Stock status of the silky shark in the eastern Pacific Ocean

Alexandre Aires-da-Silva, Cleridy Lennert-Cody and Mark Maunder

Comisión Interamericana del Atún tropical
Inter-American Tropical Tuna Commission (IATTC)

4th Meeting of the IATTC Scientific Advisory Meeting
La Jolla, USA, 29 April – 3 May 2013

Outline of talk

- Collaborative work with nations
  - Construction of time series of data for stock assessment
  - Stock Synthesis assessment model (1993-2010)
- Updated fishery indicators (2011-2012)
  - Standardized CPUE trends
- Summary Conclusion

Collaborative work with nations

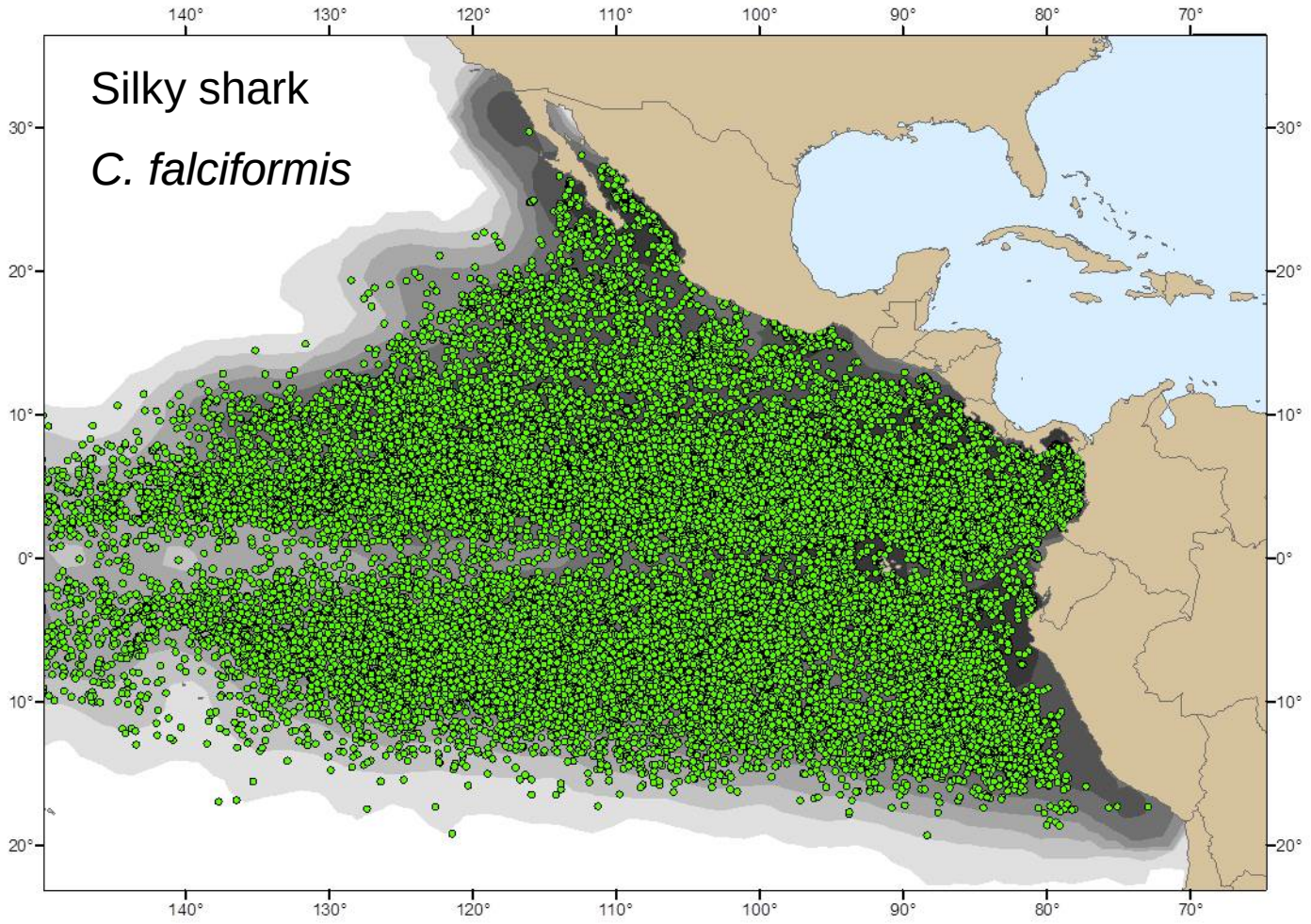
- 1st Meeting (Nov 2009)
  - Strengthen collaborative work
  - Silky shark as 1st candidate for stock assessment
- 2st Meeting (May 2011)
  - Identify silky shark data sources available
- 3st Meeting (December 2011)
  - Discuss progress on data and modeling efforts
- 4th Meeting (February 2013)
  - Preliminary Stock Synthesis model presented
  - Received input from collaborators

Biology

- Stock-structure (life-history and genetics)
- Length-weight
- Growth
- Reproduction (maturity, fecundity and frequency)
- Natural mortality

Silky spatial distribution in EPO

bycatch of purse seine tuna fisheries



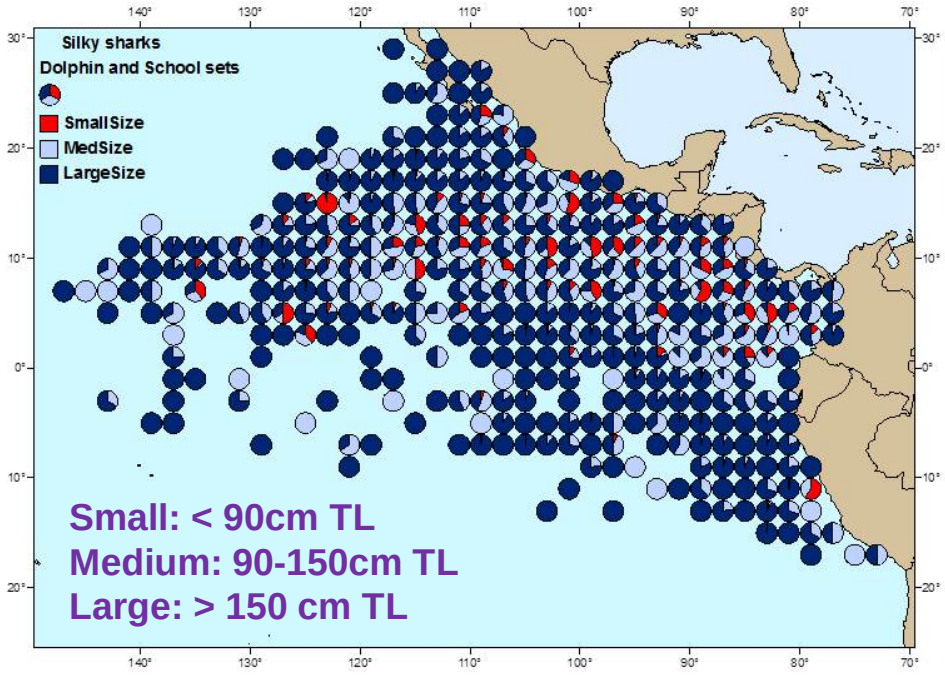
1993-present

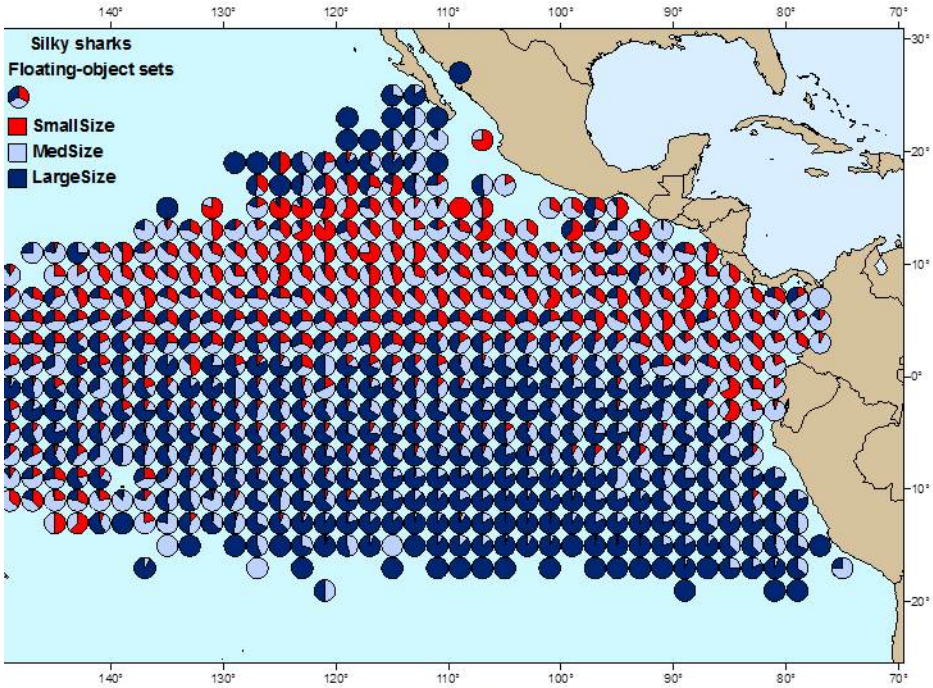
Silky spatial distribution by stage

bycatch of purse seine tuna fisheries

School and dolphin sets

Floating object sets





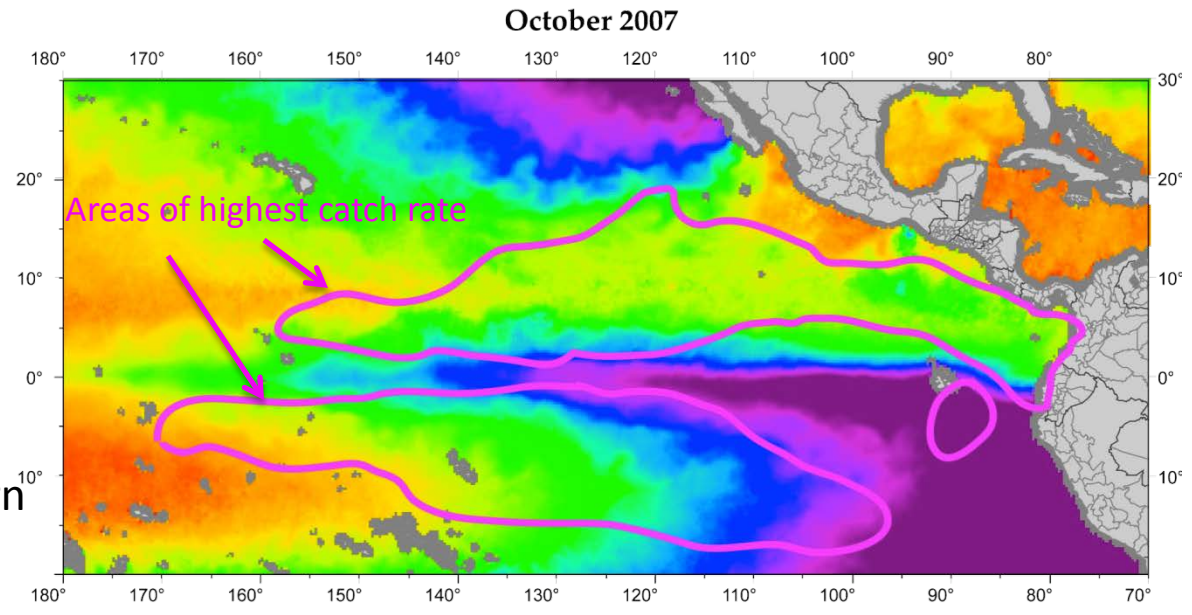
Roman-Verdesoto and Orozco-Zoller, 2005

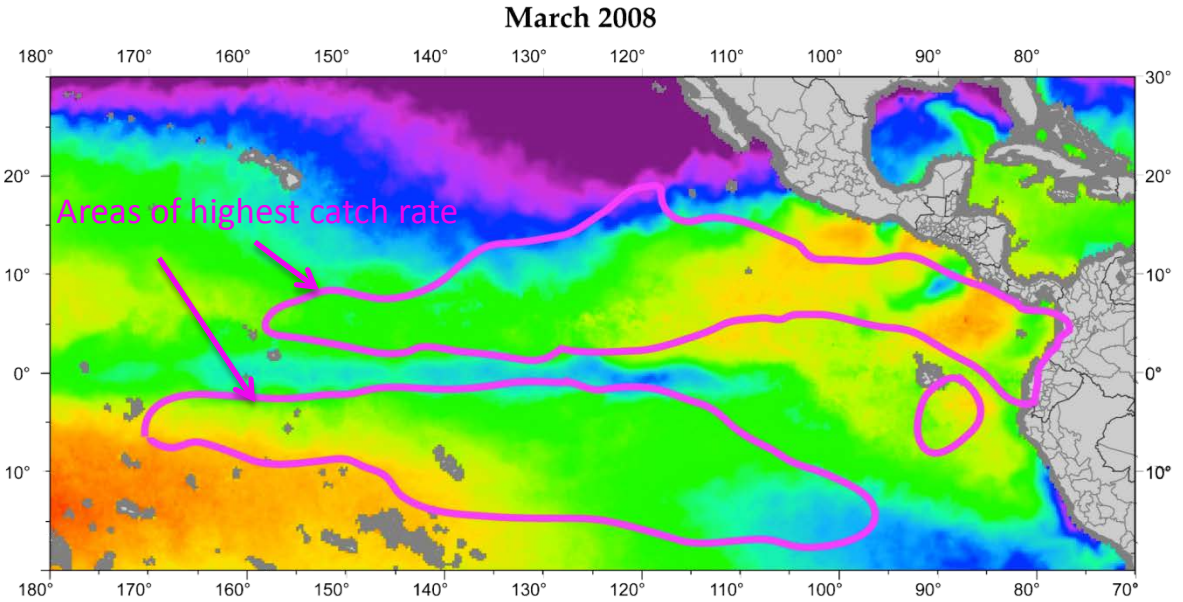
Conclusions

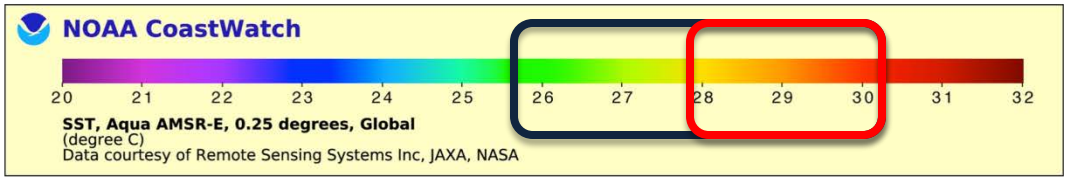
- Weak N – S structure
- Animals south of the equator and near the S. American coast most closely allied with Northern animals
  - Seasonal overlap?

Future directions?

- More satellite tagging
- More samples from central and western South Pacific

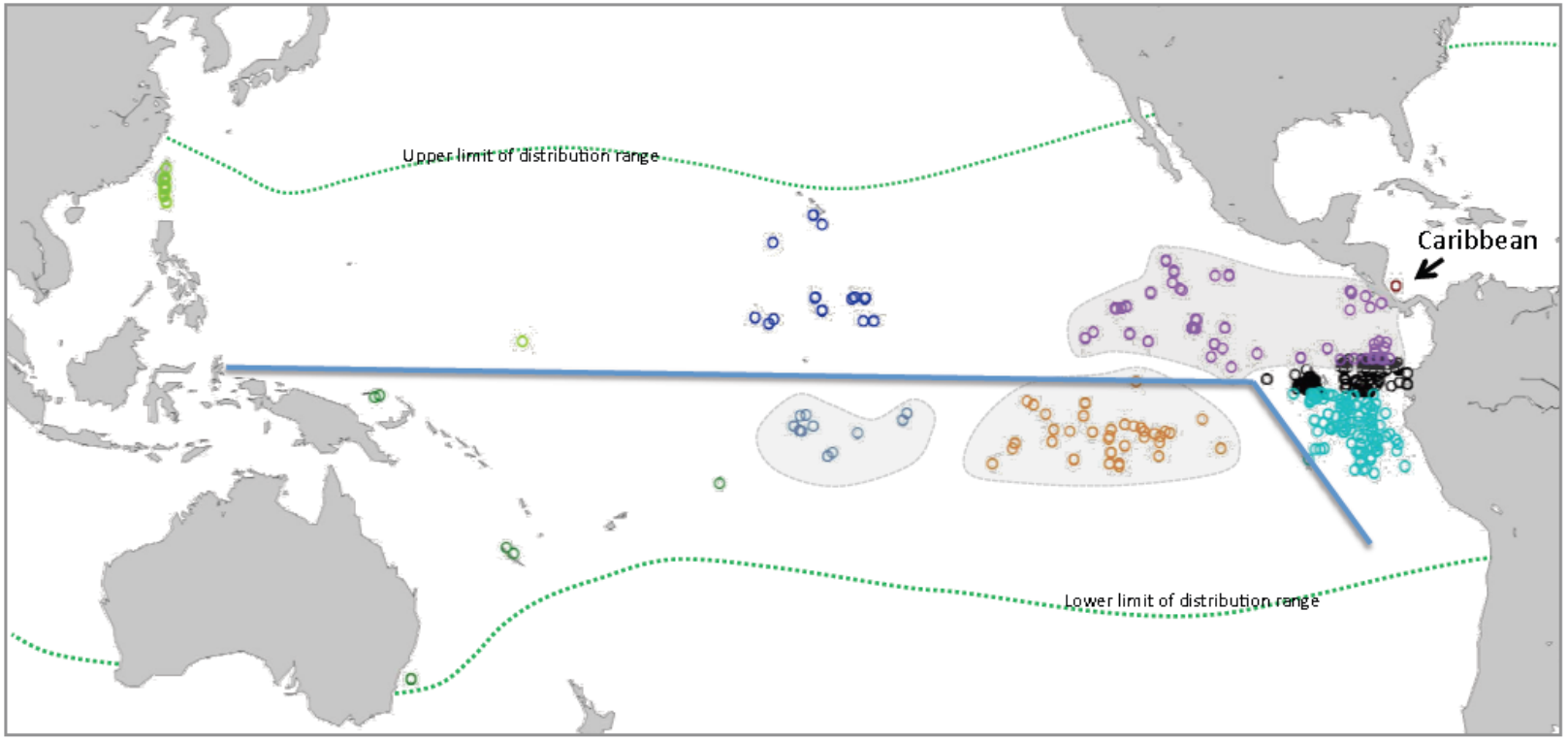






Source: John Hyde, NOAA-NMFS

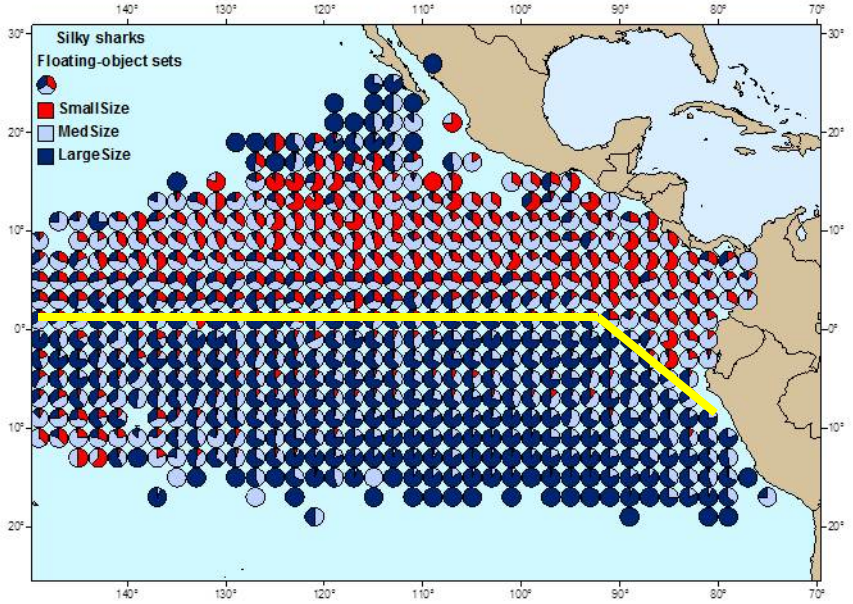
Sample distribution and hypothesized stock boundary

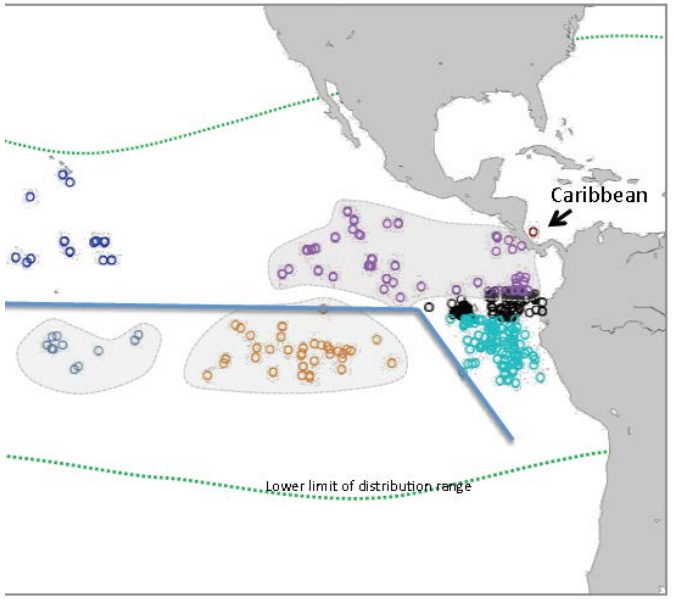


Source: John Hyde, NOAA-NMFS

Stock assessment

- Northern Stock
  - Stock Synthesis model and fishery indicators (standardized CPUE and average sizes)
- Southern Stock
  - Fishery indicators: standardized CPUE





Length-weight relationship

FISHERIES SCIENCE 2003; 69: 456–464

Age and growth of the silky shark *Carcharhinus falciformis* from the Pacific Ocean

SHUNGO OSHITANI,[1] HIDEKI NAKANO[2] AND SHO TANAKA[1]

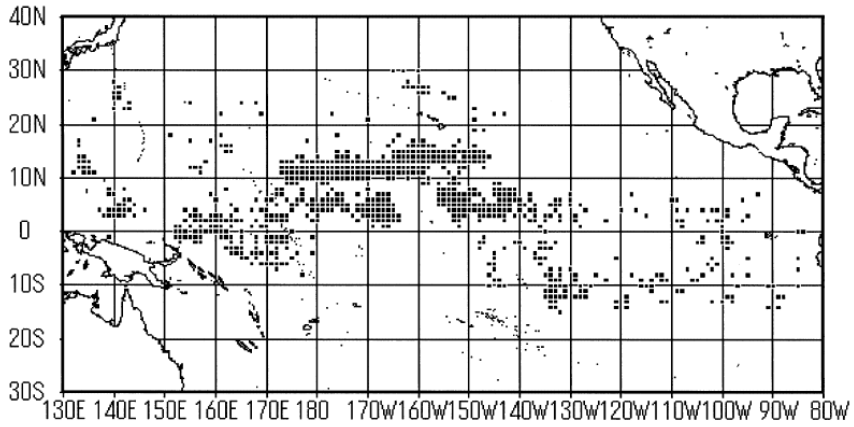
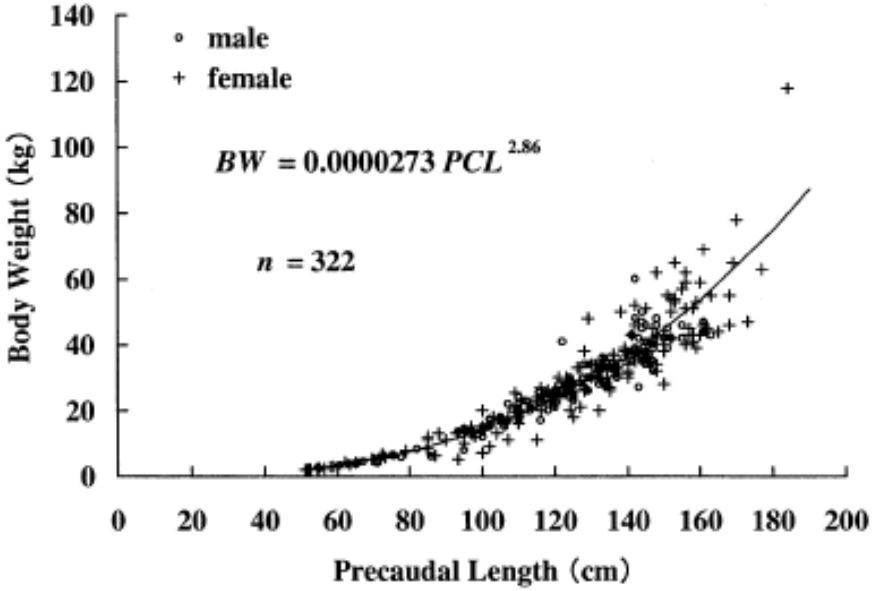
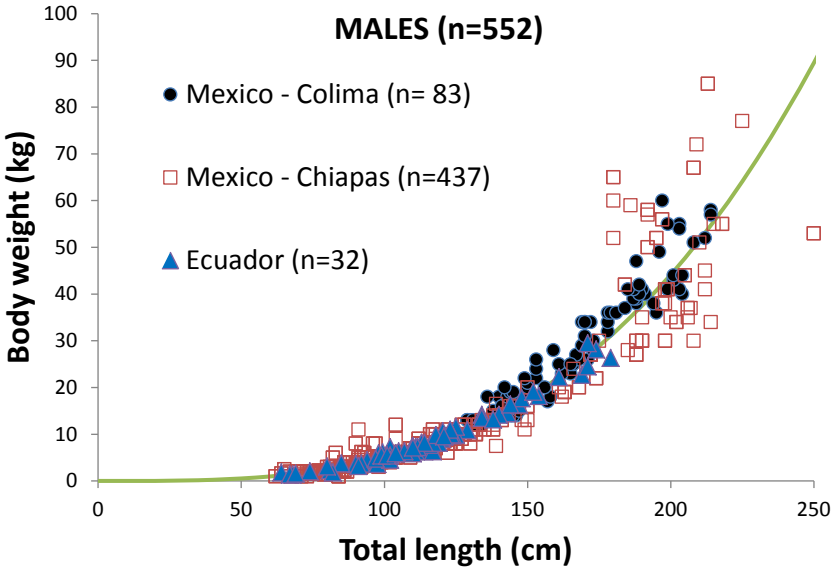
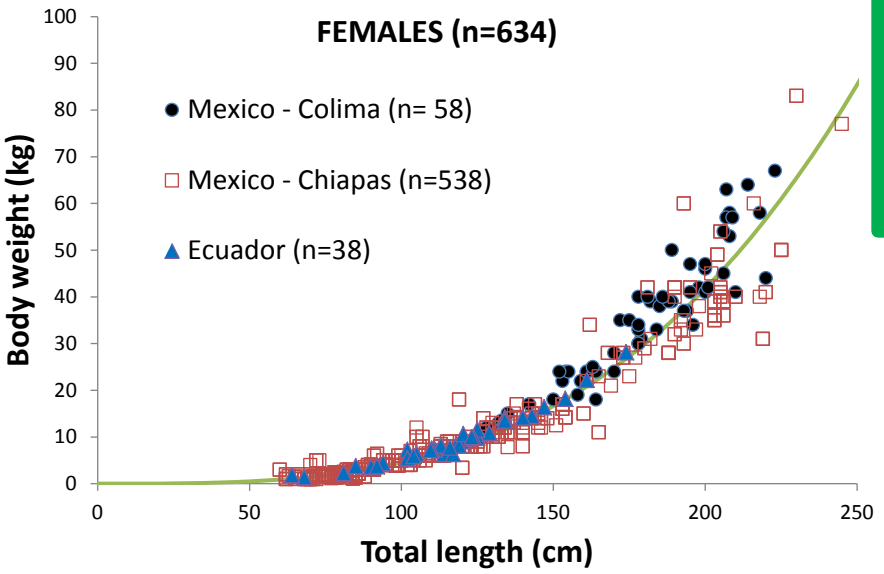


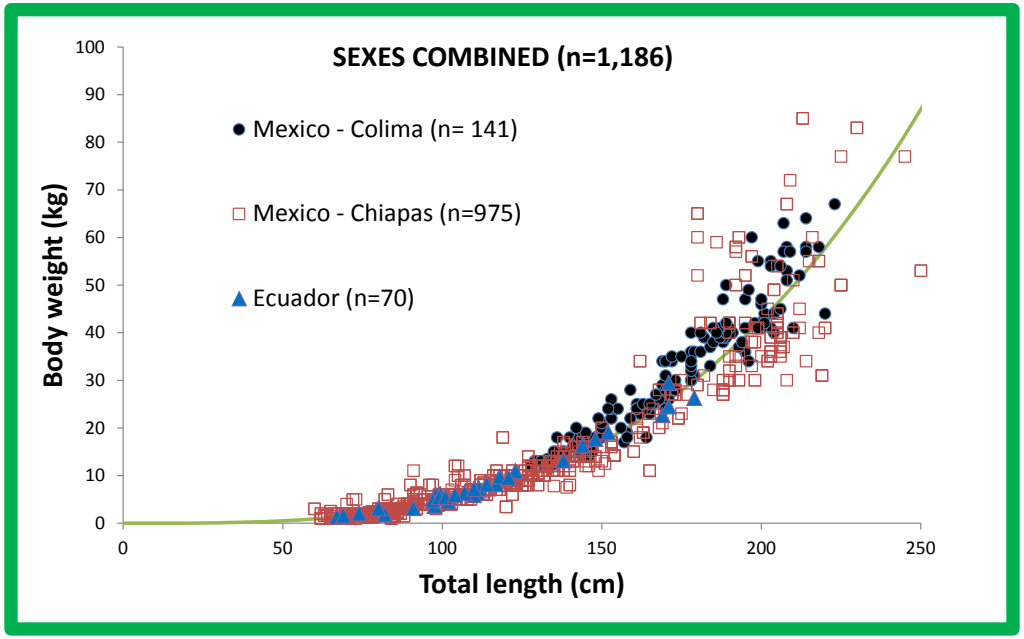
Fig. 1 Locations of sampling during the research cruise.



