starry rockfish
Greenstriped rockfish
Jack mackerel
Yellowtail rockfish
Yelloweye rockfish
Pacific hake
Widow rockfish
Speckled rockfish
Chilipepper
CDFG Site Data
-7
-5
-3
-1
1
Regression Coefficients (β)


CDFG
Site Data
35%
1400
1200
1000
800
600
400
200
0
Frequency
0.05 0.15 0.25 0.35 0.45 0.55 0.65 0.75 0.85 0.95
Probability

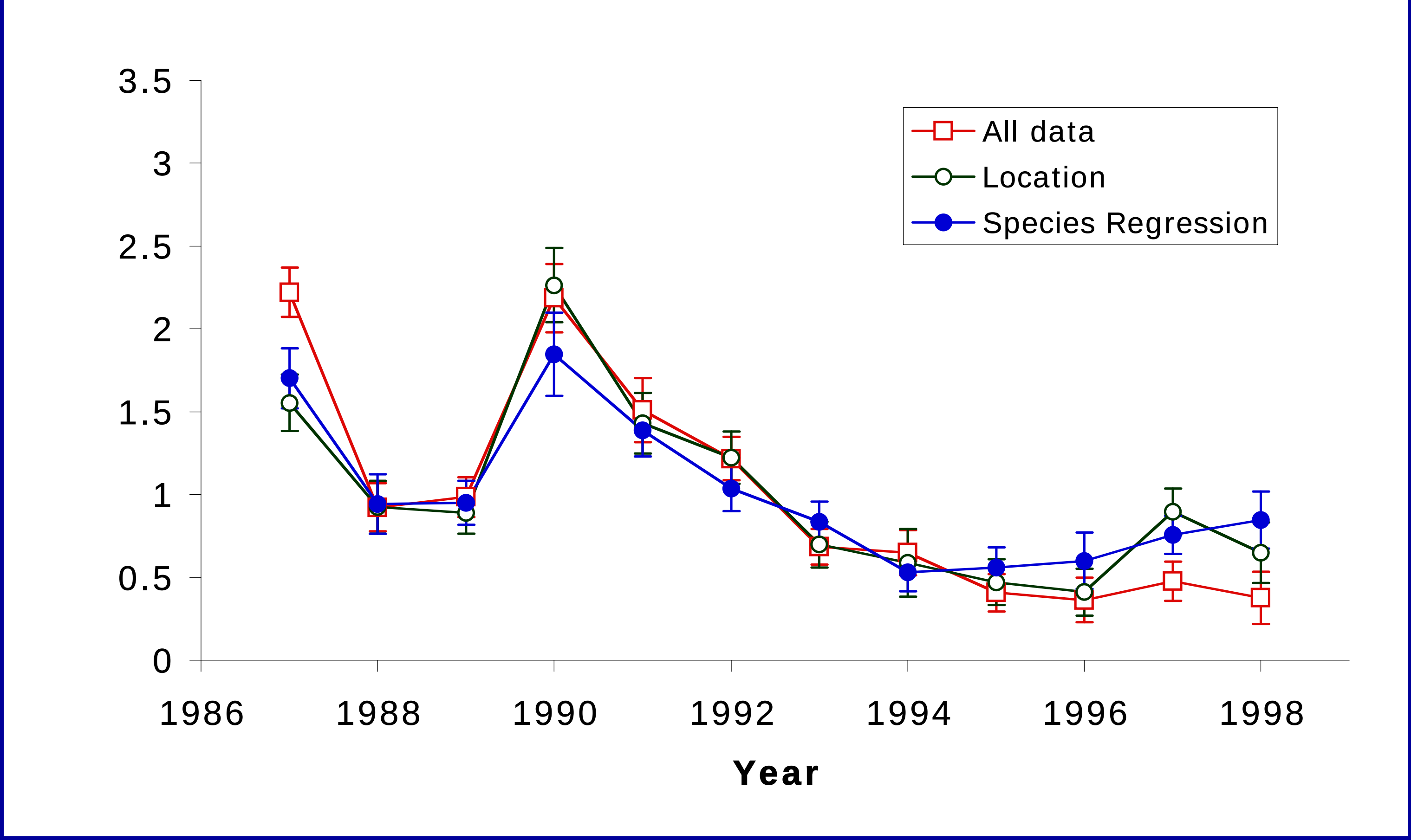
Critical Value Analysis



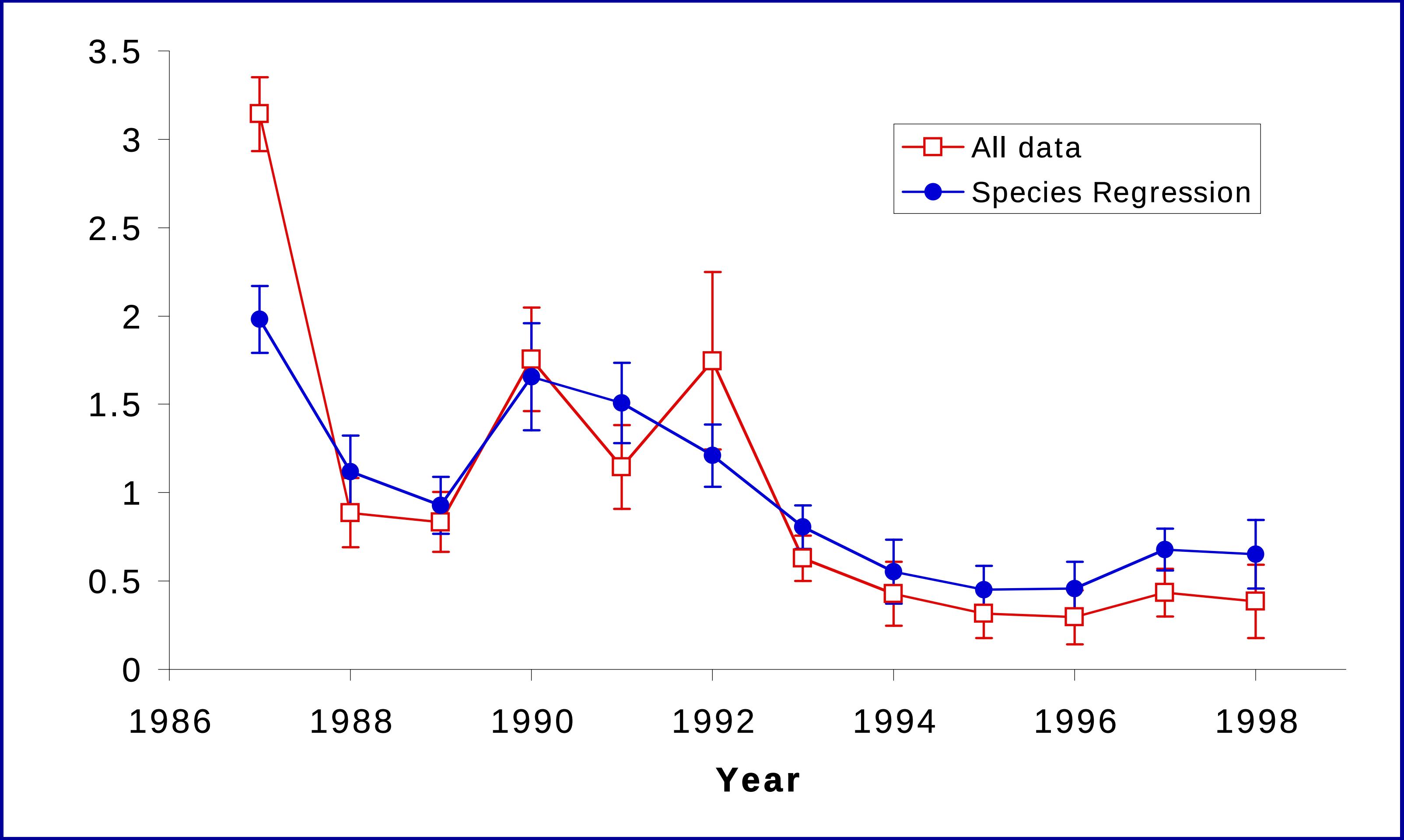
Probablity threshold for Bocaccio effort


Data Selected by Species Regression
% Relevant to bocaccio
100
90
80
70
60
50
40
30
20
10
0
CDFG Sites
CDFG Trips
MRFSS

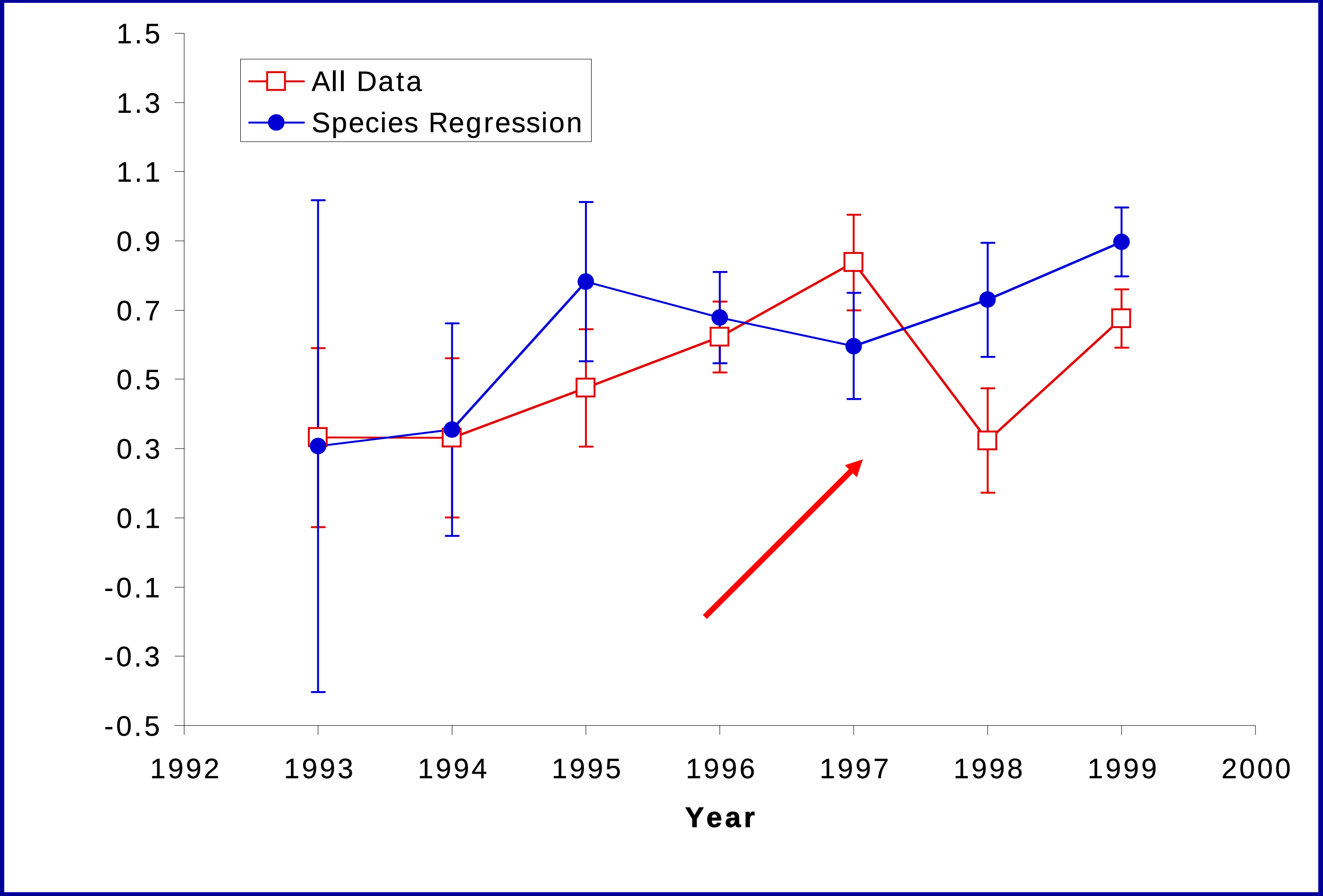
CPUE Indices
CDFG Sites



CPUE Indices
CDFG Trips

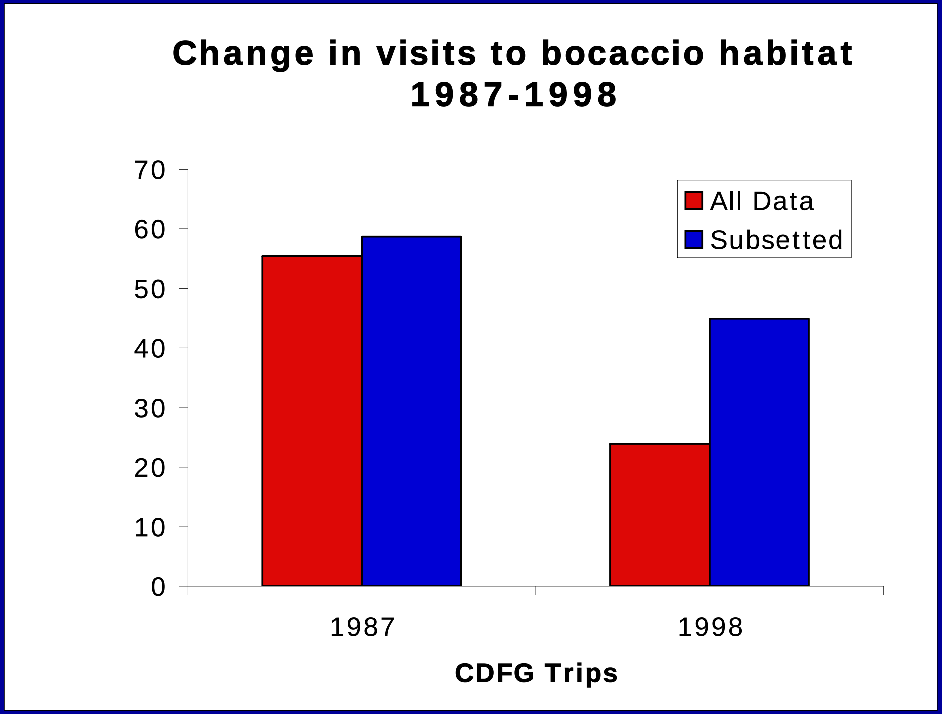


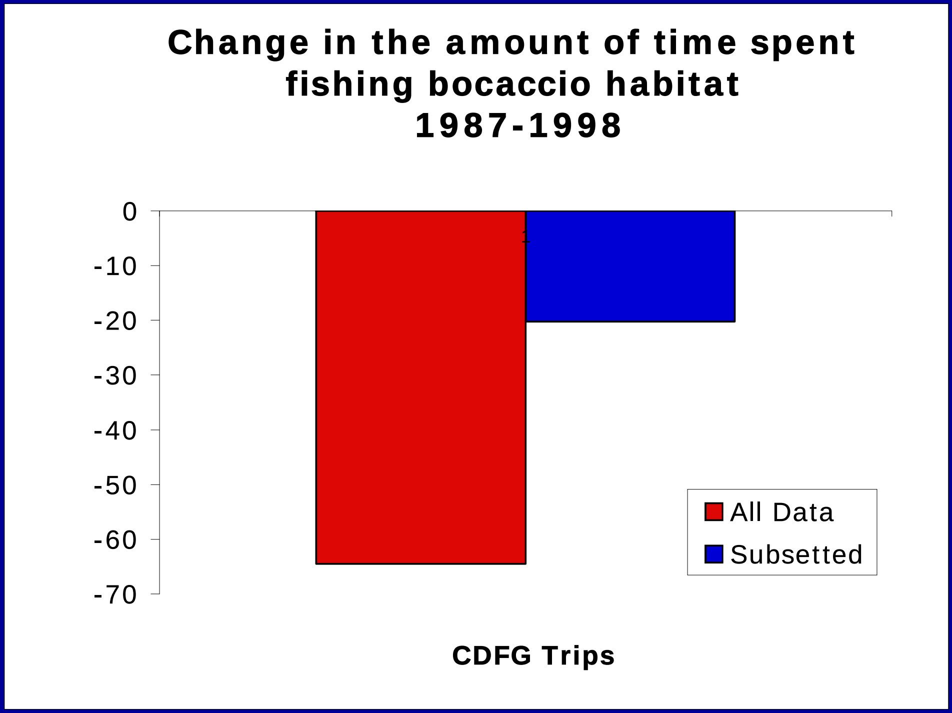
CPUE Indices MRFSS



1998: a good year to fish Tuna

Target Switching





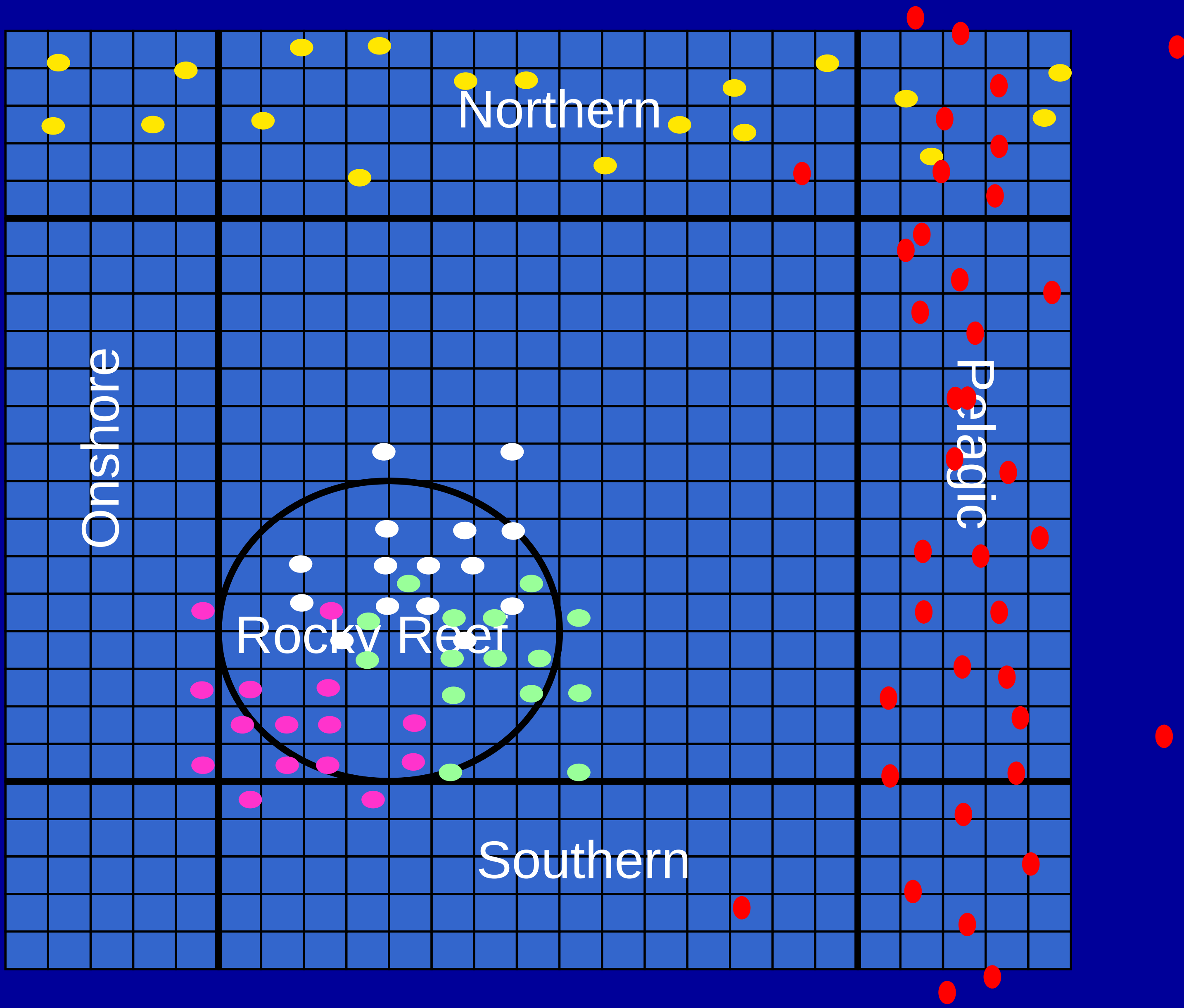
Species Regression moderates effects
of target switching

Correct Predictions

- CDFG Site-visits
  - Species Regression 81.0 %
  - Location 70.3 %
- CDFG Fishing Trip (multi-site) 79.4 %
- MRFSS Species Regression 84.5 %

When does this method fail?

- When habitats overlap too much?
- For certain types of target species?
- Too few regressors?
- Data too sparse?
- Change in habitat use?
- Population changes among species?


Northern
Onshore
Pelagic
Rocky Reef
Southern

Pseudo-Fish

- Habitat groups
  - Onshore
  - Northern
  - * Ubiquitous
  - Pelagic
  - Southern
  - Rocky Reef
- 2 – 5 species each group
- Randomly scattered from habitat center
- Fish falling outside the ocean swim away
- Species list at location is catch

Regression Diagnostics

- X^2 < degrees of freedom
- Range of regression coefficients
- Stability of regression coefficients
- Probabilities
- Predictions:

  % Correct

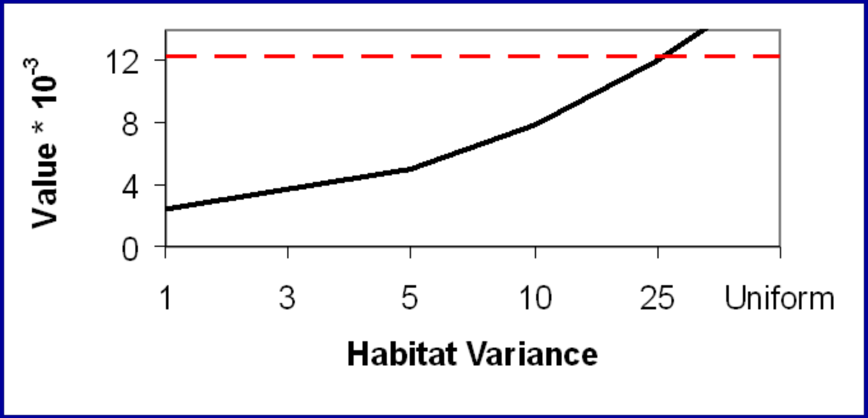
  % False Positives

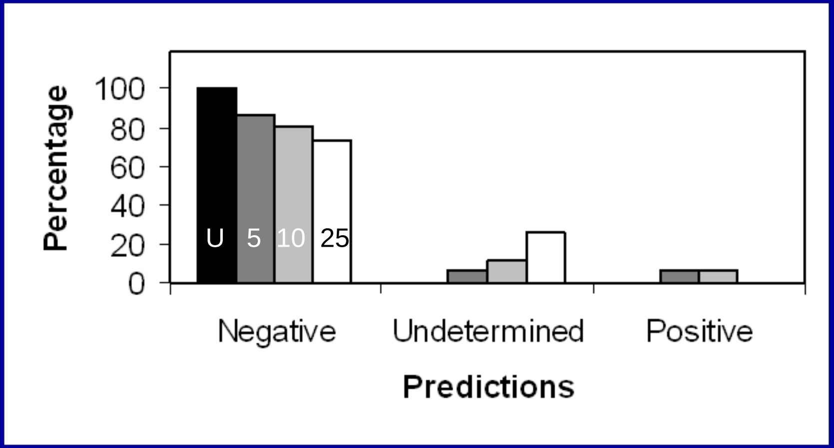
  % False Negatives

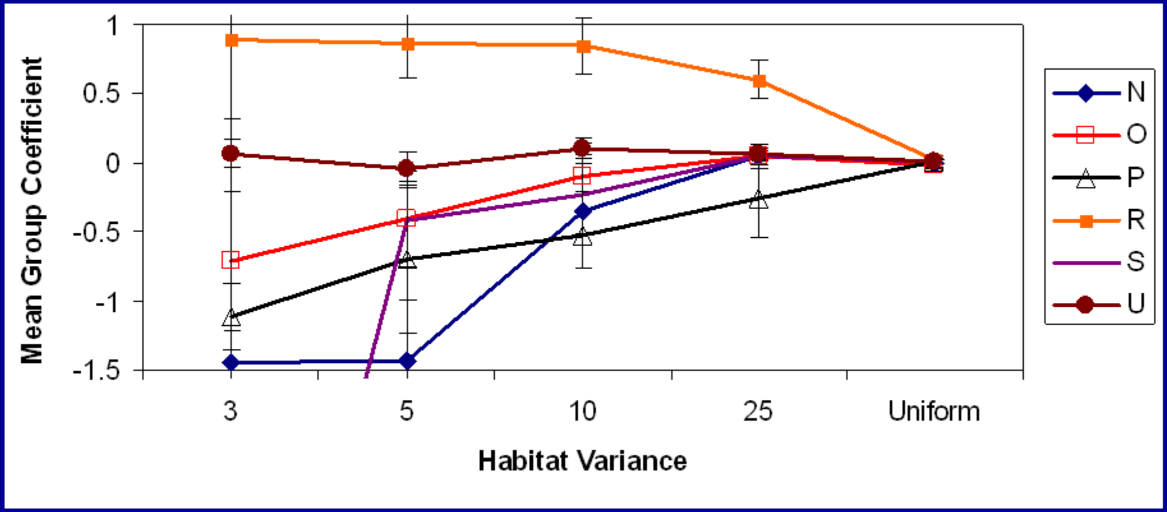
When does this method fail?