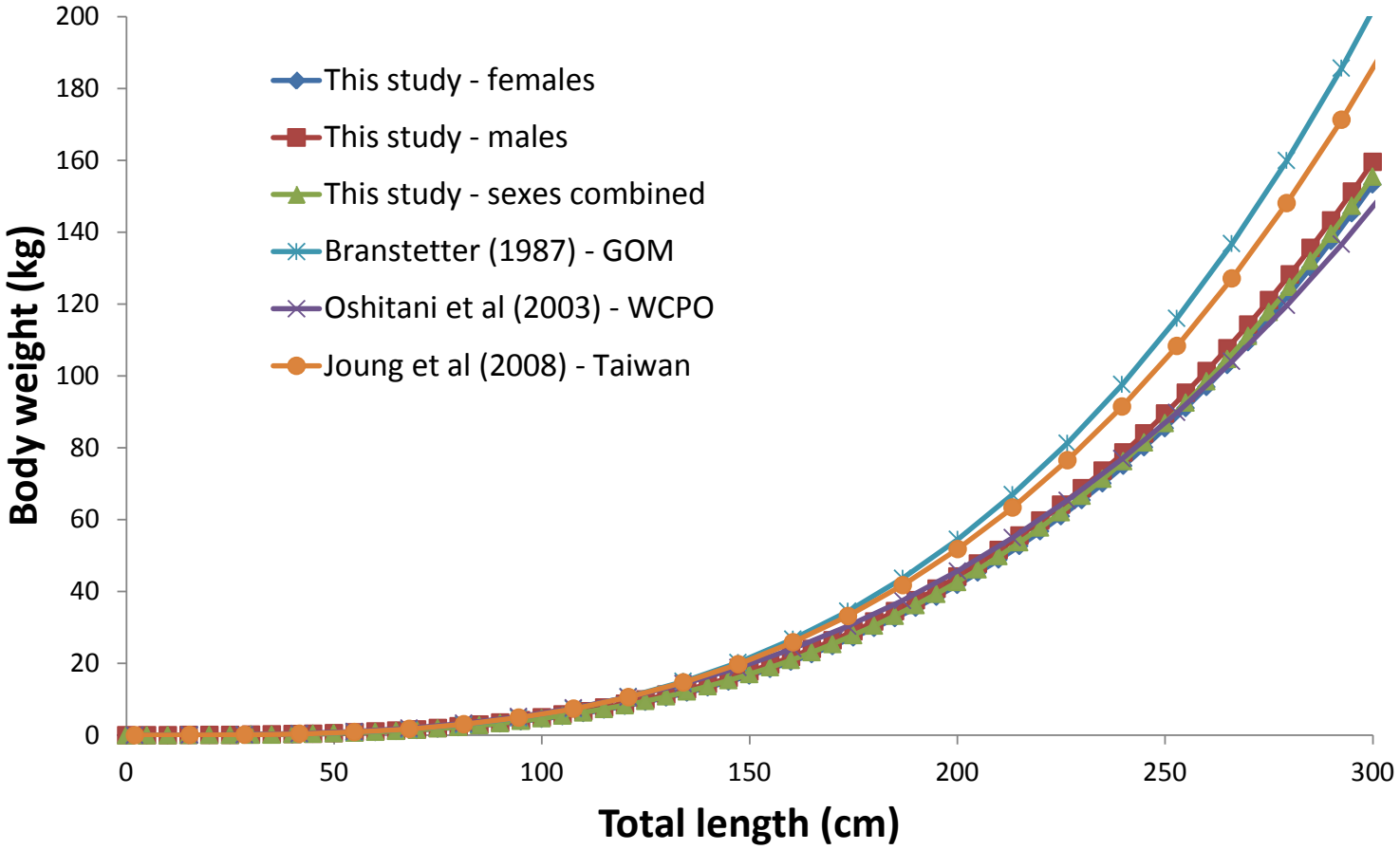
Length-weight relationship





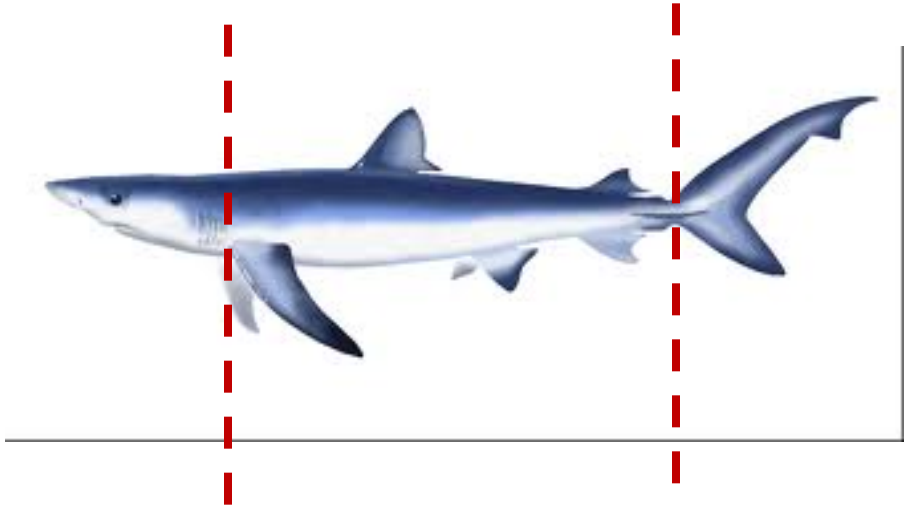


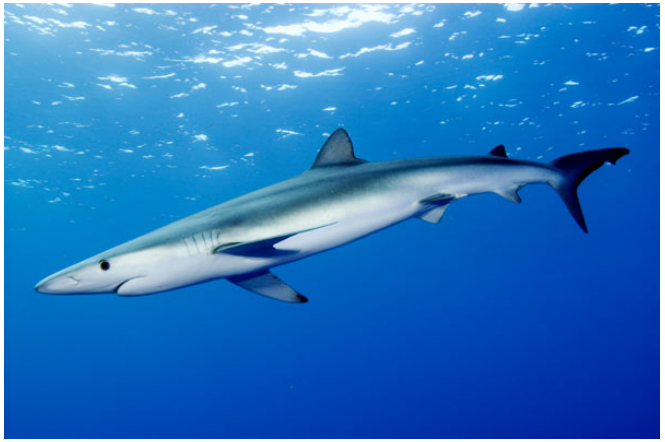
Length-weight relationship



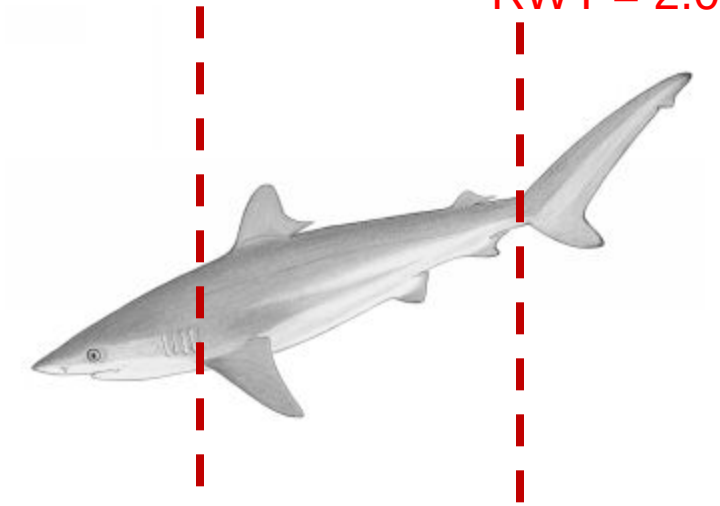
Convert from H&G to WT?

LWT = 2.4 * DWT (J. Mejuto, pers. com.)

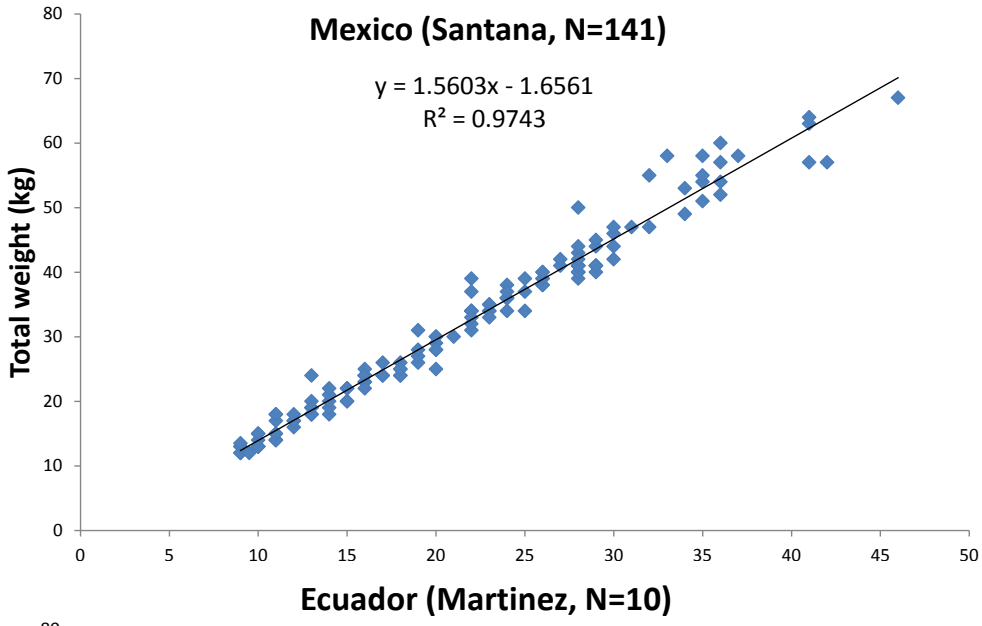


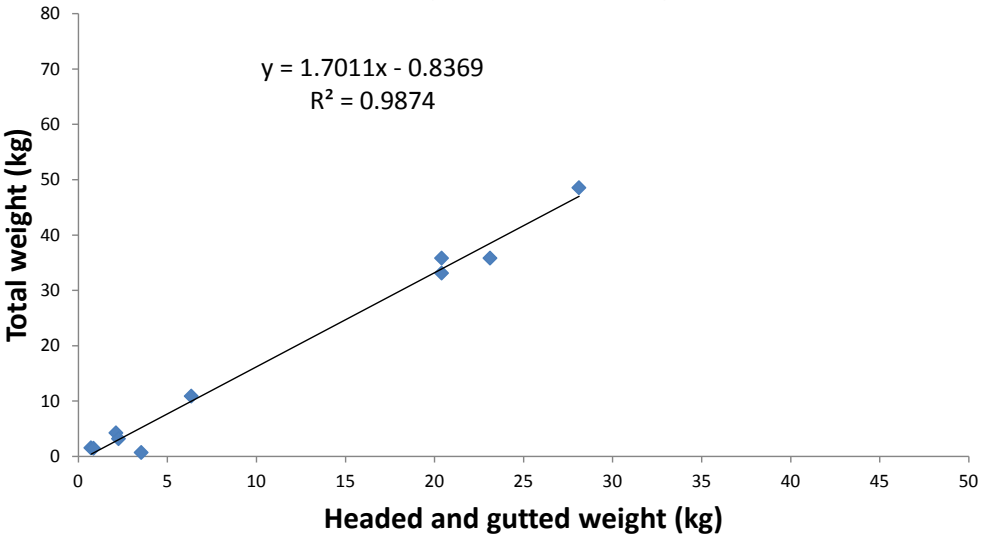


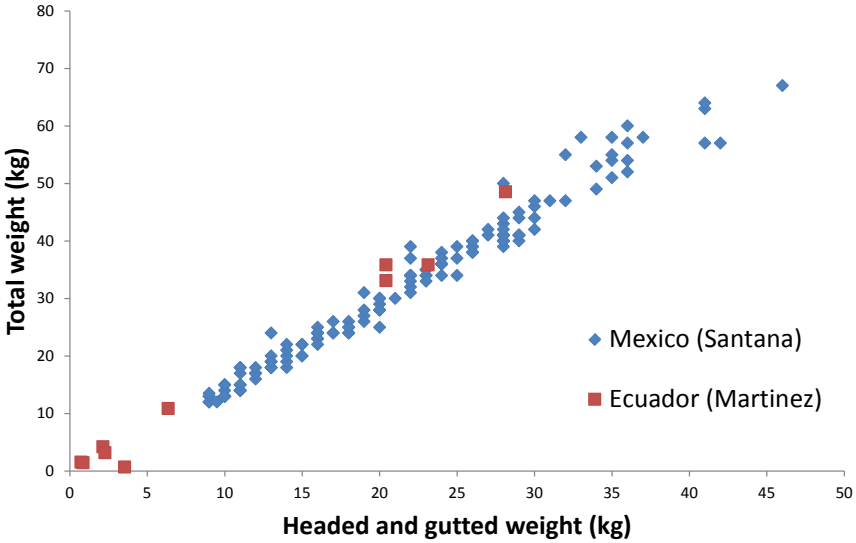
RWT = 2.0-3.0 * DWT



Convert from H&G to WT







Age and growth

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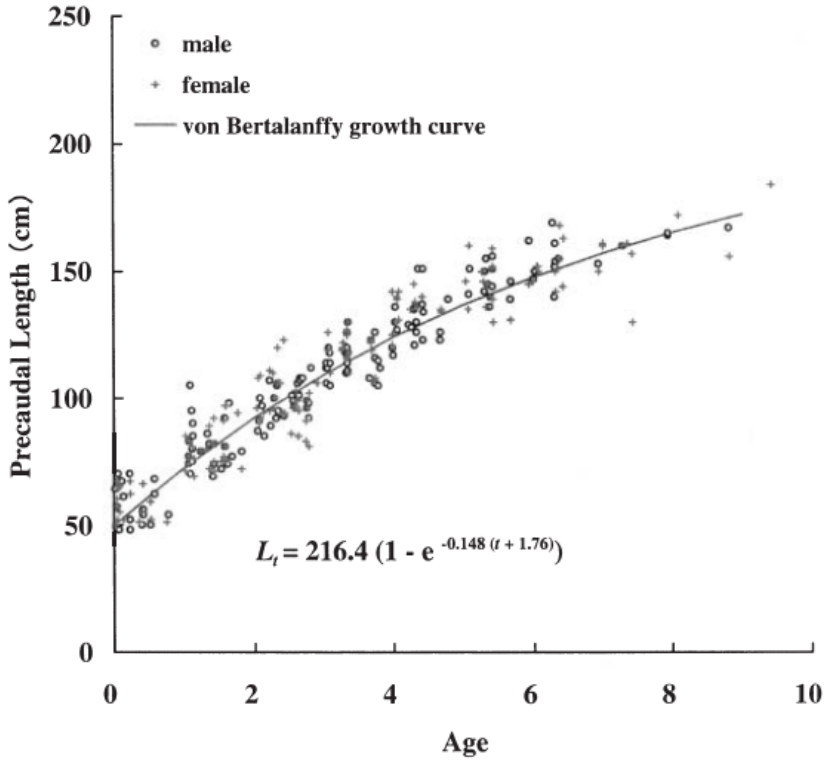

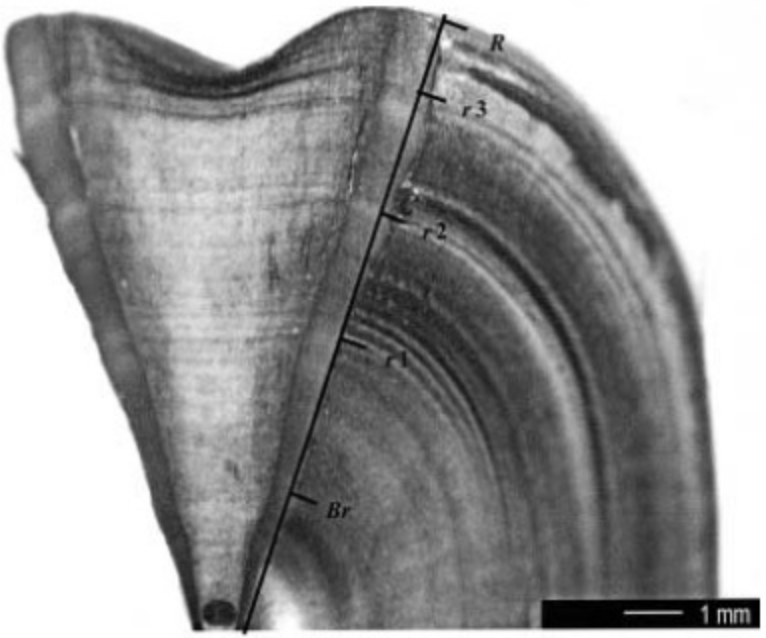

Age and growth (cont.)

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Age and growth of the silky shark *Carcharhinus falciformis* from the west coast of Baja California Sur, Mexico

By J. A. Sánchez-de Ita, C. Quiñónez-Velázquez, F. Galván-Magaña, N. Bocanegra-Castillo and R. Félix-Uraga

Centro Interdisciplinario de Ciencias Marinas, Col. Playa Palo de Santa Rita, La Paz, Baja California Sur, México

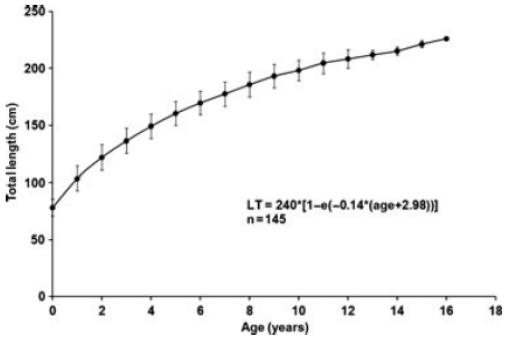
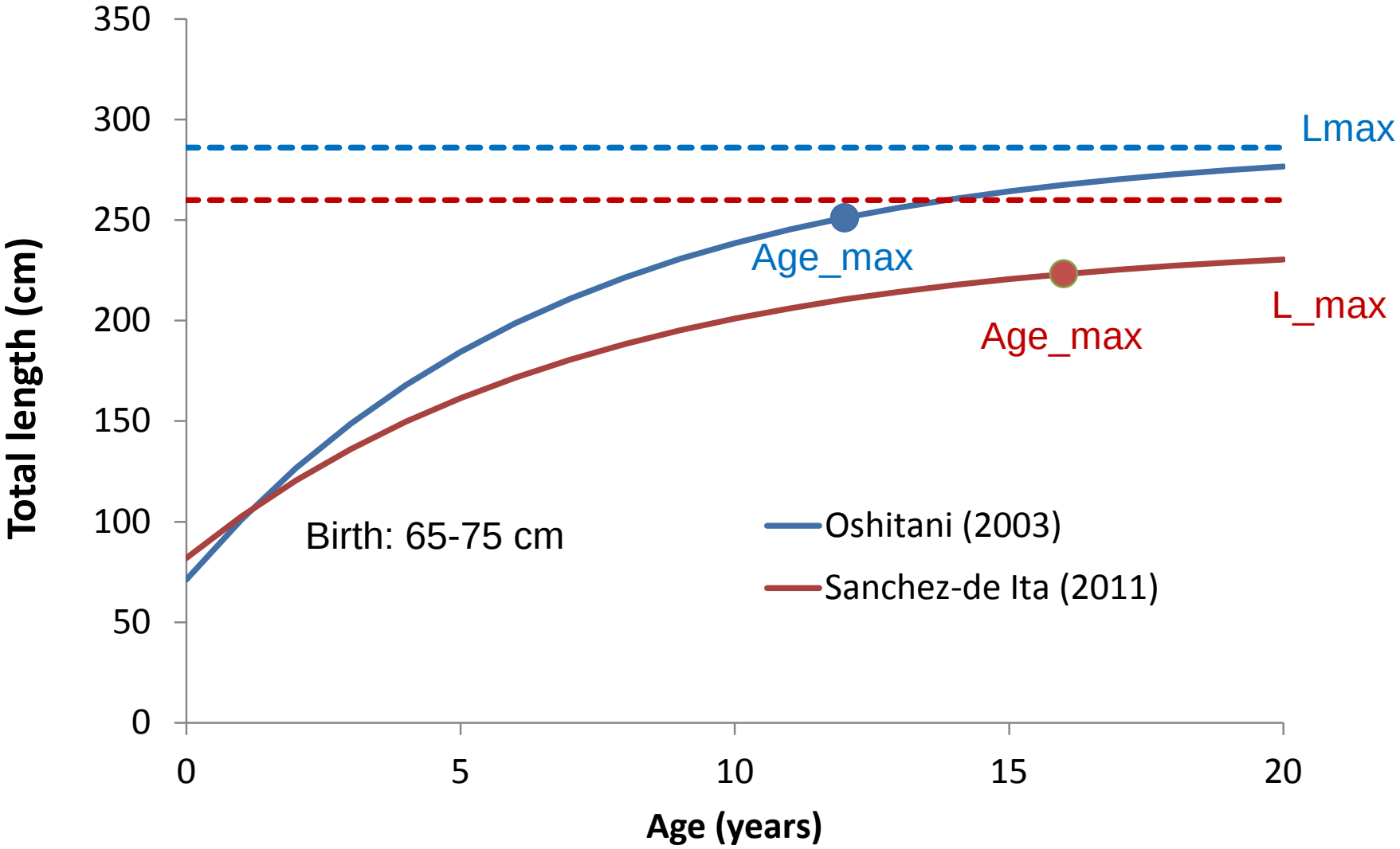
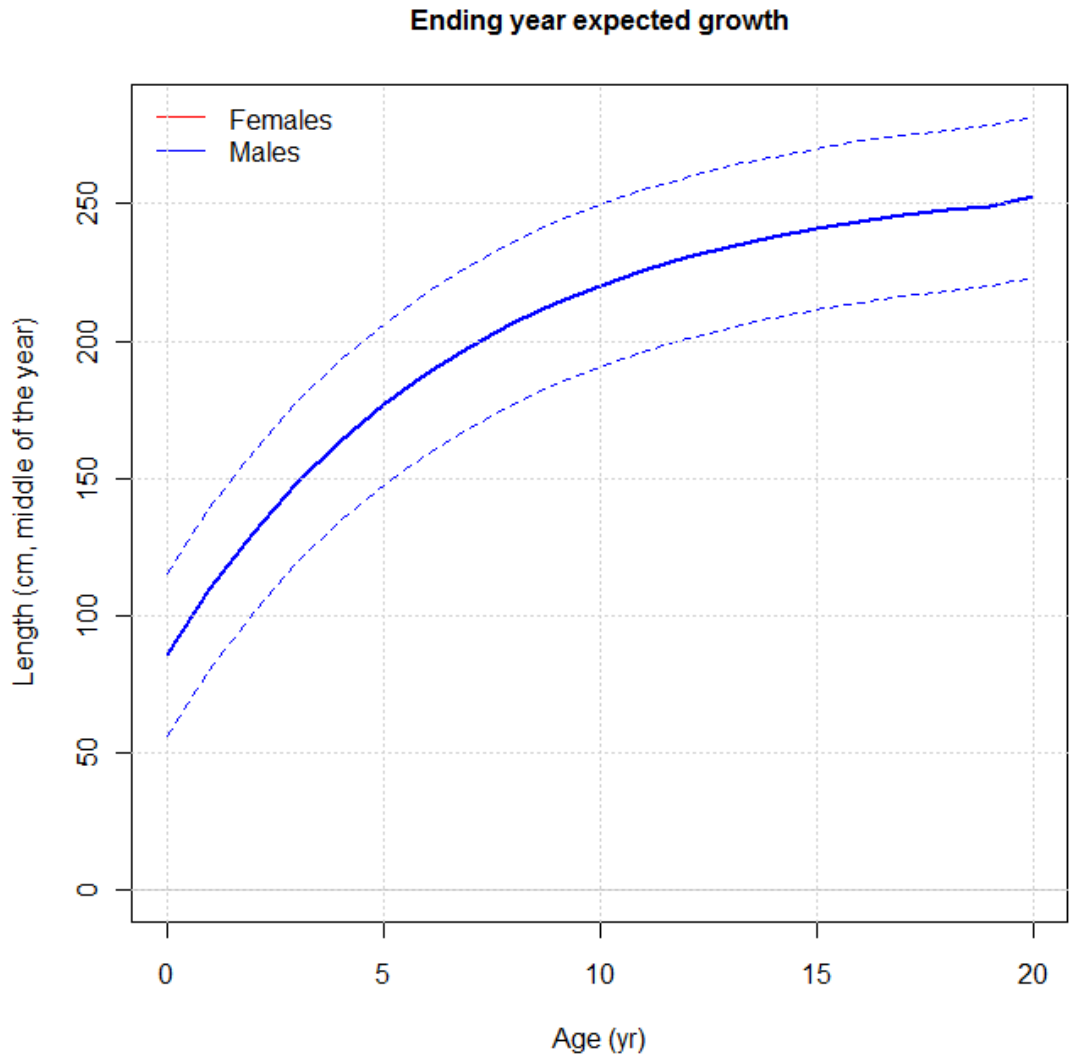


Fig. 6. Von Bertalanffy growth curve constructed with back-calculated data for *Carcharhinus falciformis*, sexes combined. Dots, mean length at age; vertical lines, standard deviation; n, number of total sample size

Age and growth (cont.)



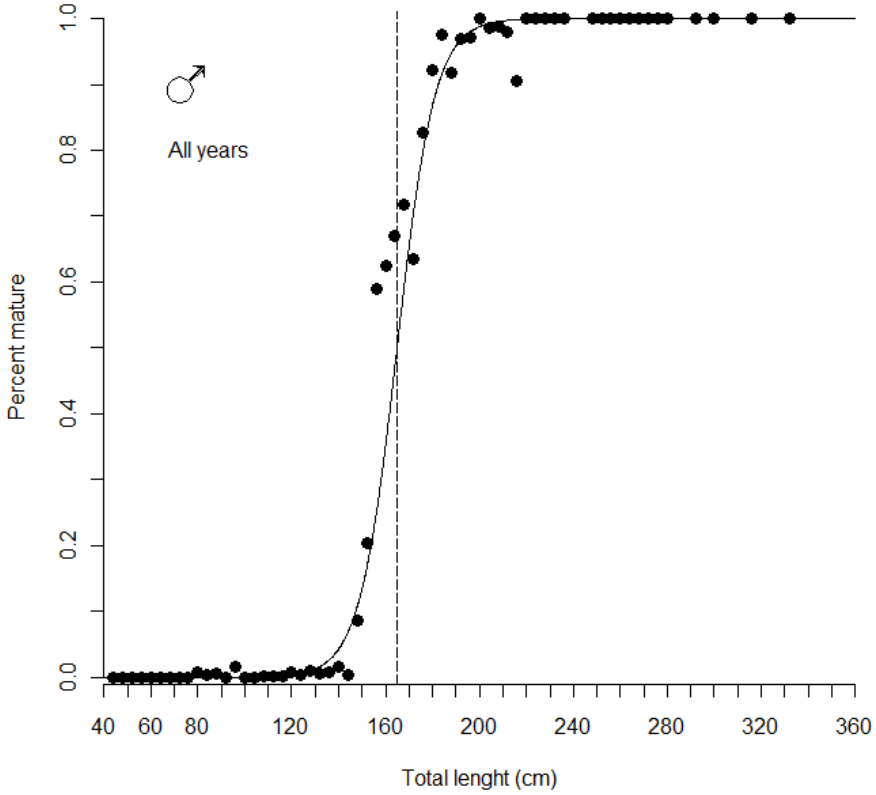
Variability of length-at-age



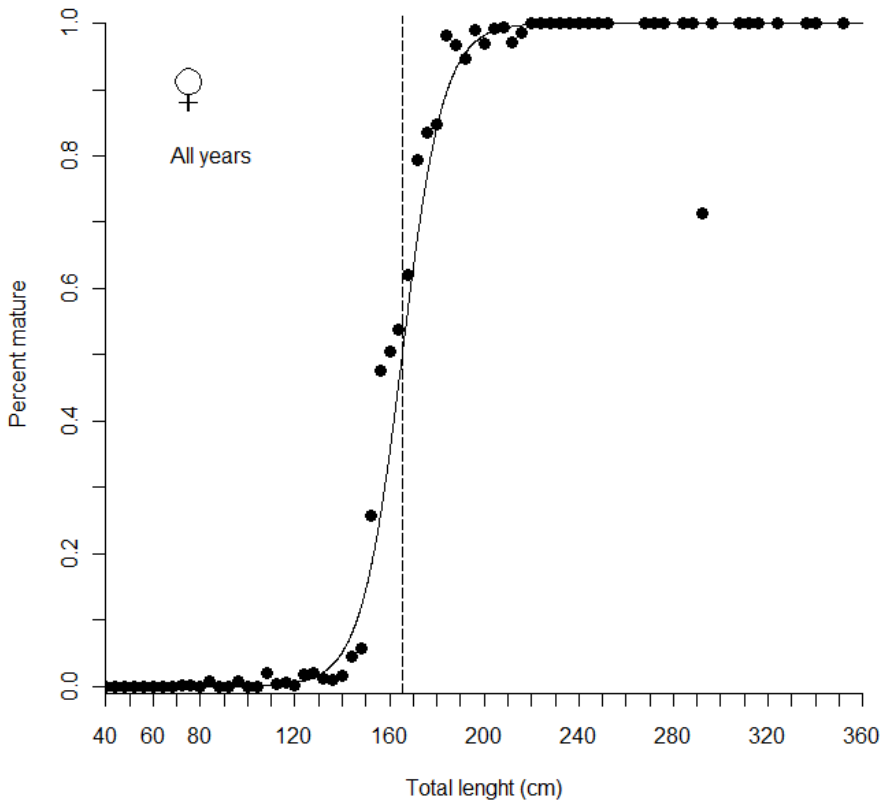
Maturity-at-length

CHIAPAS (Soriano-Castillo)

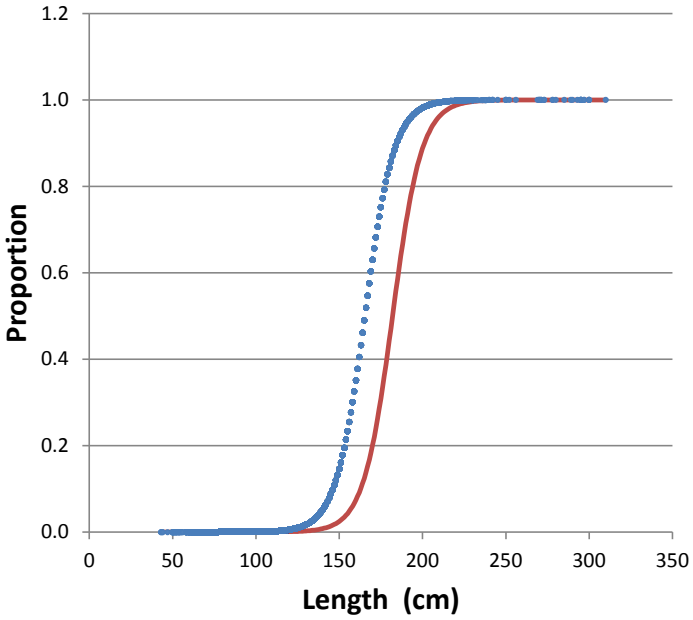
N=11,094



N=11,354



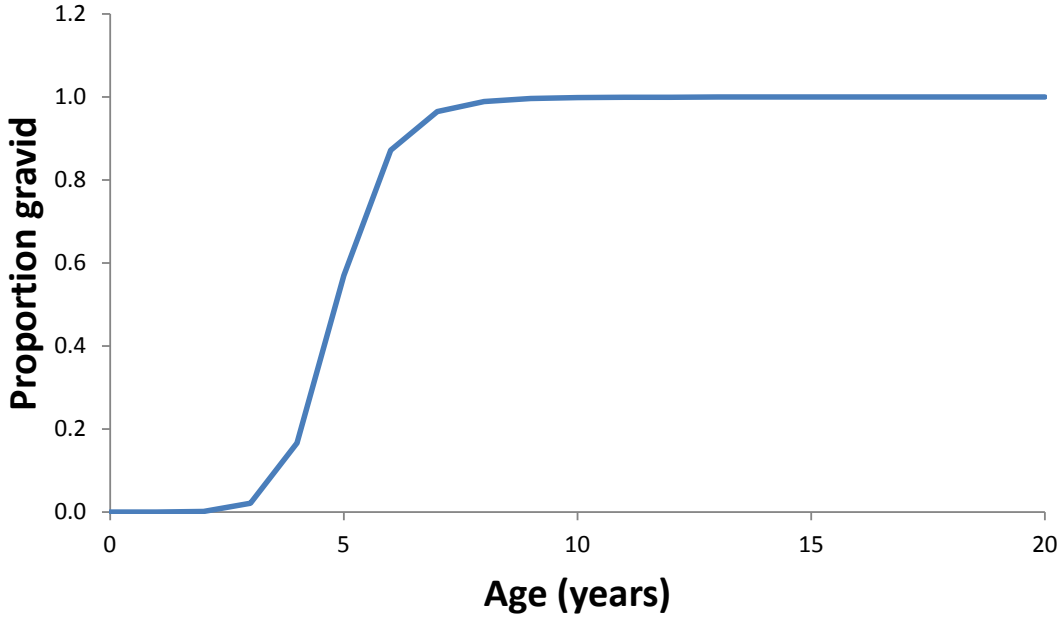
Maturity-at-length



L50=182 cm

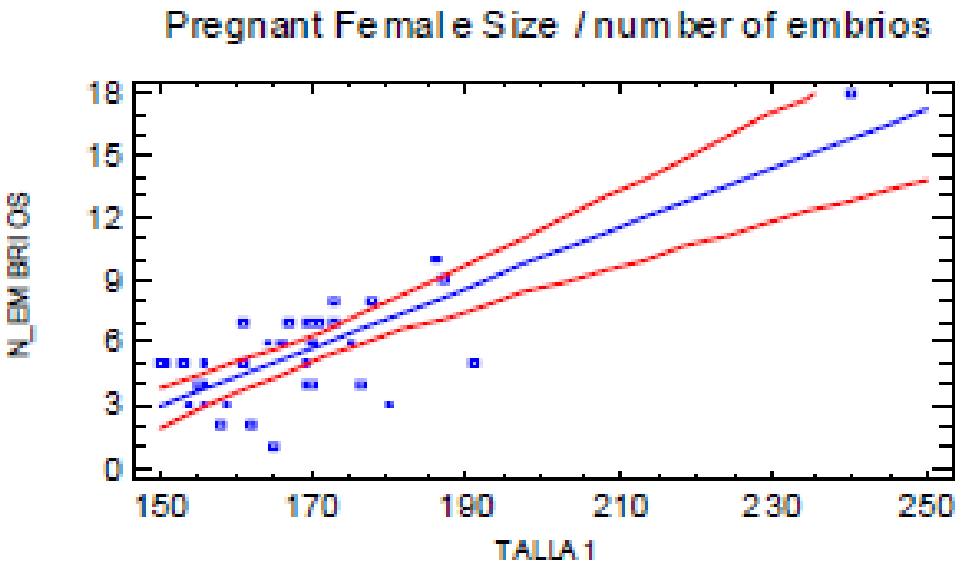
Maturity

Pregnancy



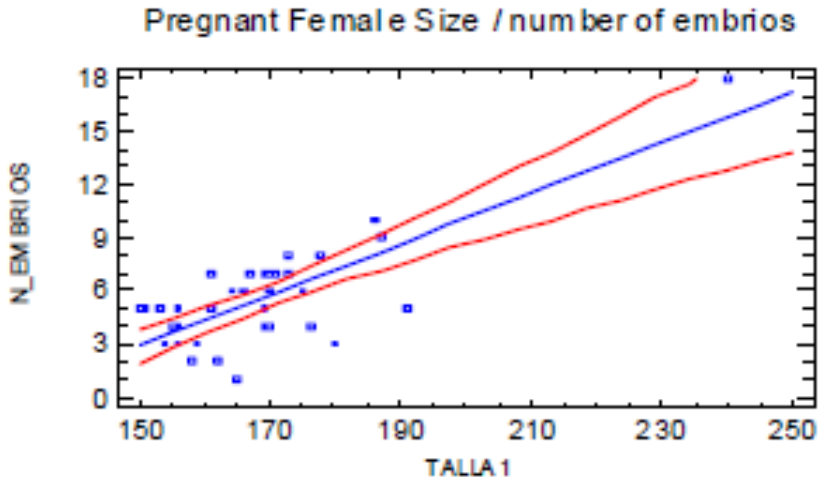
Fecundity

- Low fecund species
  - 2-16 pups (average of 6)
  - Reproductive cycle 1-2 years
  - 1:1 sex ratio at birth

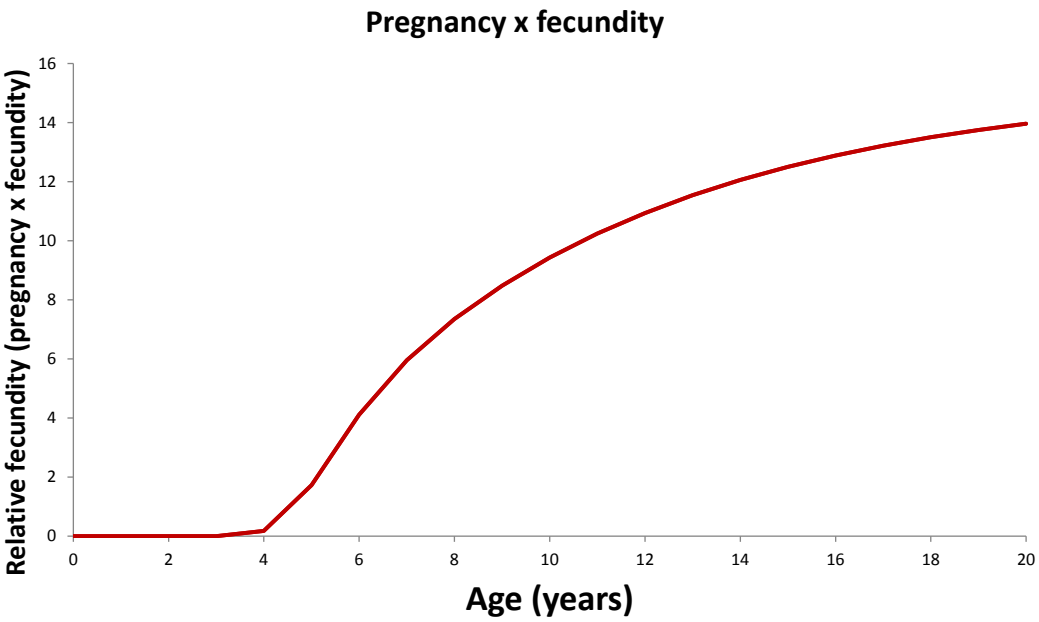


Garcia-Cortés et al.

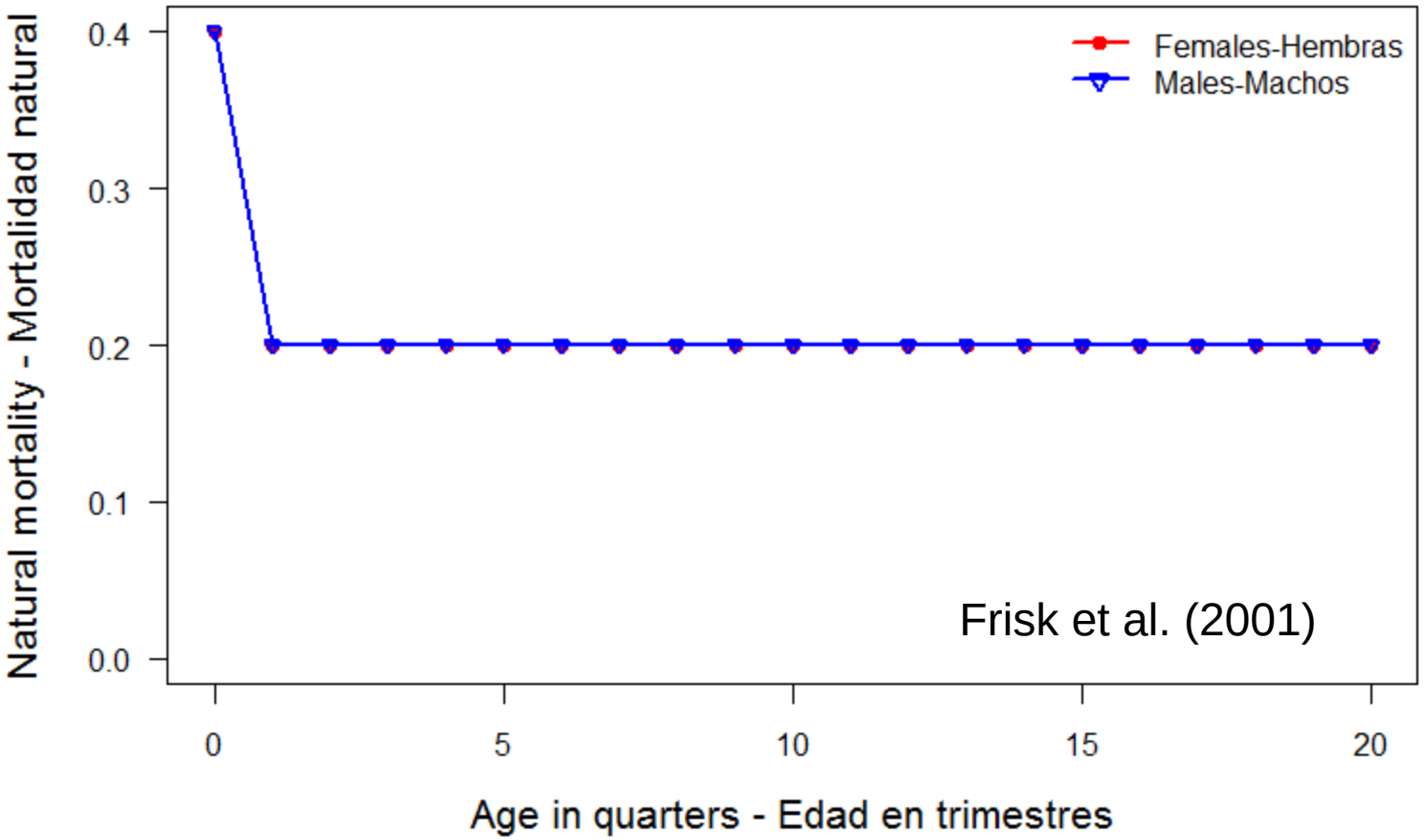
Maturity x Fecundity



Garcia-Cortés et al.



Natural mortality (M)



Fishery data

- Catch
- Indices of abundance (CPUE)
- Composition (age, length, stage/sex)

Fisheries catching FAL in EPO

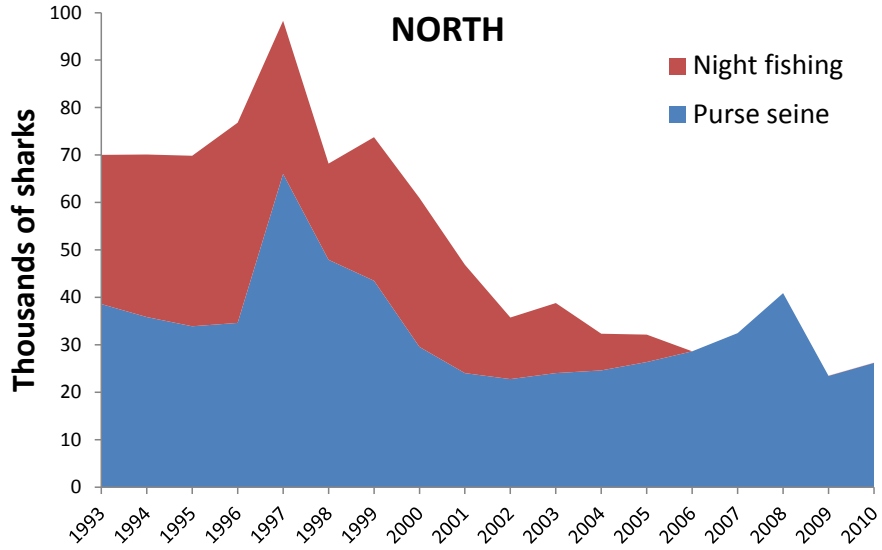
- Tuna purse seine fleets
  - Bycatch
  - Night fishing

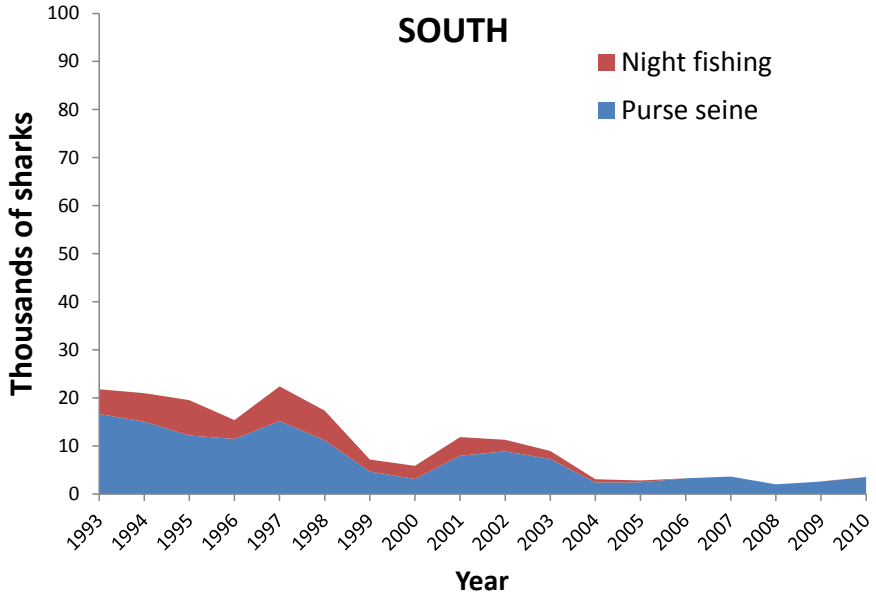
- Tuna longline fleets
  - Bycatch
  - High-seas Asian fleets

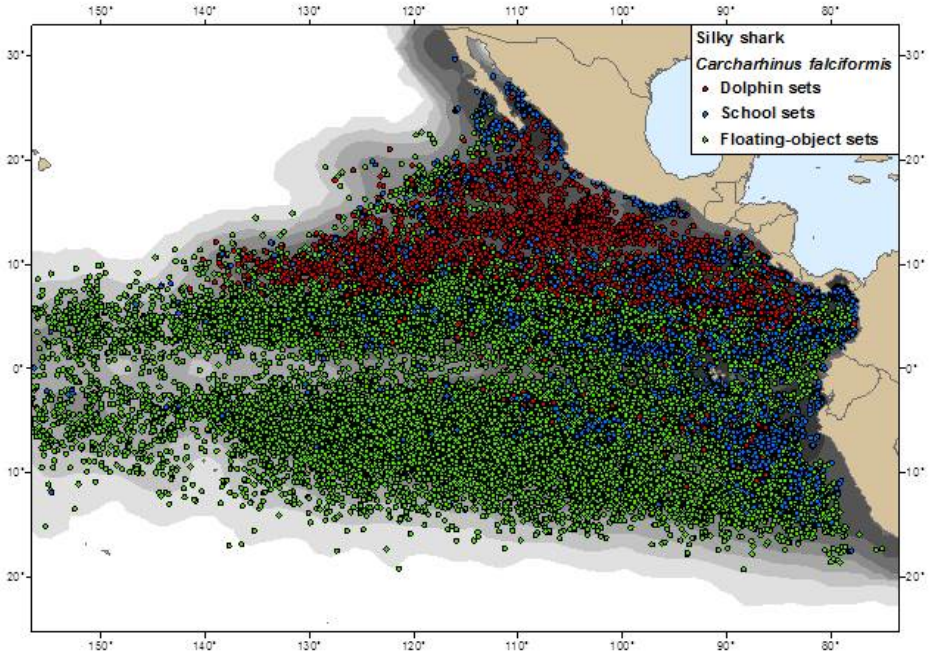
- Shark-billfish-tuna longline fleets
  - Target/bycatch, but sharks dominate
  - EPO coastal, non-coastal (flagged) fleets
  - Medium to large-size vessels