- When habitats overlap too much?
- For certain types of target species?
- Data too sparse?
- Too few regressors?
- Change in habitat use?
- Population changes among species?

Habitat Overlap





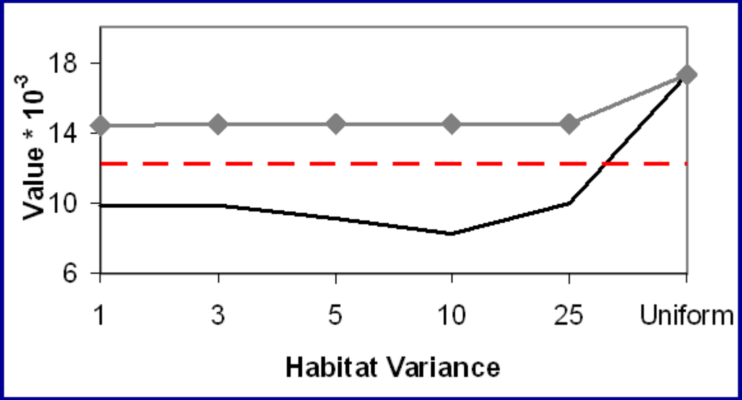


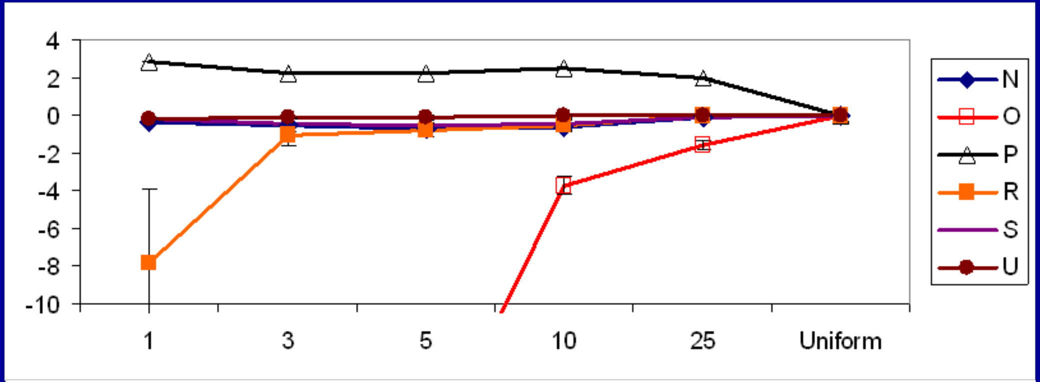
Target: Low-abundance Rocky Reef species

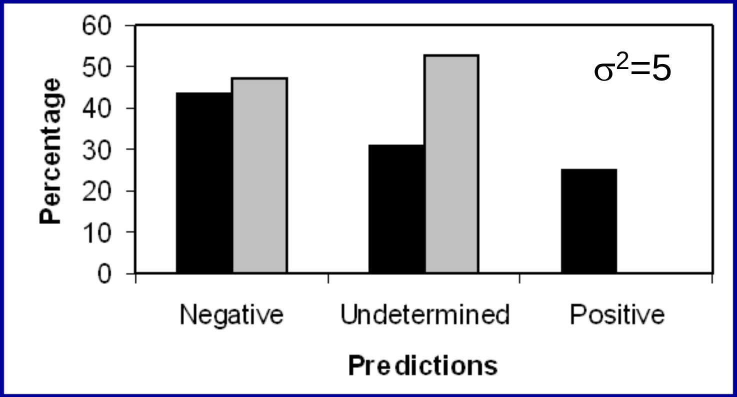
When does this method fail?

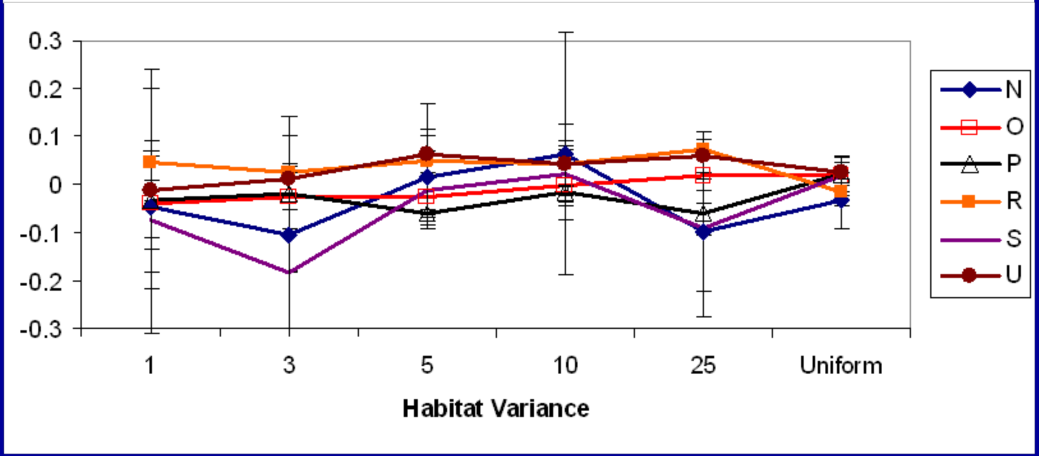
- When habitats overlap too much?
- For certain types of target species?
- Too few regressors?
- Data too sparse?
- Change in habitat use?
- Population changes among species?

Pelagic and Ubiquitous Targets





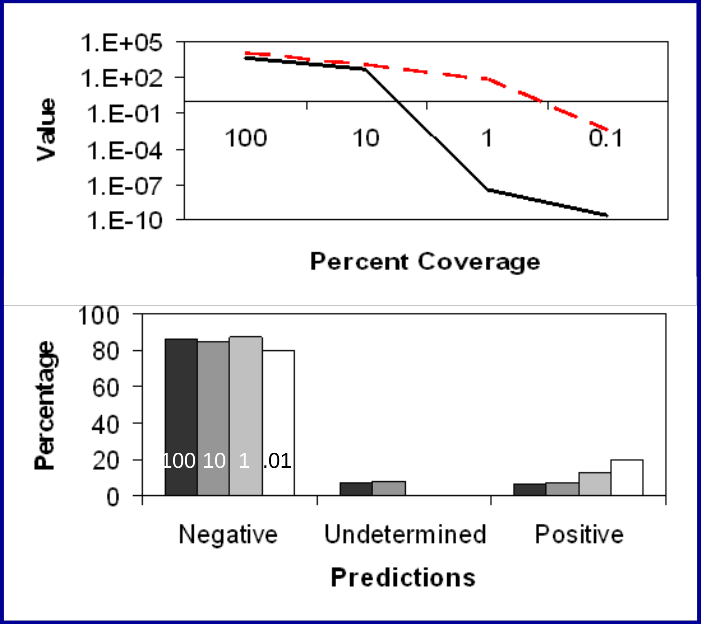


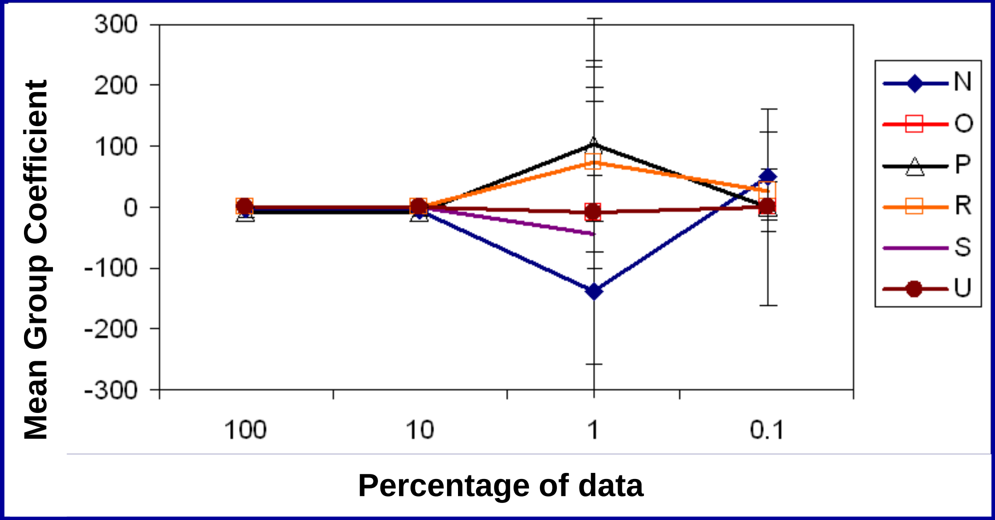


When does this method fail?

- When habitats overlap too much?
- For certain types of target species?
- Data too sparse?
- Too few regressors?
- Change in habitat use?
- Population changes among species?

Limited Data





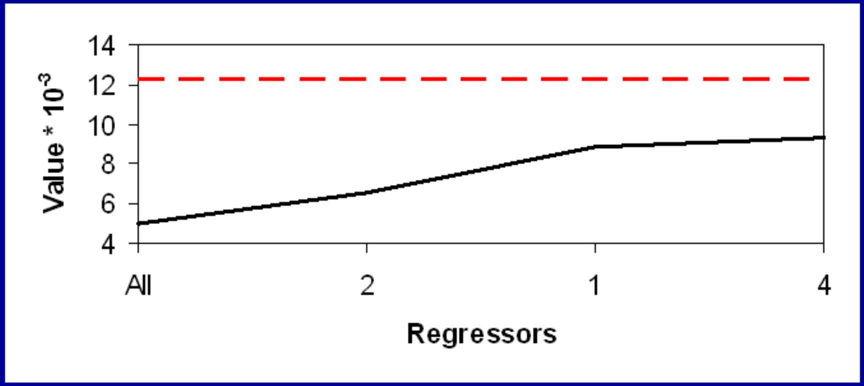
	100%	10%	1%	0.1%
Coefficient Range	16.57	17.57	779.45	357.92
Maximum Probablility	0.92	0.96	1	1

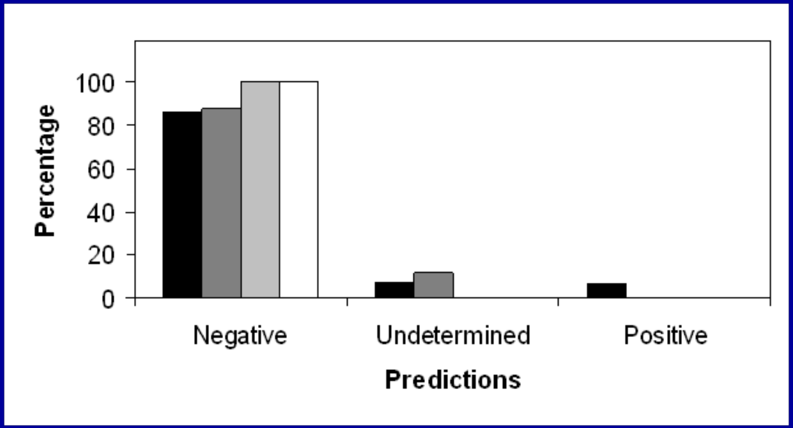
Target: Low-abundance Rocky Reef species $\sigma^2 = 5$

When does this method fail?

- When habitats overlap too much?
- For certain types of target species?
- Data too sparse?
- Too few regressors?
- Change in habitat use?
- Population changes among species?

Regressors



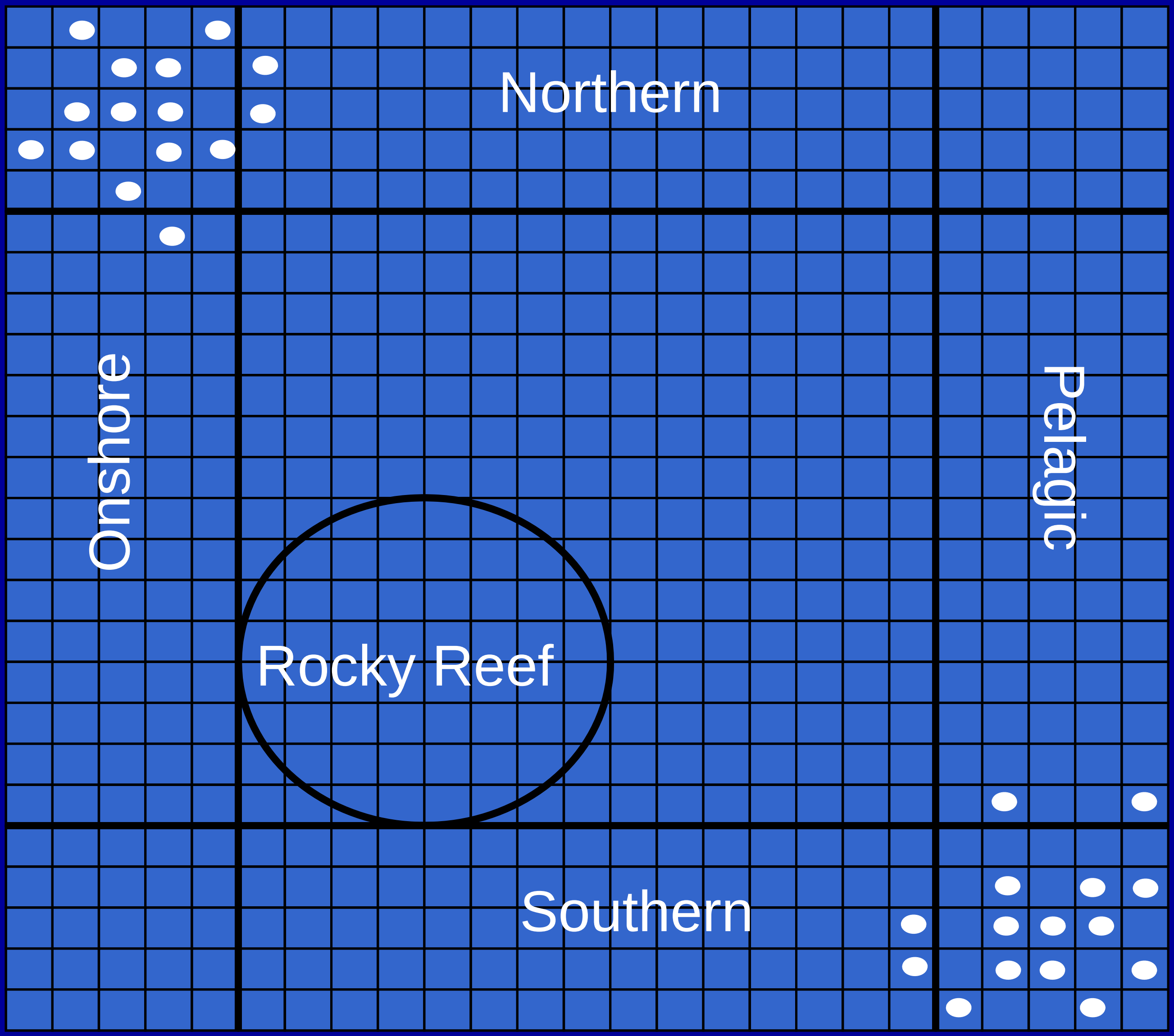


	All 22	2	1	4 U
Coefficient Range	3.14	5.10	–	0.15
Maximum Probablility	0.90	0.61	0.15	0.17

Target: Low-abundance Rocky Reef species $\sigma^2 = 5$

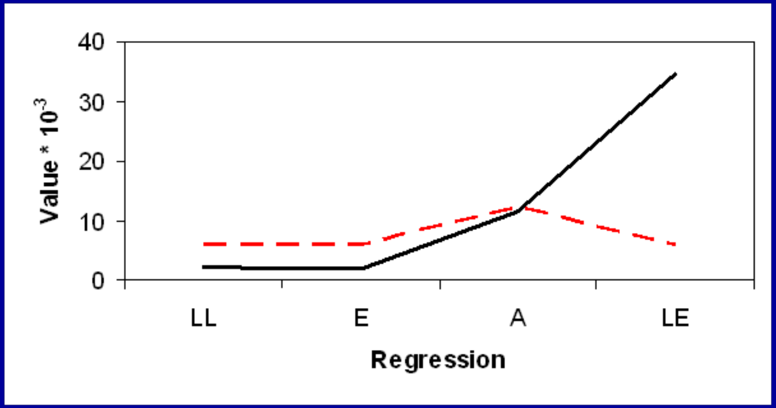
When does this method fail?

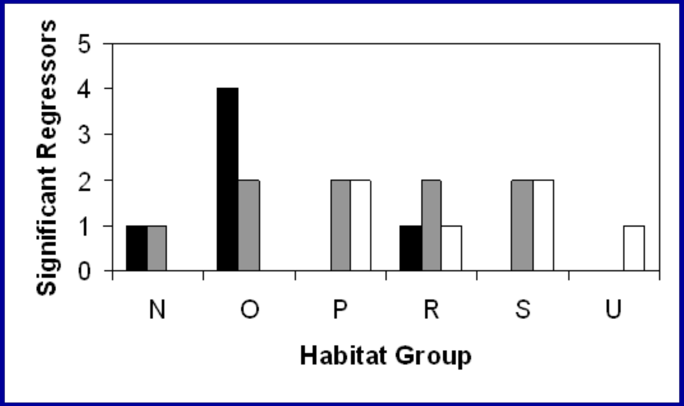
- When habitats overlap too much?
- For certain types of target species?
- Data too sparse?
- Too few regressors?
- Change in habitat use?
- Population changes among species?

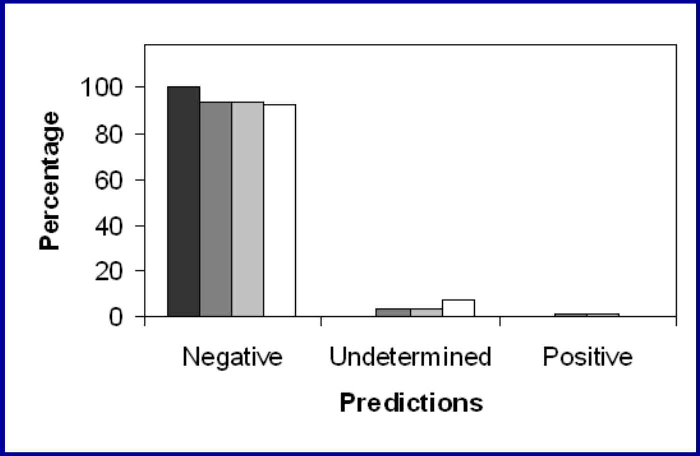


Northern
Onshore
Rocky Reef
Pelagic
Southern

Change in Habitat Use







	% Correct
Early	93
Late	93
Full	87
Early model Late data	84

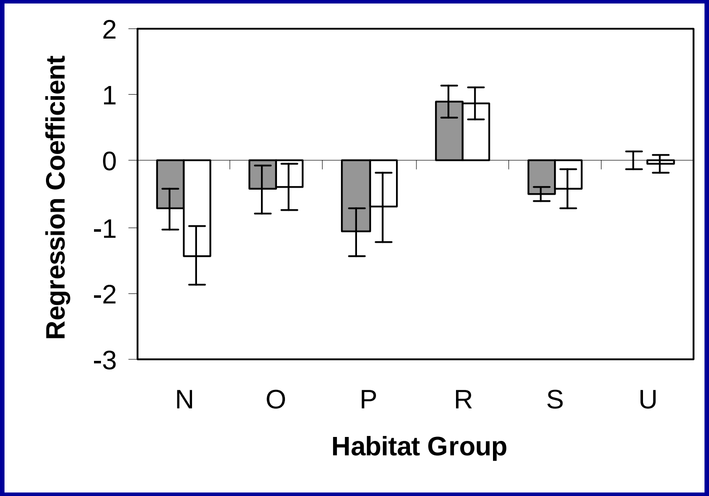
Target: Low-abundance migratory species $\sigma^2 = 3$

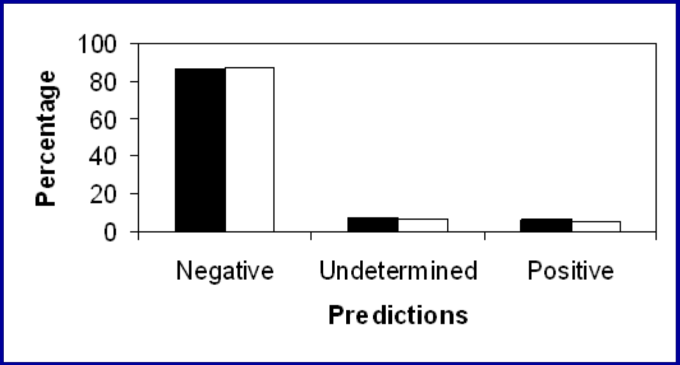
When does this method fail?

- When habitats overlap too much?
- For certain types of target species?
- Data too sparse?
- Too few regressors?
- Change in habitat use?
- Population changes among species?