- EPO “coastal” artisanal fisheries
  - Bycatch/target
  - Muti-gear (longline

Catches – Purse seine

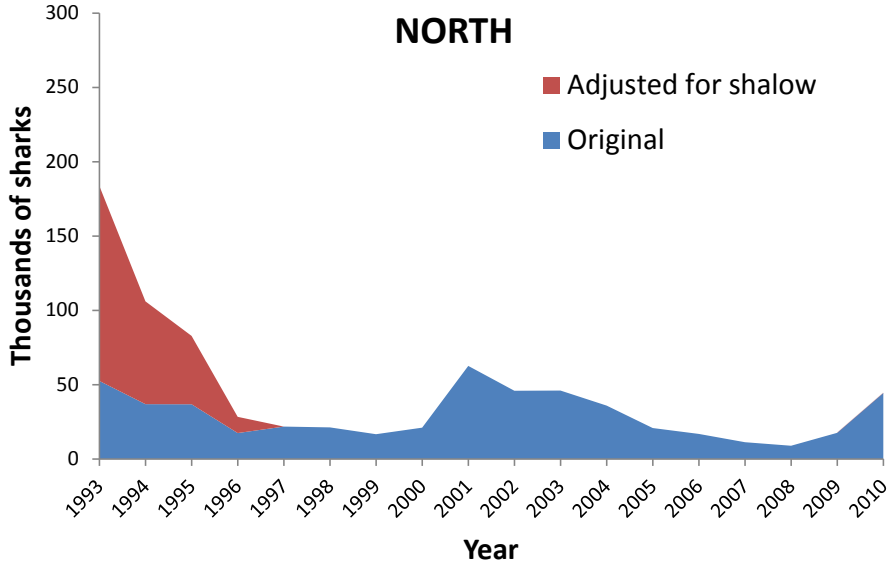


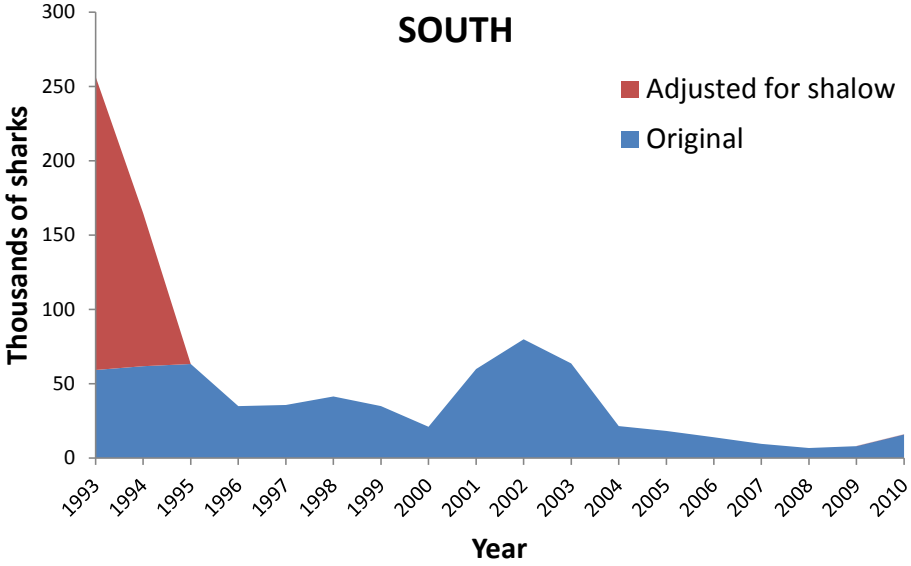


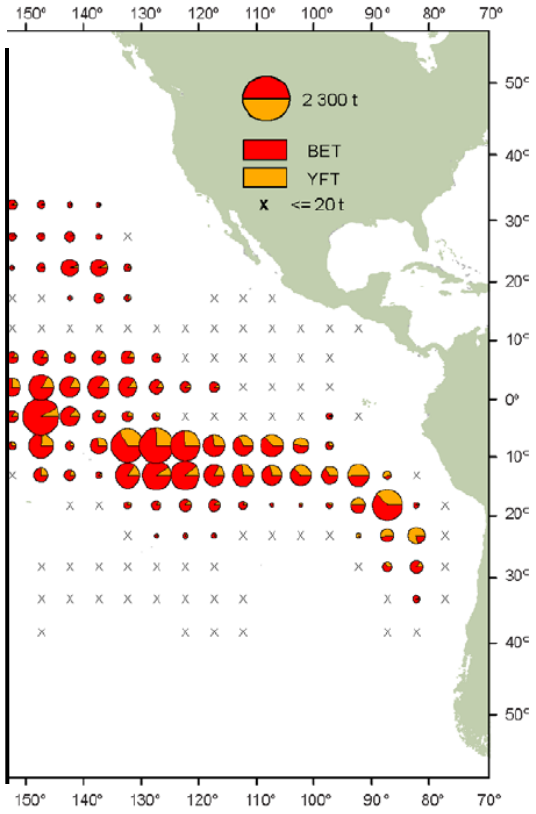


Night fishing assumptions: based on observer information

Catches – tuna longline



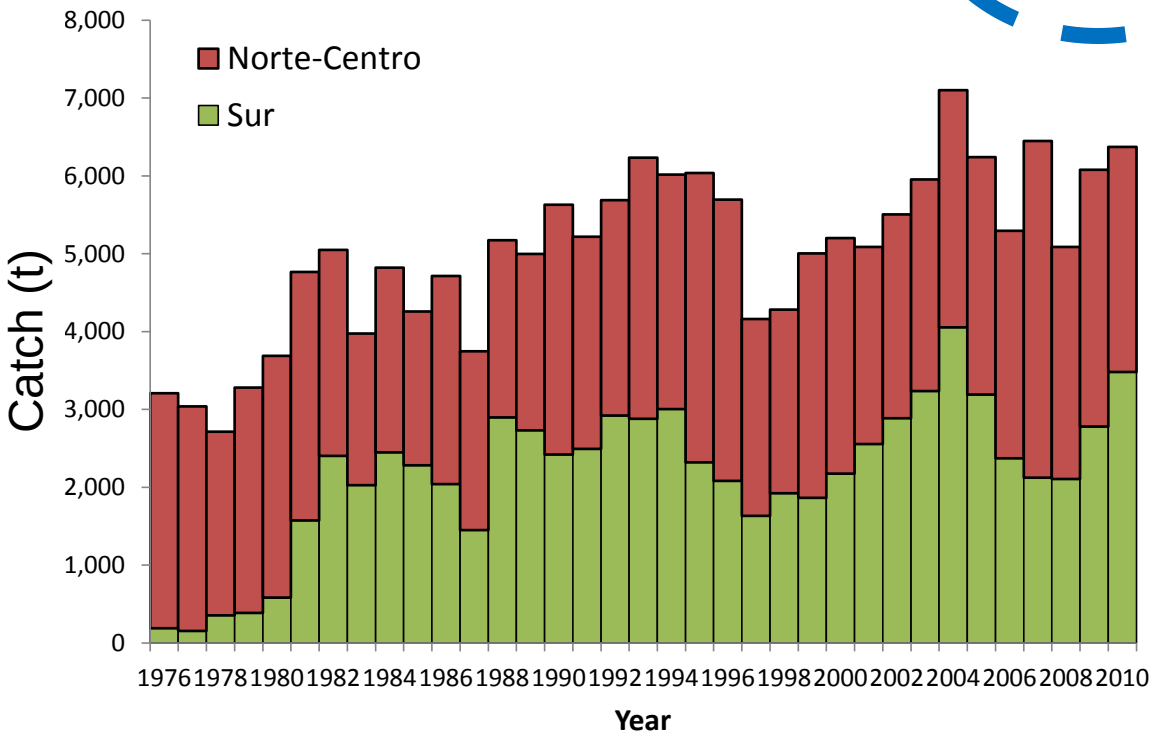


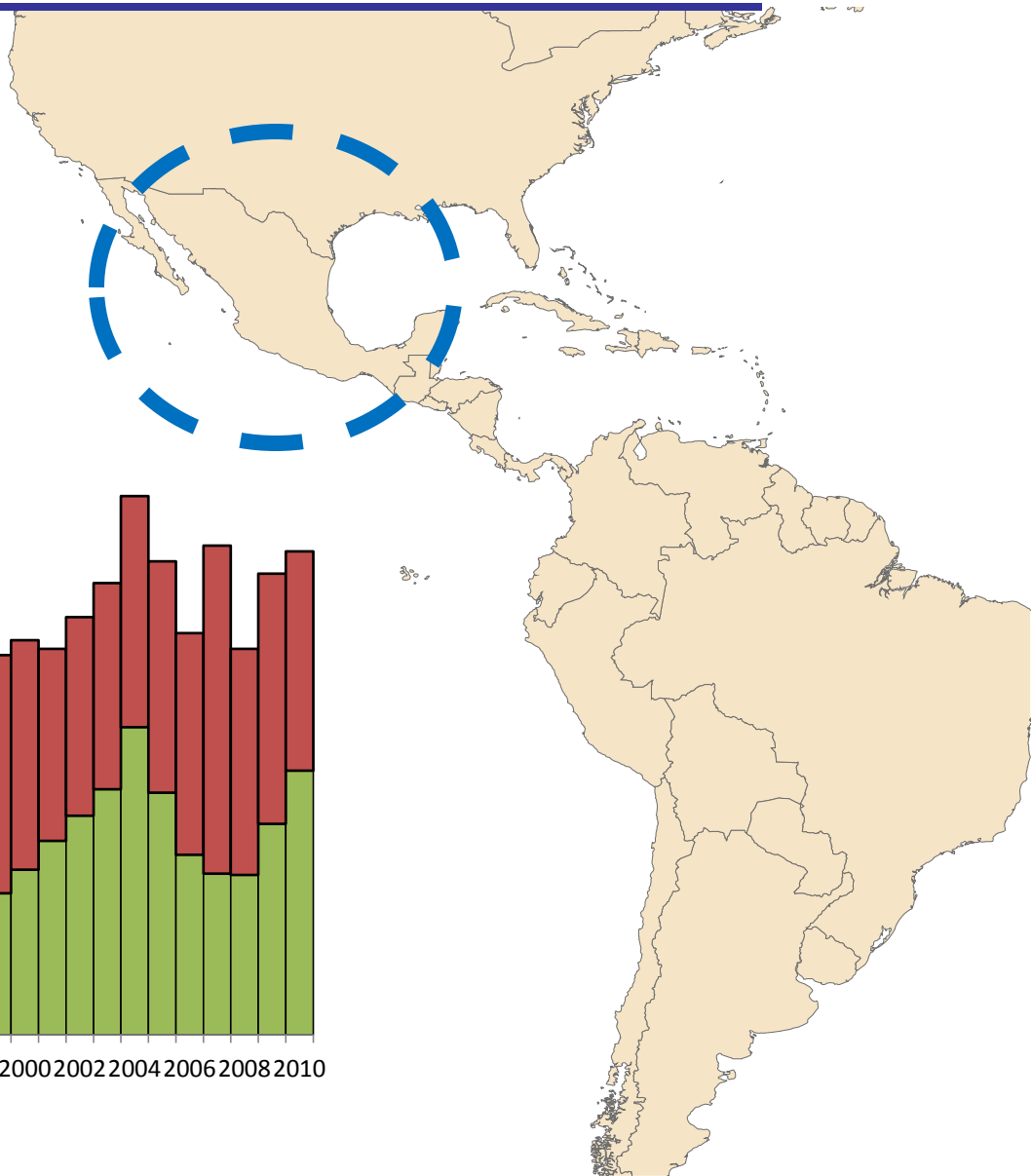


Expert opinion: Asian LL nation scientists

Catches - México

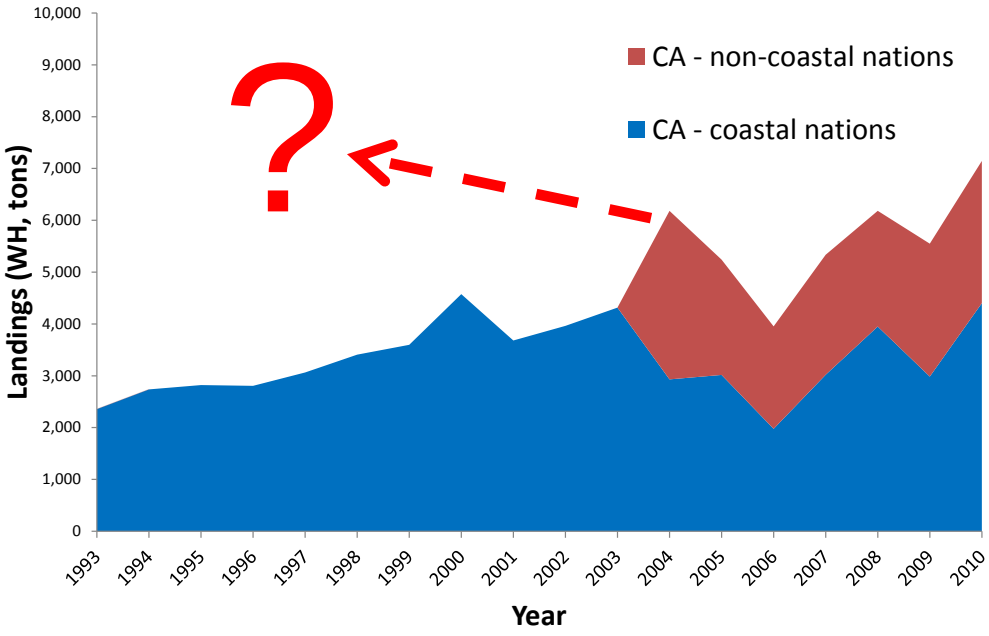
Expert opinion: Mexican scientists

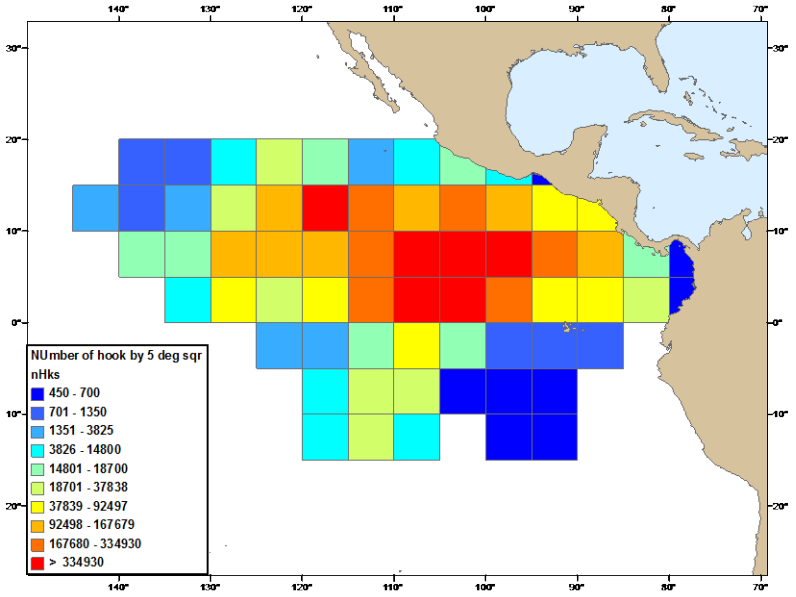




Catches – Central America

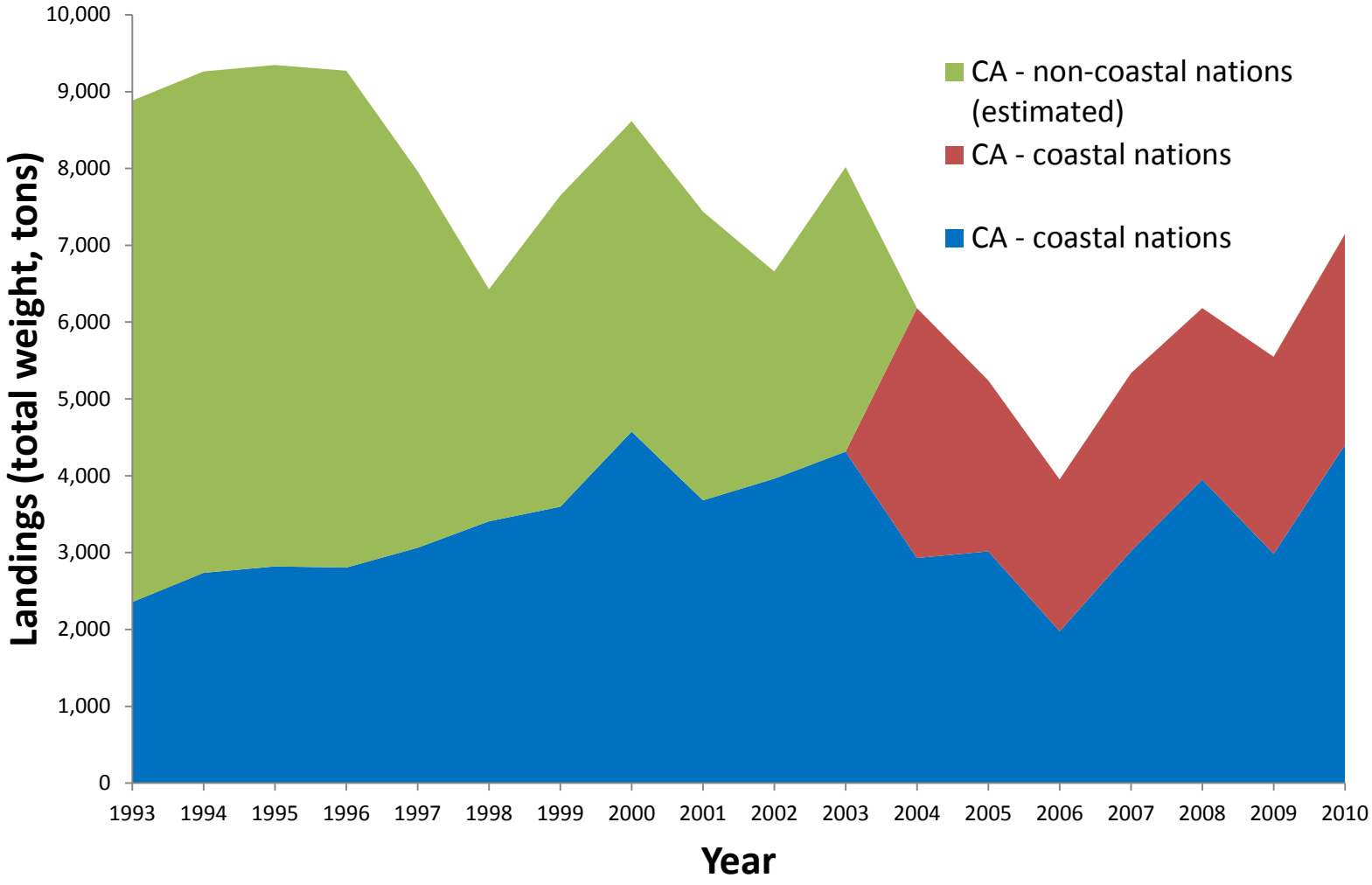
Expert opinion: Regional scientists



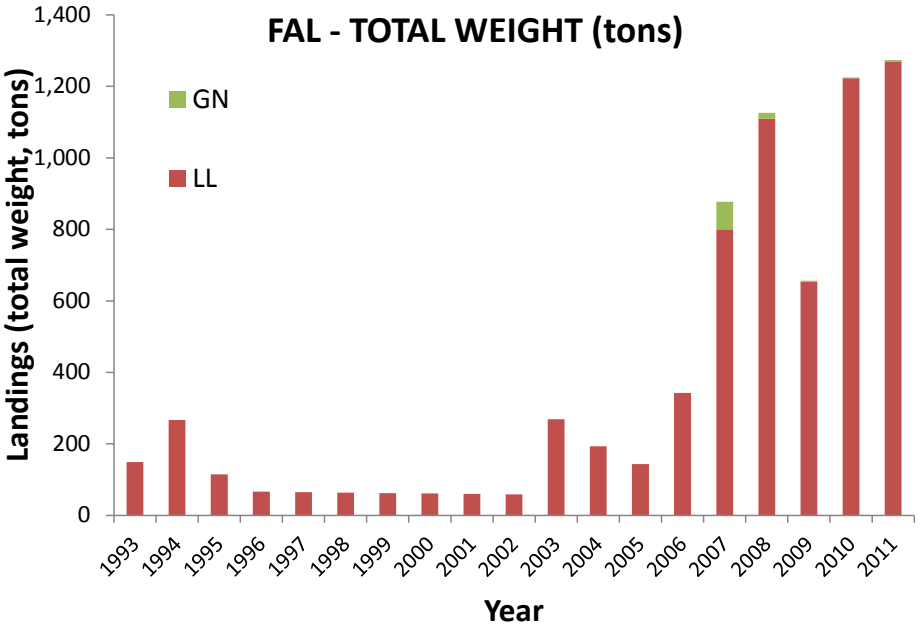


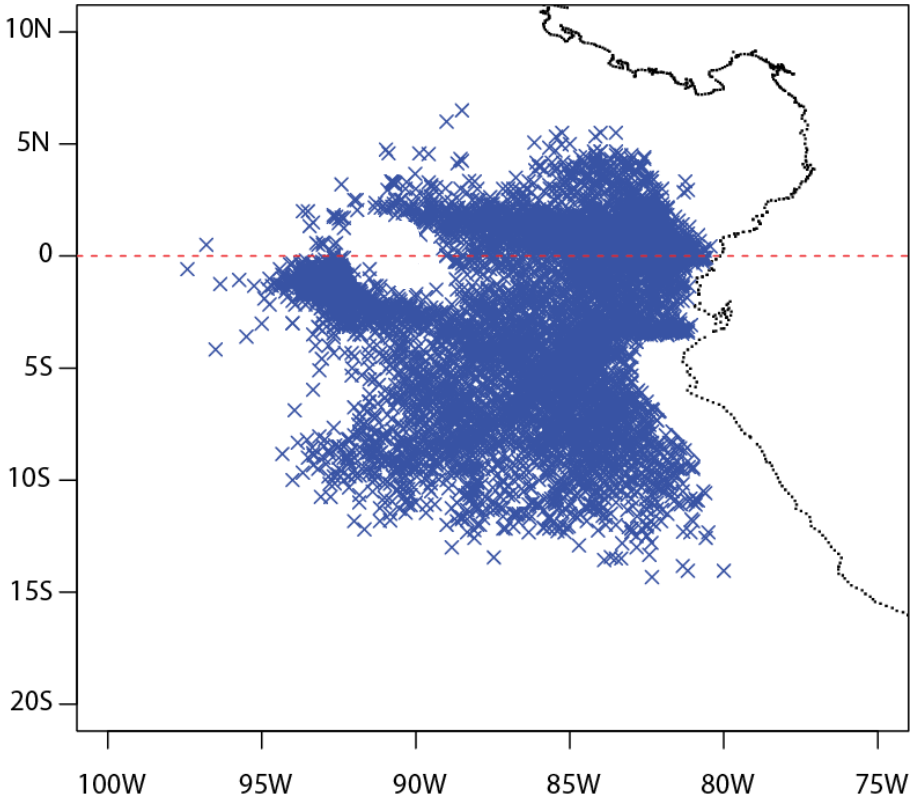
LL effort non-coastal nations (average 2005-2011)

Unreported longline catch non-coastal nations in Central America



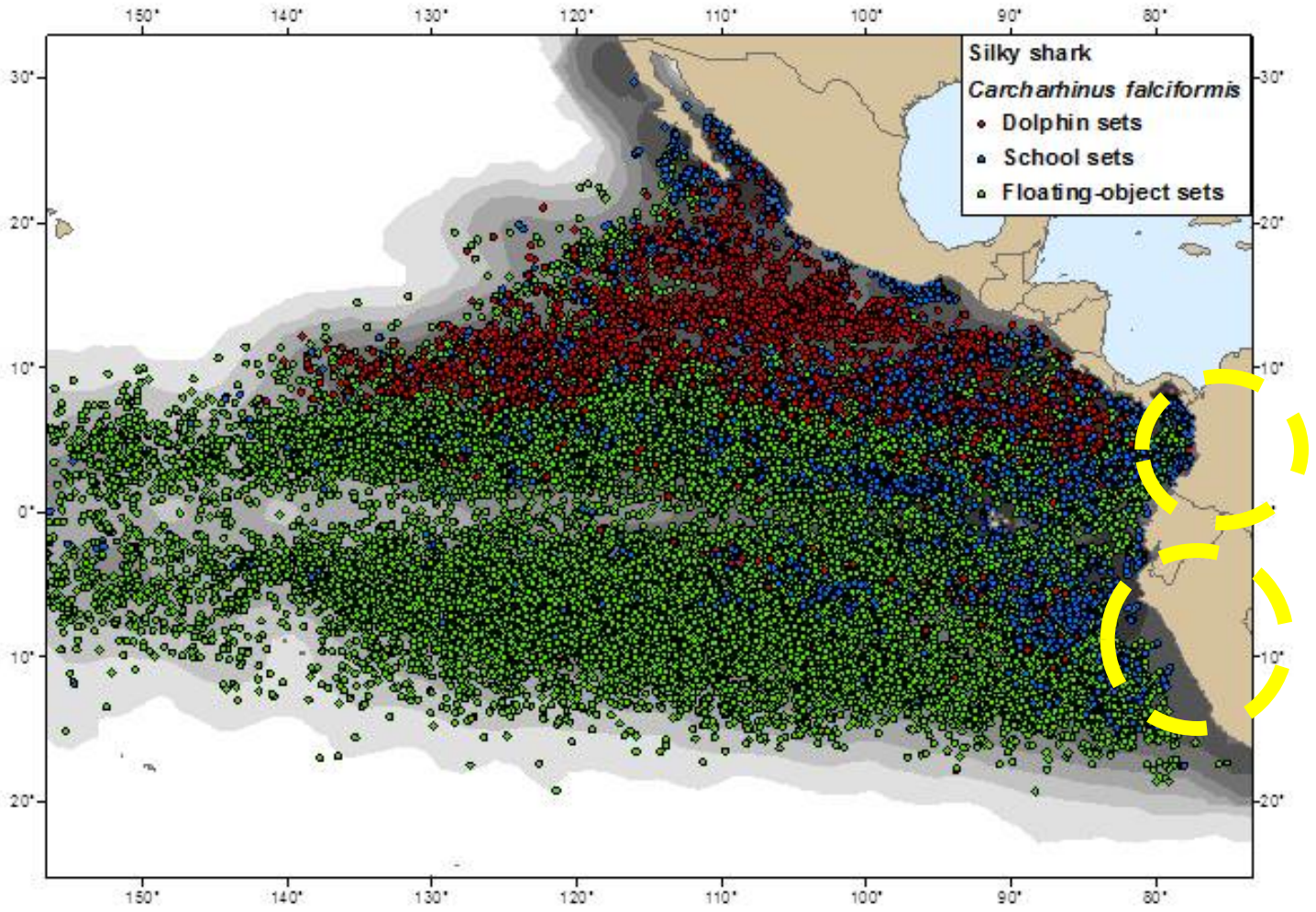
Catches – Ecuador



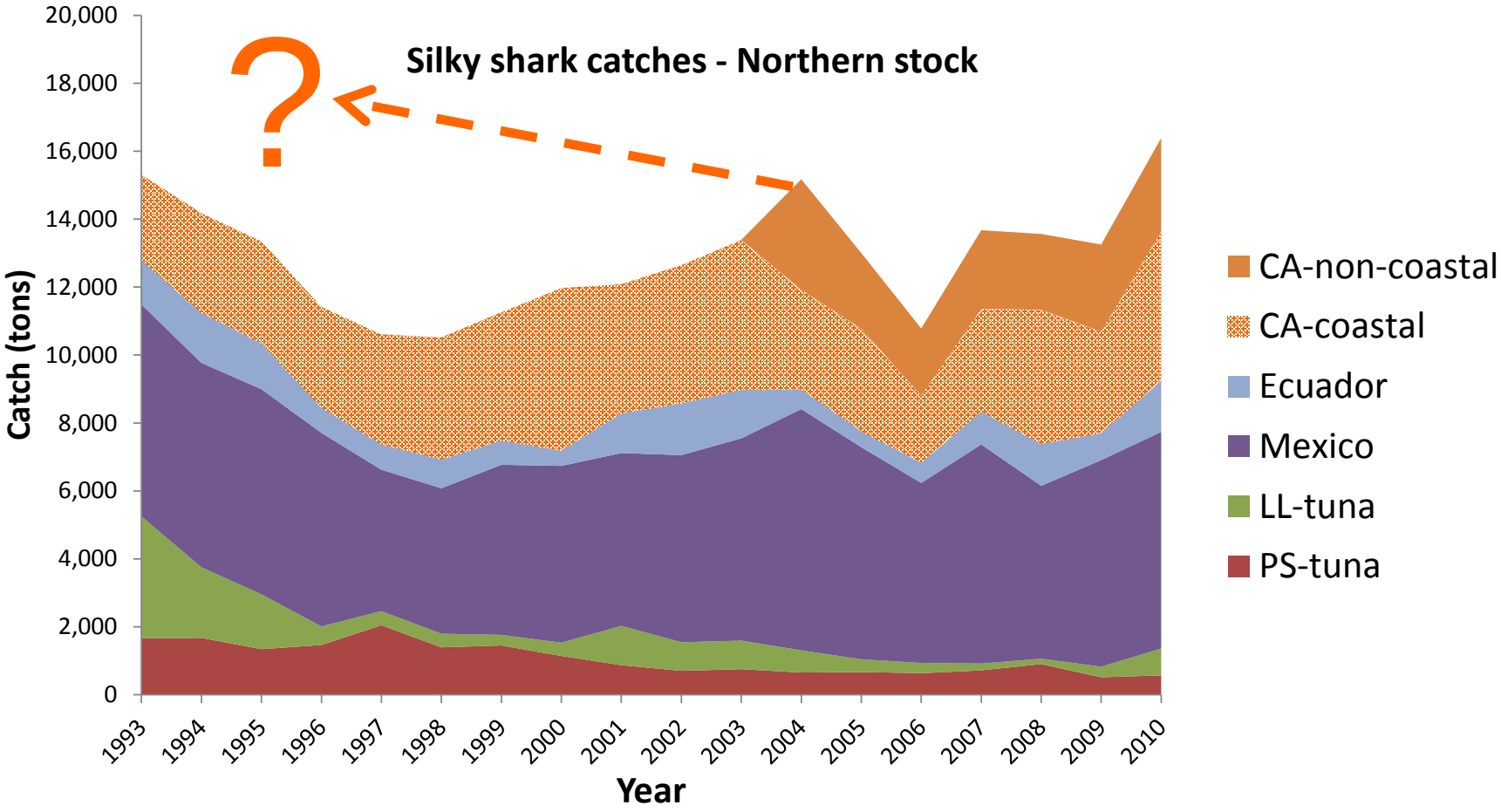


Expert opinion:
Ecuadorian scientists

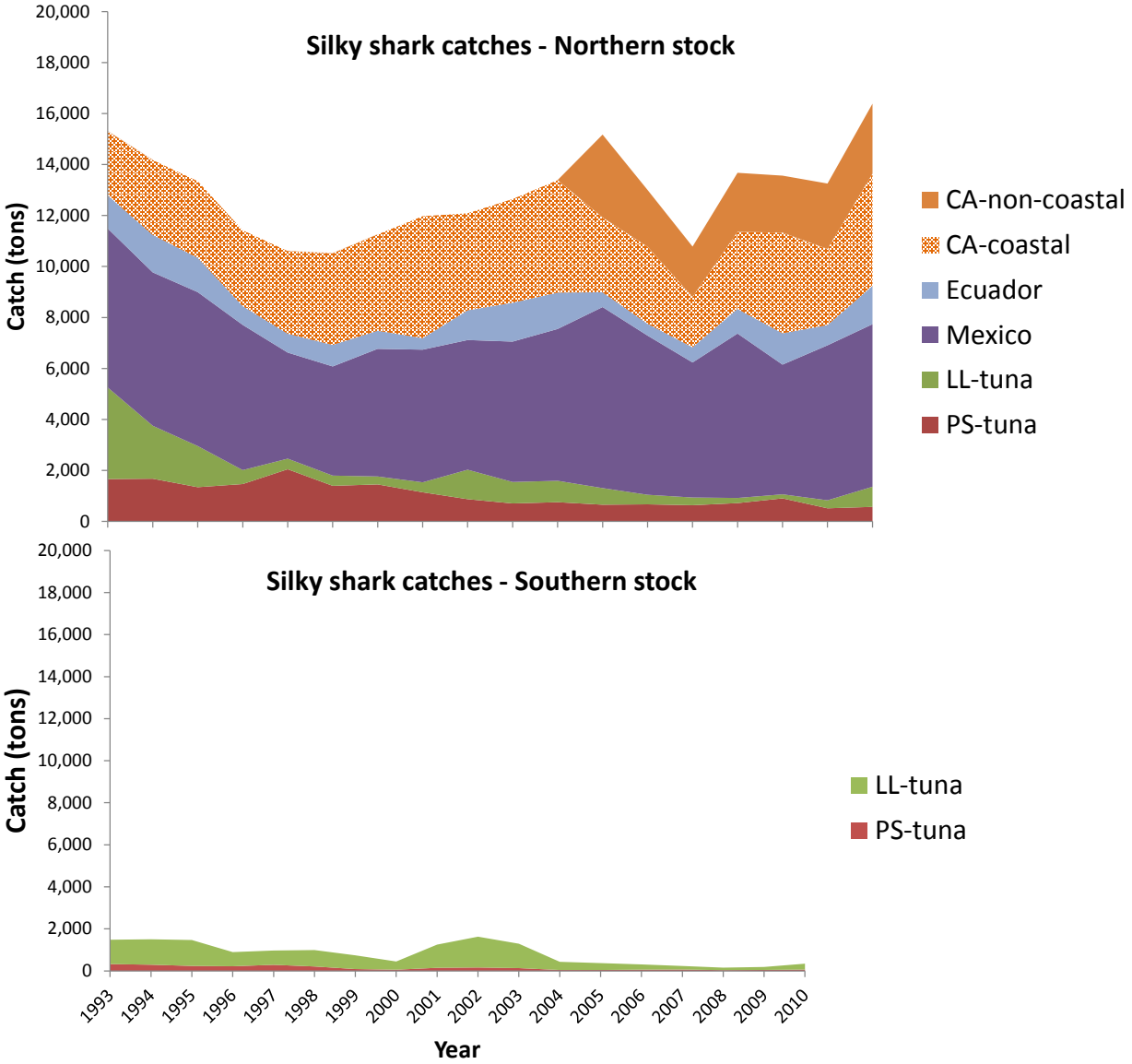
Catch – “missing” coastal nations



Catch Northern stock

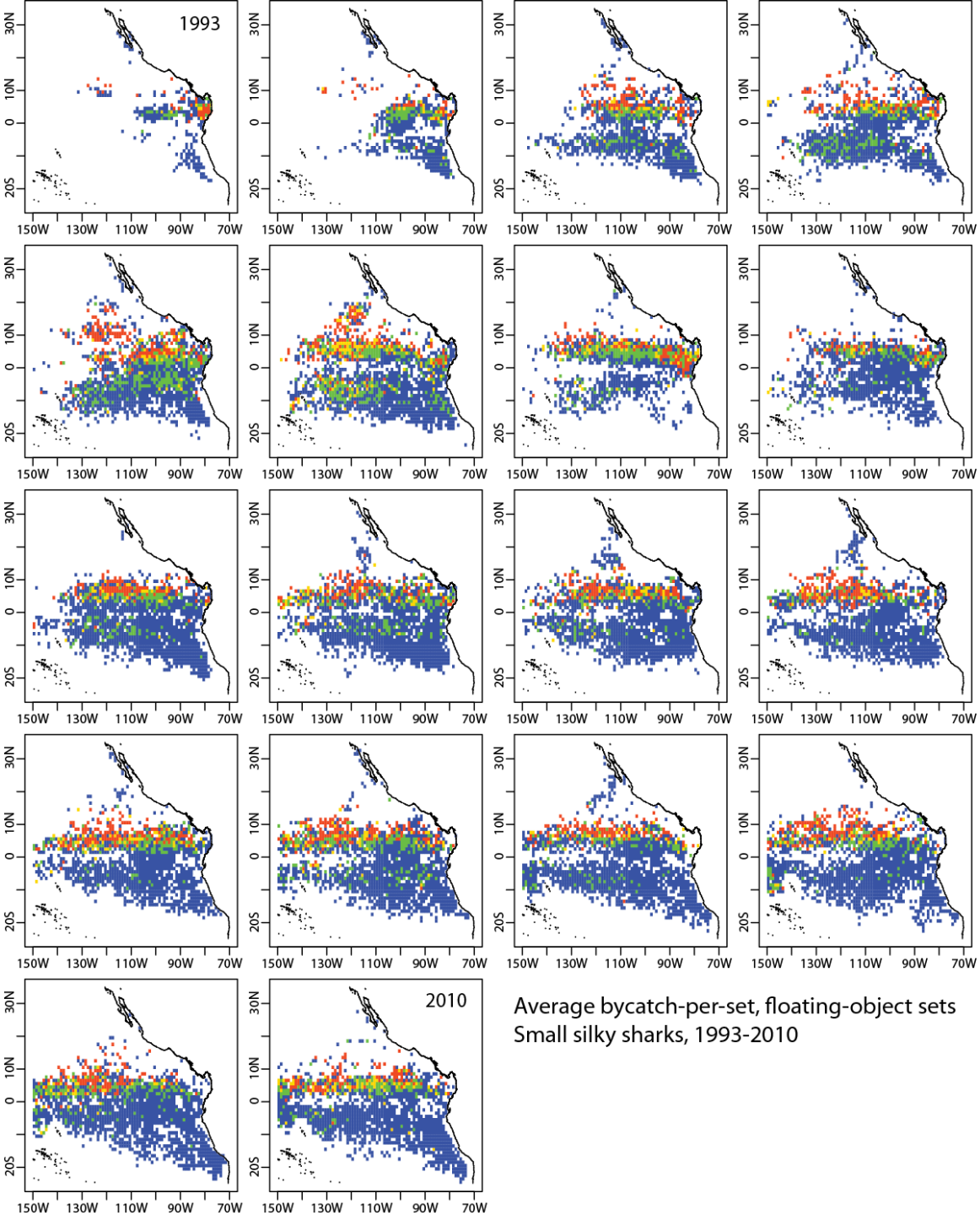


Catch Southern stock



Fltobj sets
small silky
IATTC only

Color scale:
blue: 0 bps
green: <= 1 silky/set
yellow: 1-2 silky/set
red: > 2 silky/set



Average bycatch-per-set, floating-object sets
Small silky sharks, 1993-2010

1993-1996

1997-2000

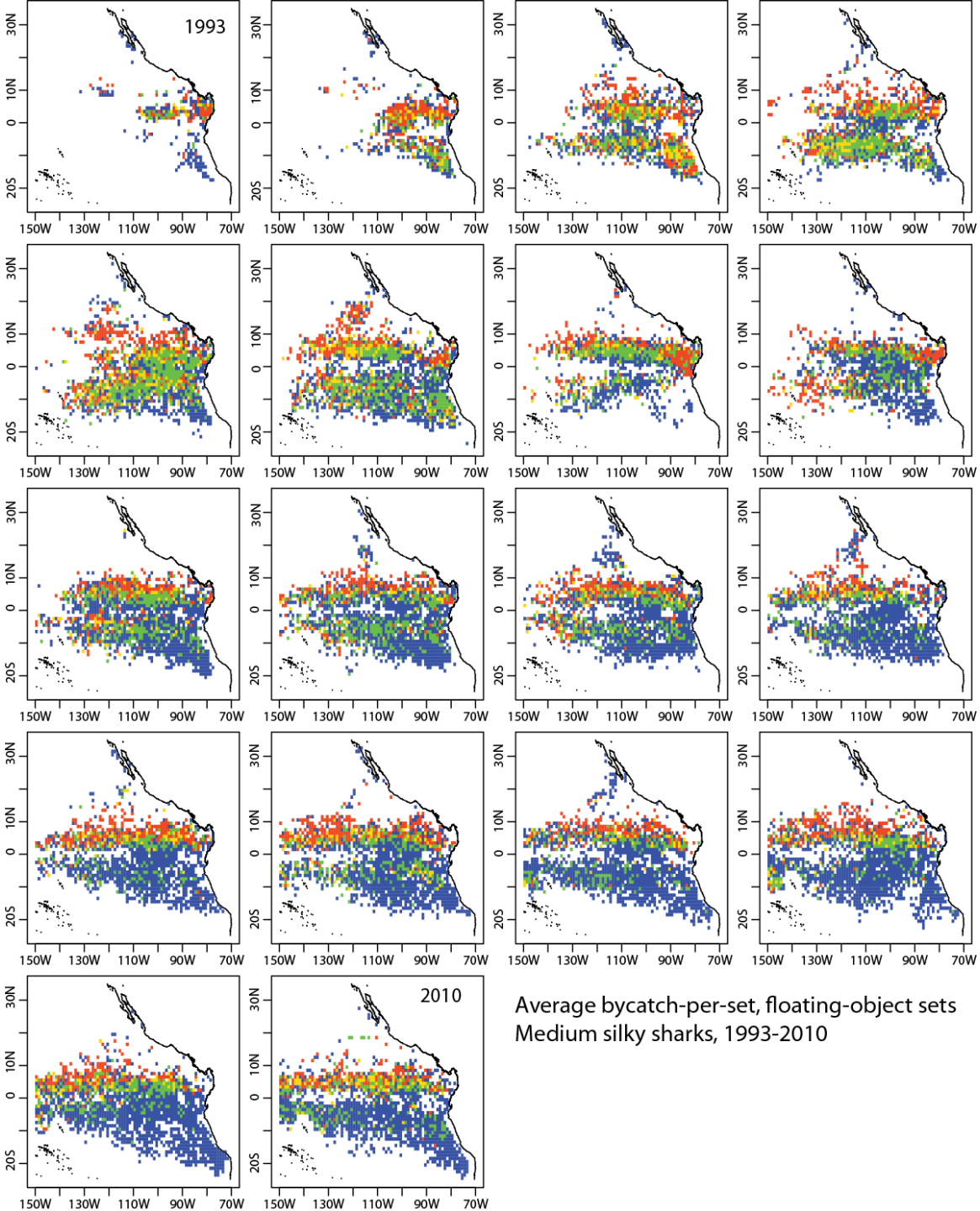
2001-2004

2005-2008

2009-2010

Fltobj sets
medium silky
IATTC only

Color scale:
blue: 0 bps
green: <= 1 silky/set
yellow: 1-2 silky/set
red: > 2 silky/set