Population Fluctuations

- Three Reef species increased 20% each year
- One N and Two S species declined 20% each year





Target: Low-abundance Rocky-Reef species $\sigma^2 = 5$

Method Failure

Violation of the habitat – species connection

- Overlapping habitats
- Ubiquitous targets
- Ubiquitous regressors
- Changing habitat use

Goodness of Fit Measures

- Magnitude of regression coefficients
- Stability of regression coefficients
- Over- vs. under-prediction
- X^2 smaller than degrees freedom
- Need to evaluate subsets of the data

Statistical Modelling GLM in R

Mauricio Ortiz
NMFS SEFSC Miami Lab
Sustainable Fisheries Div

What is Statistical Analysis ?

- Understand Nature of data, need to answer
  - Kind of response variable
  - Type and nature of explanatory variables
- Data is what is "known"
  - Model fit to the data, NOT data fit to model!!
- Best model
  - Provides the least unexplained variation subject to constraints that all parameters are statistically significant
  - Principle of Parsimony: Minimal model but adequate

Maximum Likelihood

- Best model, conventions
  - Unbiased
  - Variance minimizing estimators
- Given the data & given our choice of model then ML
  - Provides values of parameters of that model that makes the DATA most likely

Principle of Parsimony

- William of Occam:
  - "*Given a set of equally good explanations for a given phenomenon, the correct explanation is the simplest one*."
- Models should have as few parameters as possible
- Linear models should be preferred to non-linear models
- Experiments relying in few assumptions are preferred
- Models should be pared down until they are minimal

Types of Statistical Model

Null model	One parameter, overall mean, explanatory power none
Minimal adequate model	Simplified model $1 < p < p'$ parameters explanatory power r^2
Maximal model	Complex model all factors, interactions & covariates, p' parameters
Saturated model	One parameter for each observation Explanatory power none

Data for statistical models

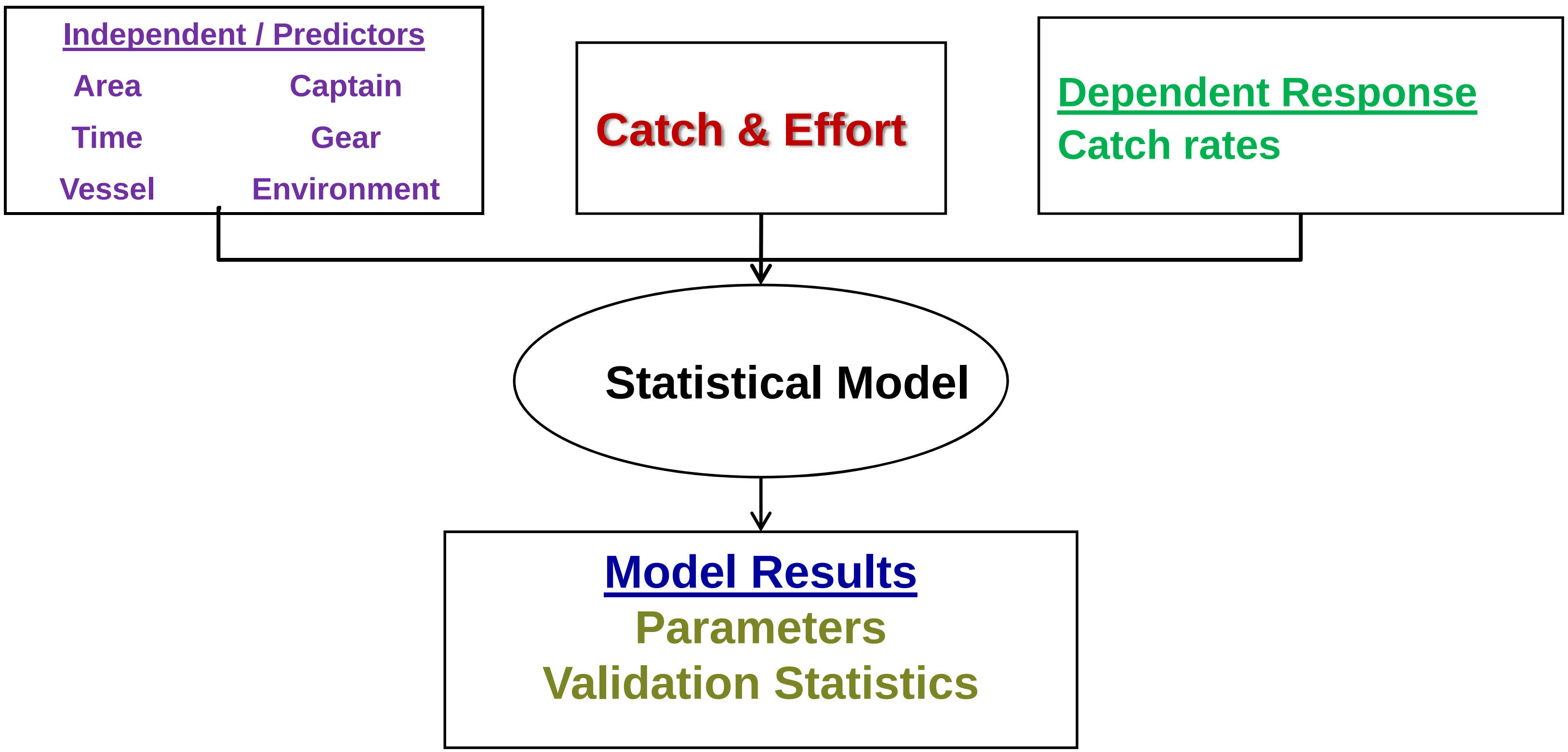
- Types of Data
  - From experimental planned designs
    - All combinations equally represented
    - Controlled explanatory variables
    - Orthogonal in nature
    - Order of explanatory variable in model not important
  - From observation studies
    - No control over number of individuals/observations
    - Missing combination treatments
    - Many likely correlated explanatory variables
    - Non-orthogonal data
    - Order of explanatory variable in model important

Model simplification

1	Fit maximal model	Fit all factors, interactions, covariates
2	Begin model simplification	Remove least significant terms first, starting with highest-order interactions
3	If deletion causes an insignificant increase in deviance	Leave that term out, inspect the parameter values again Remove the least significant term remaining
4	If deletion causes a significant increase in deviance	Put term back in the model These are the statistically significant terms
5	Keep removing terms from the model	Repeat steps 3 & 4 until only significant terms remain in the model. This is the minimal adequate model.

Purpose of Predictive Modeling

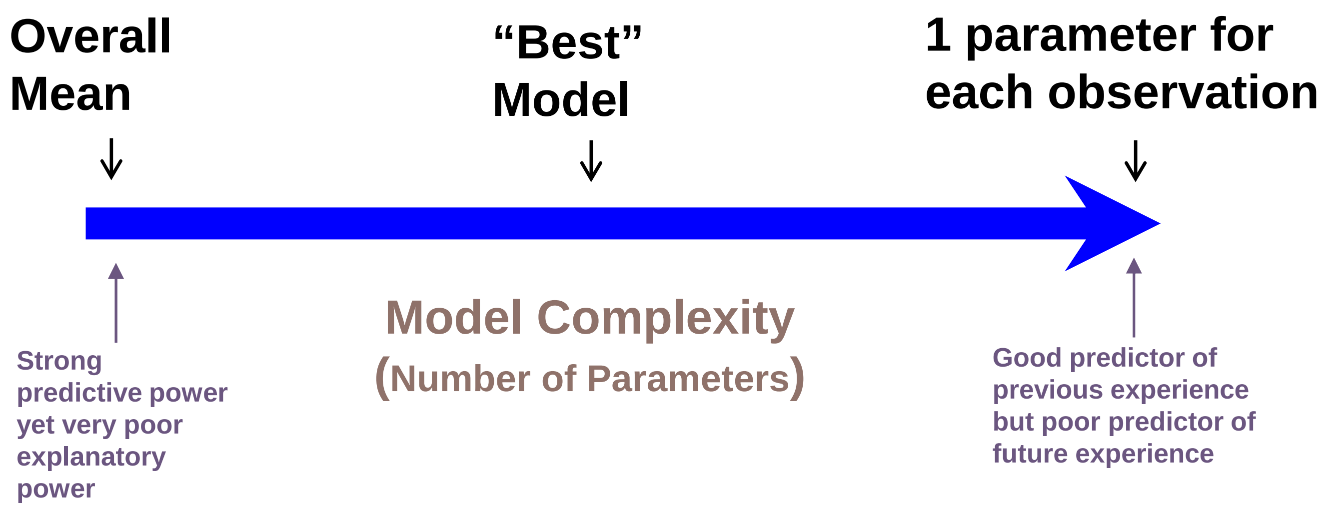
To predict a response variable using a series of explanatory variables.



Traditional methods focus on the parameters, modeling requires the analyst to consider the validation of the parameters.

Purpose of Predictive Modeling

To produce a sensible model that explains recent historical experience and is likely to be predictive of future experience.



Traditional methods tend to create unnecessarily complex structures that tend to overfit the data.

Generalized Linear Models

GLMs generalize the traditional regression models by introducing nonlinearity through the link function and loosening the normality assumption

Response Variable = Systematic Component + Random Component

Signal

Noise

y = h(Linear Combination of Factors) + Error

g=h-1 is called the LINK function and is chosen to measure the "signal" most accurately

Error should reflect underlying process and can come from the exponential family

Linear combination of rating factors is the model structure

GLMs

More formally:

Response Variable = Systematic Component + Random Component

$$Y = \hat{Y} + \varepsilon$$

Where:

Link function ($g=h^{-1}$)
Links random and systematic component.

Parameters
Quantities estimated via log likelihood function.

$$\hat{Y} = \hat{\mu} = h(X\beta + \xi)$$

Offset Term
Allows incorporation of known effects or restrictions.

Design Matrix
Identifies predictor variables for each observation.

And:

$$\mathrm{Var}(Y) = \frac{\varphi V(\hat{\mu})}{\omega}$$

Variance Function

Scale Parameter

Prior Weights

GLMs

The general solution for the GLM parameters:

$$\hat{\beta}^{(r)} = \left[X^{T}W^{(r\text{-}1)}X\right]^{-1} X^{T}W^{(r\text{-}1)}\left\{\hat{\eta}^{(r-1)} + g'\left(\hat{\mu}^{(r-1)}\right)\times\left(y-\hat{\mu}^{(r-1)}\right)\right\}$$

Where:

$$W^{(r)} = diag\left\{\frac{\omega}{g'(\hat{\mu}^{(r)})^{2}\times V(\hat{\mu}^{(r)})}\right\}$$

Error Distribution

and:

Link function

$$g = h^{-1}$$

$$\eta = g\left(\hat{\mu}\right)$$

$$\hat{\mu}^{(r)} = X\beta^{(r)}$$

Model Structure

$$\omega = weights$$

GLM Building Blocks: Link Functions

y = **h(**Linear Combination of Factors**)** + Error

Link function ($g=h^{-1}$) chosen base on how the factors are related to produce the “best” signal/response:

- Log: variables related multiplicatively (e.g., risk modelling)
- Identity: variables related additively (e.g., risk modelling)
- Logit: retention or risk modelling
- Reciprocal: canonical link for gamma distribution (e.g., severity modelling)
- Mixed: additive/multiplicative rating algorithms

GLM Building Blocks: Link Functions

Link function relates the independent predictors to the response in a non-linear form :

- Pure Multiplicative – Log

$$\hat{Y} = \eta = \exp(X\beta)$$

- Pure Additive - Identity

$$\hat{Y} = \eta = X\beta$$

- Logit

$$\hat{Y} = \eta = \frac{1}{1 + e^{-(X\beta)}}$$

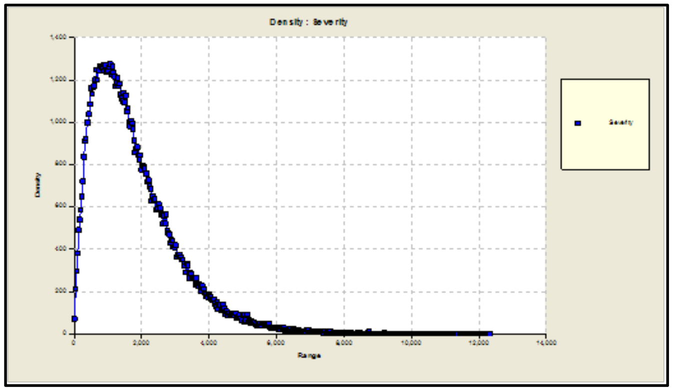
- Reciprocal

$$\hat{Y} = \eta = \frac{1}{X\beta}$$

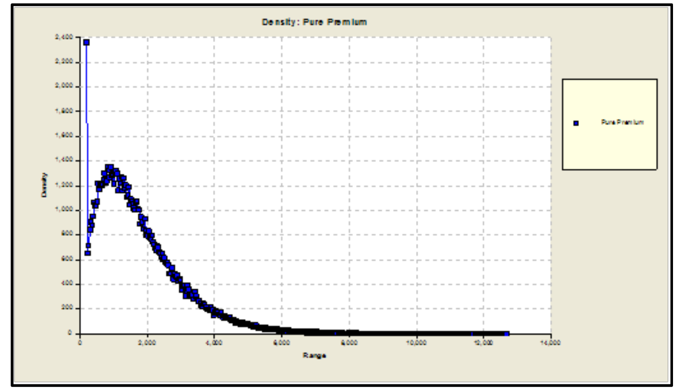
GLM Building Blocks: Error distribution

y = h(Linear Combination of Factors) + **Error**

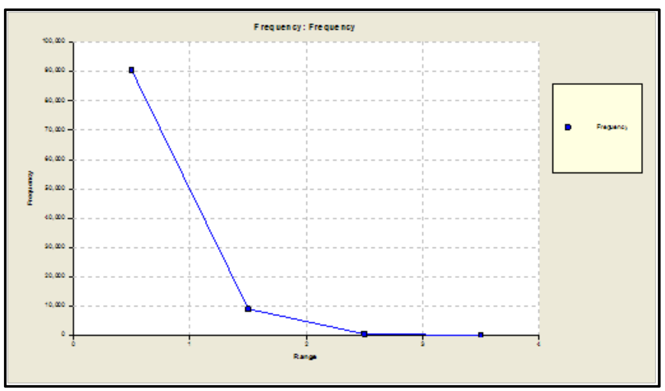
Reflects the variability of the underlying process



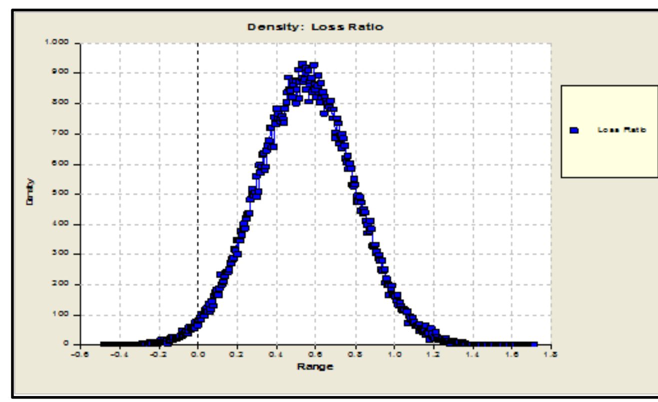
- Gamma consistent with skewed response modelling, also Inverse Gaussian



- Tweedie distribution consistent with zero and positive response modeling



- Poisson consistent with frequency modelling



- Normal useful for a variety of applications

GLM Building Blocks: Error distribution Additional Variance Functions

Error structure is also used to incorporate assumptions about the uncertainty and the predicted value

Observed Response	Error Structure	Variance Function $V(\mu)$	Scale Parameter ϕ
	Normal	μ^0	σ
Frequency counts	Poisson	μ	1
Skewed response	Gamma	μ^2	α
Increase zero proport	Tweedie	μ^T	μ^T
Binary response	Binomial	$\mu(1-\mu)$	1
Counts	Over-dispersed Poisson	μ	K
Highly skewed response	Inverse Gaussian	μ^3	α

GLM Building Blocks: Model Structure

y = h(**Linear Combination of Factors**) + Error

- Include variables that are predictive, exclude those that are not
  - Gender may not have major impact on catch rates

- Simplify some explanatory factors, if full inclusion not necessary
  - Some levels within a particular predictor may be grouped together (e.g., number of holding tanks)
  - A curve may replicate the signal (sex ratio)
  - Scoring levels to combine rating factors into a single concept thereby untangling impacts of various factors (e.g. vessel electronics)

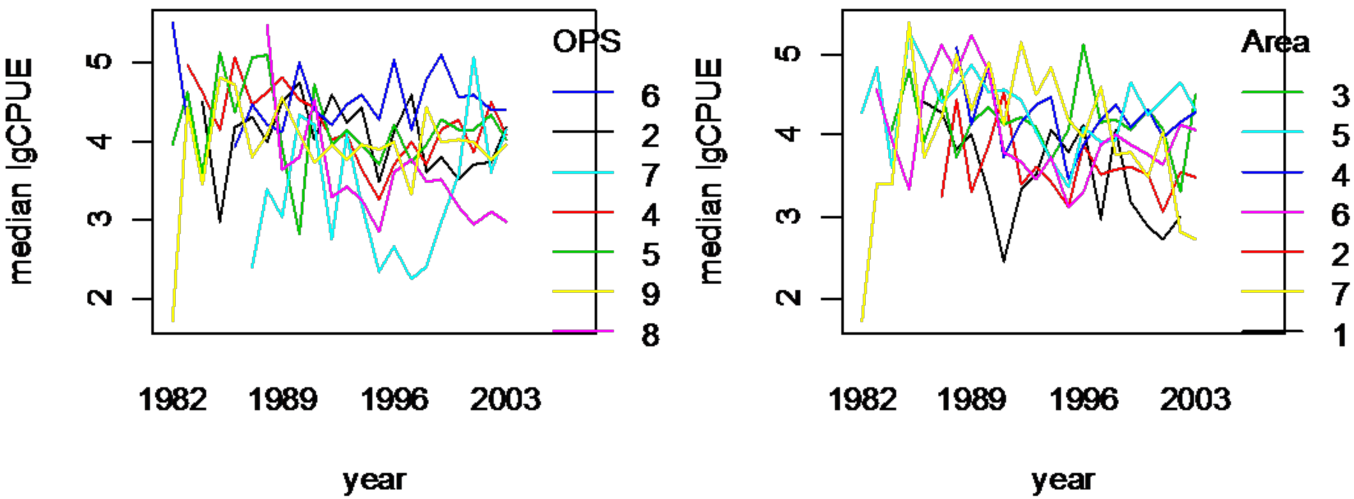
- Complicate model if the relationship between levels of one variable depends on another characteristic
  - The difference between males and females depends on age

GLM Building Blocks: Model Structure

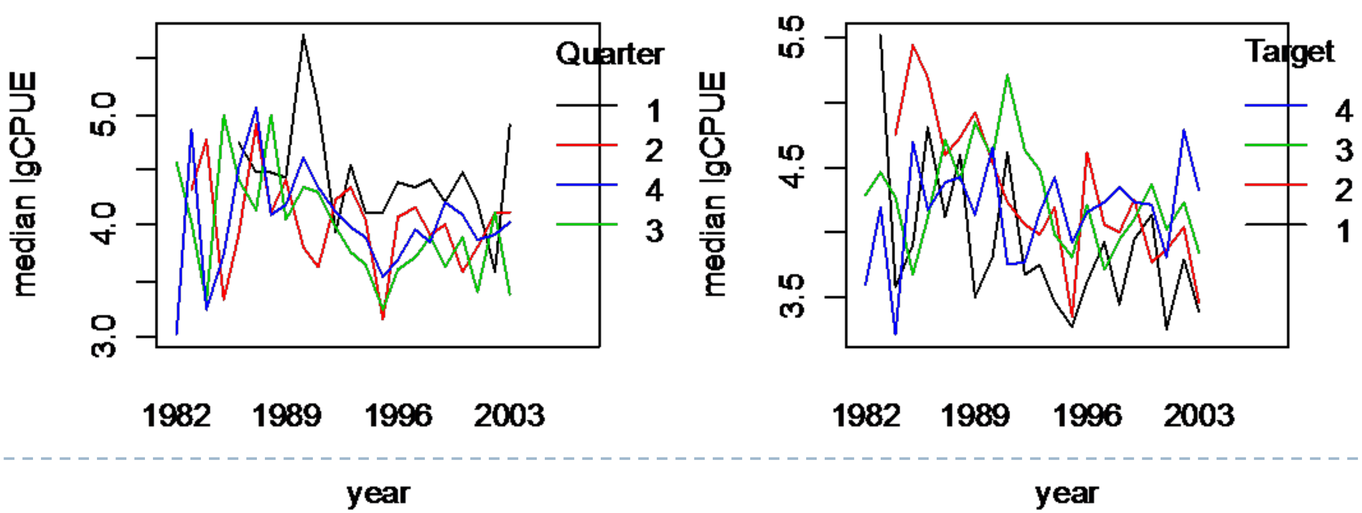
Complicating the Model: Interactions

- Interactions are required when the combined effect of multiple levels of two different independent explanatory factors is different than the additive effect of the simple parameters.
- Interaction topics
  - Interactions versus correlations
  - Identifying interactions
  - Full and partial interactions
  - Simplifying interactions

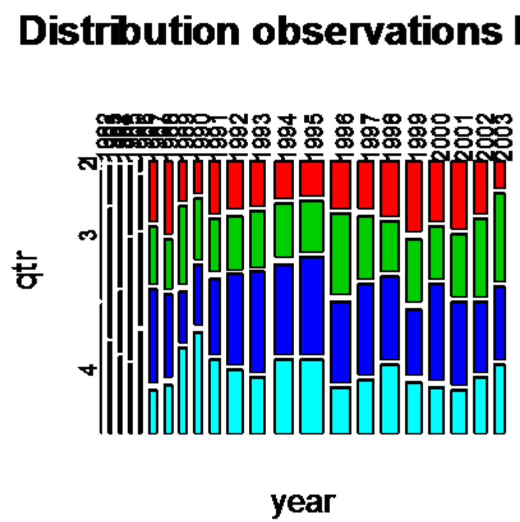
GLM Building Blocks: Model Structure

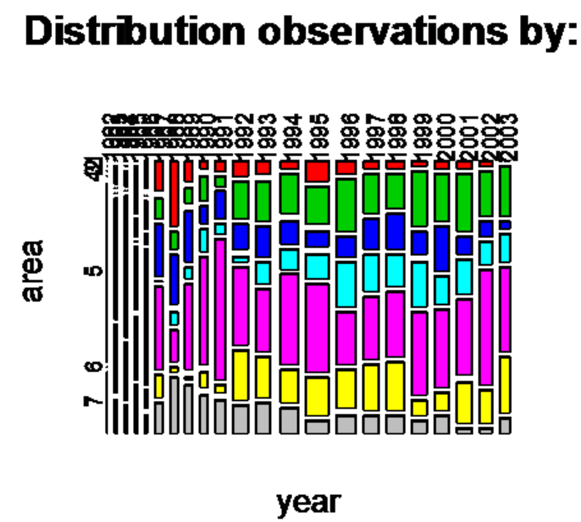


> interaction.plot(....)

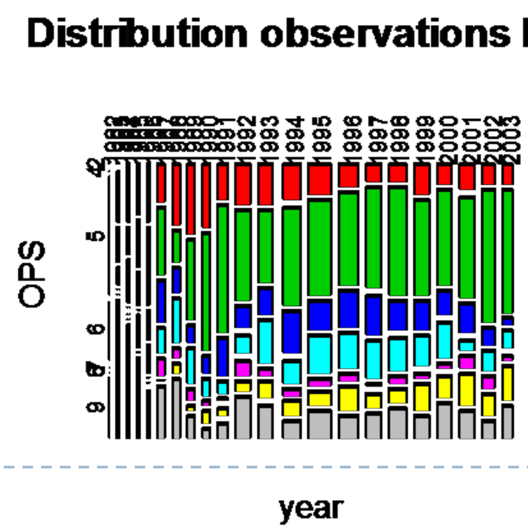


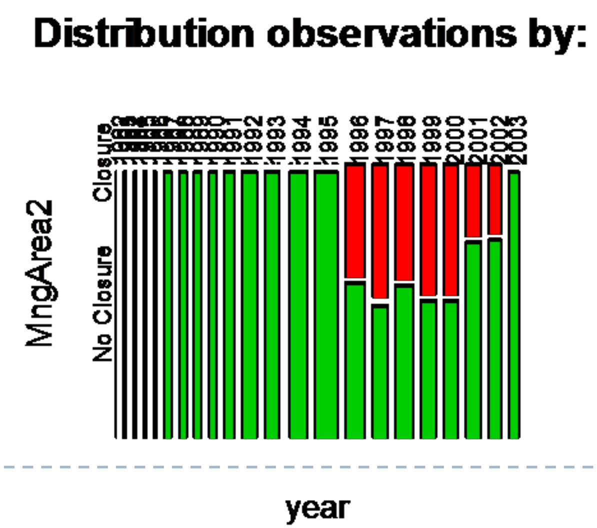
GLM Building Blocks: Model Structure





> mosaic.plot(….)





Measurements of Fit

Deviance

- A measure of the discrepancy between the observed values and the predicted by the model. Is estimated as the double difference between the Maximum Likelihood possible (i.e. one parameter for each observation) and the Maximum Likelihood of the model evaluated.

$$if:\ \hat{\theta} = \theta(\mu) \quad and \quad \tilde{\theta} = \theta(y)\,; n = p$$

$$a_i(\phi) = \phi / w_i \quad dispersion\ parameter$$

$$D(y,\mu) = 2\log\frac{L(y;y)}{L(\mu;y)}$$

$$D(y;\hat{\mu})/\phi = \sum 2w_i\left\{y_i(\tilde{\theta}_i - \hat{\theta}_i) - b(\tilde{\theta}_i - \hat{\theta}_i\right\}/\phi$$

Measurements of Fit

Normal	$\sum (y-\hat{\mu})^2$
Poisson	$2\sum \{y\log(y/\hat{\mu})-(y-\hat{\mu})\}$
Binomial	$2\sum \{y\log(y/\hat{\mu})+(m-y)\log((m-y)/(m-\hat{\mu}))\}$
Gamma	$2\sum \{-\log(y/\hat{\mu})+(y-\hat{\mu})/\hat{\mu}\}$
InvGaussian	$\sum (y-\hat{\mu})^2/(\hat{\mu}^2 y)$

Pearson X^2 statistic

another measure of discrepancy

$$X^2 = \sum (y-\hat{\mu})^2 / V(\hat{\mu})$$

Deviance Analysis

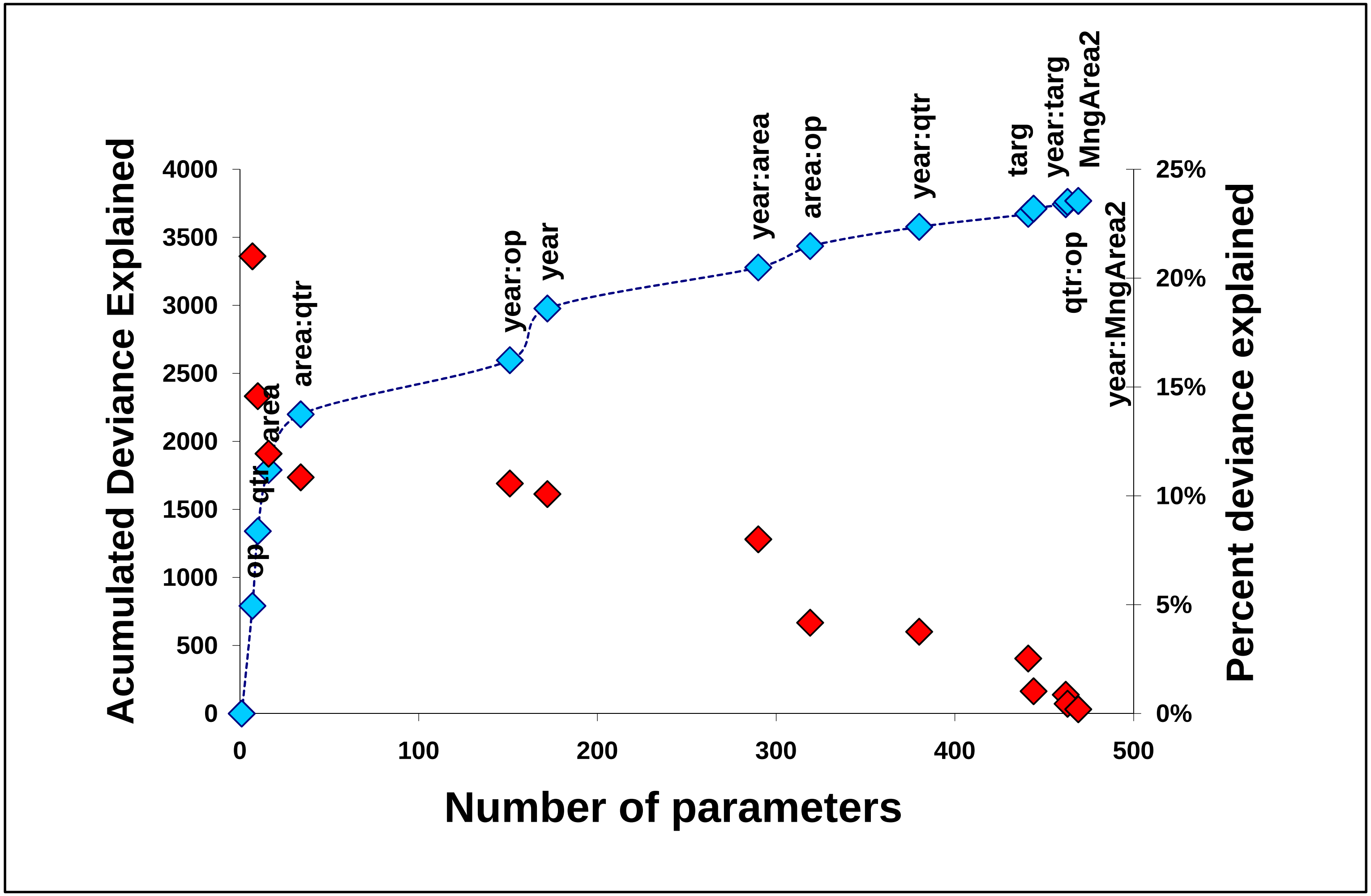
- Extension of the Analysis of Variance to the GLM that allows to evaluate the statistical effects of factors and its interactions.
- However, in GLMs the parameters in the model are not orthogonal, because the transformation through the link function is not necessarily linear.
- The difference in deviance is used as a measure of discrepancy between successive models.

…. Deviance Analysis

- In theory, if we consider Mo $\subset$ M as a sub model with $q < p$ parameters of model M.
- Knowing the dispersion parameter σ^2, the statistic given by the difference of deviance between both models scaled by σ^2, follows an approximate Chi-square distribution with $p - q$ degrees of freedom.

$$\frac{(D_{Mo} - D_M)}{\sigma^2} \approx \chi^2_{p-q}$$

…. Deviance Analysis Table



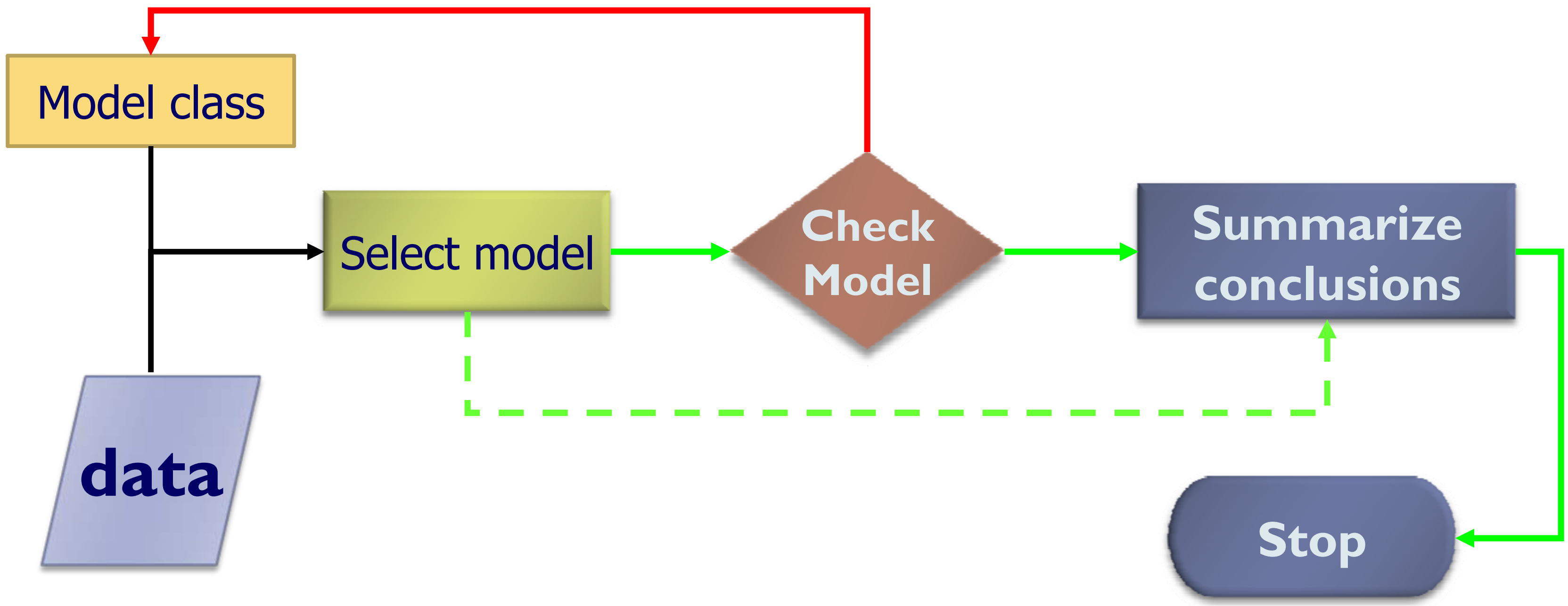
GLM Diagnostics

- Model diagnostics introduce verification in the statistical analysis process to assure that the selected model is the appropriate one given the data analyzed.
- Model checking primarily for
  - Systematic departure of the model assumptions,
  - Observations that are discrepant or inconsistent from the rest of the data (outlier analysis).
- The model checking techniques fall into two groups:
  - Informal: those that relay on subjective human decision to determine patterns or better, departure from expected patterns.
  - Formal techniques that imply a wider model (where the "selected current model" is a subset) with higher number of parameters. In this case, the current model passes the check if it can demonstrate that the extra parameter(s) in the wider model did not improve the fitting of the data. McCullagh and Nelder (1989)

Model Diagnostics

- IMPORTANT

  After evaluating the model fit and significance of the explanatory variables, it is imperative to complete the analysis with a model diagnostics to confirm the model assumptions and to detect outliers.



Model checking elements

- Model checking originally developed for classical linear models, and then McCullagh and Nelder (1989) extended it to Generalized Linear Models (GLMs).
- Analysis of residuals are the primarily element for model checking, however other components in GLM checking include the fitted values, the linear predictors, the residual variance, the dispersion parameter and the elements of the projection ('hat') matrix.

Residuals

Main tool for determining the fit of the model. Types of residuals

- Response residuals: difference between the observed values and the estimated values by the model.

$$r_i = (y_i - \hat{\mu}_i)$$

- Working residuals: difference between the response variable and the linear predictor estimated.

$$r_{w_i} = (y_i - \hat{\mu}_i)\frac{\partial \hat{\eta}_i}{\partial \hat{\mu}_i}$$

- Deviance residuals: measure the contribution of each observation to the total model deviance.

$$r_{D_i} = sign(y_i - \hat{\mu}_i)\sqrt{d_i}$$

- Pearson residuals: response residuals weighted by the estimated variance of the model.

$$r_{P_i} = \frac{y_i - \hat{\mu}_i}{\sqrt{V(\hat{\mu}_i)}}$$

… residuals

Re-scaling residuals.

Standardized / Studentized residuals:
residuals scaled by the variance or dispersion parameter and the corresponding "hat" element

$$r_{Ds_i} = \frac{r_{Di}}{\sqrt{\hat{\Phi}(1-h_i)}}$$

– Studentized Deviance residuals

– Studentized Pearson residuals

$$r_{Ps\,i} = \frac{y_i - \hat{\mu}_i}{\sqrt{\hat{\Phi}V(\hat{\mu})(1-h_i)}}$$

Jacknife or deletion residuals

represent the difference between the observed response for case *i* and the response predicted from the model excluding case (*i*) observation

$$r_{J\,(i)} = \frac{y_i - \hat{y}_{(i)}}{\hat{\sigma}_{(i)}\sqrt{(1-h_i)}}$$

Model checking for systematic departure of the model assumptions

1. Random component [Error distribution]

Plot of standardized deviance residuals against the predicted values. For distributions other that the Normal, the predicted values should be transform to a constant scale

The expected pattern is a uniform and constant range distribution of the residuals around the mean zero value

Departures

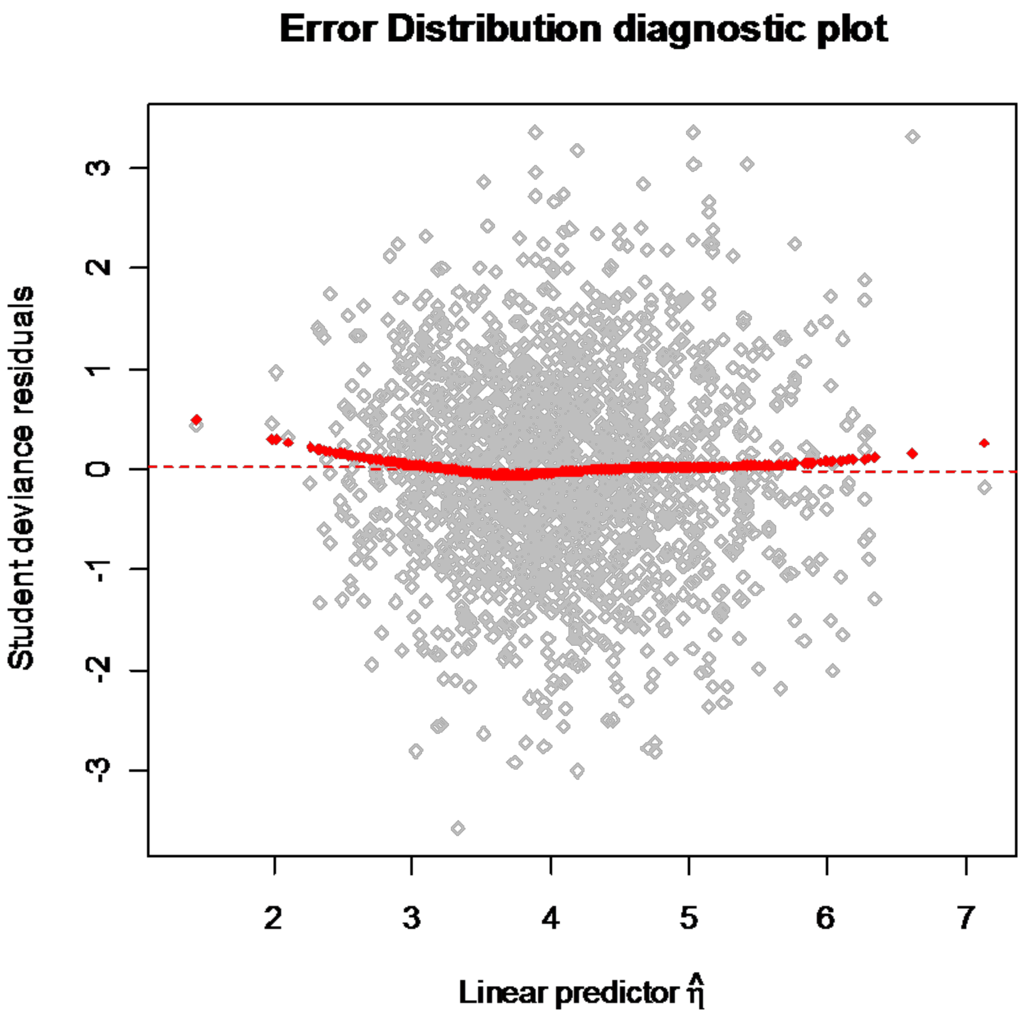
Curvature of mean trend indicates:

- incorrect link function
- wrong scale of one or more covariates
- omission of higher order terms in the model

Non-constant range of residuals

- incorrect variance function

Plot 1 Random component [Error distribution]



Model checking for systematic departure of the model assumptions

2. Diagnostic for the variance function

   Plot of the absolute value of residuals against the fitted values, transformed to a constant information scale.

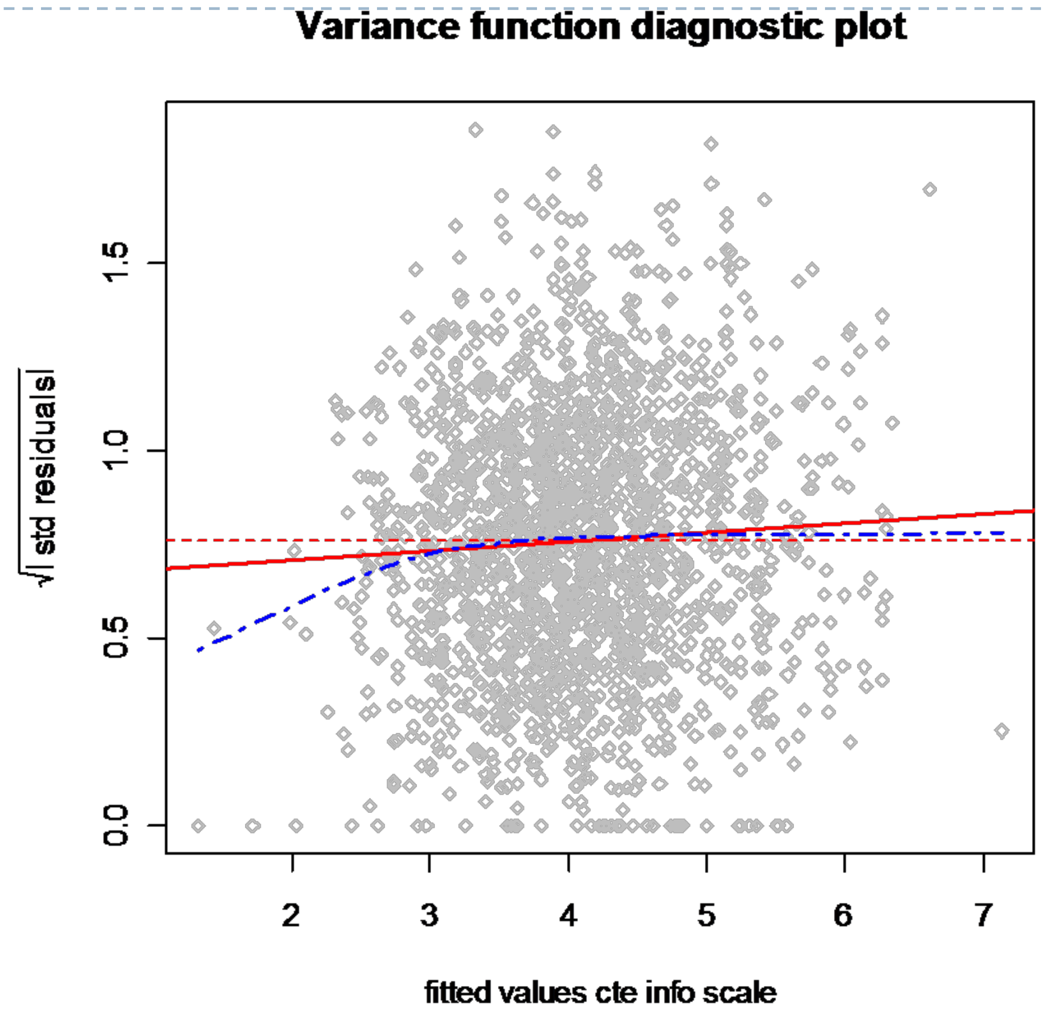
   The expected pattern is a plot without tendency in the residuals. A positive trend indicate that the observed variance increases much more rapidly than the model assumed variance.

   Departures

   Positive trend indicates that the variance function increases too slowly compare to the mean values of the data

   Negative trend indicates variance function increases much faster than the mean values of the data

2. plot for the variance function



Model checking for systematic departure of the model assumptions

3. Diagnostic for the link function

   Plot of the adjusted dependent variable against the linear predictor.

   The expected pattern is a linear trend.

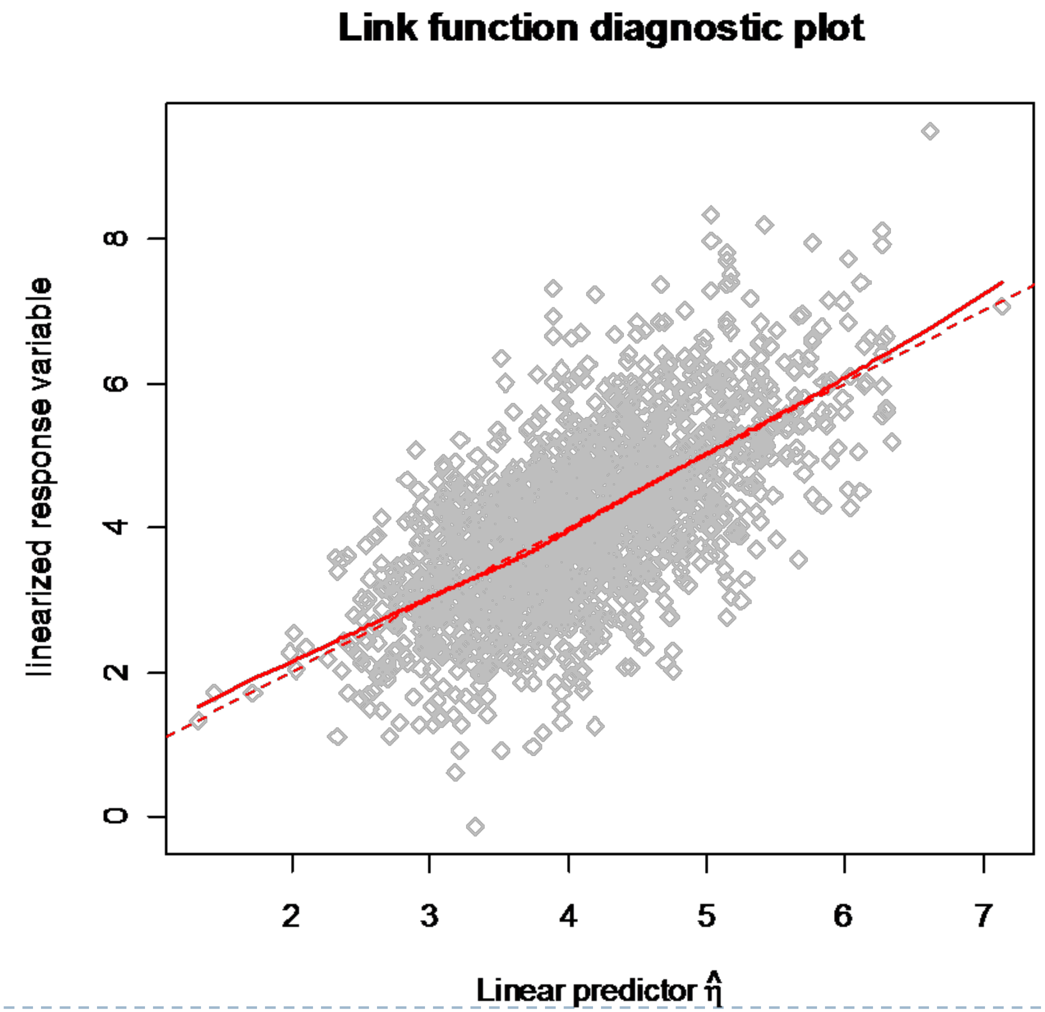
   Departures

   curvatures in the plot trend indicate a low or high power in the exponential link assumption

   non-informative for binary data

In general when the number of observations is high, trends can be inferred by using 'smoothers' such as the Loess function.