Average bycatch-per-set, floating-object sets
Medium silky sharks, 1993-2010

1993-1996

1997-2000

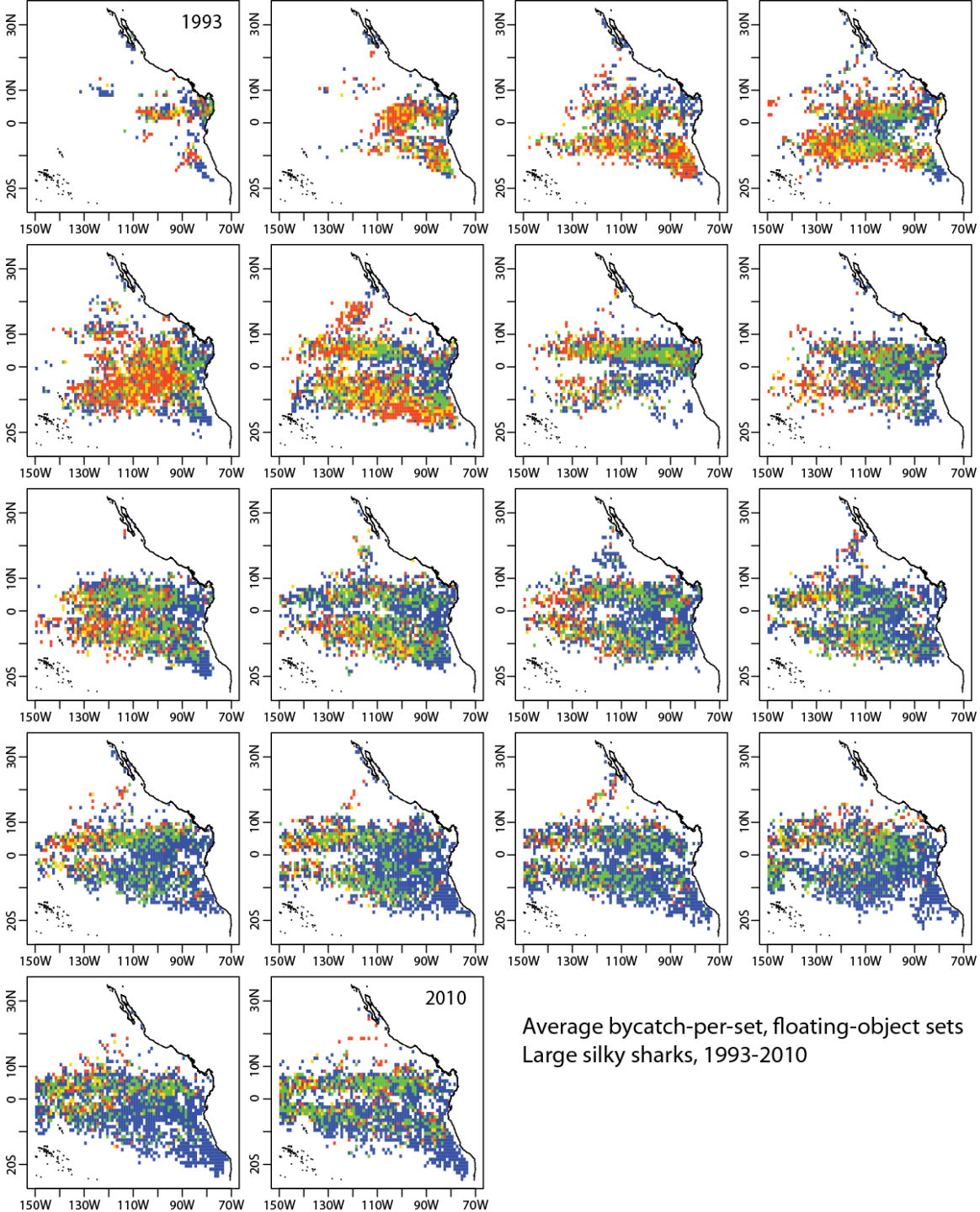
2001-2004

2005-2008

2009-2010

Fltobj sets
large silky
IATTC only

Color scale:
blue: 0 bps
green: <= 1 silky/set
yellow: 1-2 silky/set
red: > 2 silky/set



Average bycatch-per-set, floating-object sets
Large silky sharks, 1993-2010

1993-1996

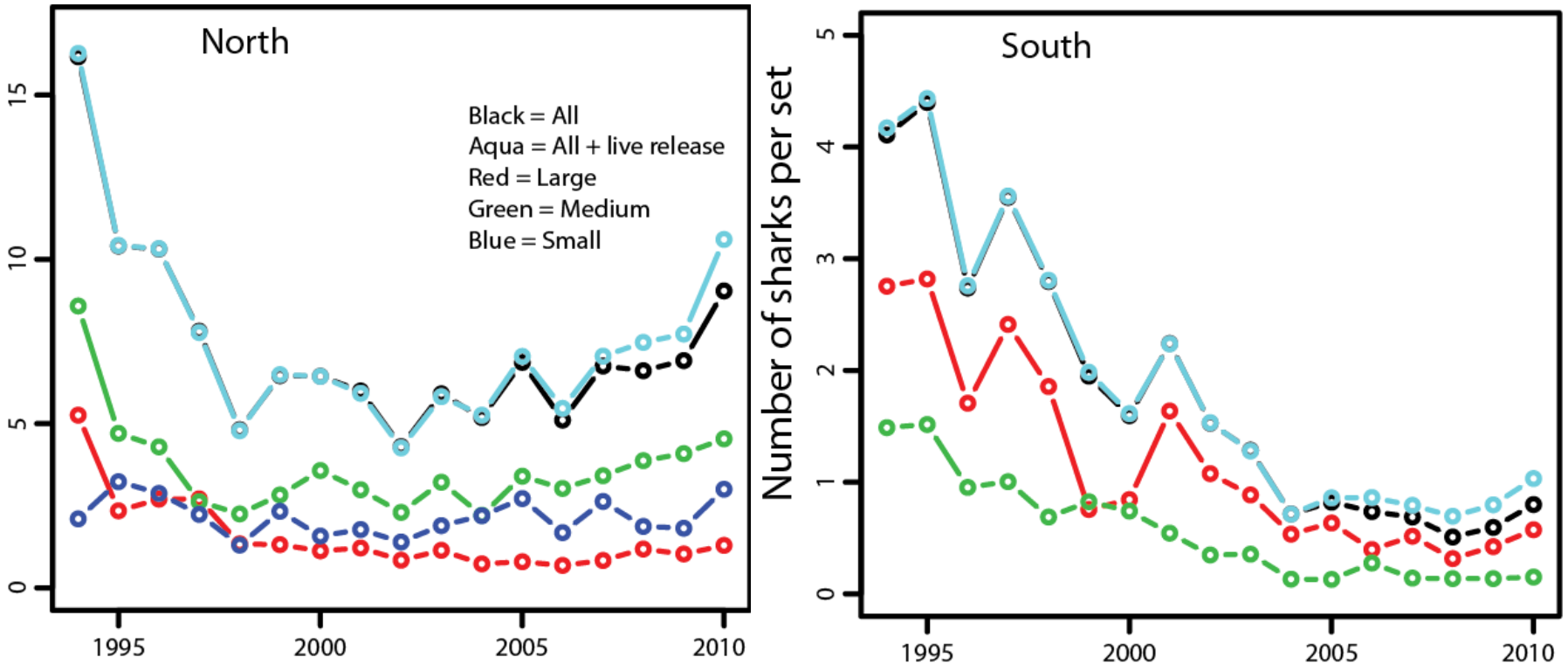
1997-2000

2001-2004

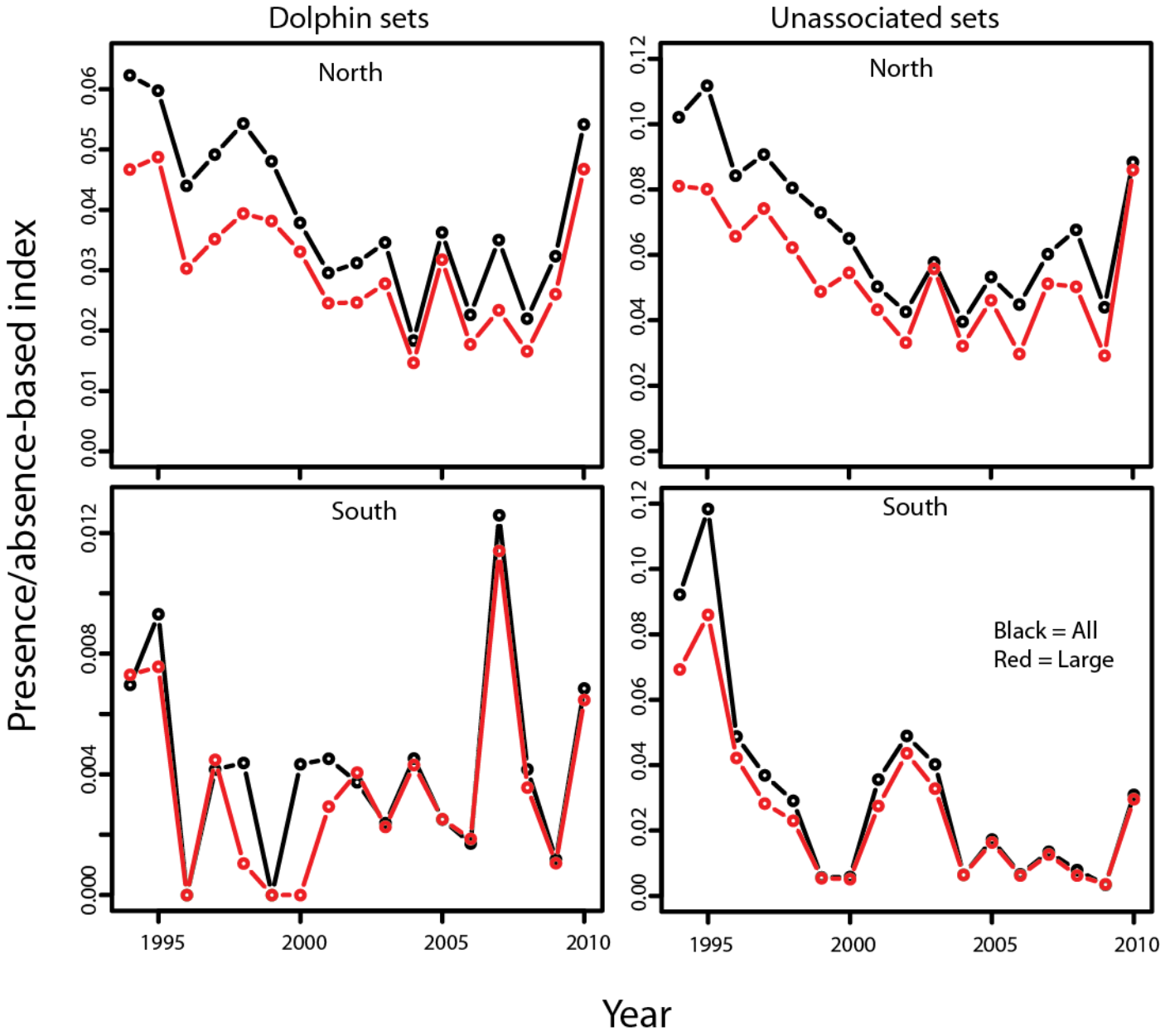
2005-2008

2009-2010

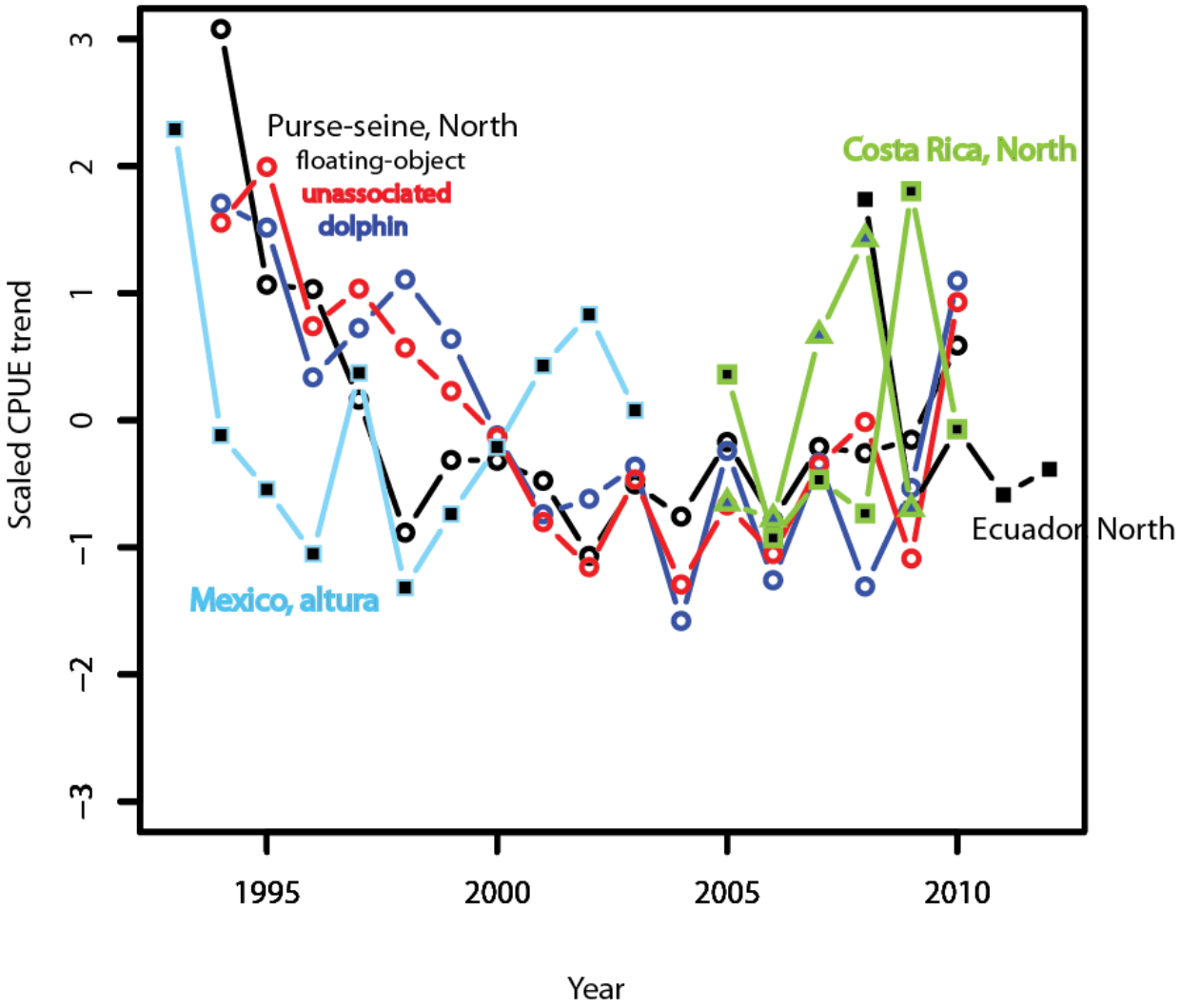
Purse-seine standardized trends: floating-object sets

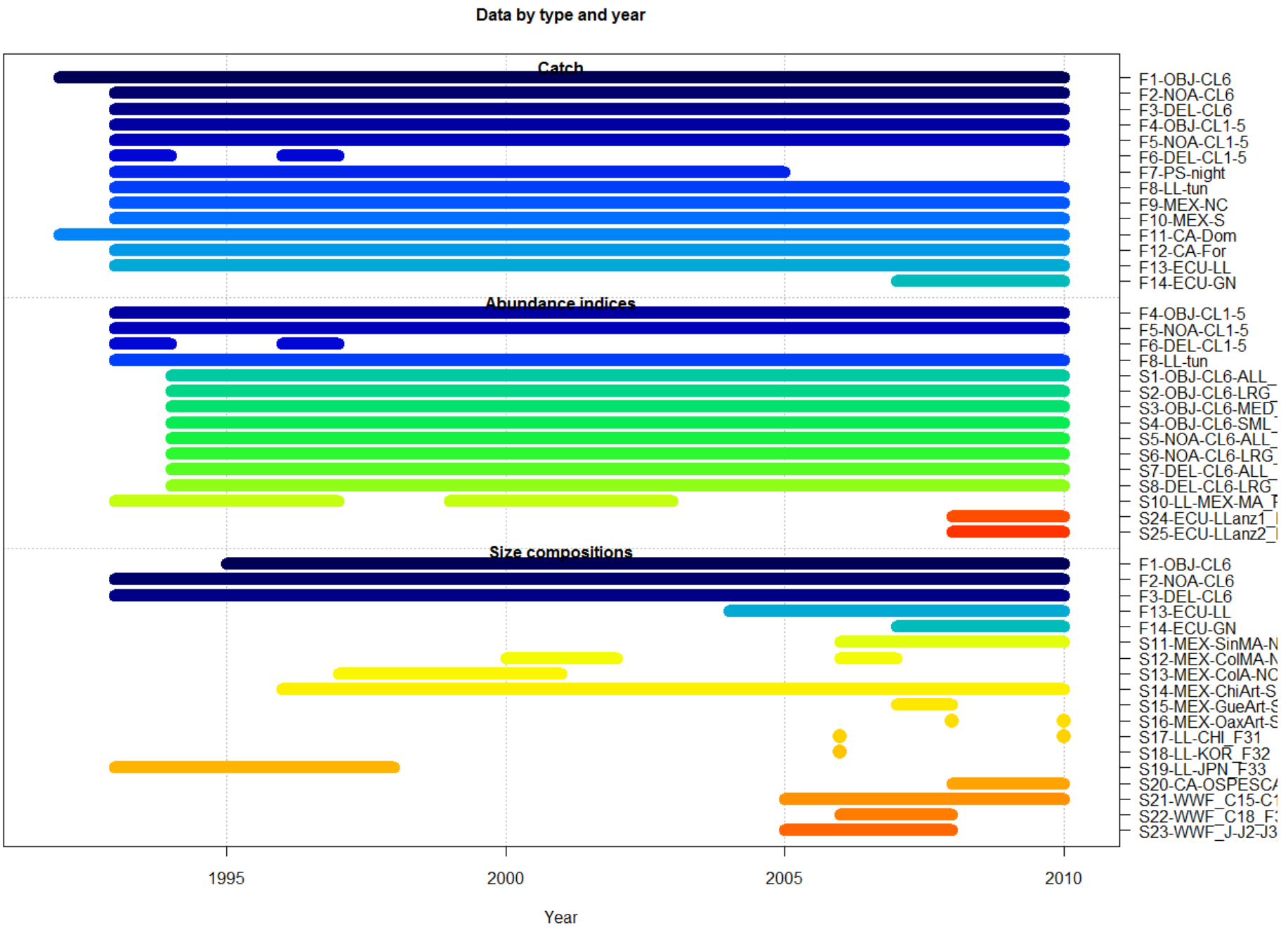


Purse-seine Standardized trends: dolphin and unassociated sets



All indices


Purse-seine, North
floating-object
unassociated
dolphin
Costa Rica, North
Ecuador North
Mexico, altura
Scaled CPUE trend
3
2
1
0
−1
−2
−3
1995
2000
2005
2010
Year


Data by type and year
Catch
F1-OBJ-CL6
F2-NOA-CL6
F3-DEL-CL6
F4-OBJ-CL1-5
F5-NOA-CL1-5
F6-DEL-CL1-5
F7-PS-night
F8-LL-tun
F9-MEX-NC
F10-MEX-S
F11-CA-Dom
F12-CA-For
F13-ECU-LL
F14-ECU-GN
Abundance indices
F4-OBJ-CL1-5
F5-NOA-CL1-5
F6-DEL-CL1-5
F8-LL-tun
S1-OBJ-CL6-ALL_
S2-OBJ-CL6-LRG_
S3-OBJ-CL6-MED_
S4-OBJ-CL6-SML_
S5-NOA-CL6-ALL_
S6-NOA-CL6-LRG_
S7-DEL-CL6-ALL_
S8-DEL-CL6-LRG_
S10-LL-MEX-MA_
S24-ECU-LLanz1_
S25-ECU-LLanz2_
Size compositions
F1-OBJ-CL6
F2-NOA-CL6
F3-DEL-CL6
F13-ECU-LL
F14-ECU-GN
S11-MEX-SinMA-N
S12-MEX-ColMA-N
S13-MEX-ColA-NC
S14-MEX-ChiArt-S
S15-MEX-GueArt-S
S16-MEX-OaxArt-S
S17-LL-CHI_F31
S18-LL-KOR_F32
S19-LL-JPN_F33
S20-CA-OSPESCA
S21-WWF_C15-C1
S22-WWF_C18_F3
S23-WWF_J-J2-J3
1995
2000
2005
2010
Year

Stock Synthesis model results

- Model setup
- Model fits (CPUE and size compositions)
- Total biomass
- Recruitment
- Fishing mortality

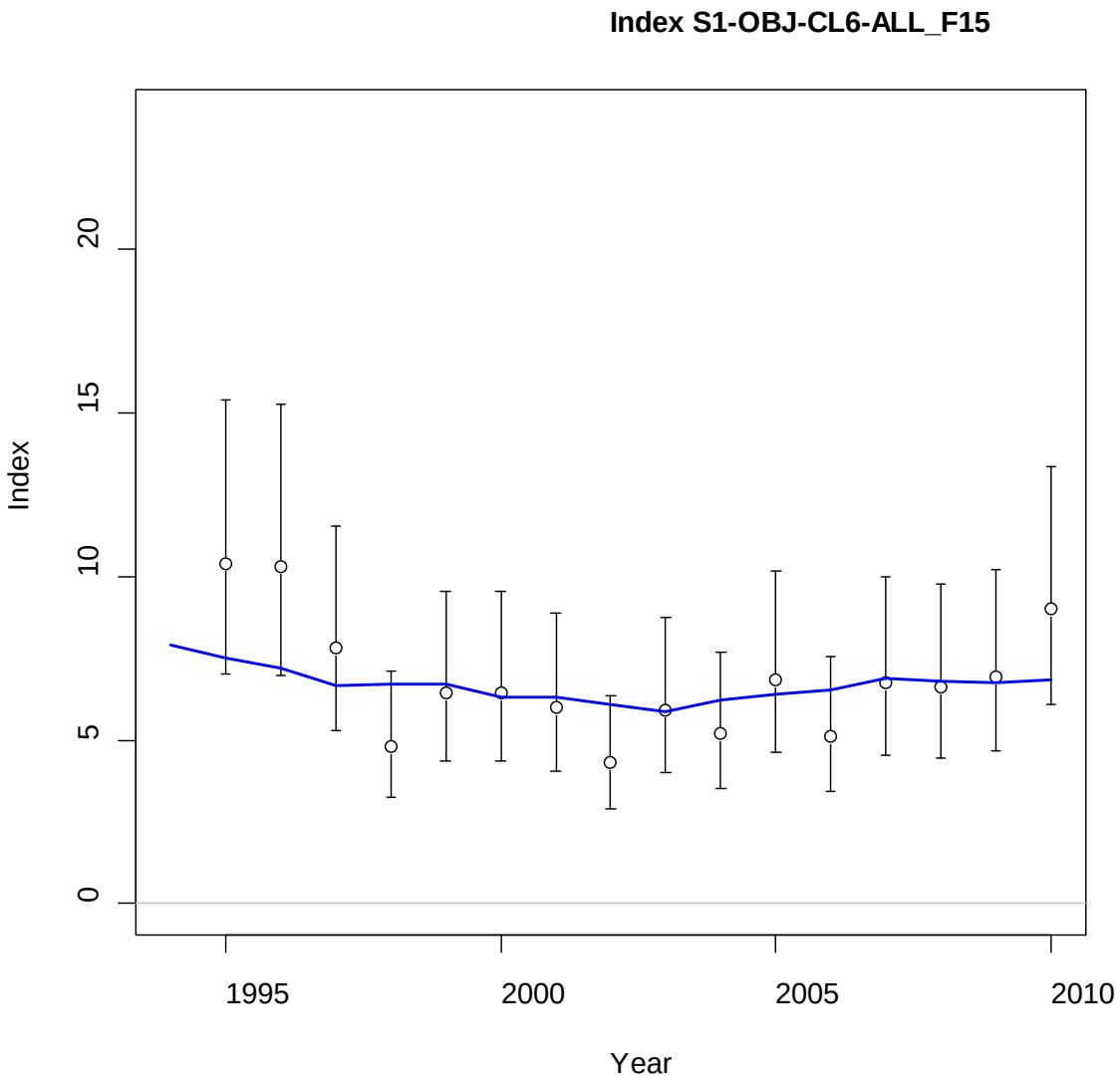
Model setup

- Data
  - Catch
  - CPUE based index of abundance
  - Length composition data
- Fixed quantities
  - Growth
  - Natural mortality
  - Form of the stock-recruitment relationship
  - Fecundity
- Estimated quantities
  - Annual recruitment (S-R parameters and annual deviates)
  - Initial age structure (initial fishing mortality and cohort deviates)
  - Selectivity parameters

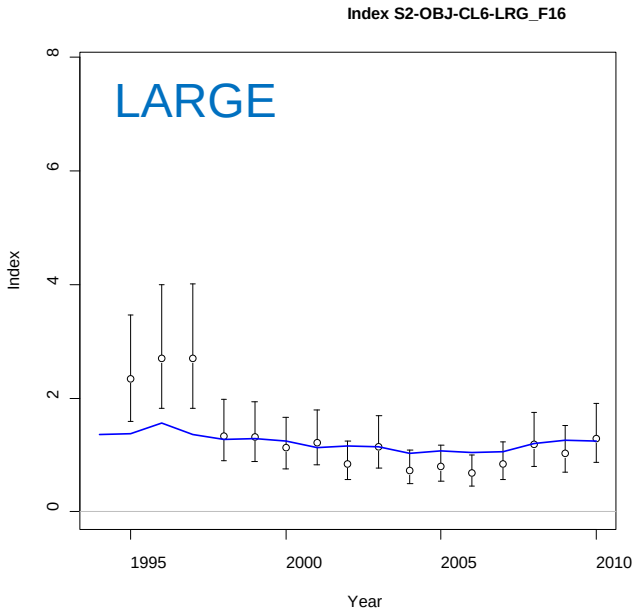
Model setup

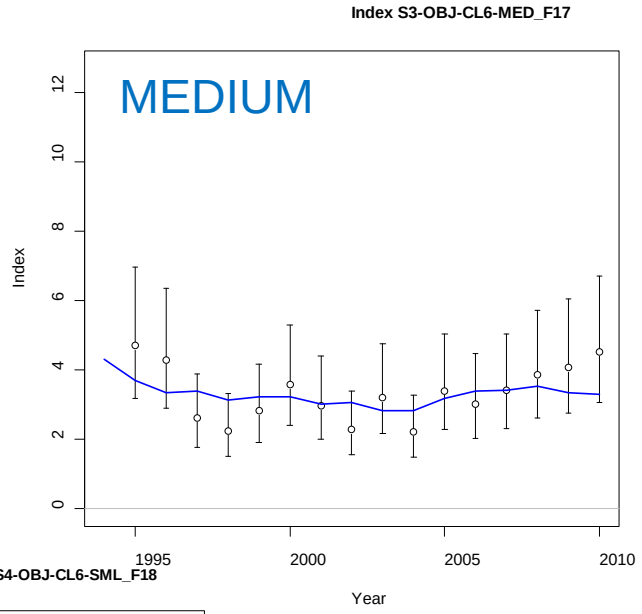
- Emphasis on fitting to floating object purse seine CPUE and length composition data
- Also fit to
  - Unassociated PS length composition
  - Dolphin associated PS length composition
  - Floating object PS size group data
  - Japanese longline length composition
  - Sinaloa, Mexico, length composition
  - Chiapas, Mexico, length composition
  - Ecuador longline and gillnet composition data
  - WWF J hook composition data