3. Plot for the link function



Model checking for systematic departure of the model assumptions

4. Diagnostic for the scale of explanatory covariates / factors

Plot of the standardized deviance residuals against the explanatory variable.

The expected pattern is a constant range distribution with mean of zero.

Departures

Missing interactions or higher order terms in some factor(s)

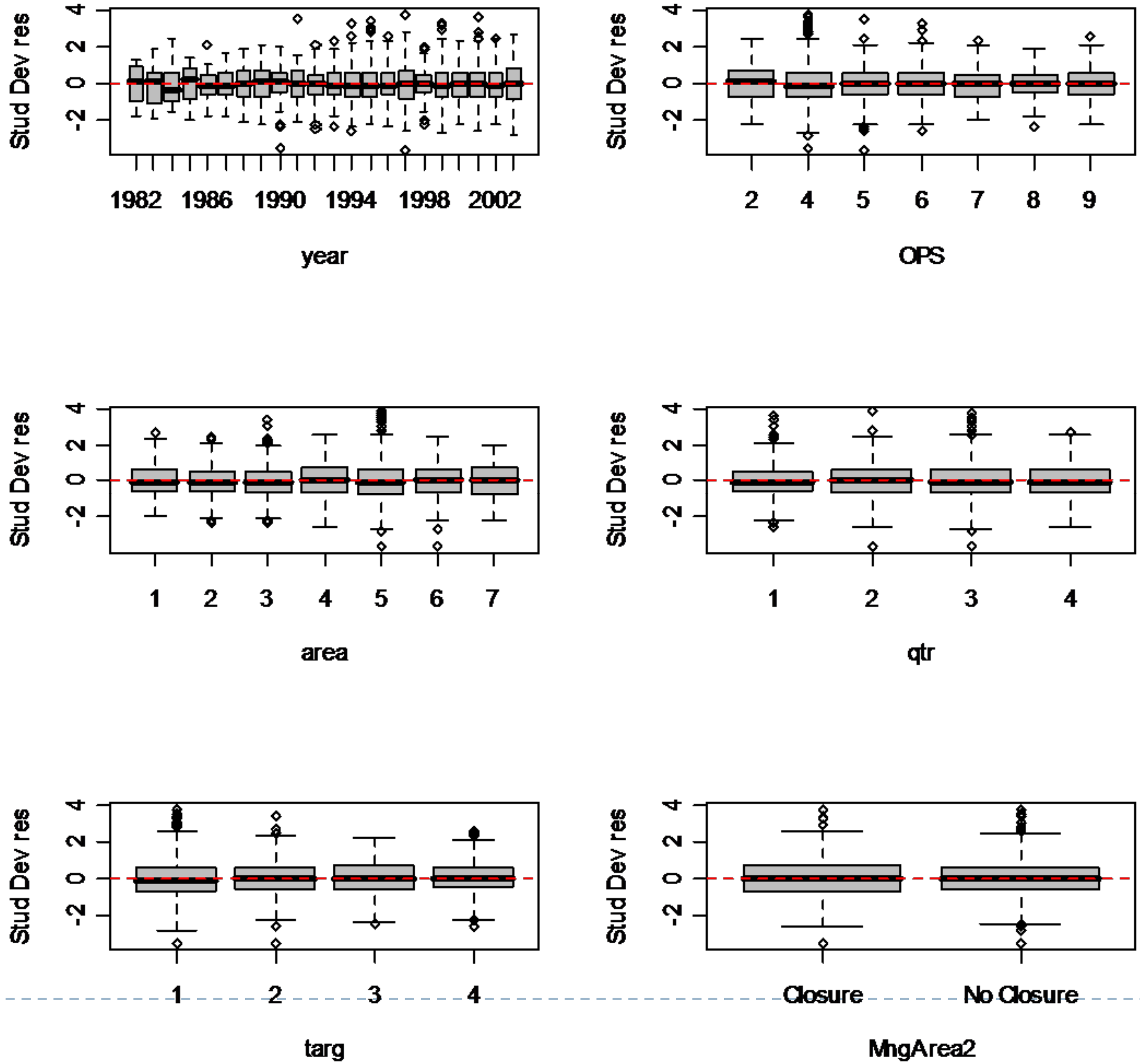
incorrect scale for explanatory variable

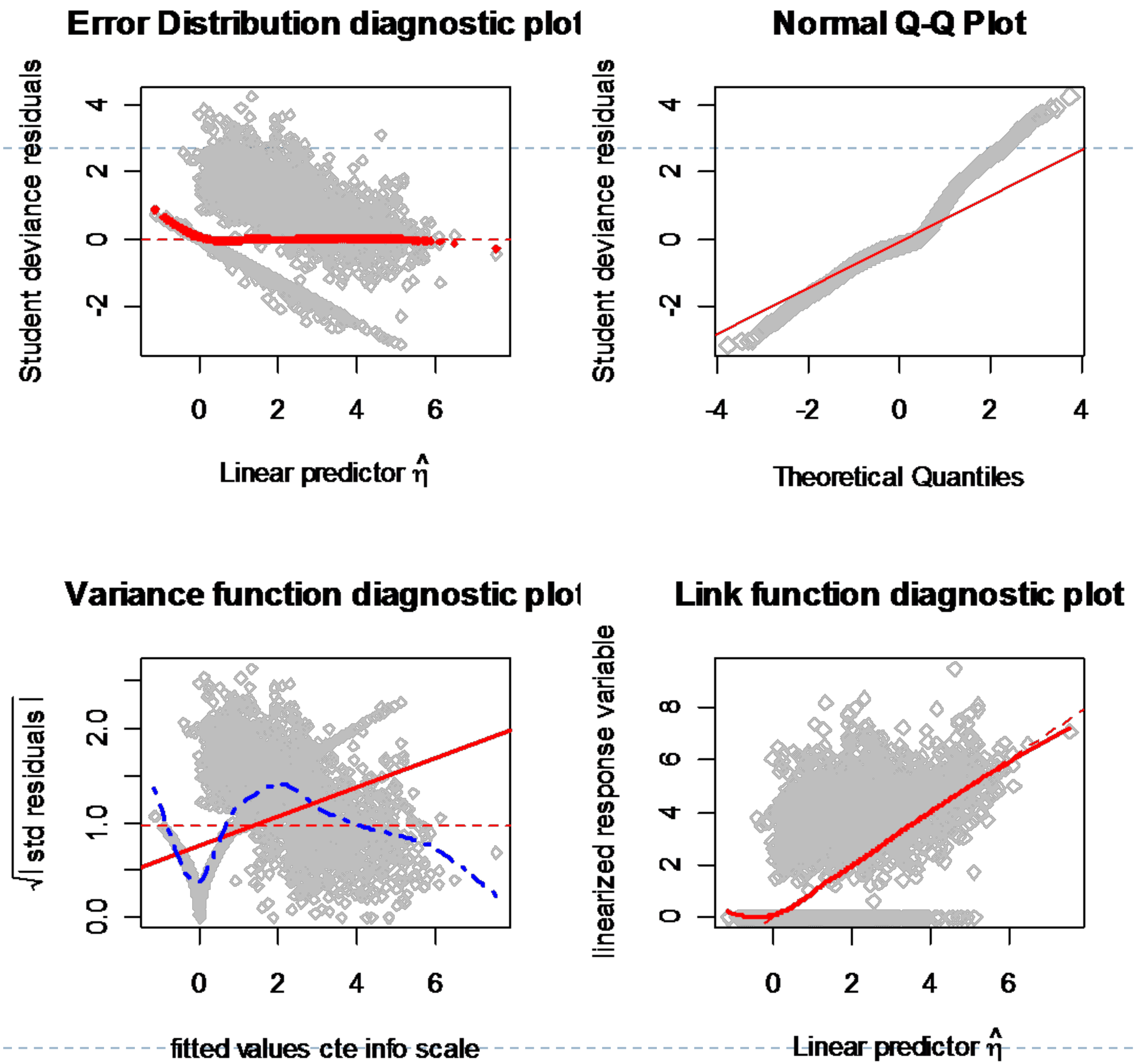
incorrect link function

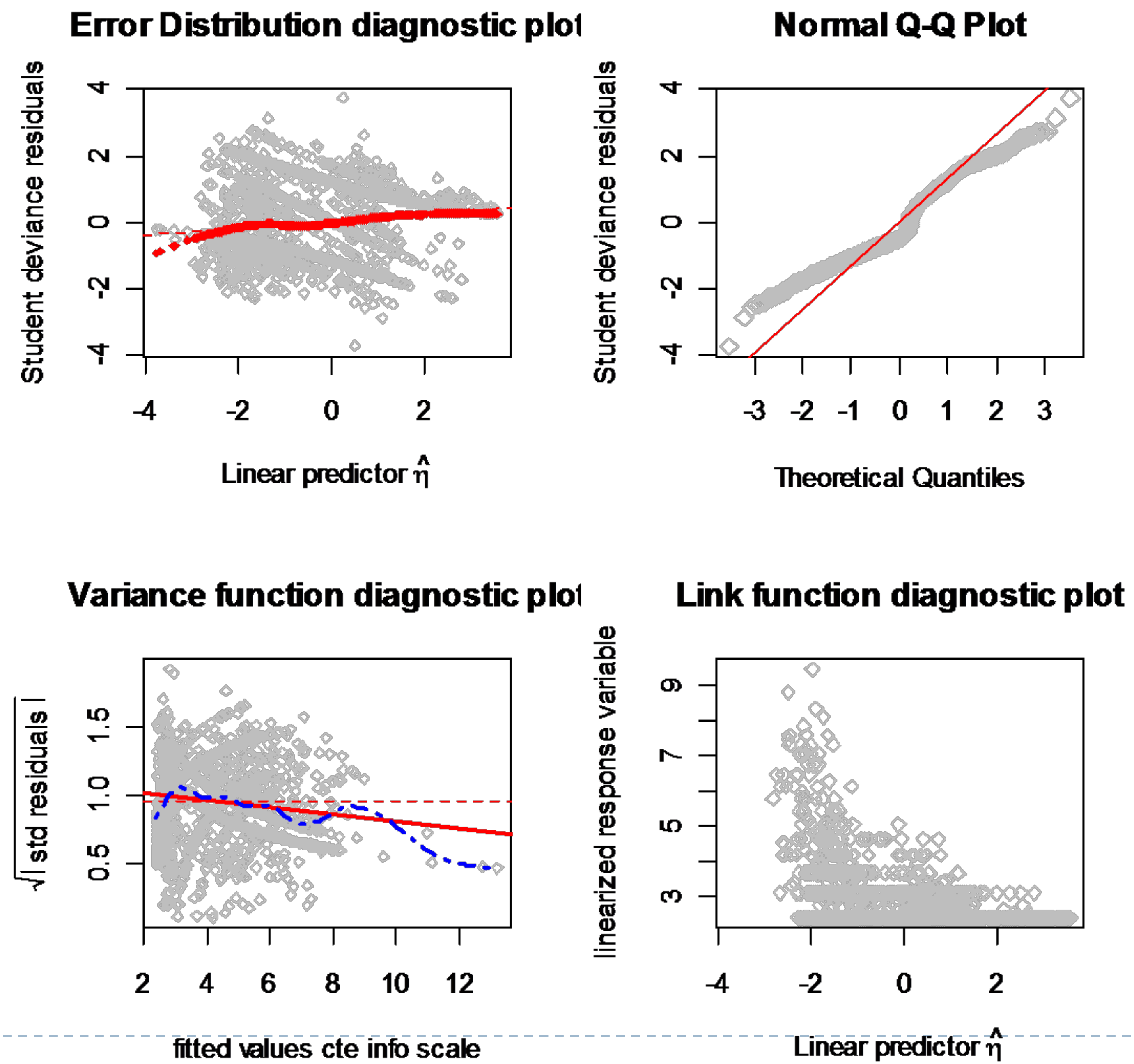
Alternative plot: Partial residual plot for each factor/covariate.

null pattern is a linear trend (continuous covariates only).

4. Plot for the scale explanatory variables




Error Distribution diagnostic plot
Student deviance residuals
4
2
0
-2
0
2
4
6
Linear predictor η̂
Normal Q-Q Plot
Student deviance residuals
4
2
0
-2
-4
-2
0
2
4
Theoretical Quantiles
Variance function diagnostic plot
√| std residuals |
2.0
1.0
0.0
0
2
4
6
fitted values cte info scale
Link function diagnostic plot
linearized response variable
8
6
4
2
0
0
2
4
6
Linear predictor η̂


Error Distribution diagnostic plot
Student deviance residuals
4
2
0
-2
-4
-4
-2
0
2
Linear predictor $\hat{\eta}$
Normal Q-Q Plot
Student deviance residuals
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
Theoretical Quantiles
Variance function diagnostic plot
$\sqrt{|\text{std residuals}|}$
1.5
1.0
0.5
2
4
6
8
10
12
fitted values cte info scale
Link function diagnostic plot
linearized response variable
9
7
5
3
-4
-2
0
2
Linear predictor $\hat{\eta}$

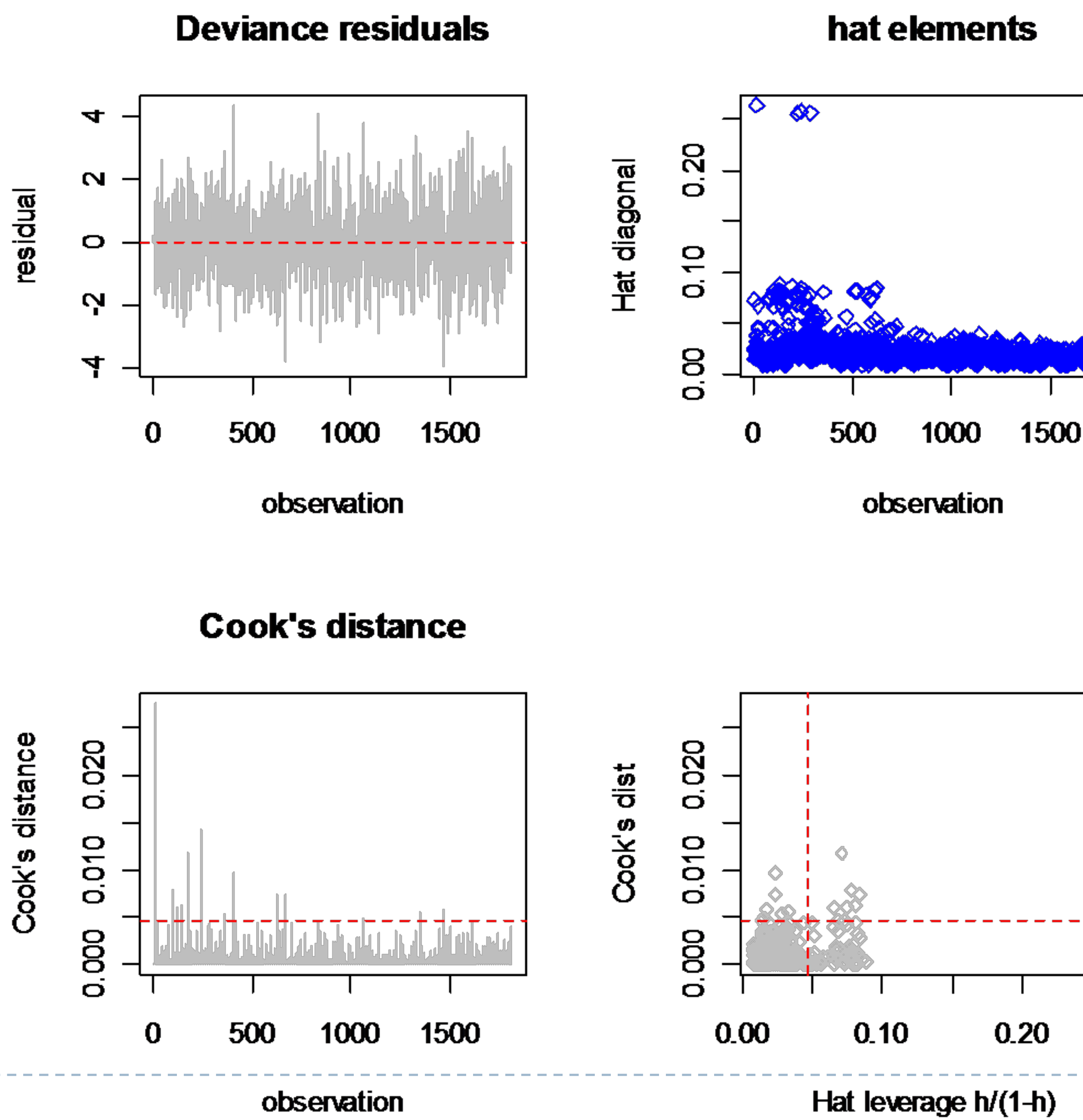
Transformations to constant information scale of error distribution

$\hat{\mu}$	*Normal*	*error*
$2\sqrt{\hat{\mu}}$	*Poisson*	*error*
$2/\sin(\sqrt{\hat{\mu}})$	*Binomial*	*error*
$2\log\hat{\mu}$	*Gamma*	*error*
$-2/\sqrt{\hat{\mu}}$	*Inverse*	*gaussian*

Model checking for Observations that are discrepant or inconsistent from the rest of the data

Residual analysis focus on the influence and/or "leverage" of a given observation and the effect on the parameters estimated by the model.

- Leverage:
  - Diagonal elements of the 'hat' matrix
  - They represent the influence of a given point in the fit, large value of h_i indicates that the fit may be sensitive to the response observation *i*.
  - A plot of leverage values indicating those values of $h_i > 2p/n$ is an informative tool.
- Influence:
  - Influence is normally measured as weighted combination of the changes of estimates with and without a given extreme point.
  - Cooke (1977) introduce an statistic, 'Cook distances' that approximates the residual scaled difference between the model fit with observation response for case *i* and the model fit without the observation *i*.


Deviance residuals
residual
4
2
0
-2
-4
0
500
1000
1500
observation
hat elements
Hat diagonal
0.00
0.10
0.20
0
500
1000
1500
observation
Cook's distance
Cook's distance
0.000
0.010
0.020
0
500
1000
1500
observation
Cook's dist
0.000
0.010
0.020
0.00
0.10
0.20
Hat leverage h/(1-h)

Model checking Results

Influence

leverage	Small	Large
Small	OK	OK
Large	OK	Problem

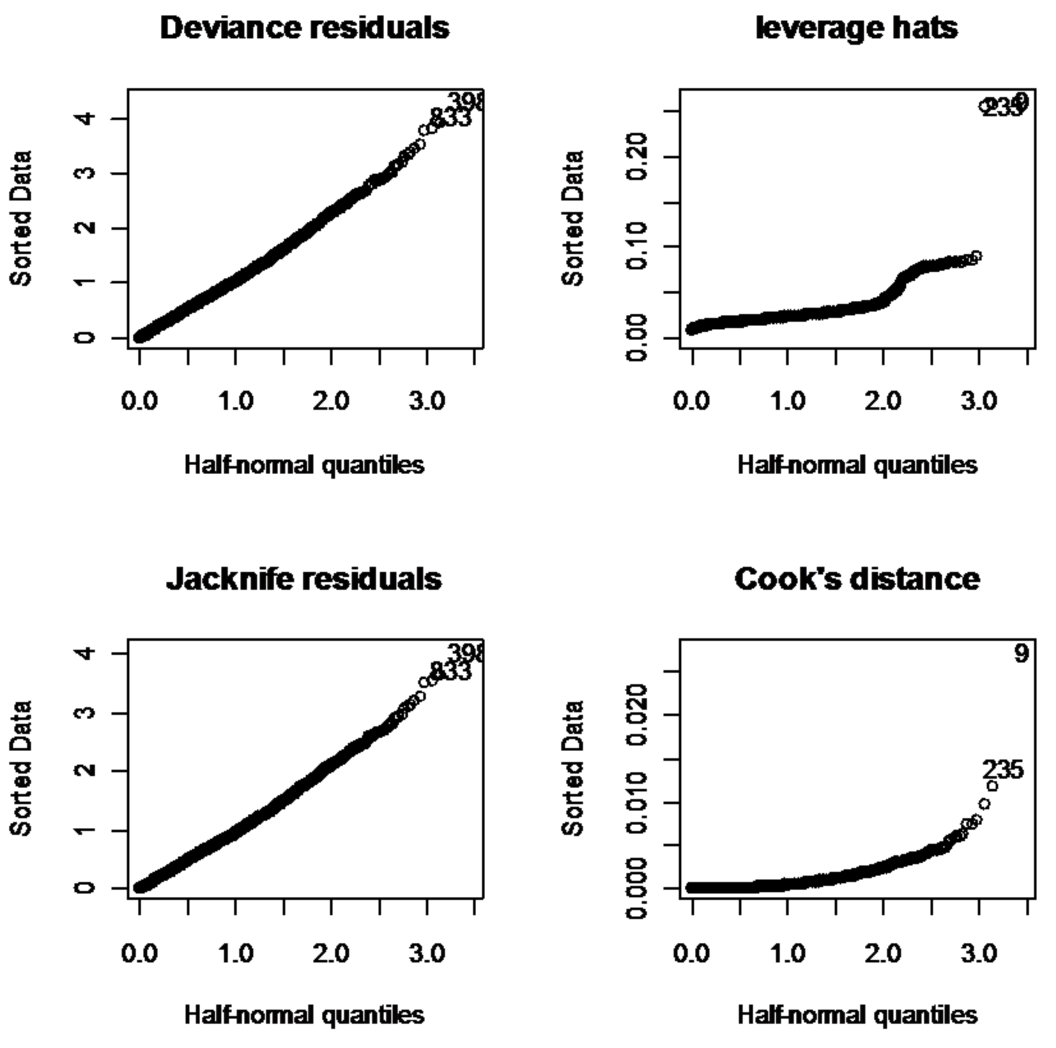
Residual analysis

leverage cutoff small < $8/(n-2p)$ < large

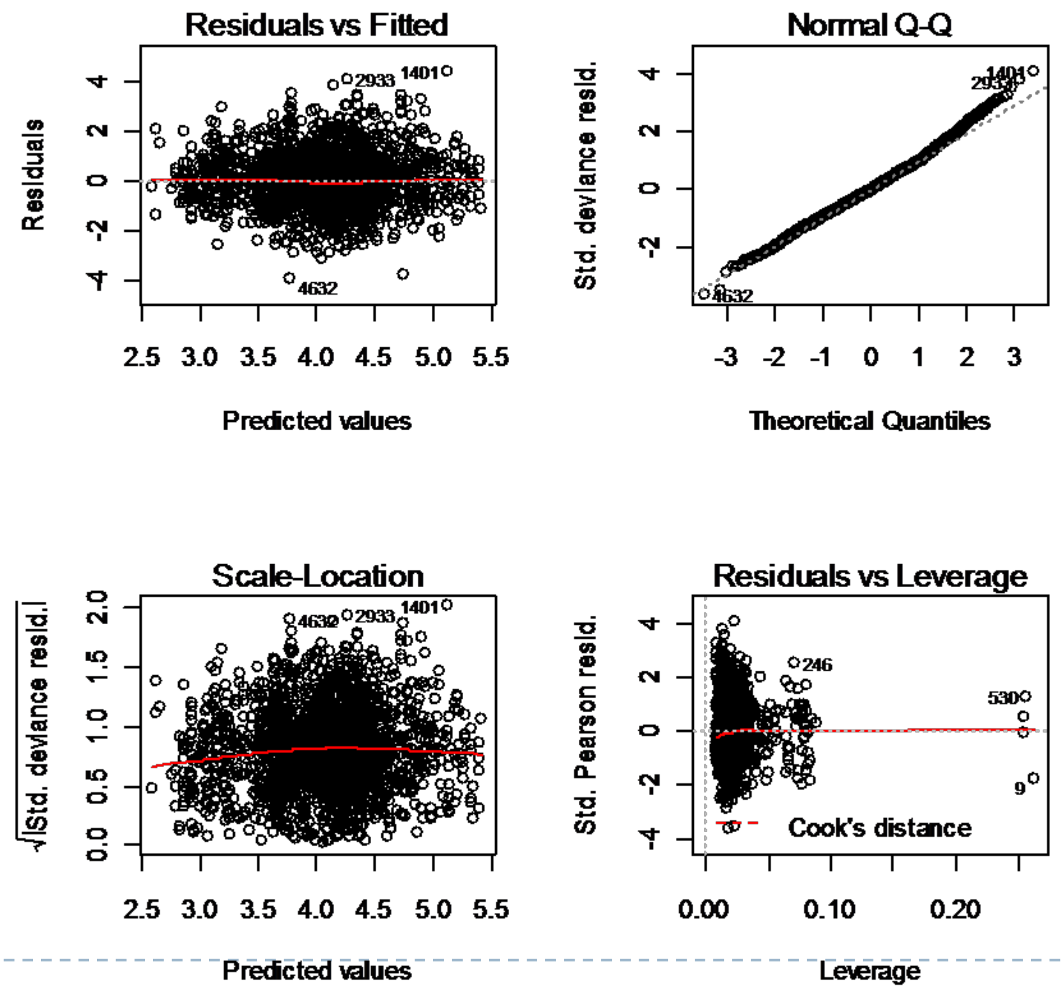
influence cutoff small < $2p/(n-2p)$ < large

where n = number observations, p = number parameters

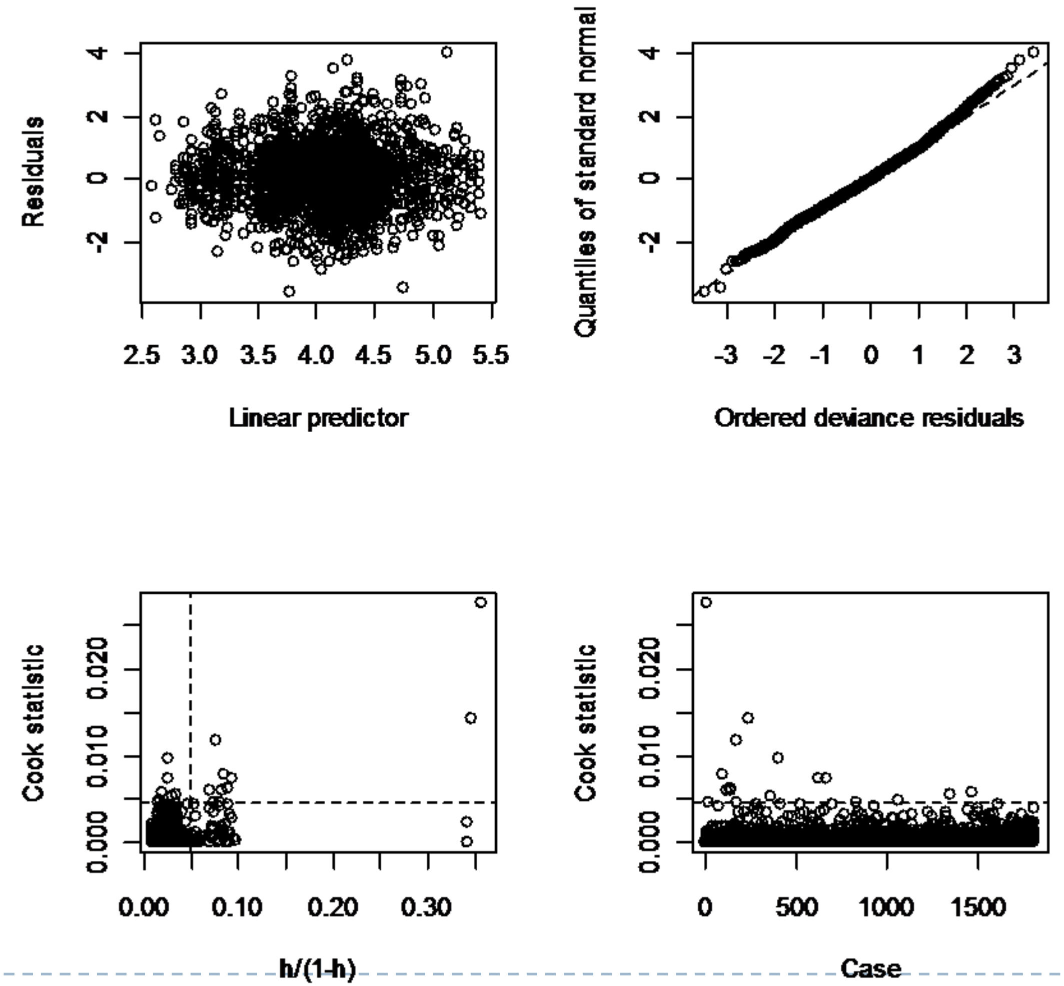
> halfnorm plots (….) library faraway

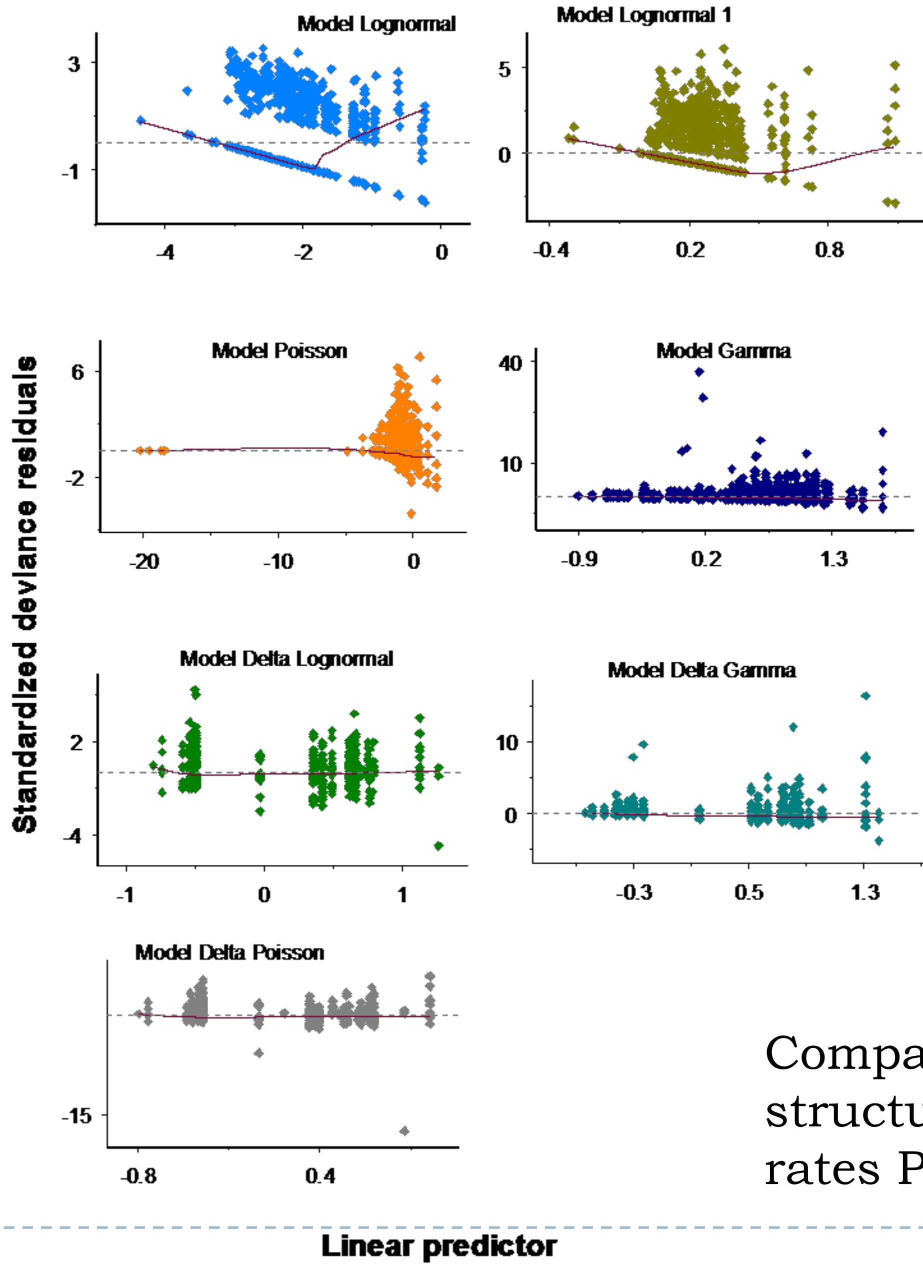


> plot(glm.object)

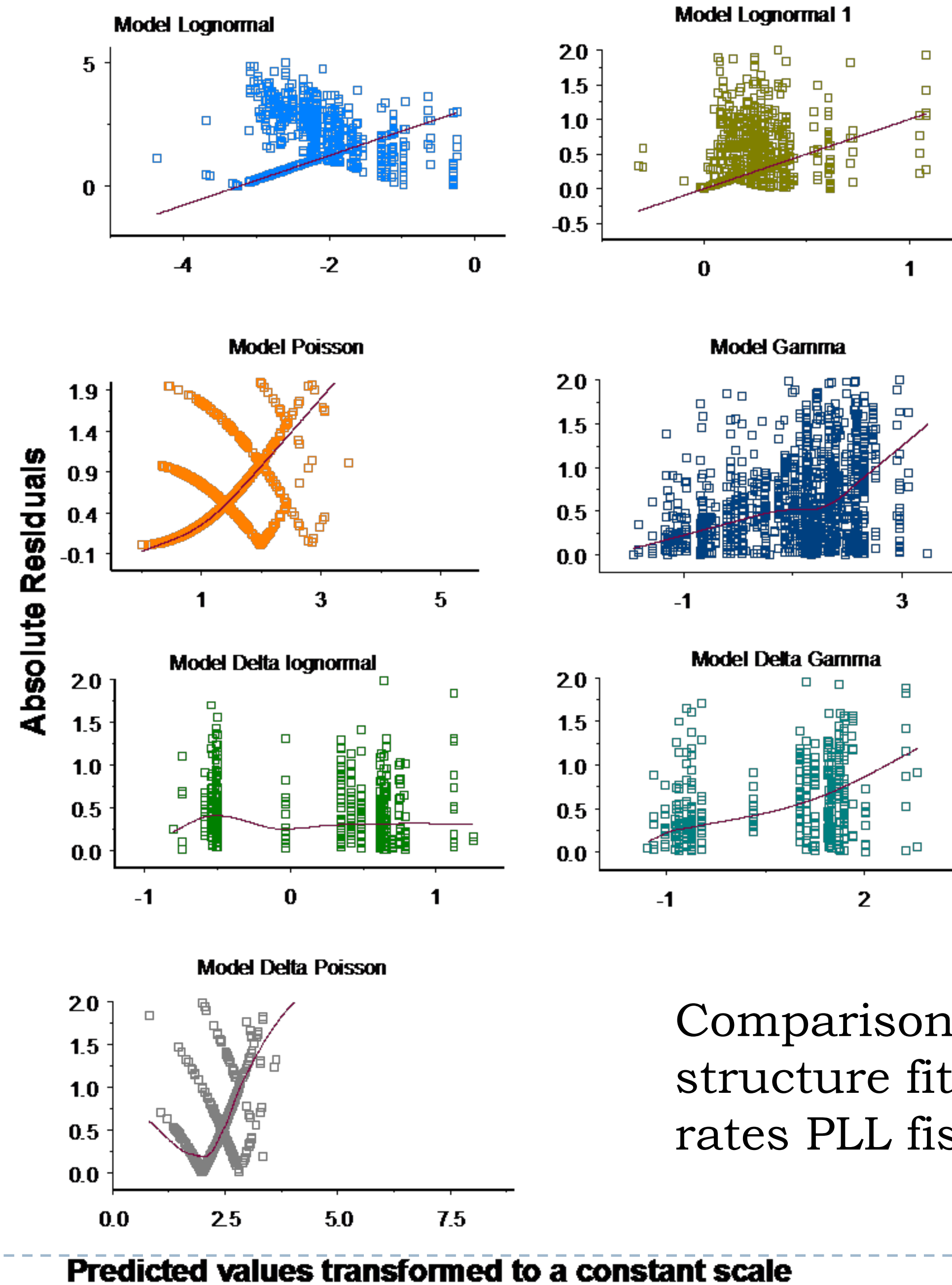


> glm.diag.plots(glm.object) library boot

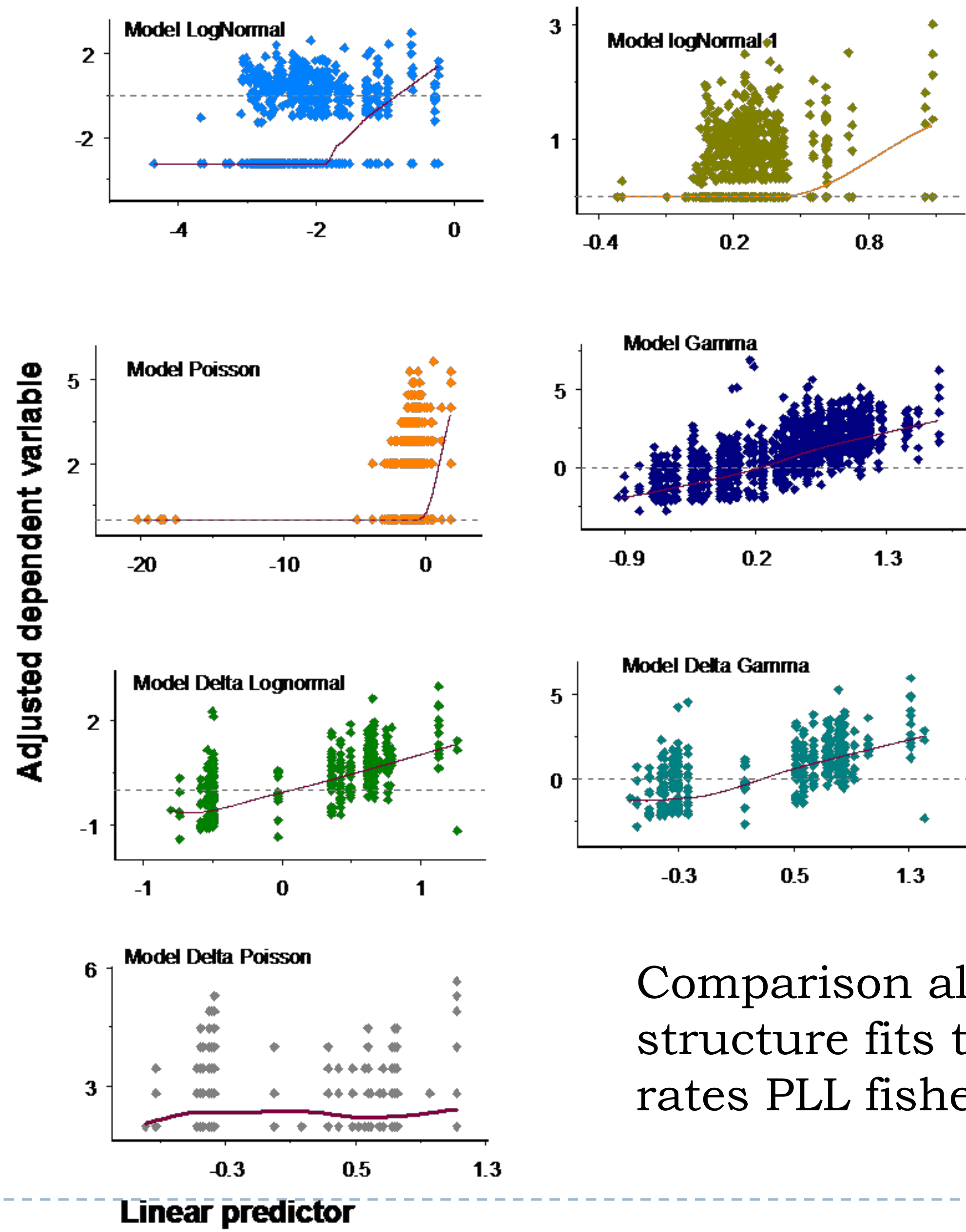




Comparison alternative model structure fits to billfish catch rates PLL fishery



Comparison alternative model structure fits to billfish catch rates PLL fishery

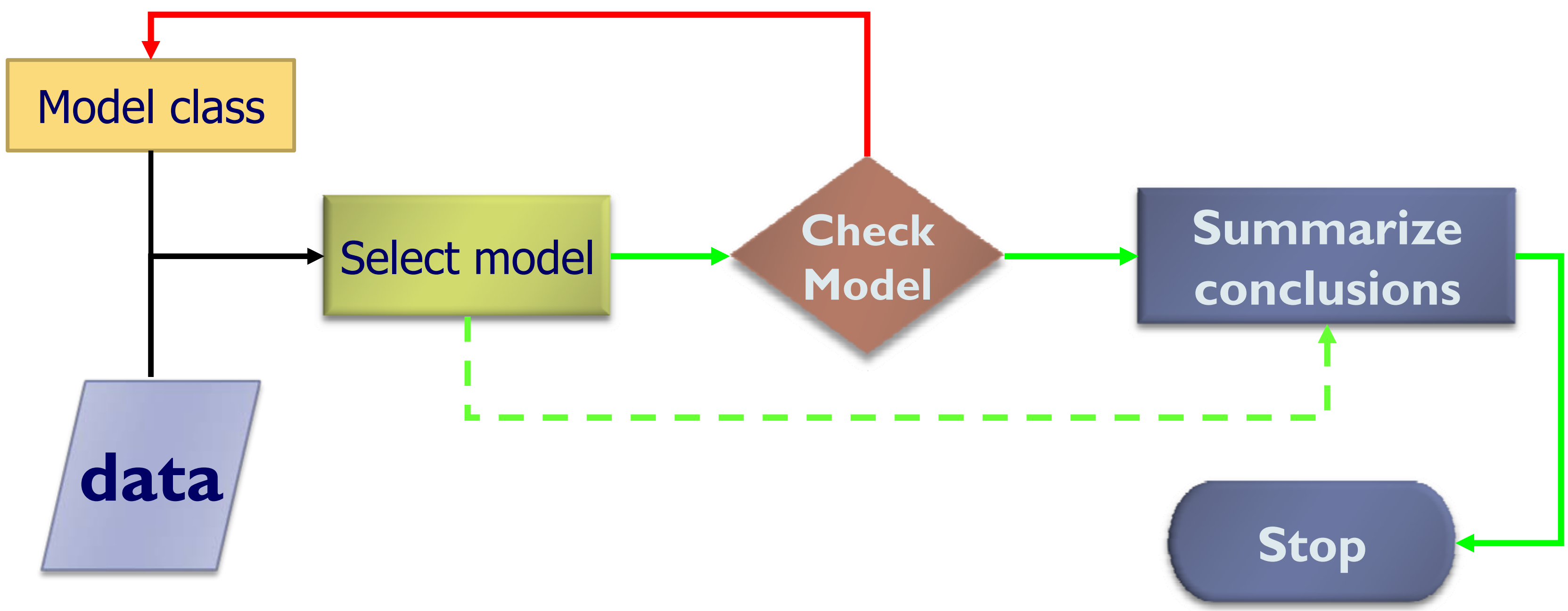


Comparison alternative model structure fits to billfish catch rates PLL fishery

Final model …. Testing

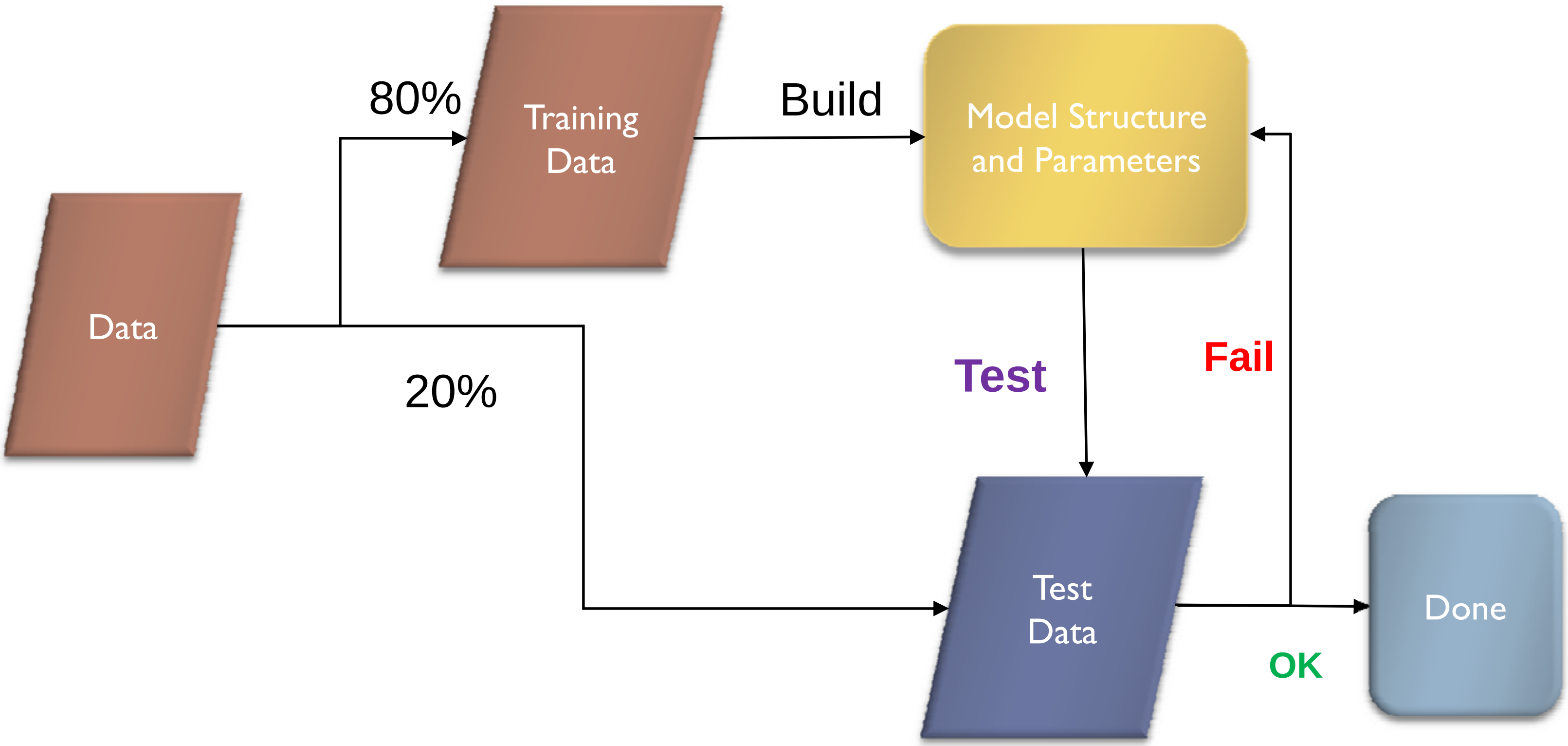
- IMPORTANT

After evaluating the model fit and significance of the explanatory variables, it is imperative to complete the analysis with a model diagnostics to confirm the model assumptions and to detect outliers.