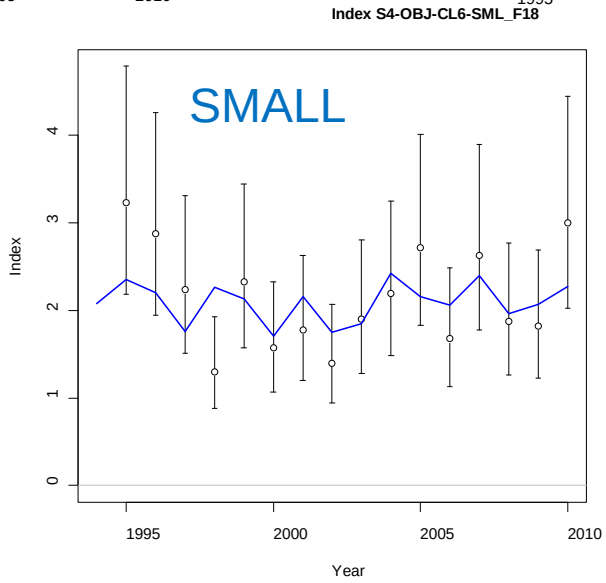
Model fits to main OBJ CPUE data



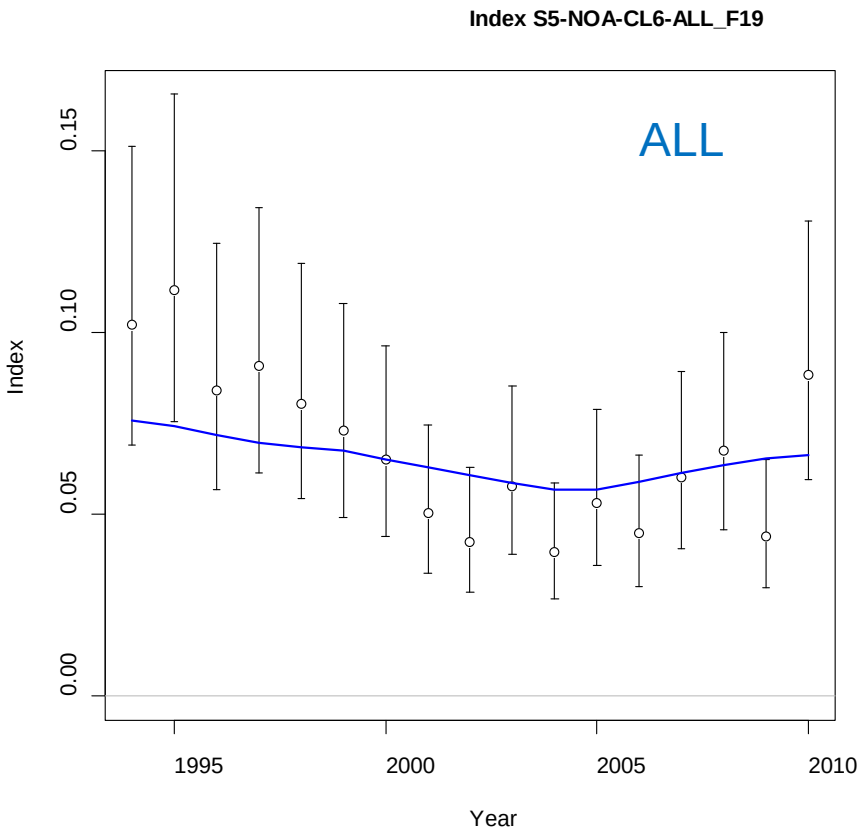
Model fits to CPUE data – OBJ others

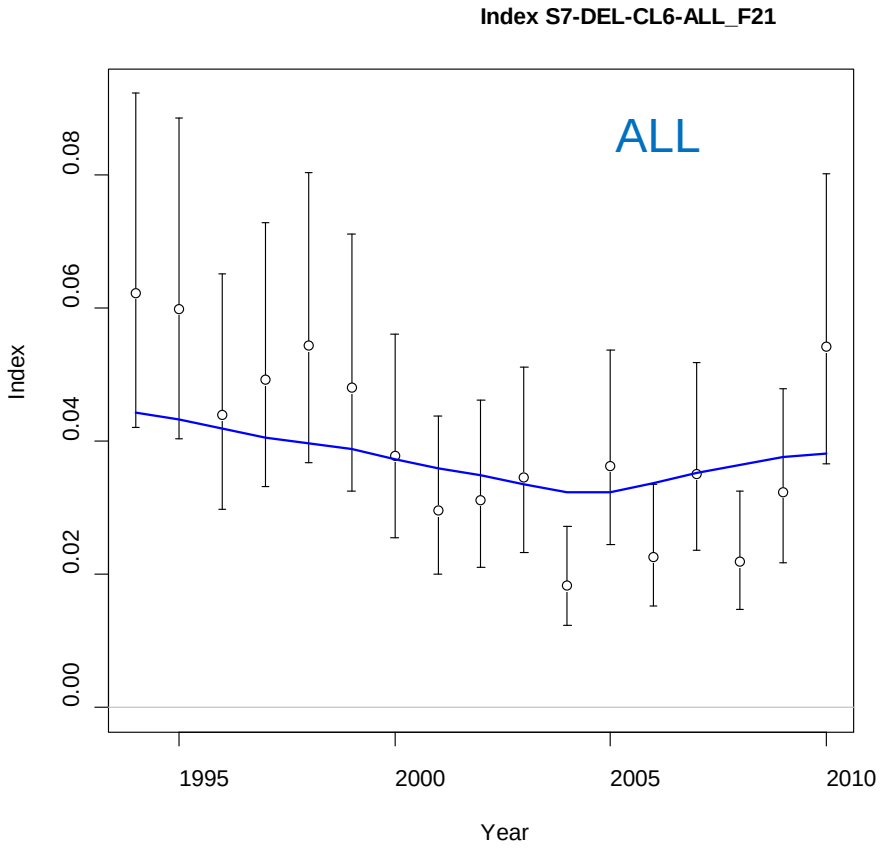




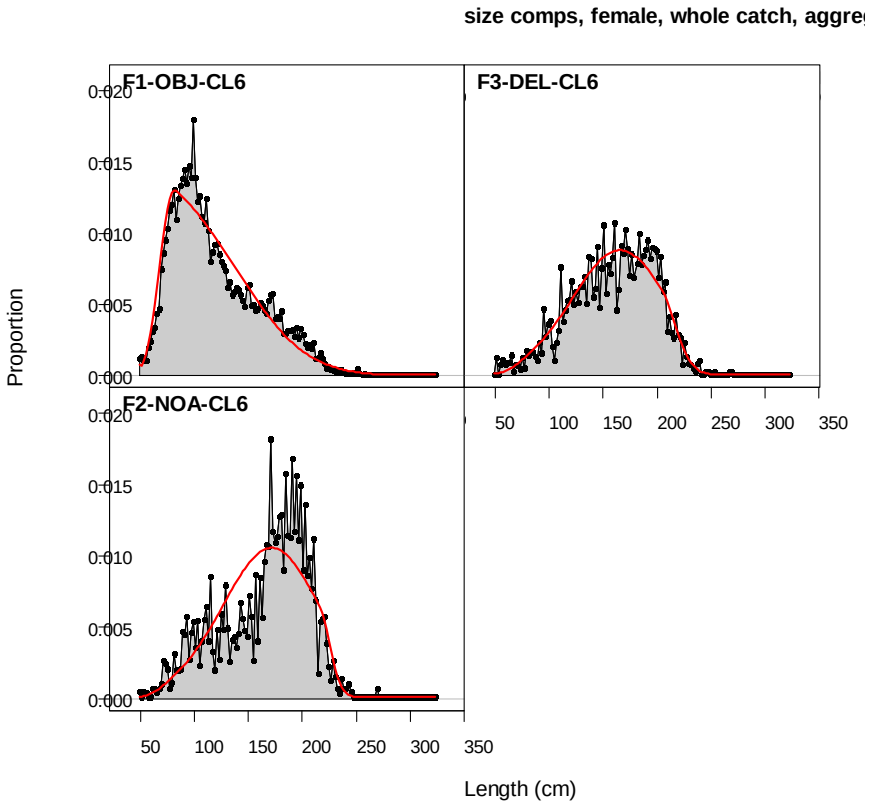


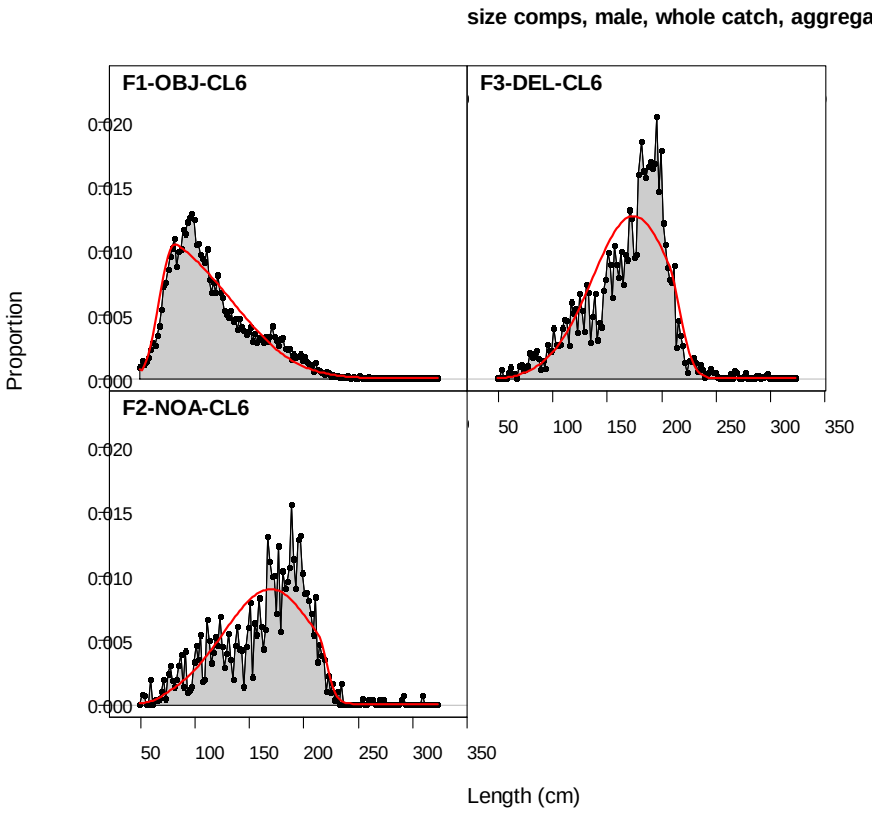
Model fits to CPUE data – NOA & DEL



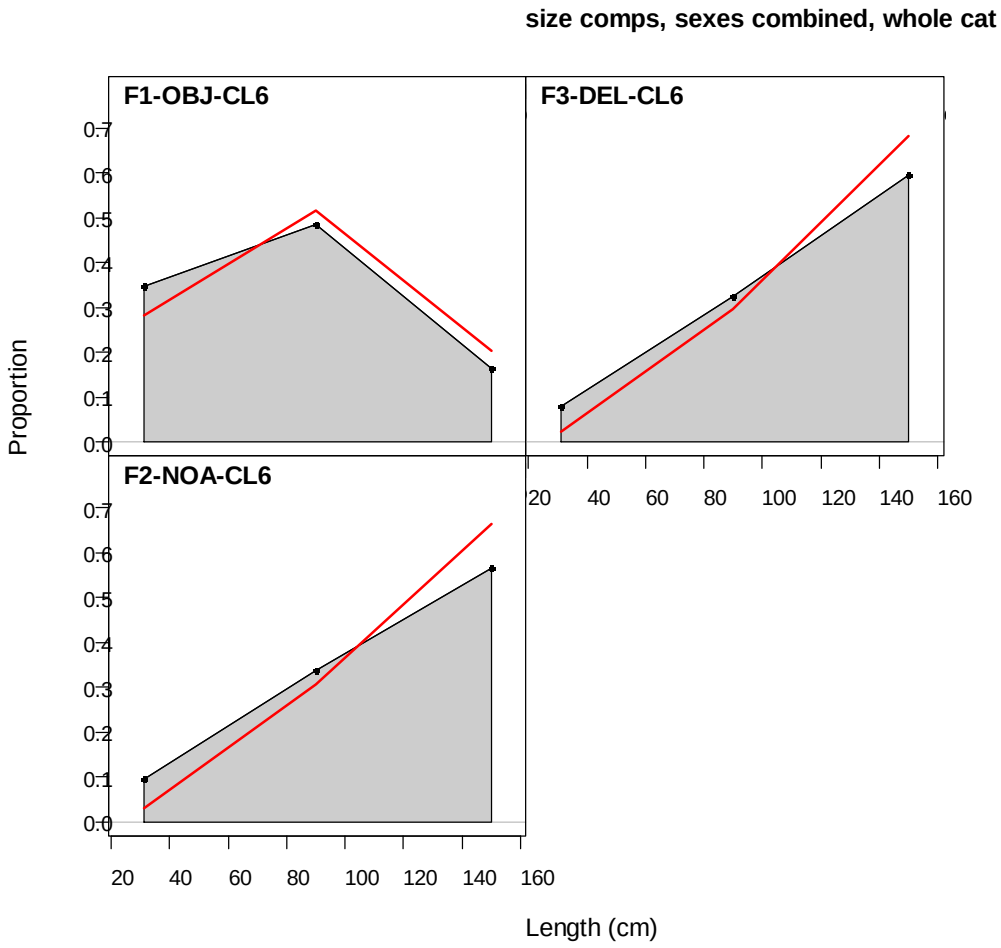


Fits to length comps - OBJ

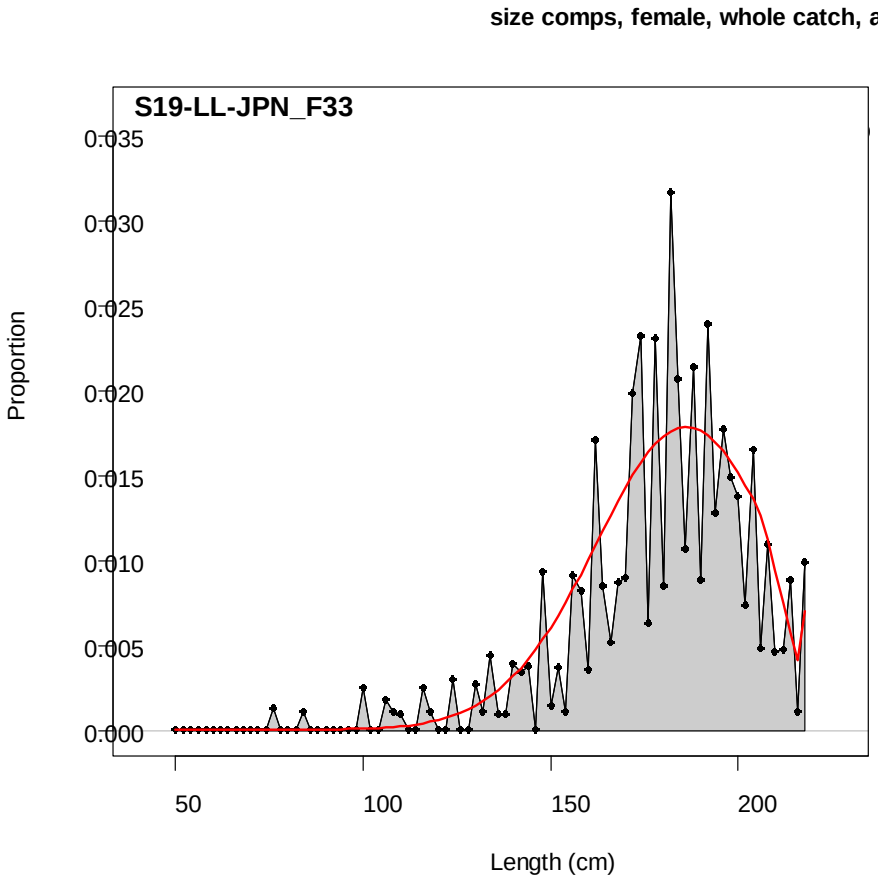


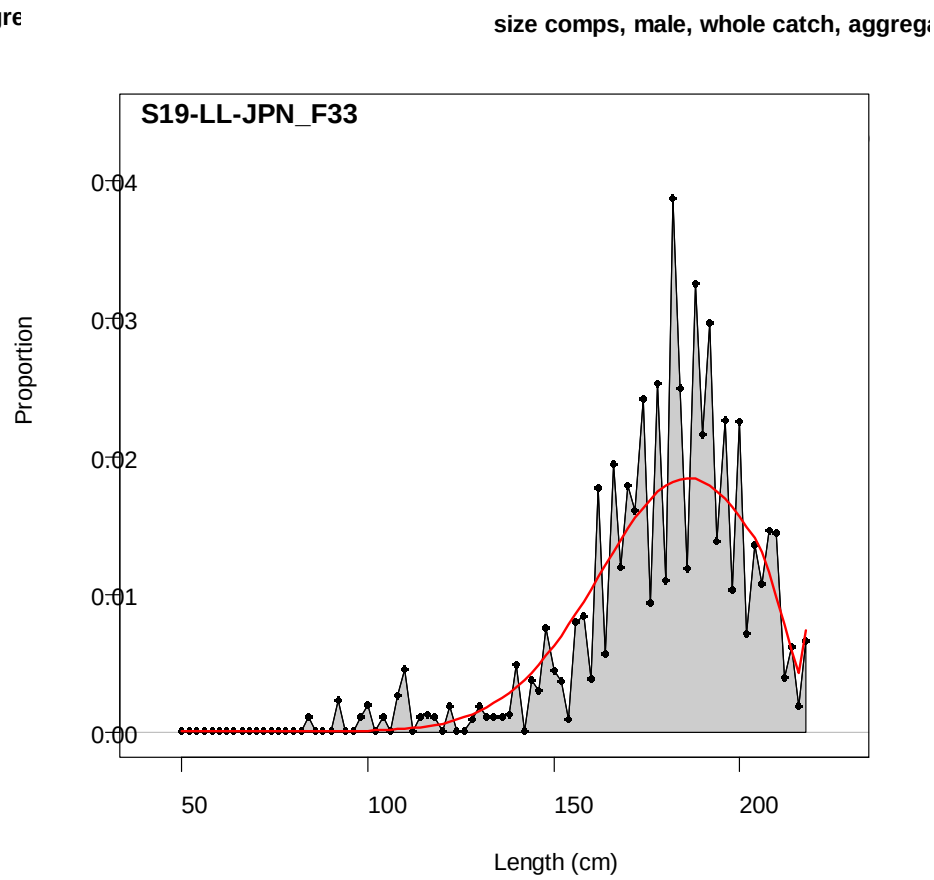


Fits to size comps - OBJ

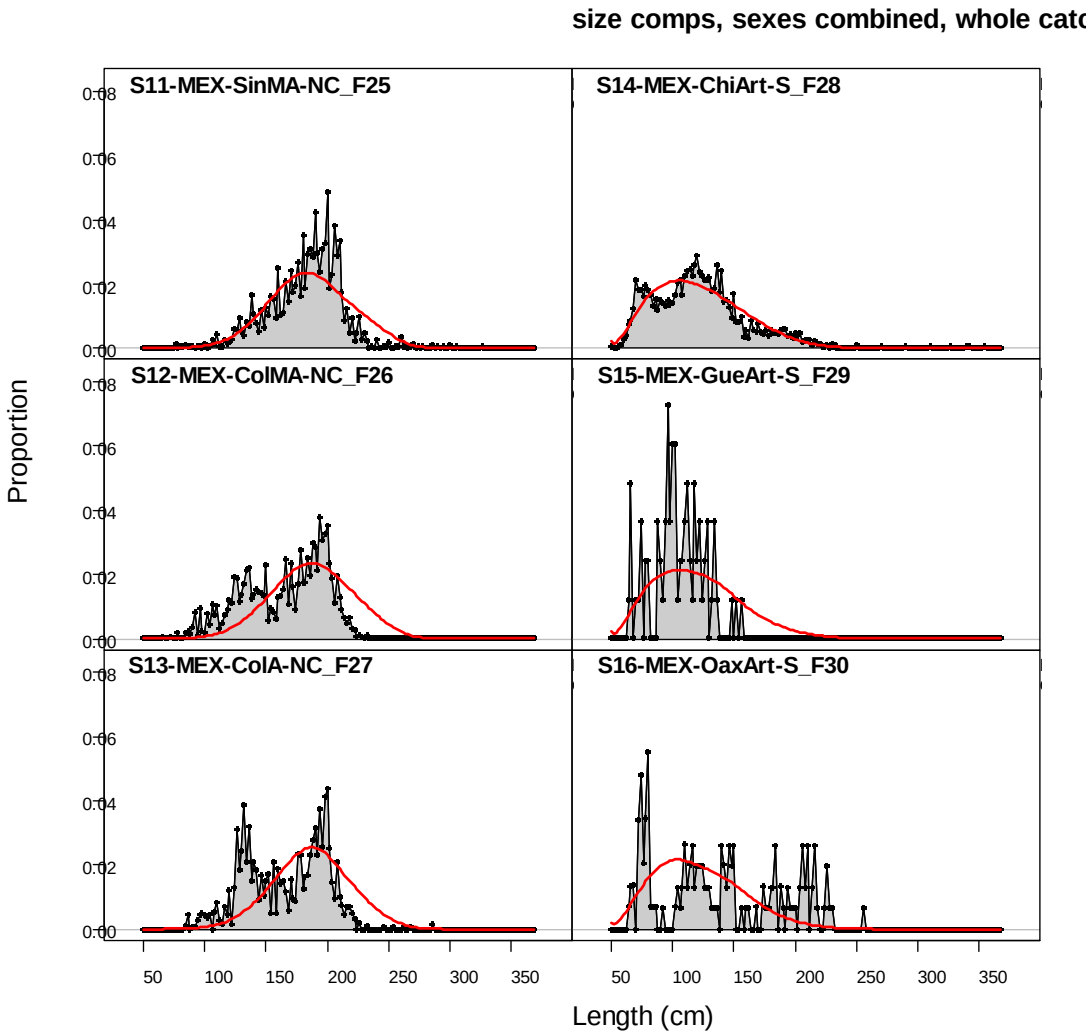


Fits to length comps – LL-Japan

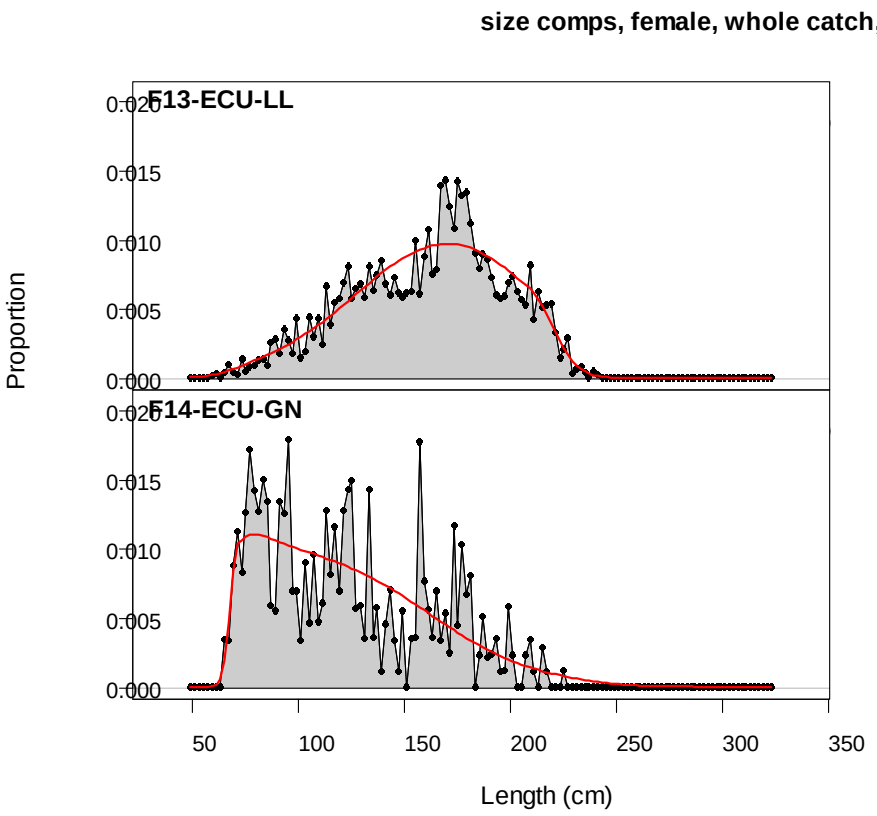


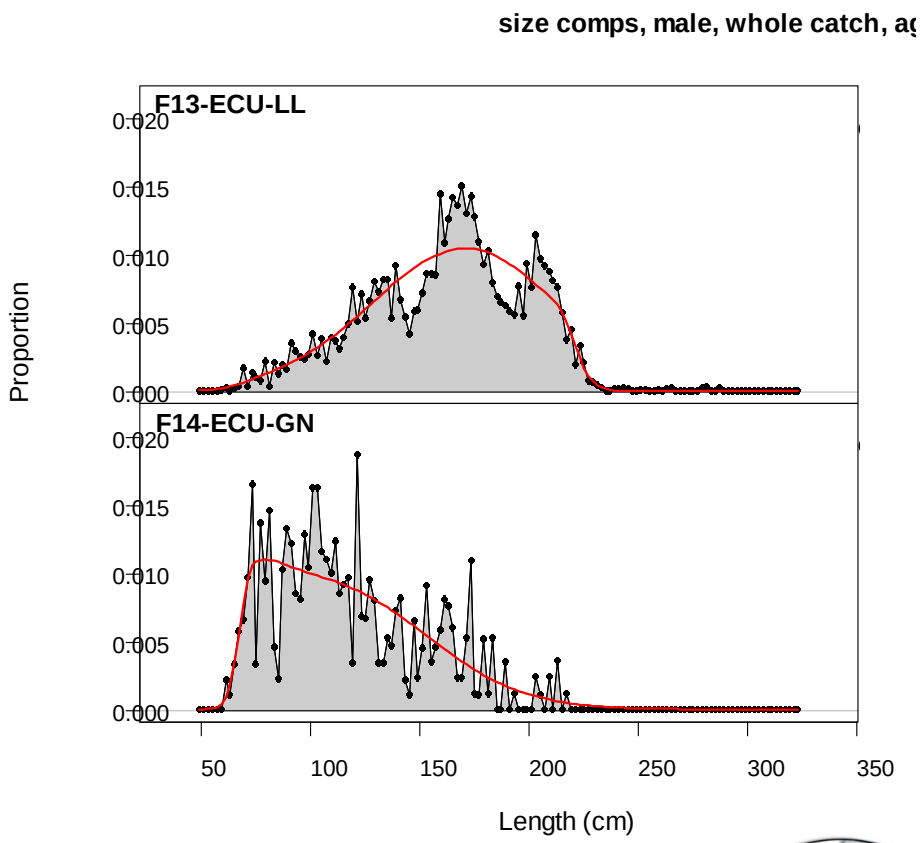


Fits to length comps – Mexico

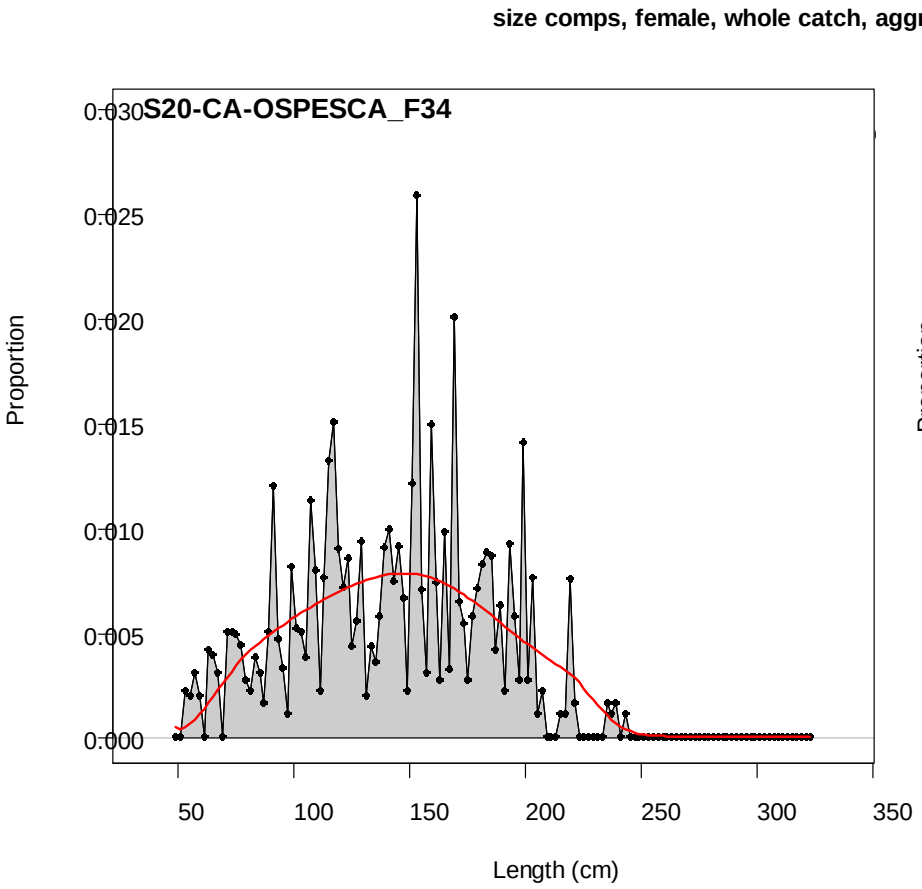