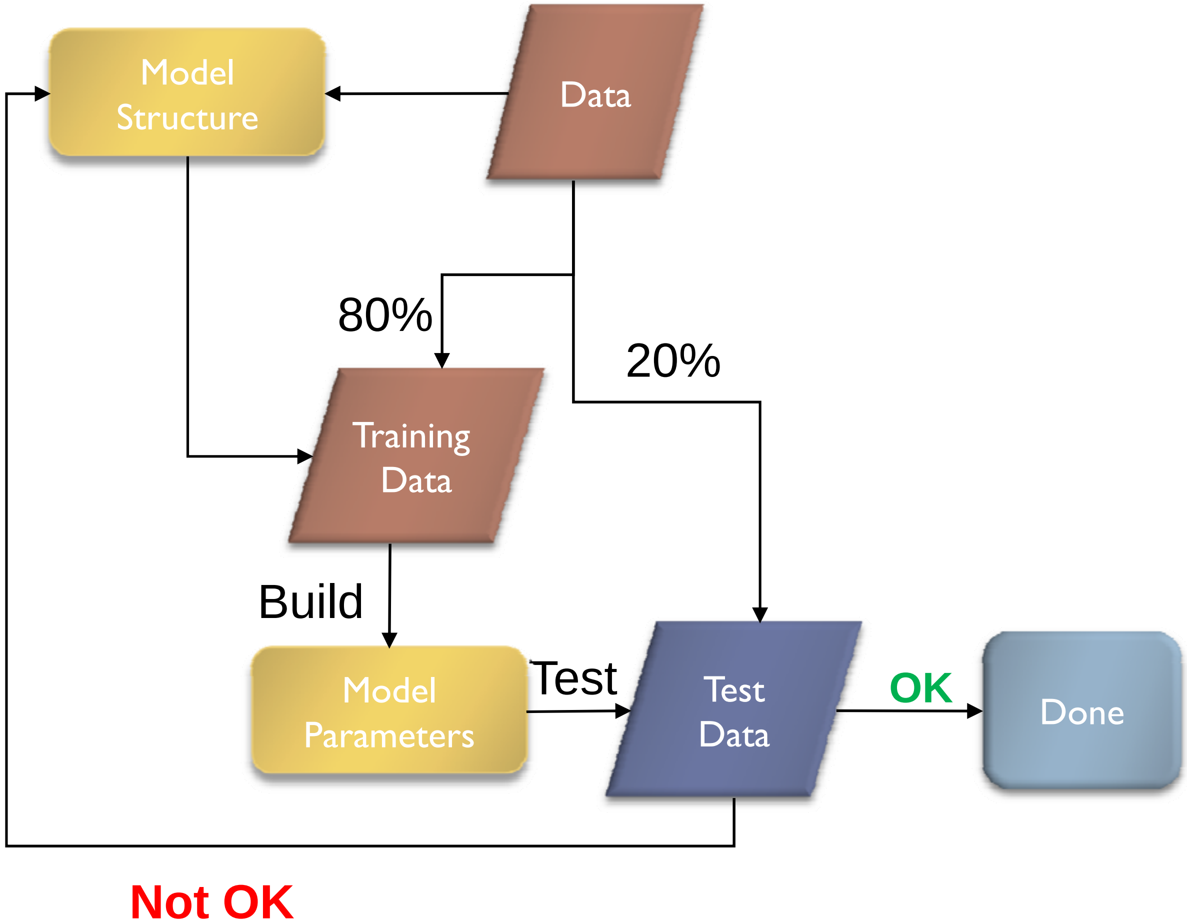
Testing final model predictiveness: Sampling

1. Training and Testing



Testing final model predictiveness: Bootstrapping

2. Bootstrapping



Conclusions

- Selecting a model class and fit the data
  - Just the beginning of Statistical Analysis
- Model diagnostics
  - An important component to validate statistical model assumptions
  - Two main topics
    - Systematic departures of the model assumptions
    - Isolated departures of observations
  - Model testing
    - Cross-validation
    - Model robustness
- Final Model …

Science, Service, Stewardship

A Review of Index Weighting Schemes for Stock Assessments

Clay E. Porch

October 20, 2008

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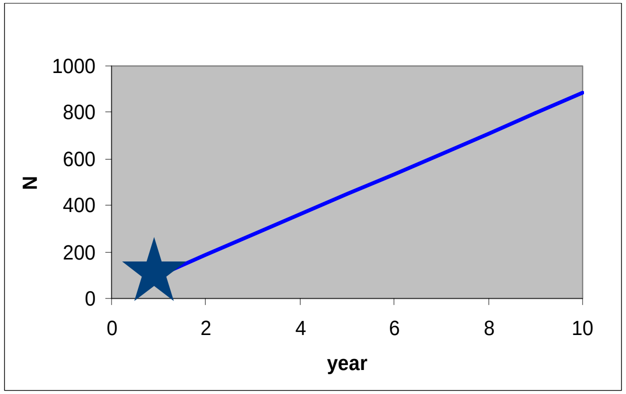
Why it matters: A simple example



MODEL:

$U_y = q(N_0+G^*y) + \varepsilon_y$

$P(\varepsilon_y) \sim \text{Normal}(0, \sigma)$

$P(U_y) \sim \text{Normal}(q(N_0+G^*y), \sigma)$

$L(U_1,U_2,\ldots,U_n)=P(U_1)P(U_2)\ldots P(U_n)$ if i.i.d.

ESTIMATION:

$\text{MAX}_{G,q,\sigma_a}\ L(U_{a1},U_{a2},\ldots,U_{an})$

If there exists an efficient unbiased estimator, the maximum likelihood method will produce it

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Why it matters: A simple example

$$-\ln L(U_{1y},U_{2y}) = \quad \Sigma\, 0.5*[U_{1y}-q_1(N_0+Gy)]^2 / \sigma_1^2 + \ln(\sigma_1) +$$
$$\Sigma\, 0.5*[U_{2y}-q_2(N_0+Gy)]^2 / \sigma_2^2 + \ln(\sigma_2)$$

Parameters $q_1,q_2,\sigma_1,\sigma_2,$***G***

1) Set σ equal to arbitrary constant
2) Minimize -lnL function over both q and σ
3) Minimize concentrated likelihood function for σ over q

SOLVER DEMO

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WEIGHTING SCHEMES ARE TIED TO THE ASSUMED ERROR STRUCTURE

EQUAL (fixed or estimated σ)

U_j's must be the same average magnitude

•Normal **(additive)**
implies constant variance

$$\sum_{j,y} 0.5\left(\frac{U_{j,y}-\hat{U}_{j,y}}{\sigma}\right)^2+\ln(\sigma)$$

•Lognormal **(multiplicative)**
implies constant log-scale variance (constant CV)

$$\sum_{j,y} 0.5\left(\frac{\ln U_{j,y}-\ln \hat{U}_{j,y}}{\sigma\{\ln U\}}\right)^2+\ln(\sigma\{\ln U\})$$

No-rescaling necessary

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WEIGHTING SCHEMES ARE TIED TO THE ASSUMED ERROR STRUCTURE

MLE **(iterative reweighting, concentrated likelihood, direct search)**

- **Normal (additive)**
  = constant variance

$$\sum_{j,y} 0.5\left(\frac{U_{j,y}-\hat{U}_{j,y}}{\hat{\sigma}_j}\right)^2 + \ln\left(\hat{\sigma}_j\right)$$

$$\hat{\sigma}_j = \frac{1}{n}\sum_y \left(U_{j,y}-\hat{U}_{j,y}\right)^2$$

- **Lognormal (multiplicative)**
  = constant log-scale variance (constant CV)

$$\sum_{j,y} 0.5\left(\frac{\ln U_{j,y}-\ln\hat{U}_{j,y}}{\hat{\sigma}_j\{\ln U\}}\right)^2 + \ln\left(\hat{\sigma}_j\{\ln U\}\right)$$

$$\hat{\sigma}_j = \frac{1}{n}\sum_y \left(\ln U_{j,y}-\ln\hat{U}_{j,y}\right)^2$$

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BRIEF REVIEW OF SOME ALTERNATIVE WEIGHTING SCHEMES

- EQUAL (fixed or estimated σ)
- MLE (iterative reweighting, direct search, concentrated likelihood)
- **INPUT VARIANCE (σ derived externally)**

$$0.5\sum_{j,y}\frac{\left(U_{j,y}-\hat{U}_{j,y}\right)^2}{\sigma^2_{j,y}}+\ln\left(\sigma^2_{j,y}\right)$$

Note: σ may be derived from sample size as from GLM, expert opinion, area covered, etc….

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BRIEF REVIEW OF SOME ALTERNATIVE WEIGHTING SCHEMES

- **EQUAL (fixed or estimated σ)**
- **MLE (iterative reweighting, direct search, concentrated likelihood)**
- **INPUT VARIANCE (σ derived externally)**
- **ADDITIONAL VARIANCE (σ derived externally, ω estimated)**

$$0.5\sum_{j,y}\frac{\left(U_{j,y}-\hat{U}_{j,y}\right)^2}{\sigma_{j,y}^2+\hat{\omega}_j^2}+\ln\left(\sigma_{j,y}^2+\hat{\omega}_j^2\right)$$

Note: if observation error is independent of process error, then the variance should be additive

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BRIEF REVIEW OF SOME ALTERNATIVE WEIGHTING SCHEMES

- **EQUAL (fixed or estimated σ)**
- **MLE (iterative reweighting, direct search, concentrated likelihood)**
- **INPUT VARIANCE (σ derived externally)**
- **ADDITIONAL VARIANCE (σ derived externally, ω estimated)**
- **MULTIPLICATIVE VARIANCE (σ derived externally, ω estimated)**

$$0.5\sum_{j,y}\frac{\left(U_{j,y}-\hat{U}_{j,y}\right)^2}{\hat{\omega}_j^2\sigma_{j,y}^2}+\ln\left(\hat{\omega}_j^2\sigma_{j,y}^2\right)$$

Note: useful if one trusts σ as a measure of relative precision from one year to the next (but not necessarily across indices)

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BRIEF REVIEW OF SOME ALTERNATIVE WEIGHTING SCHEMES

- **EQUAL (fixed or estimated σ)**
- **MLE (iterative reweighting, direct search, concentrated likelihood)**
- **INPUT VARIANCE (σ derived externally)**
- **ADDITIONAL VARIANCE (σ derived externally, ω estimated)**
- **MULTIPLICATIVE VARIANCE (σ derived externally, ω estimated)**

Instead of estimating ω (or σ) one can solve for them such that average variance is the same for each series (equal-weighting of sorts, but maintaining inter-annual variation)…

or come up with your own mischievous combinations!

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Fitting fisheries models to standardised CPUE abundance indices (Maunder and Starr, 2003)

- **Equal weighting vs. Input variance weighting**
- **Simple biomass dynamic model with known survival, constant recruitment, single estimated parameter (virgin biomass)**
- **Simulated raw CPUE and ran it through standardization procedure (obtain year-specific CV's)**
- **Fit simple biomass model to indices using equal weighting and input variance weighting**

Results indicate additional bias and reduced precision will be introduced into the population parameter estimates if the CV's differ between abundance indices and this difference is not incorporated into the fitting procedure.

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Comparisons of index weighting schemes for tuned virtual population analyses (Legault and Porch, 2001)

- **Equal weighting vs. maximum likelihood weighting**
- **Simulated bluefin tuna data 1970-1997**

  8 indices with 25% or 50% CV

  different age ranges (age-specific vs. combined ages)

  different estimation schemes for terminal F parameters

Results indicate no clear pattern in the bias or uncertainty of estimates between the two weighting schemes

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Comparisons of index weighting schemes (general considerations)

- **Fixed variances based on external considerations may not account for all sources of uncertainty**

- **Estimating variances (or components of variances)**

  -can have too many parameters (asymptotic properties)

  -estimates are conditioned on model structure

  -variance estimation complicated when multiple types of data are used (must specify ratios: e.g., $\sigma_{catch}/\sigma_{index}$)

- **Insufficient testing to make general conclusions**

Qualitative evaluation of CPUE series used for west Atlantic bluefin stock assessment (Suzuki, 2001)

- Notes that weighting methods generally discussed in context of precision among abundance indices, but not their relative accuracy
- Relative accuracy is more important
- Qualitative ranking of indices (example Western Bluefin tuna)

Fishery	Canada	USRR	JLLGOM	JLLNW	USLLGOM	Larval
Area	1	2	5	4	4	4
Time	2	2	5	3	3	3
Change in operational aspects	2	2	5	4	1	5
Total	5	6	15	11	8	12

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POSSIBLE CRITERIA FOR SELECTING A METHOD (e.g., McAllister et al 2001)

A priori criteria

Flow chart?

1. **Are year to year variations in uncertainty likely to be substantial and measurable for a given index?**

   -reliable measures of relative uncertainty? (e.g., GLM)

   -reliable measures of absolute uncertainty? (e.g., designed-based)

2. **Does the level of uncertainty likely vary substantially among indices?**

   -is available expertise sufficient and able to reach consensus ranking

   -is candidate estimation method well-understood (widely-practiced, simulation tested, easily applied in current assessment framework)

POSSIBLE CRITERIA FOR SELECTING A METHOD (e.g., McAllister et al 2001)

A posteriori criteria

1. **Does the method accord unrealistically high or low variance to some data series?**

    -What level should be deemed unrealistic?

2. **Do the estimates of variance strongly disagree with expert judgment on the relative reliability of each series as an index of abundance**
3. **Are estimates statistically defensible**

    -goodness of fit (e.g., Chi-square deviance statistic)

    -model selection criteria (e.g., AIC)

Minimum Requirements for the Indices Working Group Report Section

Julie A. Neer
SEDAR Coordinator

Indices Procedural Workshop
Miami, FL
October 2008

INDICES GROUP TERM OF REFERENCE

Provide measures of population abundance that are appropriate for stock assessment.

Consider all available and relevant fishery dependent and independent data sources.

Document all programs evaluated, addressing program objectives, methods, coverage, sampling intensity, and other relevant characteristics.

Provide maps of survey coverage.

Develop CPUE and index values by appropriate strata (e.g., age, size, area, and fishery); provide measures of precision and accuracy.

Evaluate the degree to which available indices adequately represent fishery and population conditions.

Recommend which data sources are considered adequate and reliable for use in assessment modeling.

REPORT OUTLINE

- Measures of Population Abundance
  1. Overview (Group membership, leader, issues)
  2. Review of Working Papers
  3. Fishery Independent Surveys
     - ❖ Methods, Gears, and Coverage (Map Survey Area)
     - ❖ Sampling Intensity – Time Series
     - ❖ Size/Age data
     - ❖ Catch Rates – Number and Biomass
     - ❖ Uncertainty and Measures of Precision
     - ❖ Comments on Adequacy for assessment
  4. Fishery-Dependent Measures
     - ❖ Methods of Estimation
     - ❖ Sampling Intensity
     - ❖ Size/Age data
     - ❖ Catch Rates – Number and Biomass
     - ❖ Uncertainty and Measures of Precision
     - ❖ Comments on Adequacy for Assessment
  5. Consensus Recommendations and Survey Evaluations
  6. Research Recommendations
  7. Itemized list of tasks for completion following workshop (Include expected completion dates and responsible parties)
  8. Literature Cited
  9. Tables
  10. Figures

Weighting guidance

TABLES

INDICES SUMMARY

INDEX VALUES

Indices Summary Tables

Table 5.1. A summary of catch-effort time series available for the SEDAR 15 data workshop.

Fishery Type	Data Source	Area	Years	Units	Standardization Method	Size Range	Issues	Use?
Recreational	Headboat	Atlantic	1976-2006	Number per angler-hr	Stephens and MacCall; delta-lognormal GLM	Same as fishery	Fishery dependent	Y
Commercial	Handline	Atlantic	1993-2006	Pounds per hook-hr	Stephens and MacCall; delta-lognormal GLM	Same as fishery	Fishery dependent	Y
Recreational	MRFSS	Atlantic	1983-2006	Number per angler-trip	Angler-trips included if species was targeted or caught (A+B1+B2); Nominal	Same as fishery	Fishery dependent	Y
Independent	MARMAP Chevron trap	Atlantic	1988-2006	Number per trap-hr	Nominal	—	Low sample sizes; freq. annual zero (n = 4 to 41 per year)	N
Independent	MARMAP Hook and line	Atlantic	1979-2002	Number per hook-hr	Nominal	—	Low sample sizes; freq. annual zeros (n = 0 to 39 per year)	N
Independent	MARMAP Short longline	Atlantic	1980-2006	Number per hook-hr	Nominal	—	Low sample sizes; freq. annual zeros (n = 0 to 10 per year)	N
Independent	SEAMAP	Atlantic	1990-2006	Number per hectare	Nominal	—	Extremely low sample sizes; mostly annual zeros (n = 0 to 4 per year)	N
Independent	USC Baruch Institute nekton survey	South Carolina	—	—	—	—	n = 0	N

Indices Summary Tables

Table 5.2. Issues with each data set considered for CPUE.

<u>Fishery dependent indices</u>

Commercial Logbook – Handline (*Recommended for use*)

Pros:
- Complete census
- Covers entire management area
- Continuous, 14-year time series
- Large sample size

Cons:
- Fishery dependent
- Data are self-reported and largely unverified
- Little information on discard rates
- Catchability may vary over time and/or abundance

Issues Addressed:
- Possible shift in fisherman preference [Stephens and MacCall (2004) approach]
- In some cases, self-reported landings have been compared to TIP data, and they appear reliable
- Increases in catchability over time (e.g., due to advances in technology or knowledge) can be addressed in the assessment model

Recreational Headboat (*Recommended for use*)

Pros:
- Complete census
- Covers entire management area
- Longest time series available
- Data are verified by port samplers
- Consistent sampling
- Large sample size
- Non-targeted for focal species

Cons:
- Fishery dependent
- Little information on discard rates
- Catchability may vary over time and/or abundance

Issues Addressed:
- Possible shift in fisherman preference [Stephens and MacCall (2004) approach]
- The impression of some people that trip duration has shifted toward half-day trips is not consistent with the data (Exploratory data analysis reveals no such shift on red snapper trips or on headboat trips overall. In addition, trip duration is accounted for as a factor in the GLM.)
- Increases in catchability over time (e.g., due to advances in technology or knowledge) can be addressed in the assessment model

Indices Summary Tables

Table 3.1. A summary of catch series available for review at the LCS 05/06 Data Workshop.

Species	*Series*	*Author*	*Reference*	*Data Source*	*Area*	*Years*	*Season*	*Biomass/ Number*	*Fishery Type*	*Standardized*	*Selectivity Info*	*Age Range*	*Positive Aspects*	*Negative Aspects*	*Utility for Assessment*
Sharks	NC #	Anon.	LCS05/06-DW-01	6 Directed longline boats	North Carolina	1988-1992	All	Biomass/Number	Commercial	GLM	None	None	Historic	Not species specific, low sample sizes, possible changes in fishing methodology not accounted for	Not recommended
SB	LPS	Brown	LCS05/06-DW-09	Angler interviews	Virginia-Mass.	1986-2004	June-October	Number	Recreational	Lo method	Length frequency	None			Usable, revisit cv calculation
LCS	Gillnet Observer	Carlson	LCS05/06-DW-11	Shark drift gillnet fishery	Florida, Georgia	1993-1995, 1998-2004	All	Number	Commercial	Lo method	Length by mesh size (based on fishery independent study)	None	standardized		Rerun with new effort calculation, need to attempt calcs for all LCS scenarios
BT	Gillnet Observer	Carlson	LCS05/06-DW-11	Shark drift gillnet fishery	Florida, Georgia (Atl)	1993-1995, 1998-2004	All	Number	Commercial	Lo method	Length by mesh size (based on fishery independent study)	None	standardized		Rerun with new effort calculation, restricted to Atlantic only
LCS	PC LL	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Longline Survey	NW Florida	1993-2000	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable, need to attempt calcs for all LCS scenarios
BT-Juvenile	PC LL	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Longline Survey	NW Florida	1993-2000	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
LCS	PC Gillnet	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable, need to attempt calcs for all LCS scenarios
BT	PC Gillnet	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable
BT-Juvenile	PC Gillnet - juveniles	Carlson and Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	Age 1 to 4 years			Usable
BT-YOY	PC Gillnet – Age 0	Carlson and Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	Age-0			Usable
SB	PC Gillnet	Carlson & Bethea	LCS05/06-DW-12	PC NMFS Gillnet Survey	NW Florida	1996-2004	Spring, Summer, Fall	Number	Independent	Lo method	Length frequency	None			Usable, as nominal series
LCS	ENP	Carlson et al.	LCS05/06-DW-13	Angler interviews	Everglades	1972-2002	All (wet and dry seasons)	Number	Recreational	Lo method	None	None			Usable, only possible for total LCS

66

Suggested Fields for Indices Description Summary Table

Series Name
Document #
Data Source (longline obs; angler interview)
Area
Years
Season
Biomass/number
Units
Sampling Design
Fishery Type (FI, FD-R, FD-C)
Standardization Method (GLM; Lo method; none)
Selectivity info
Age range
Size range

Suggested Fields for Indices “Usefulness” Summary Table

Series Name
Document #
Pros
Cons
Issues Addressed
Recommendation for use (Base, sensitivity, not)

Indices Values

Table 5.3 The recommended indices of abundance and the associated CVs. These are the raw indices scaled to the mean each time series (e.g. the mean value of each index = 1.0).