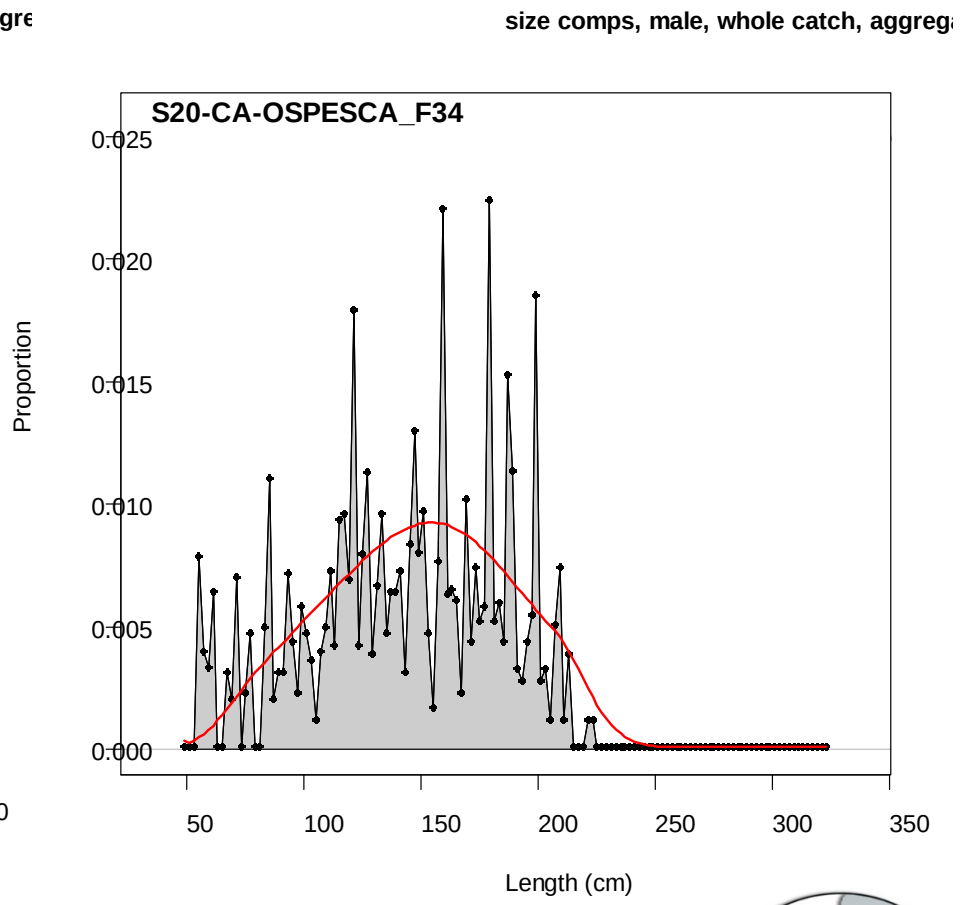
Fits to length comps – Ecuador



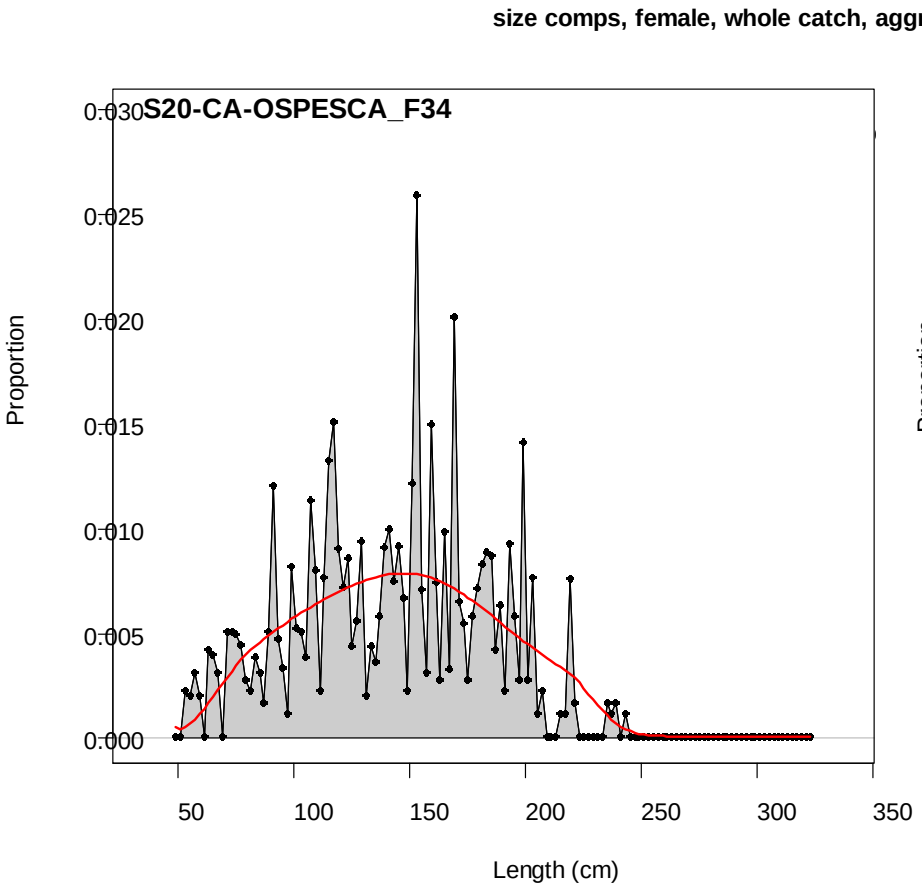


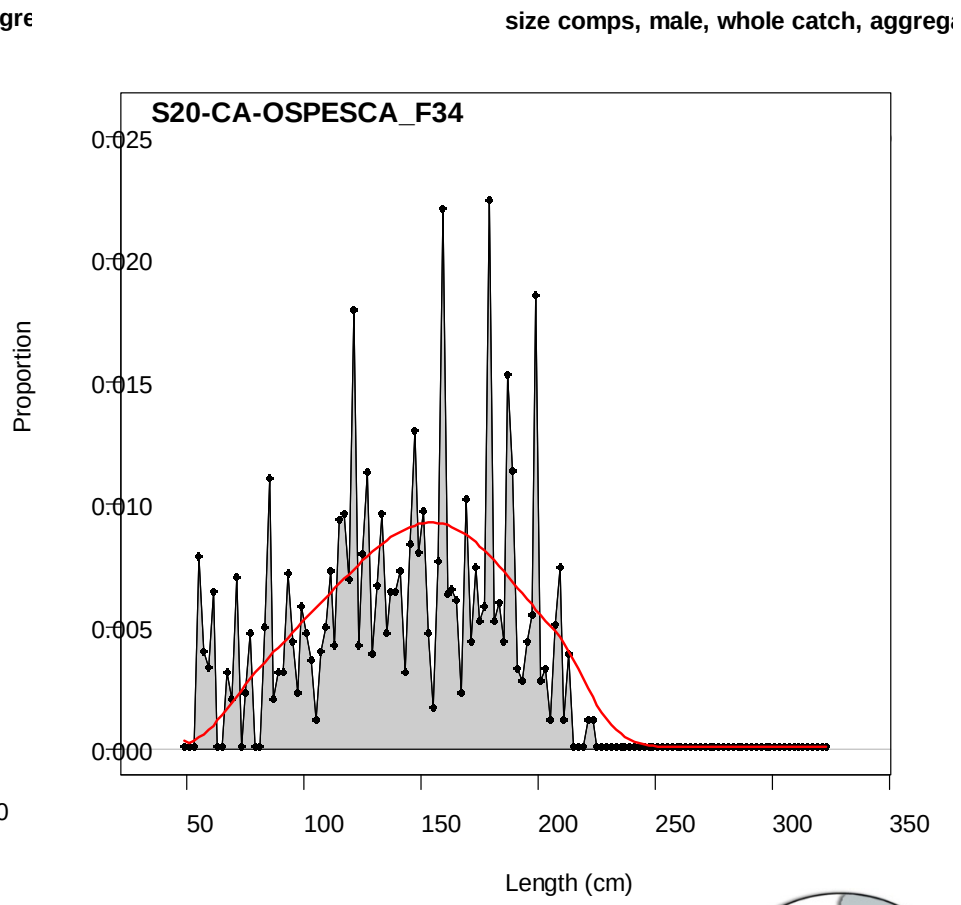
Fits to length comps – OSPESCA



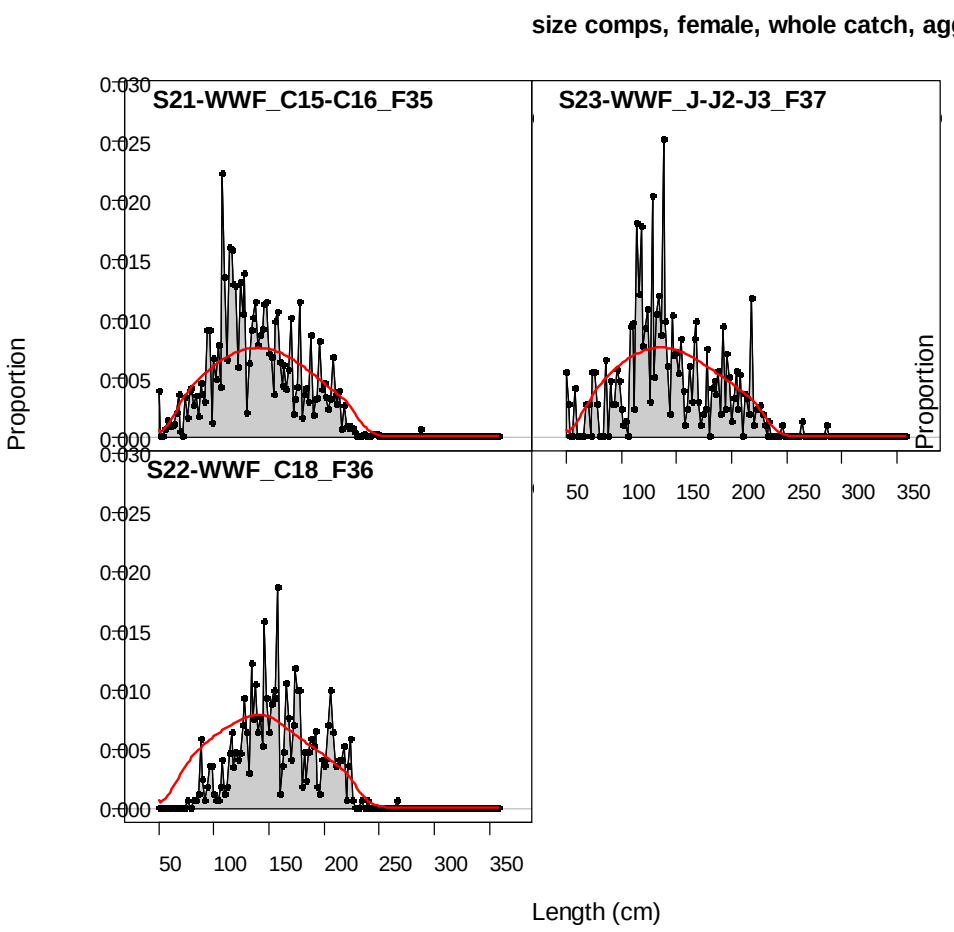


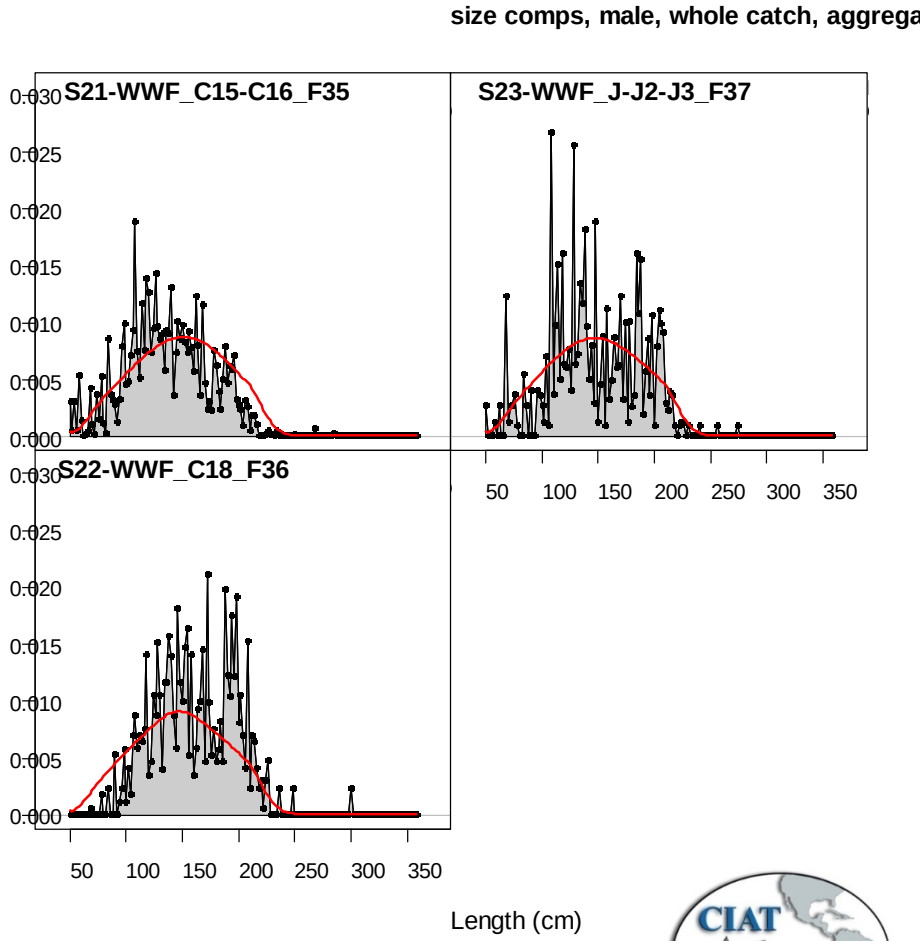
Fits to length comps – OSPESCA



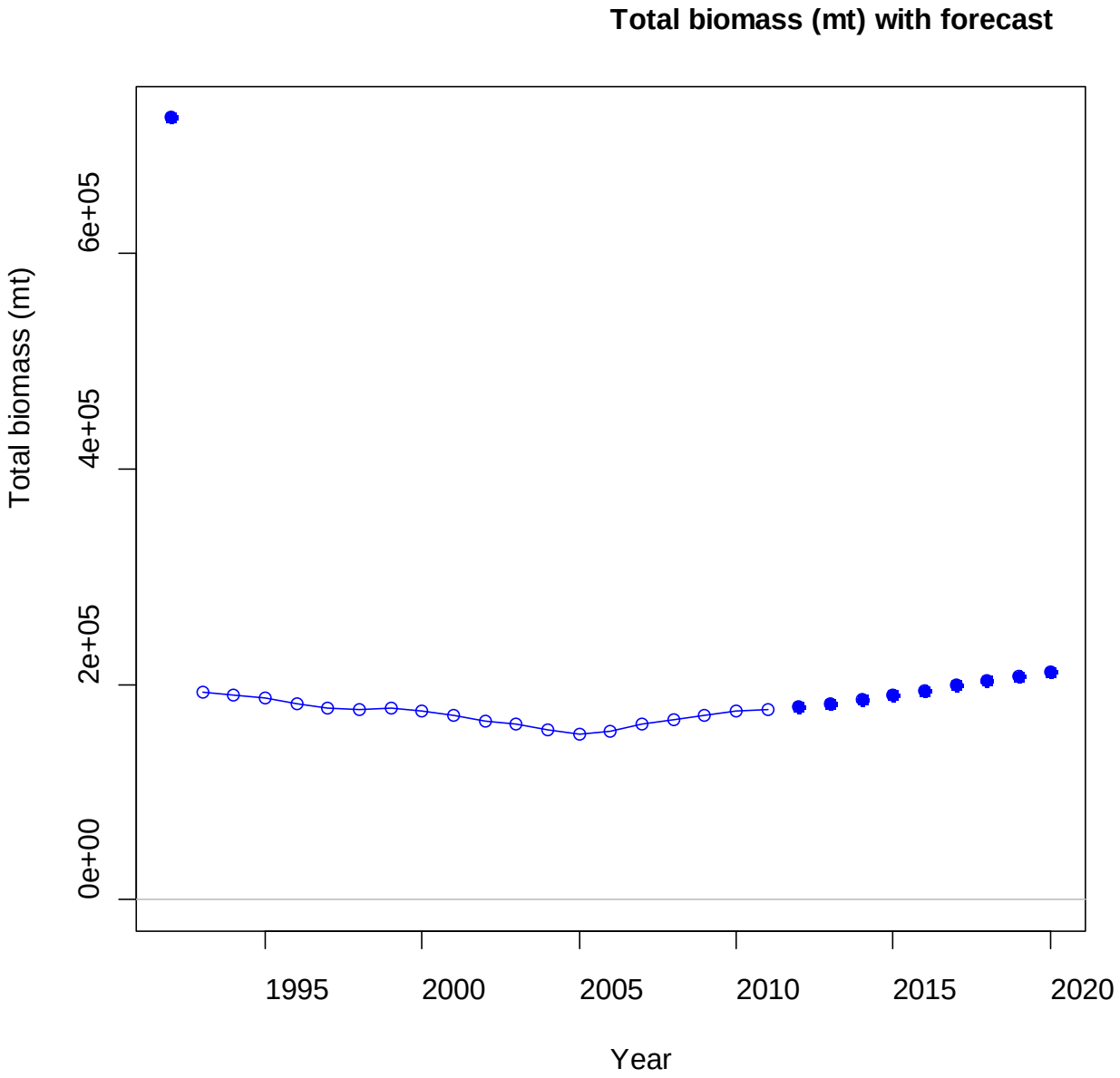


Fits to length comps – WWF

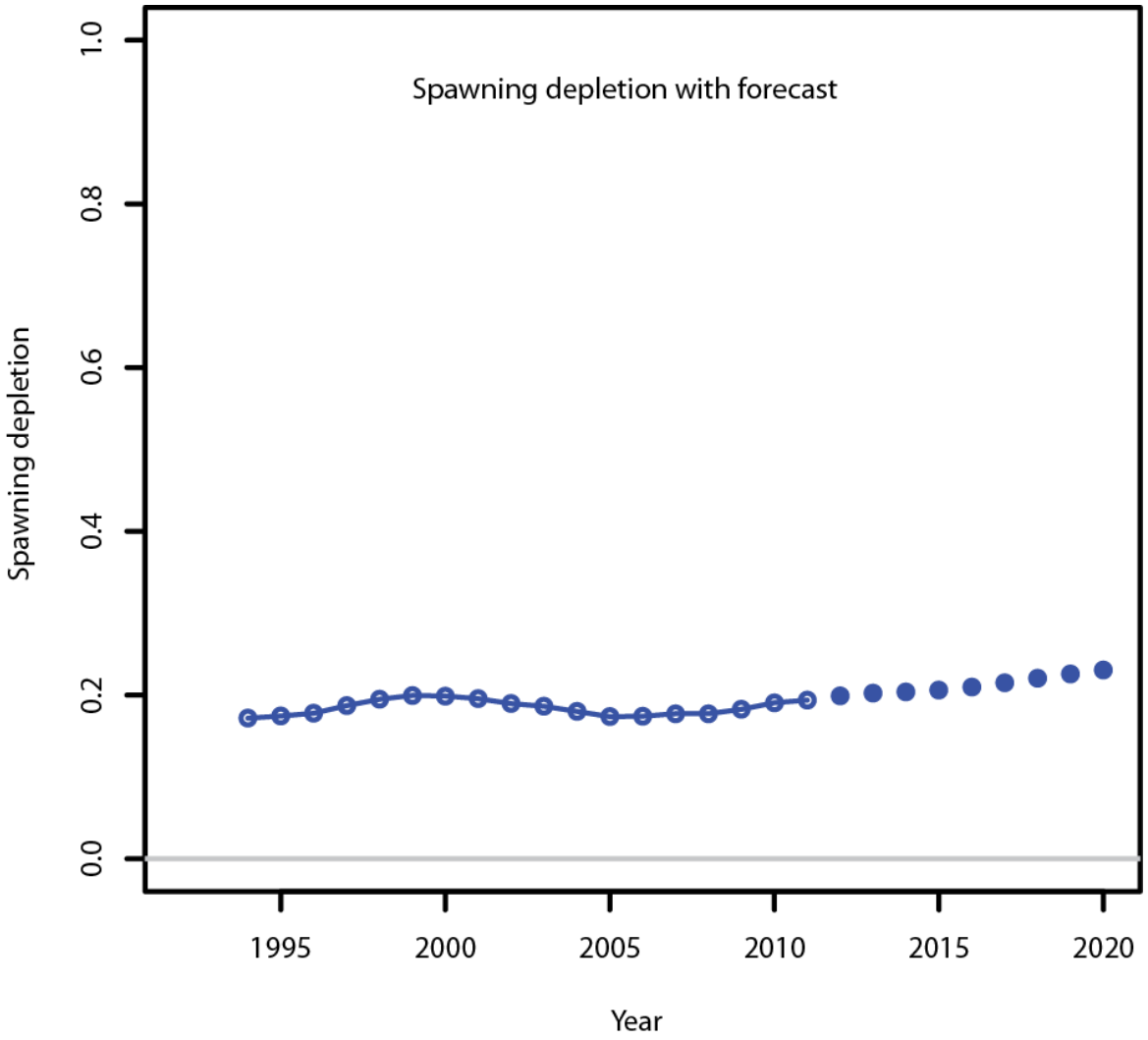




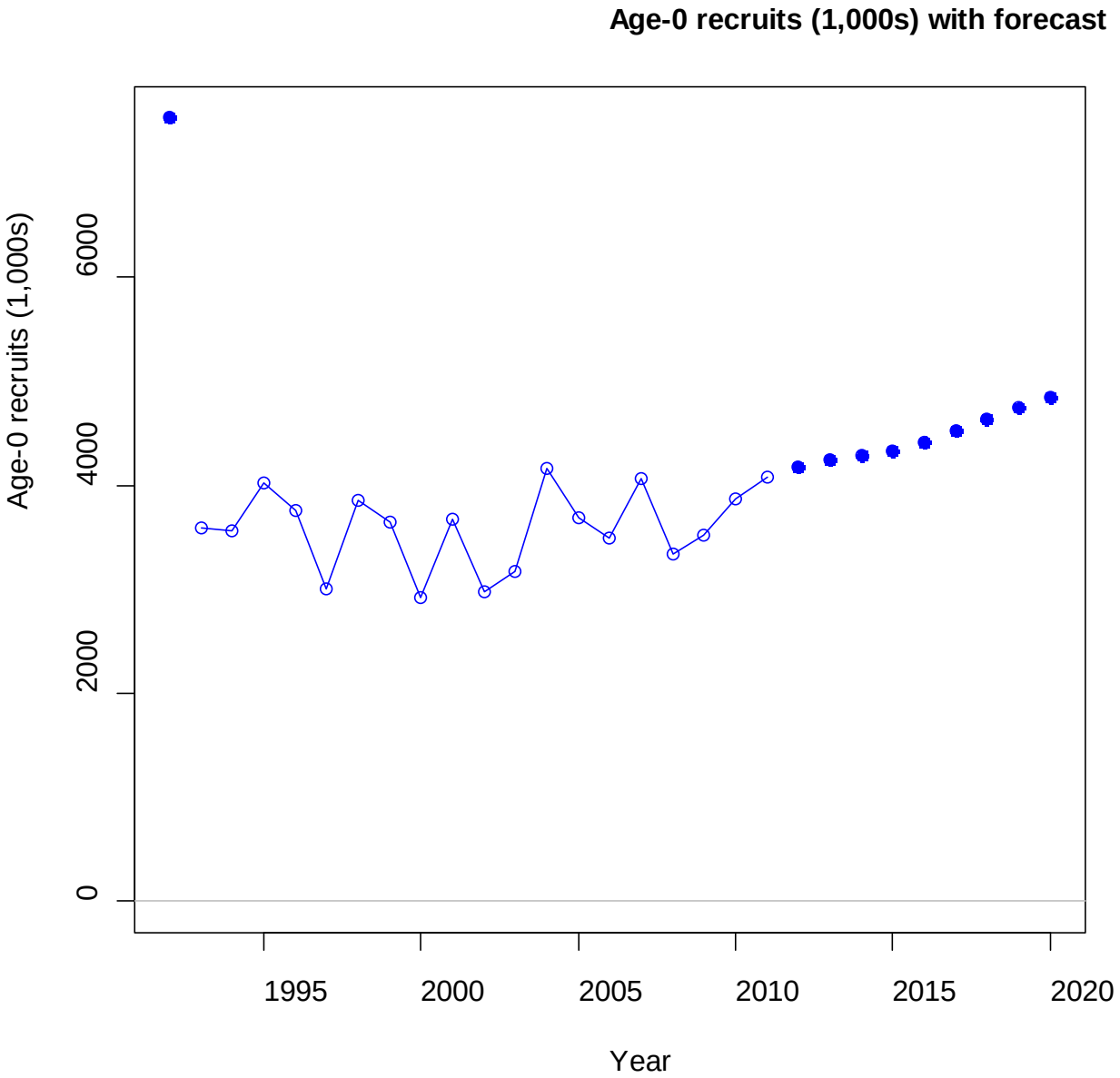
Total biomass



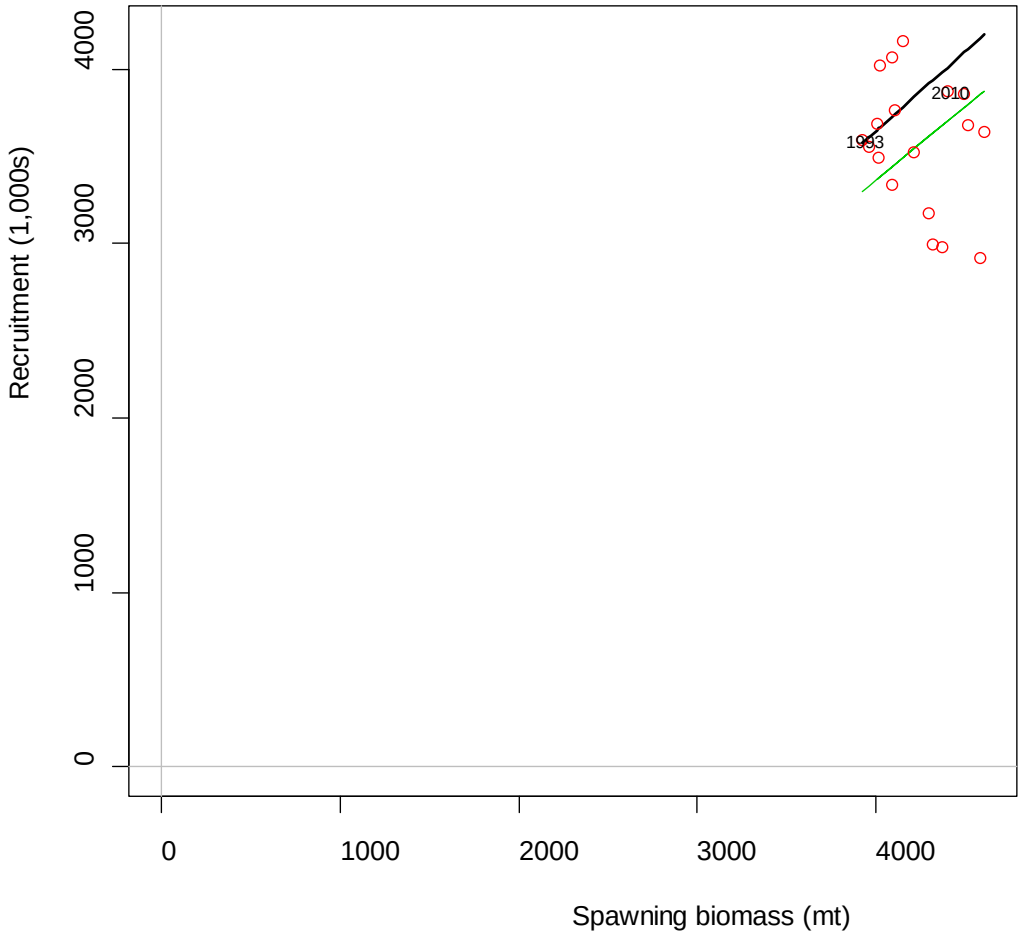
Spawning depletion



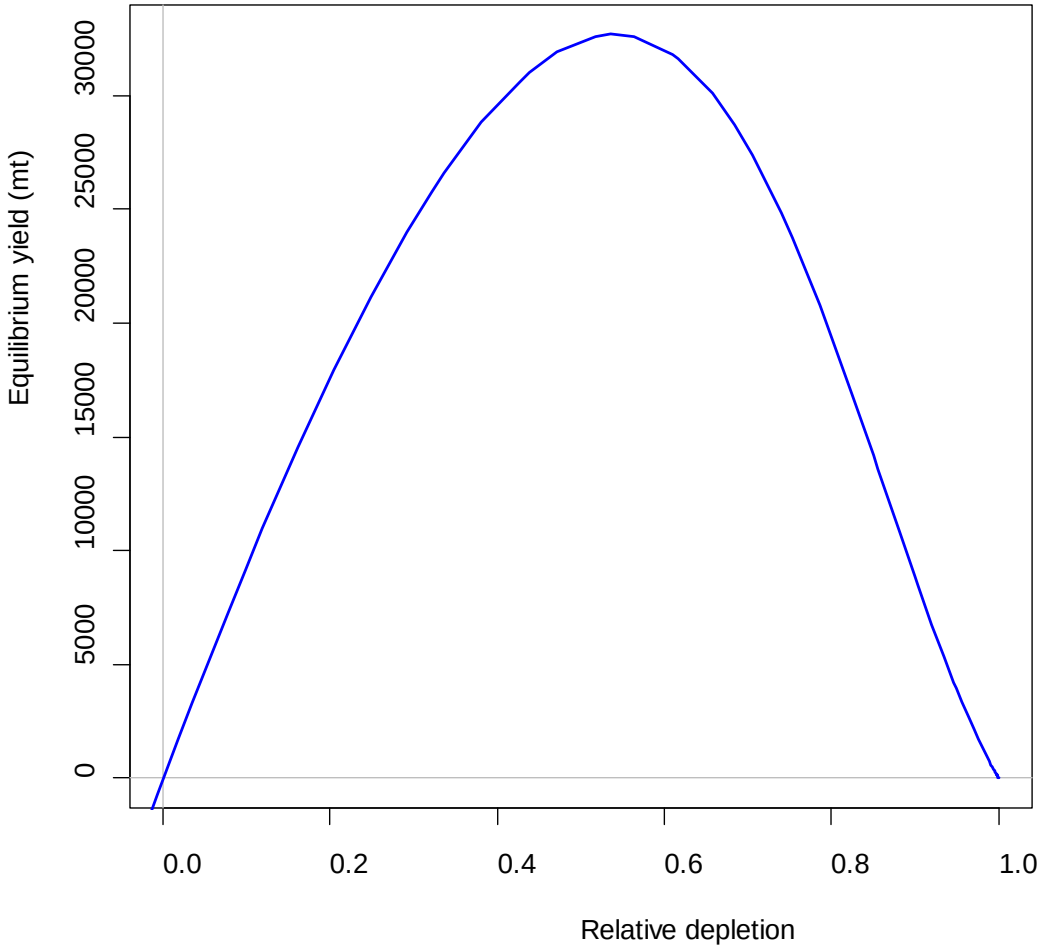
Recruitment



Stock-recruitment



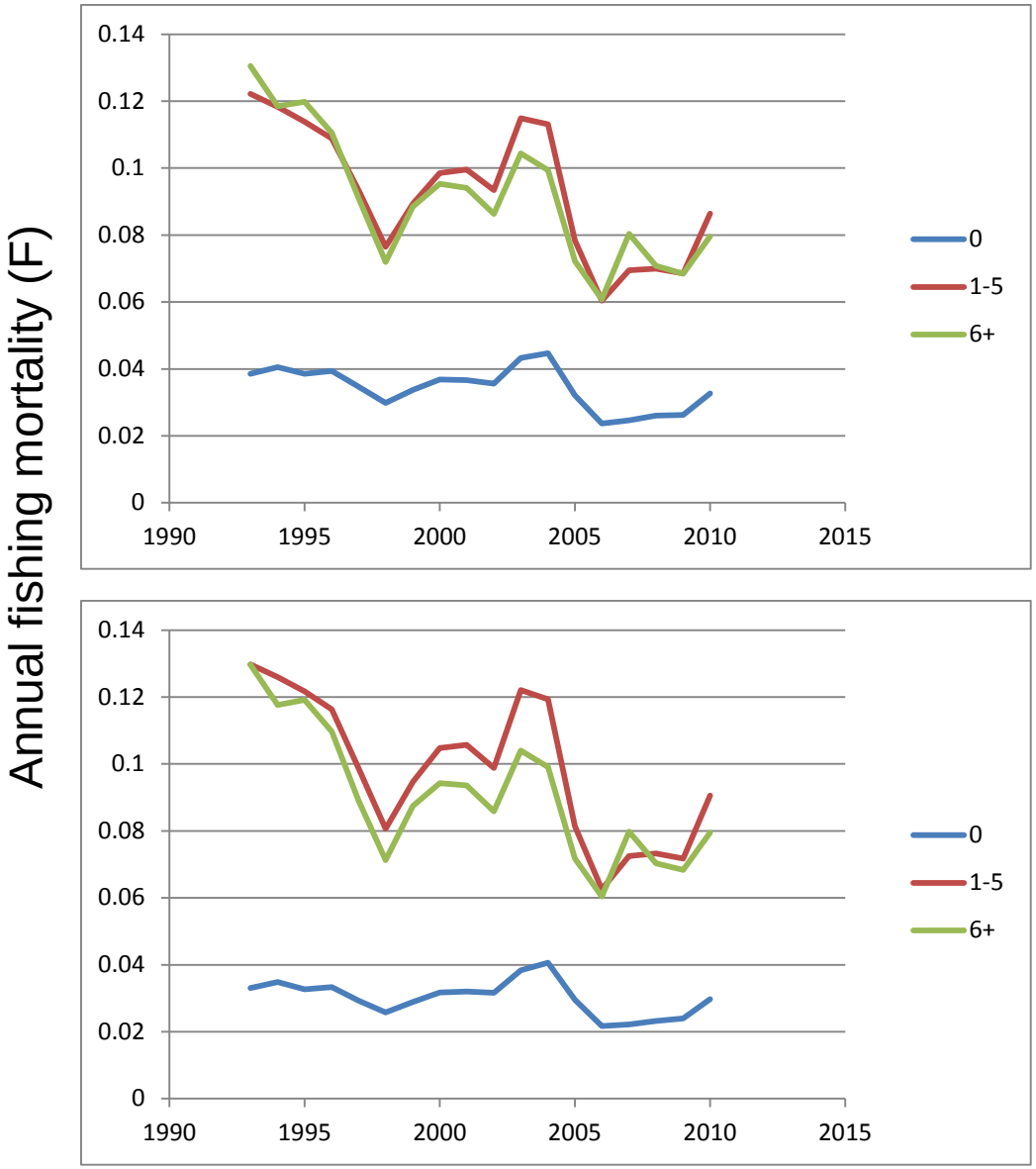
Stock-recruitment



Fishing mortality (*F*)