	Fisheries-independent				Fisheries-dependent									
	Bottom Longline		Video		Comm LL		Comm HL		HB (18" MSL)		HB (20" MSL)		MRFSS	
Year	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV	Index	CV
1986									0.7449	0.6107			0.6877	0.5493
1987									1.1838	0.4983			0.6576	0.5638
1988									1.0426	0.5136			0.9247	0.4661
1989									1.2184	0.5011			1.3183	0.4346
1990					0.7737	0.1327	0.6959	0.2279	0.8103	0.6458	0.8481	0.5446	1.8693	0.4526
1991					0.7786	0.1204	0.6475	0.2119			0.9423	0.5352	1.1475	0.4996
1992					0.6804	0.1333	0.7476	0.1961			0.7955	0.5576	1.2673	0.4226
1993			0.8879	0.1842	0.9729	0.1060	0.6832	0.1751			0.7635	0.5365	0.7809	0.4801
1994			0.8557	0.1531	0.8317	0.1037	0.8822	0.1664			0.8033	0.5433	0.9319	0.4468
1995			0.6481	0.2147	0.9769	0.1028	0.8712	0.1642			0.9190	0.5423	0.7691	0.5021
1996			0.9199	0.1602	0.8437	0.1029	0.6078	0.1704			0.7417	0.5698	0.6046	0.5141
1997			0.9445	0.1261	1.0119	0.0990	0.5657	0.1747			0.5691	0.5777	0.5448	0.5383
1998					0.9825	0.1013	0.5366	0.1745			0.6346	0.5745	0.7546	0.4446
1999					1.0022	0.1047	0.7175	0.1638			0.6312	0.5568	0.9295	0.4019
2000	0.5646	0.6673			0.9942	0.1013	0.9867	0.1583			0.8734	0.5499	1.0472	0.3967
2001	0.6539	0.2889			1.3186	0.0973	1.4534	0.1552			0.8444	0.5314	0.8691	0.3973
2002	1.6735	0.8118	1.1164	0.1012	1.0246	0.1011	1.5219	0.1518			0.9270	0.5296	0.9032	0.3919
2003	1.0420	0.2289			0.9776	0.1010	1.1400	0.1508			1.3753	0.4891	1.1128	0.3610
2004	1.3907	0.1925	1.2912	0.0865	1.2777	0.0982	1.7734	0.1477			2.0143	0.4701	1.6755	0.3046
2005	0.6753	0.5804	1.3365	0.0710	1.5529	0.0984	2.1694	0.1495			2.3172	0.4693	1.2045	0.3378

Table 3.2 Available catch rates series for the small coastal shark complex, Atlantic sharpnose, blacknose, bonnethead, and finetooth sharks. Absolute index is the absolute estimated mean CPUE, relative index is the estimated mean CPUE divided by the overall mean and the CV is the estimated precision of the mean value. Type refers to whether the index is fishery – independent (FI) or fishery-dependent (FD), recreational (R) or commercial (C). Recommendation refers to the recommendation by the Indices Working Group to include the particular index as a base index (Base), use it for sensitivity runs (Sensitivity) or not recommended for use in the assessment (NR); AS indicates the series is for an age-structured model (excludes young of the year individuals), SPM indicates a series useful for a surplus production approach. Series with no model indicated are useful for both approaches.

Small Coastal Shark Complex

					Index		
Document Number	Series Name	Type	Recommendation	Year	Absolute	Relative	CV
SEDAR 13-DW-05	PC LL	FI	Base	1993	0.517	0.843	0.507
				1994	0.235	0.383	0.544
				1995	0.343	0.559	0.483
				1996	1.073	1.750	0.092
				1997	0.594	0.969	0.185
				1998	0.439	0.716	0.378
				1999	1.170	1.908	0.116
				2000	0.534	0.871	0.296
SEDAR 13-DW-06	PC Gillnet	FI	Base	1996	5.091	1.817	0.238
				1997	14.715	5.251	0.144
				1998	1.121	0.400	1.436
				1999	1.174	0.419	1.253
				2000	0.697	0.249	1.294
				2001	1.327	0.474	0.732
				2002	1.167	0.416	1.013
				2003	1.454	0.519	0.531
				2004	0.668	0.238	0.896
				2005	0.611	0.218	0.645
SEDAR 13-DW-09	Gillnet Obs	FD-C	Base	1993	3.014	0.149	0.879
				1994	9.942	0.490	0.172
				1995	10.934	0.539	0.218
				1996			
				1997			
				1998	20.516	1.011	0.130
				1999	12.287	0.606	0.109
				2000	9.998	0.493	0.140
				2001	5.548	0.273	0.220
				2002	72.233	3.560	0.016
				2003	11.597	0.572	0.133
				2004	8.254	0.407	0.180
				2005	58.842	2.900	0.029

FIGURES

INDEX PLOTS

INDEX COVERAGE MAPS

CORRELATIONS/PAIRWISE COMPARISONS

INDEX PLOTS

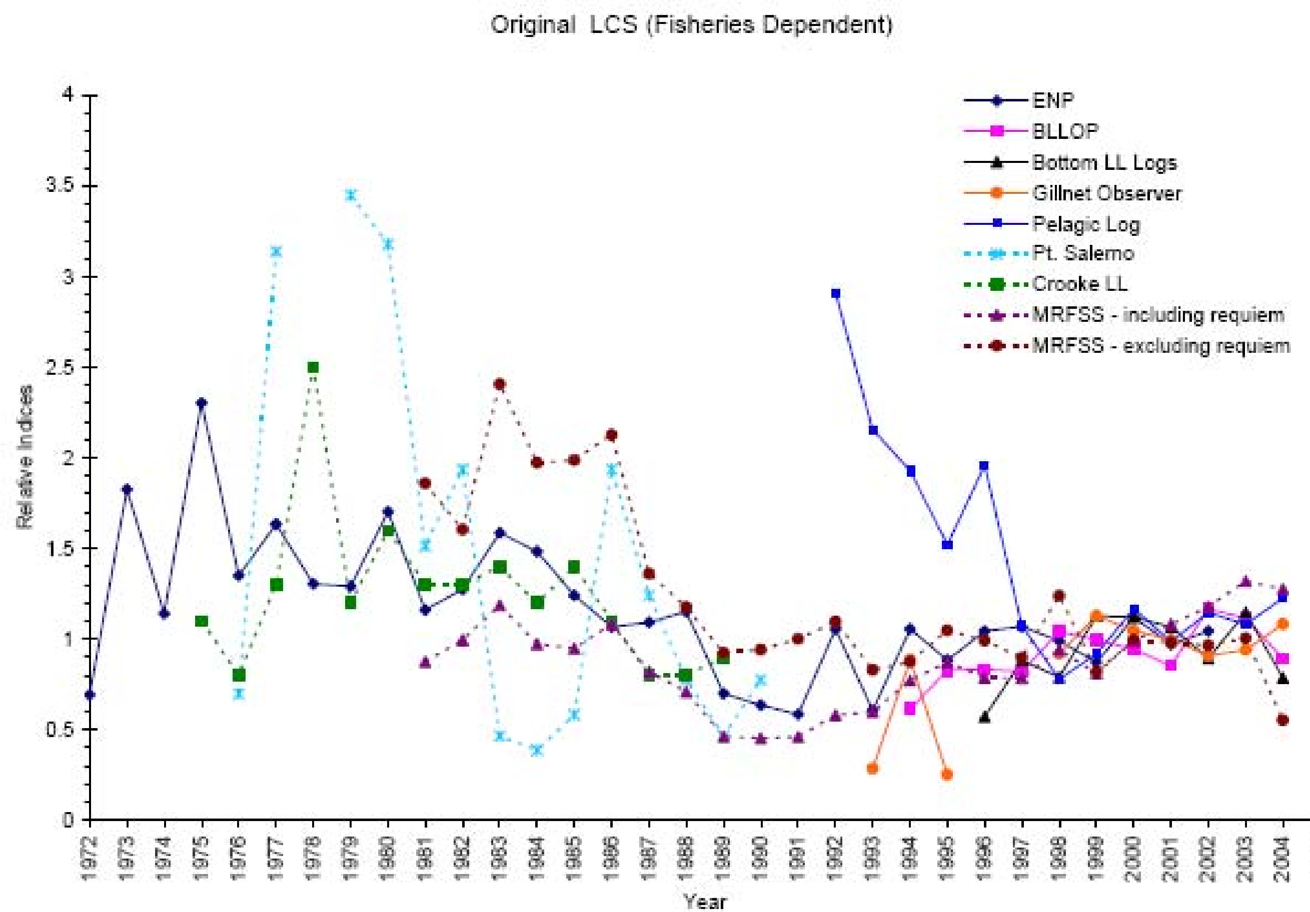


Figure 3.1. Fishery dependent catch rate series for the original large coastal shark complex containing 22 species. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

INDEX PLOTS

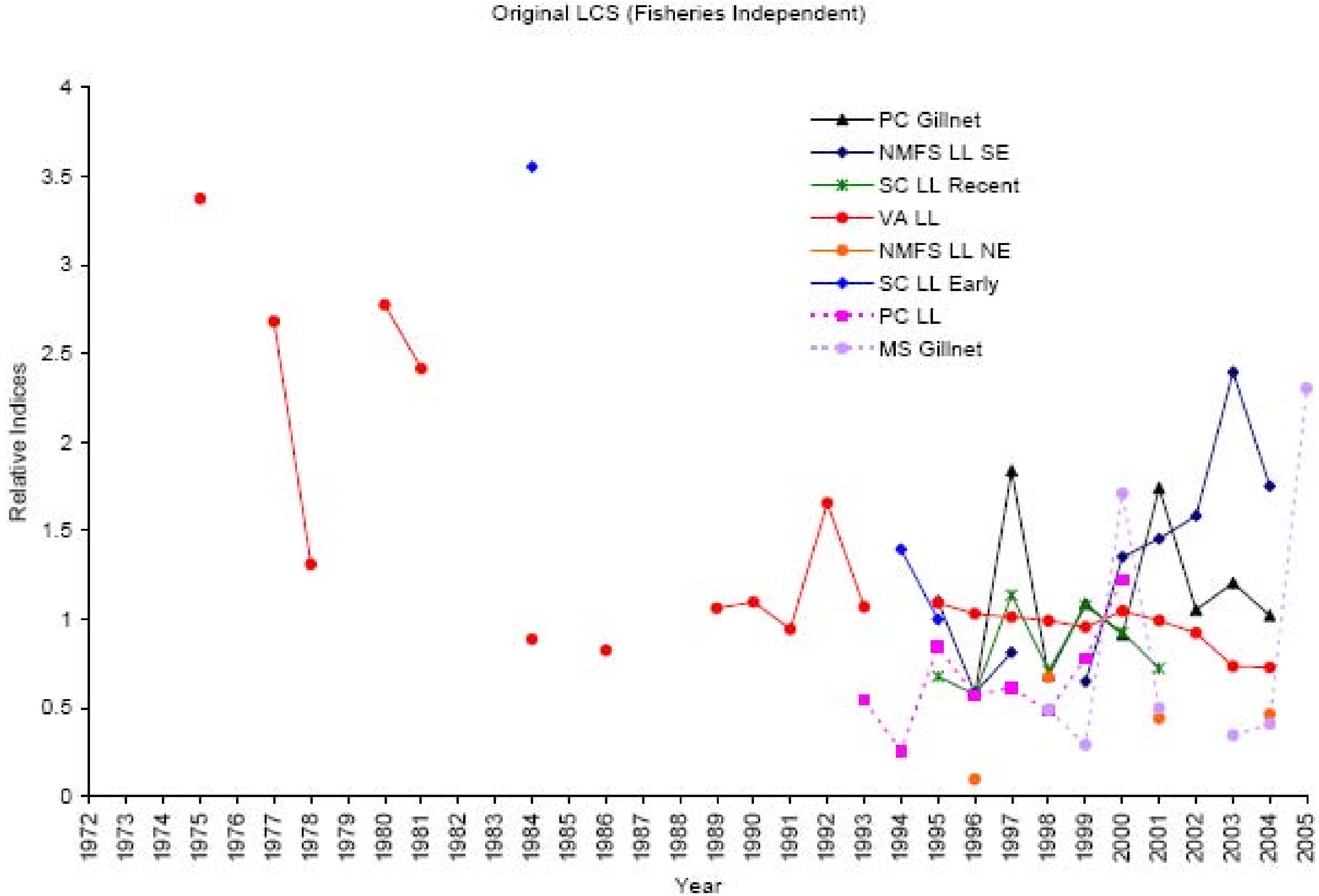


Figure 3.2. Fishery independent catch rate series for the original large coastal shark complex containing 22 species. Solid lines indicate base case indices while dashed lines are for series to be used in sensitivity analysis. Series are scaled (each series is divided by the mean of the years within that series which overlap between all series) to appear on a common scale.

INDICES COVERAGE MAPS

B. Atlantic Sharpnose Shark

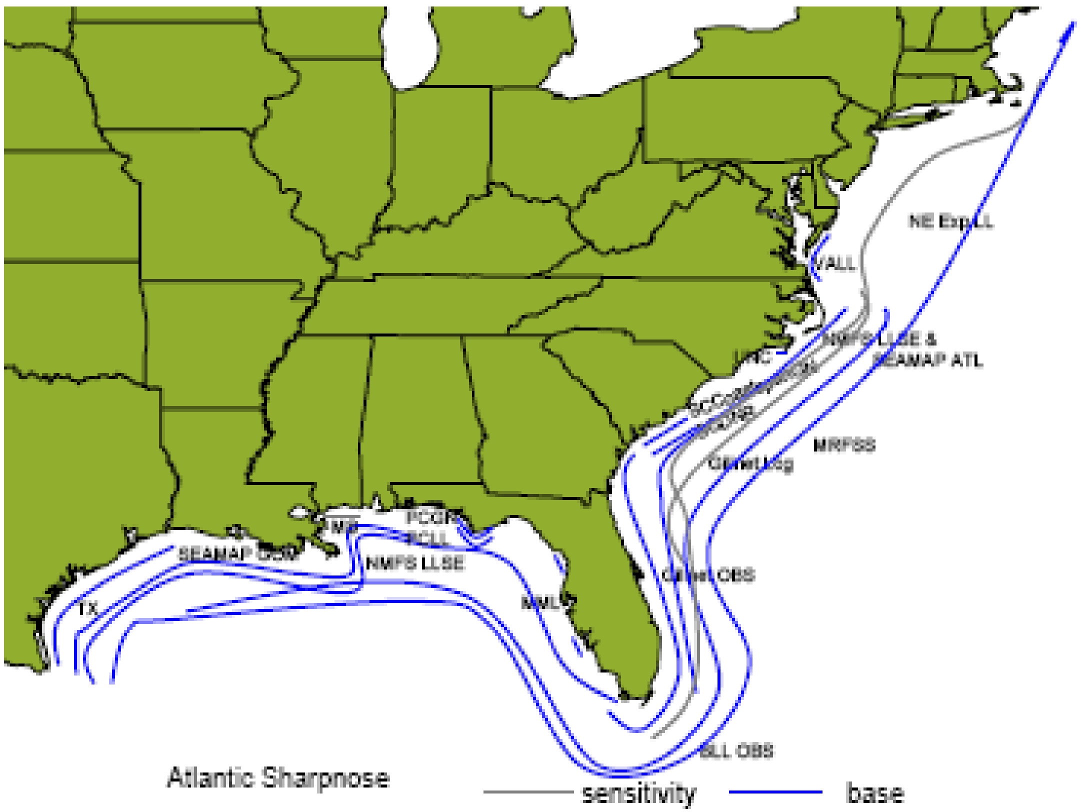
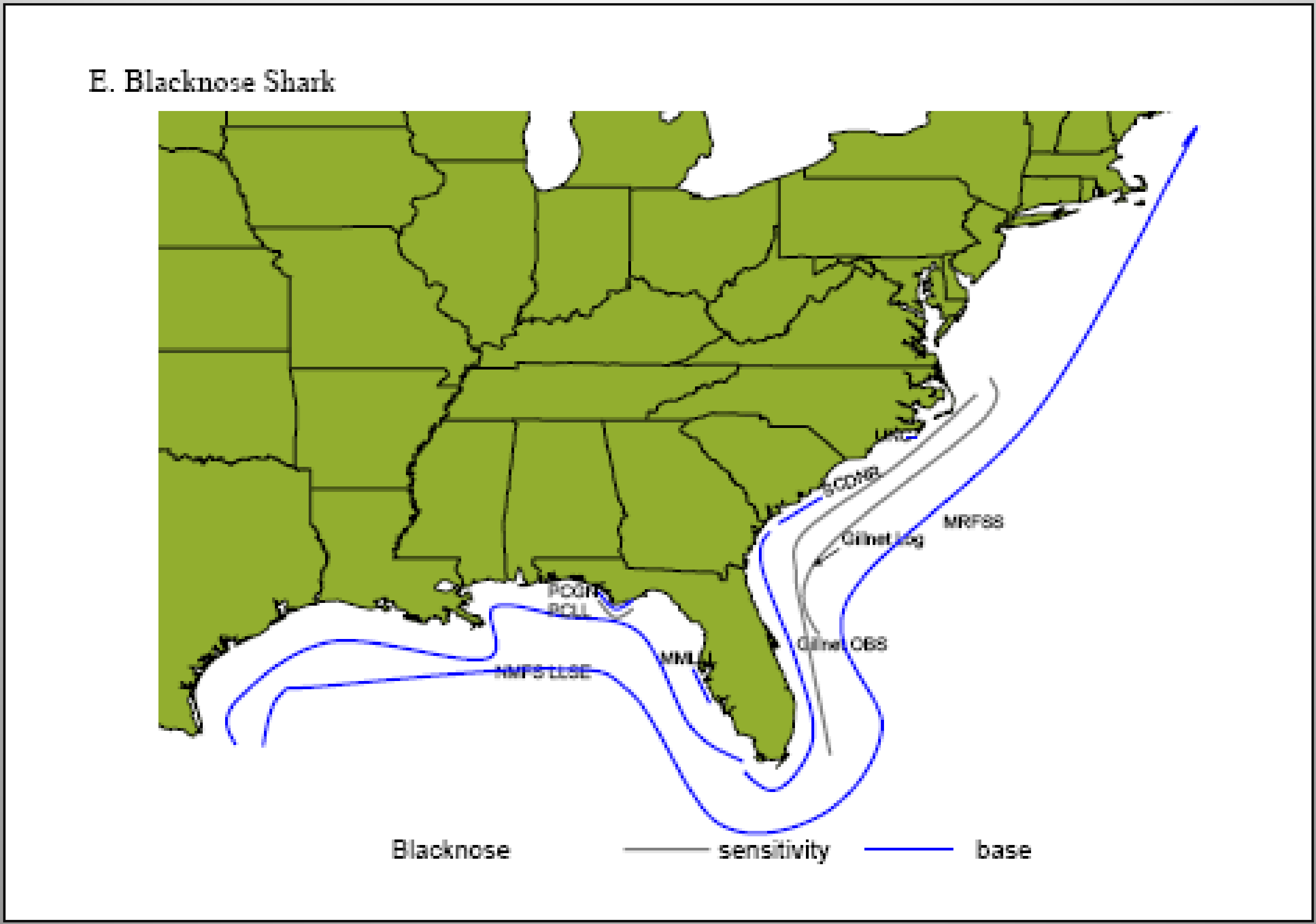


Figure 3.11. General geographic coverage of relative abundance indices reviewed at the Data Workshop.

INDICES COVERAGE MAPS



SEDAR 13

COMPARISONS

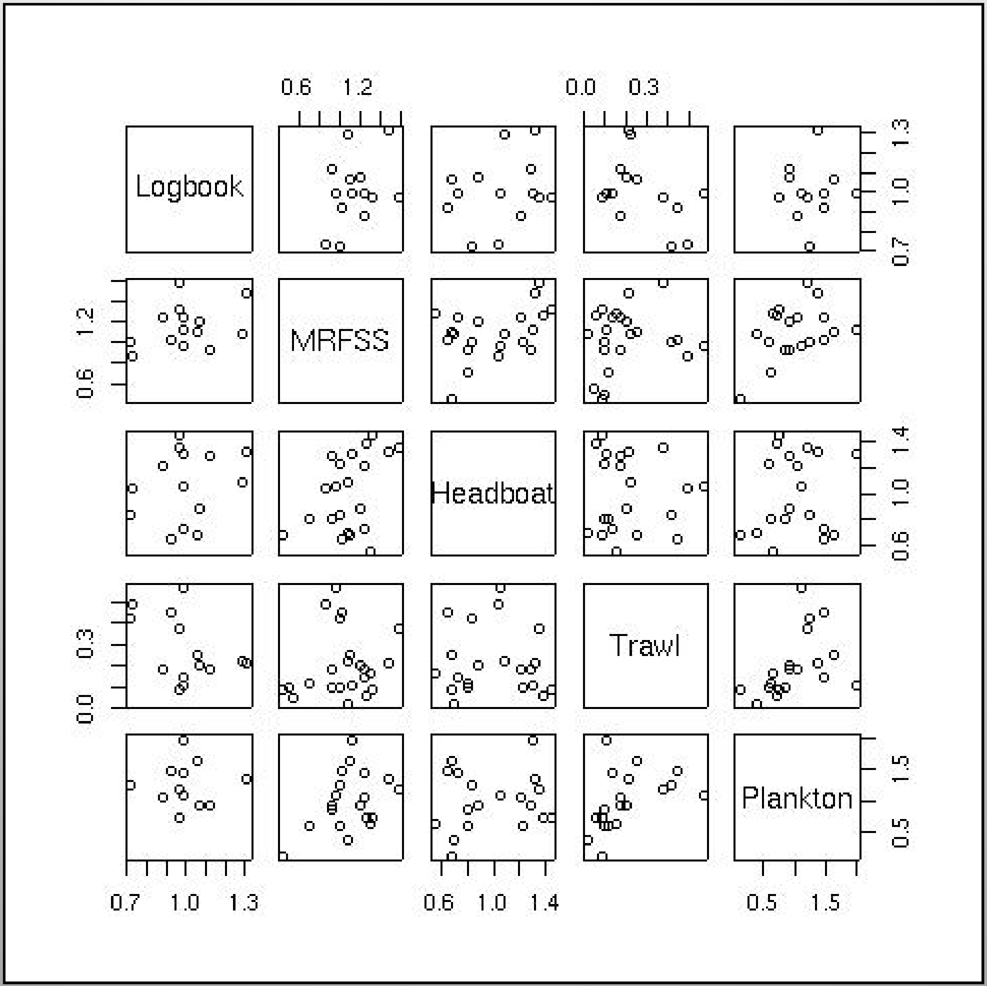


Figure 2.3.1. Pairwise scatterplots of the abundance indices used in fitting the base case for the Gulf of Mexico.