Females

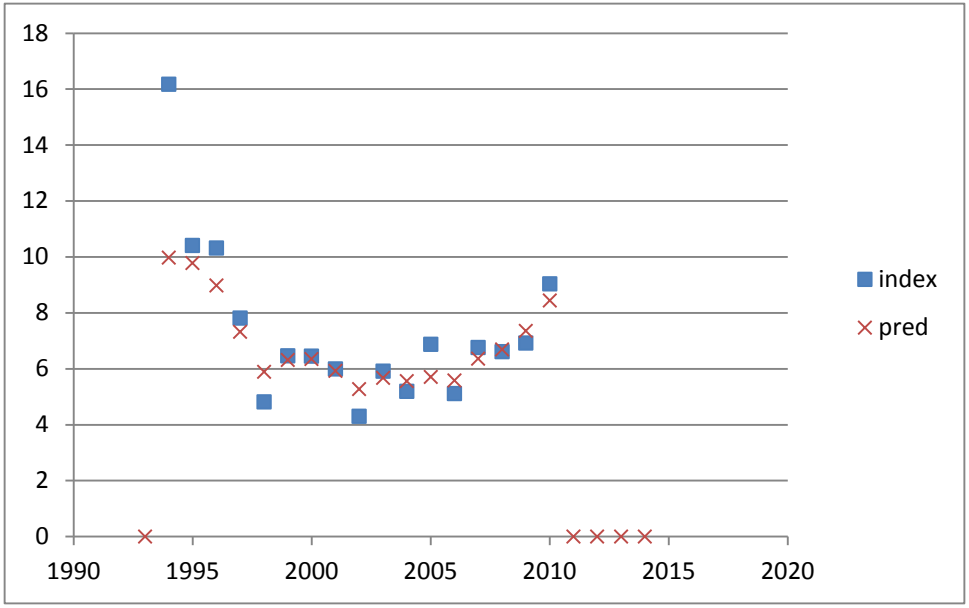
Males



Surplus production model

- Model fits (CPUE)

Surplus production model



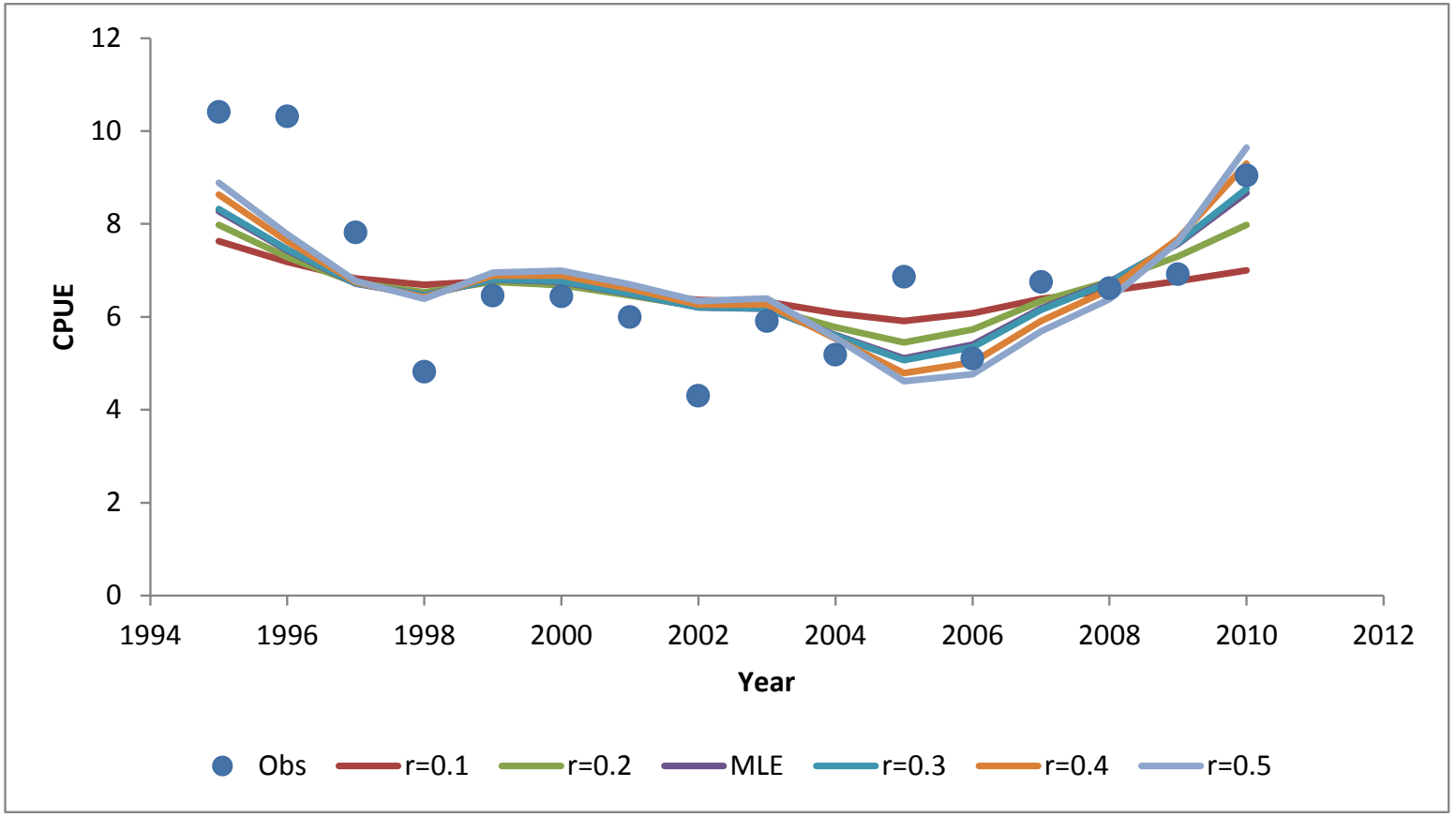
$$(A1) \quad B_{t+1} = B_t + \frac{r}{\left(\frac{1}{m} - 1\right)} \left(\frac{B_t^m}{B_0^{m-1}} - B_t \right) - C_t$$

$$(A2) \quad \frac{B_{\mathrm{MSY}}}{B_0} = \frac{1}{\left(m^{\frac{1}{m-1}} \right)}$$

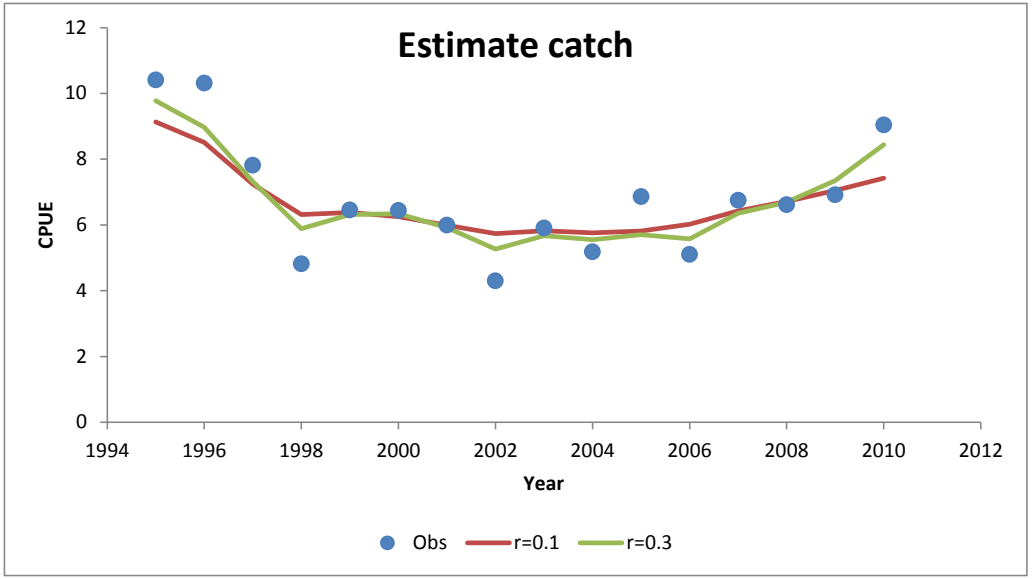
$$(A3) \quad r = \frac{\mathrm{MSY}}{B_{\mathrm{MSY}}}$$

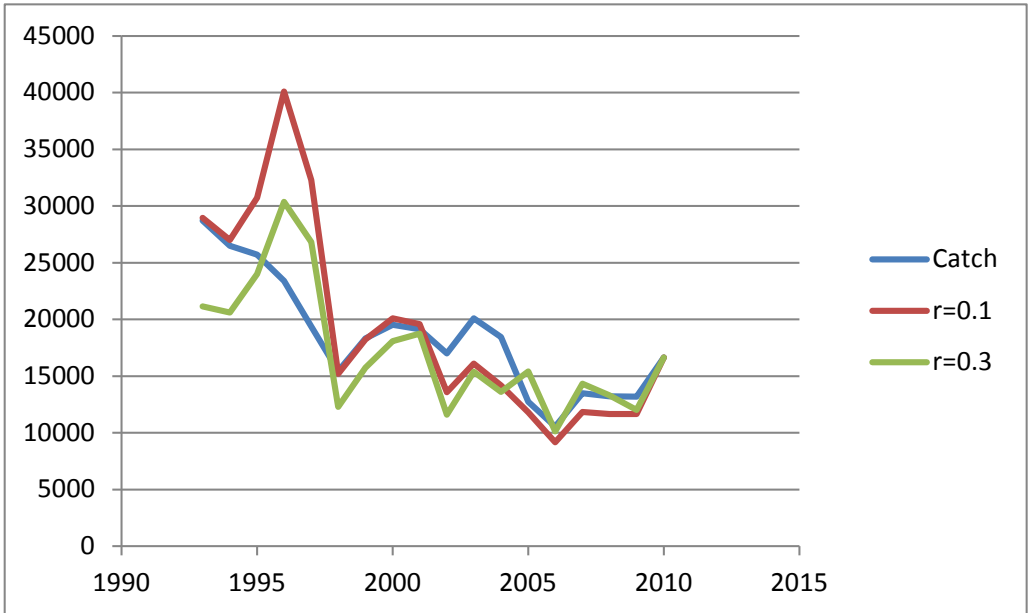
Surplus production model

Increase productivity (*r*)



Surplus production model





Summary

- Since 2009, IATTC staff, national observer program staff and scientists of member countries have worked together to accumulate, process, and analyze data for the silky shark in the EPO.
- This collaborative effort has produced a wealth of information on stock structure, biological parameters (length-weight, age and growth, reproduction), and fishery data (catch, effort, CPUE indices).
- With this information a silky shark stock assessment model was attempted.
- Configuring a stock assessment model that is consistent with the data has been problematic
- Incomplete knowledge of total catch for the EPO is a serious problem, particularly in the early period of the assessment.

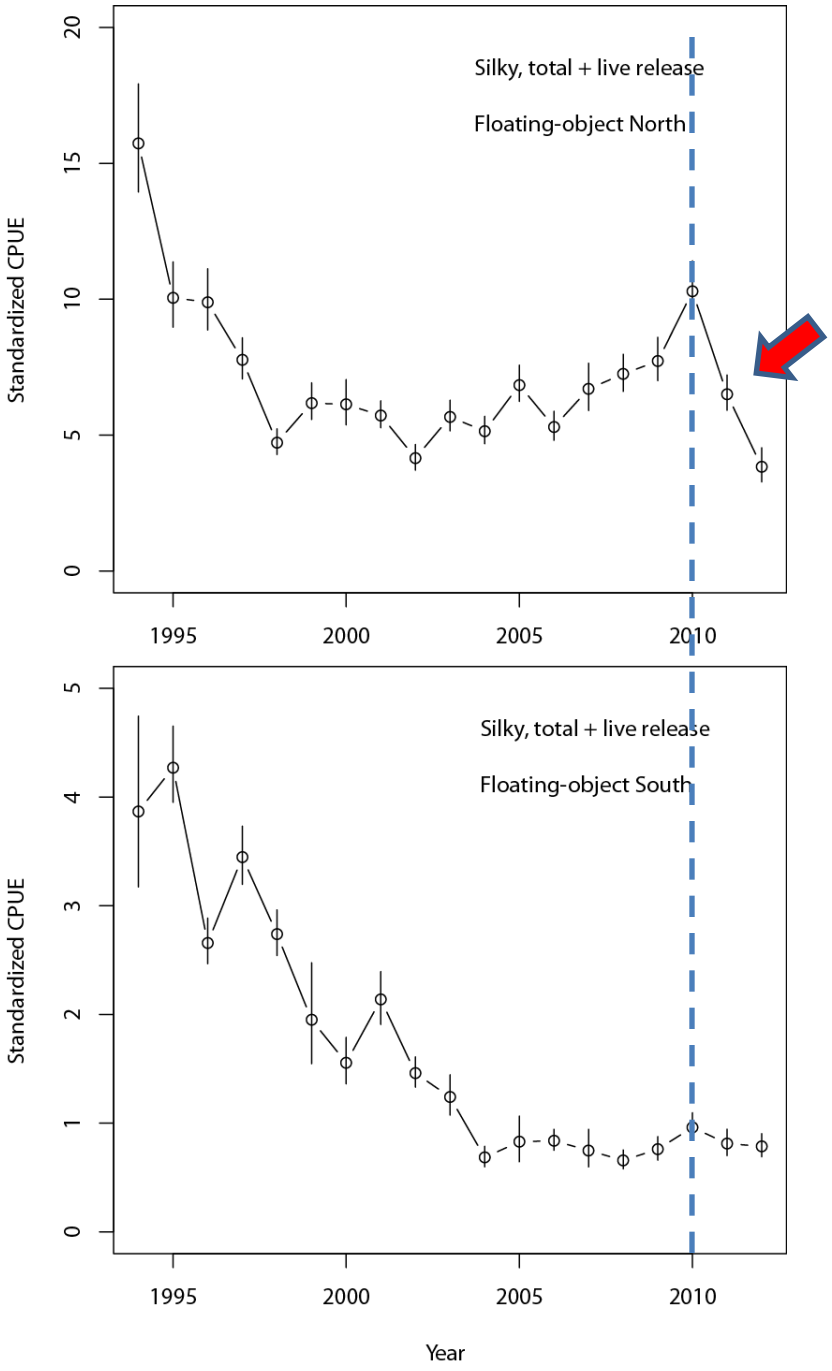
Conclusions

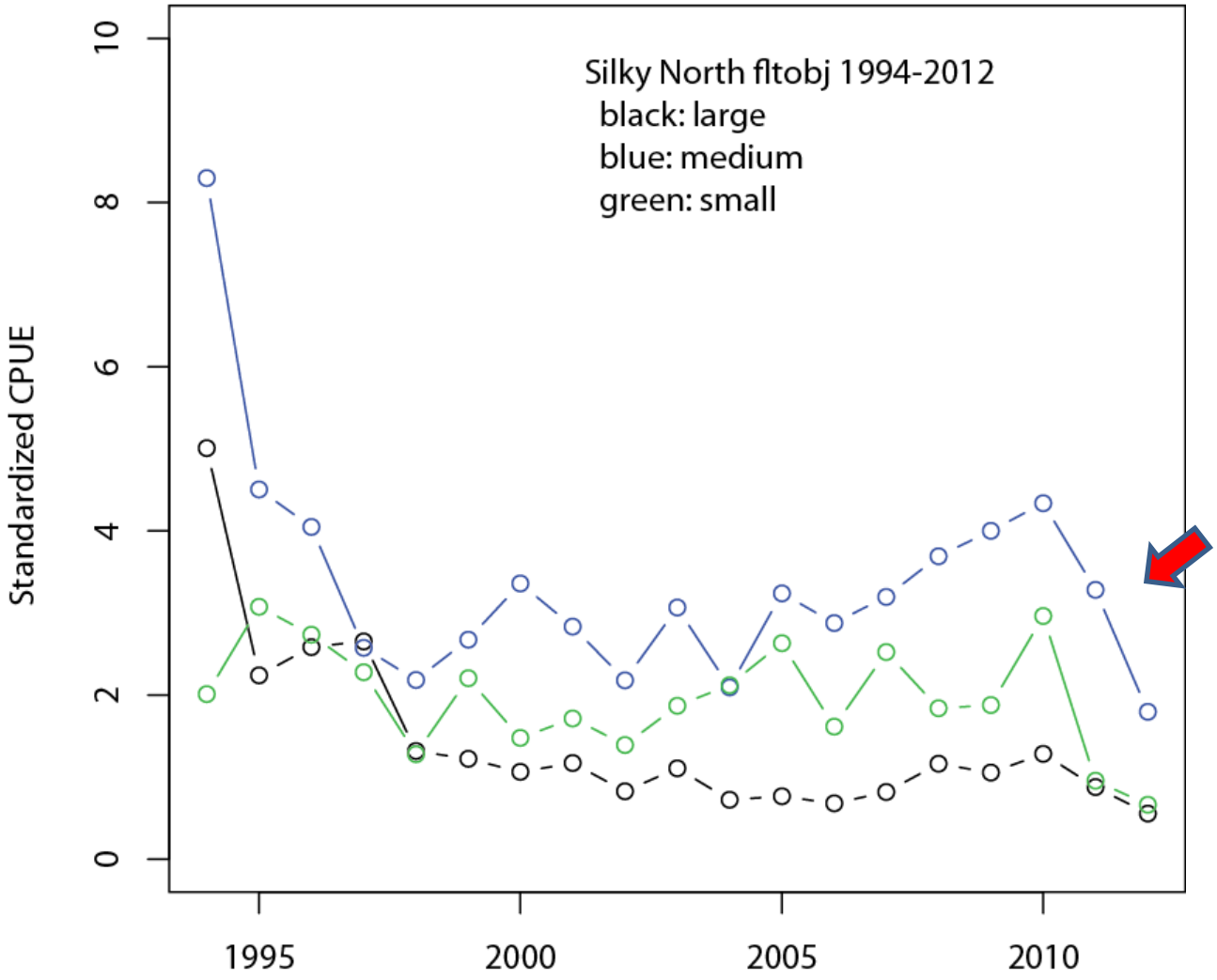
- There appears to be two populations: North and south
- Based on the available data, the purse seine and high seas longline fisheries that target tuna in the EPO catch a minor component of the catch
- There is substantial uncertainty in the historical catch for most fisheries
- There is uncertainty in
  - The length of the oldest individuals
  - The variation of length-at-age
  - Natural mortality
  - The stock-recruitment relationship
- Given these uncertainties, the current fishing mortality rates are predicted to allow the stock size to increase in the future

Acknowledgements

Updated fishery indicators (2010-2012)

- Average lengths
- Indices of abundance (CPUE)

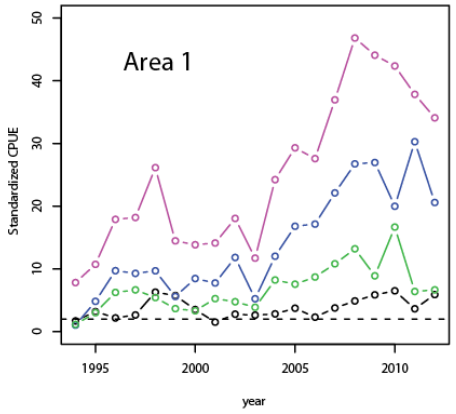

Silky, total + live release
Floating-object North
Standardized CPUE
0
5
10
15
20
1995
2000
2005
2010
Silky, total + live release
Floating-object South
Standardized CPUE
0
1
2
3
4
5
1995
2000
2005
2010
Year

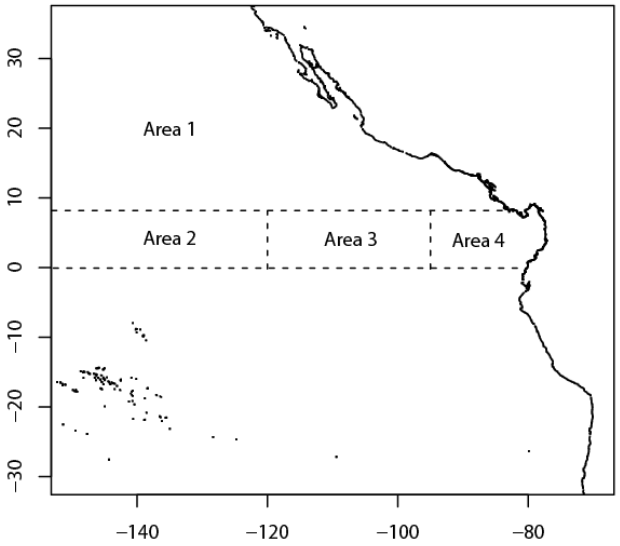

Silky North fltobj 1994-2012
black: large
blue: medium
green: small
Standardized CPUE
0
2
4
6
8
10
1995
2000
2005
2010

Silky shark standardized trends
floating-object sets
1994-2012

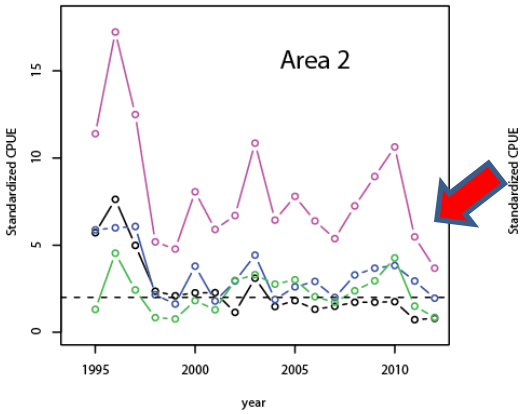
pink : total silky
black : large silky
blue : medium silky
green : small silky

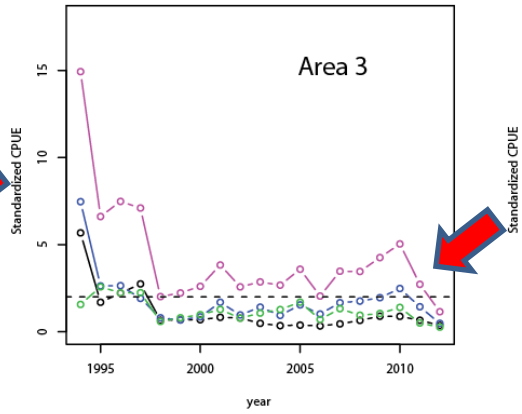
Notes:
- fit for large unstable in Area 4;
- no data for 1994 in Area 2;
- y-axis range different for Area 1;
- horizontal dashed line at 2.0 is just for visual reference.

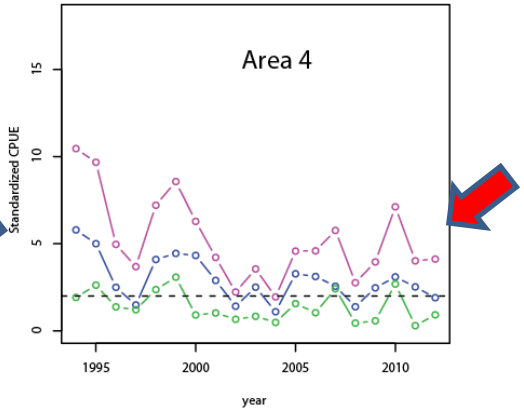




Area 1: north of 8N
Area 2: 120-150W and 0-8N
Area 3: 95-120W and 0-8N
Area 4: coast -95W and 0-8N



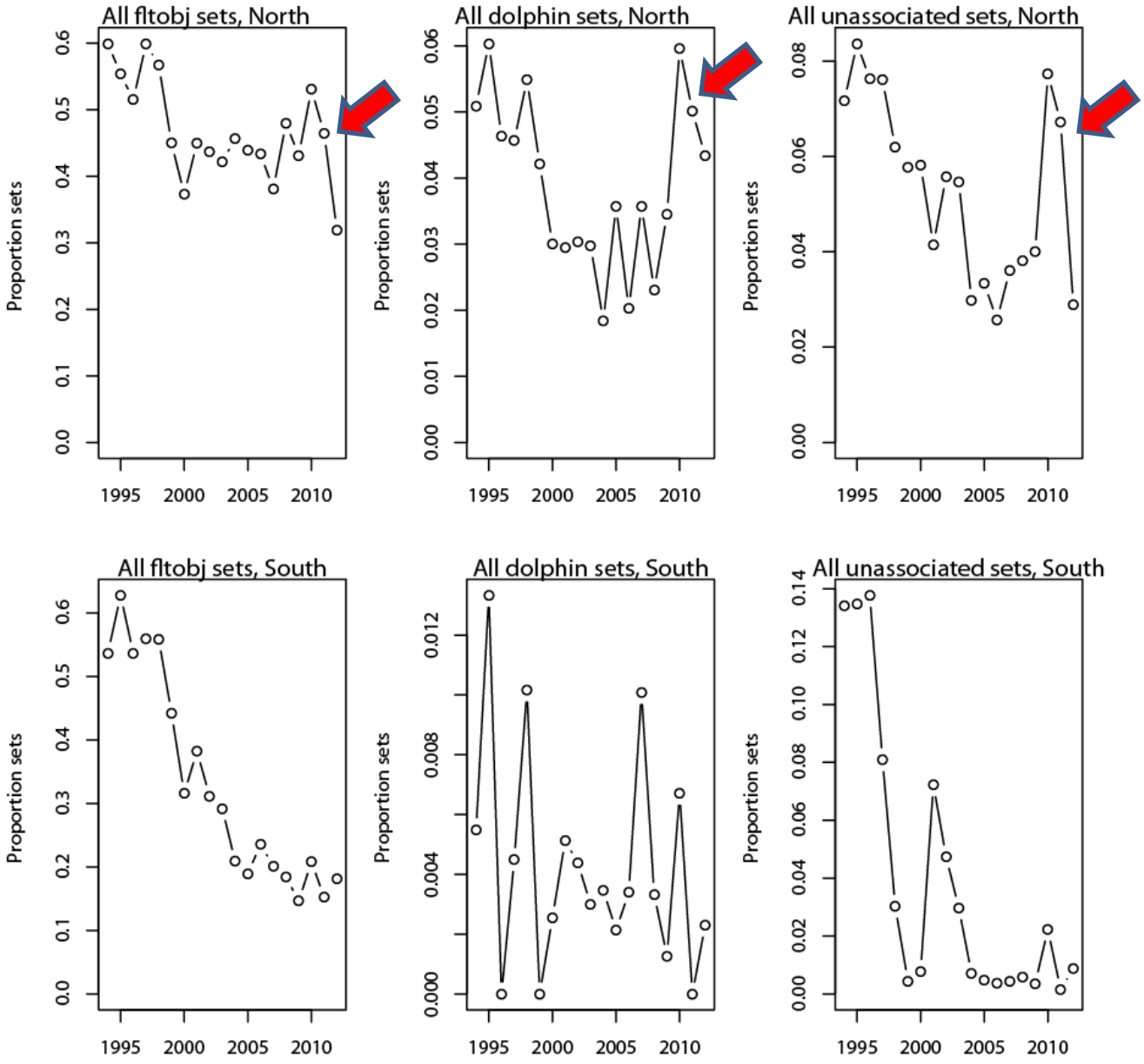




Nominal PS presence/absence

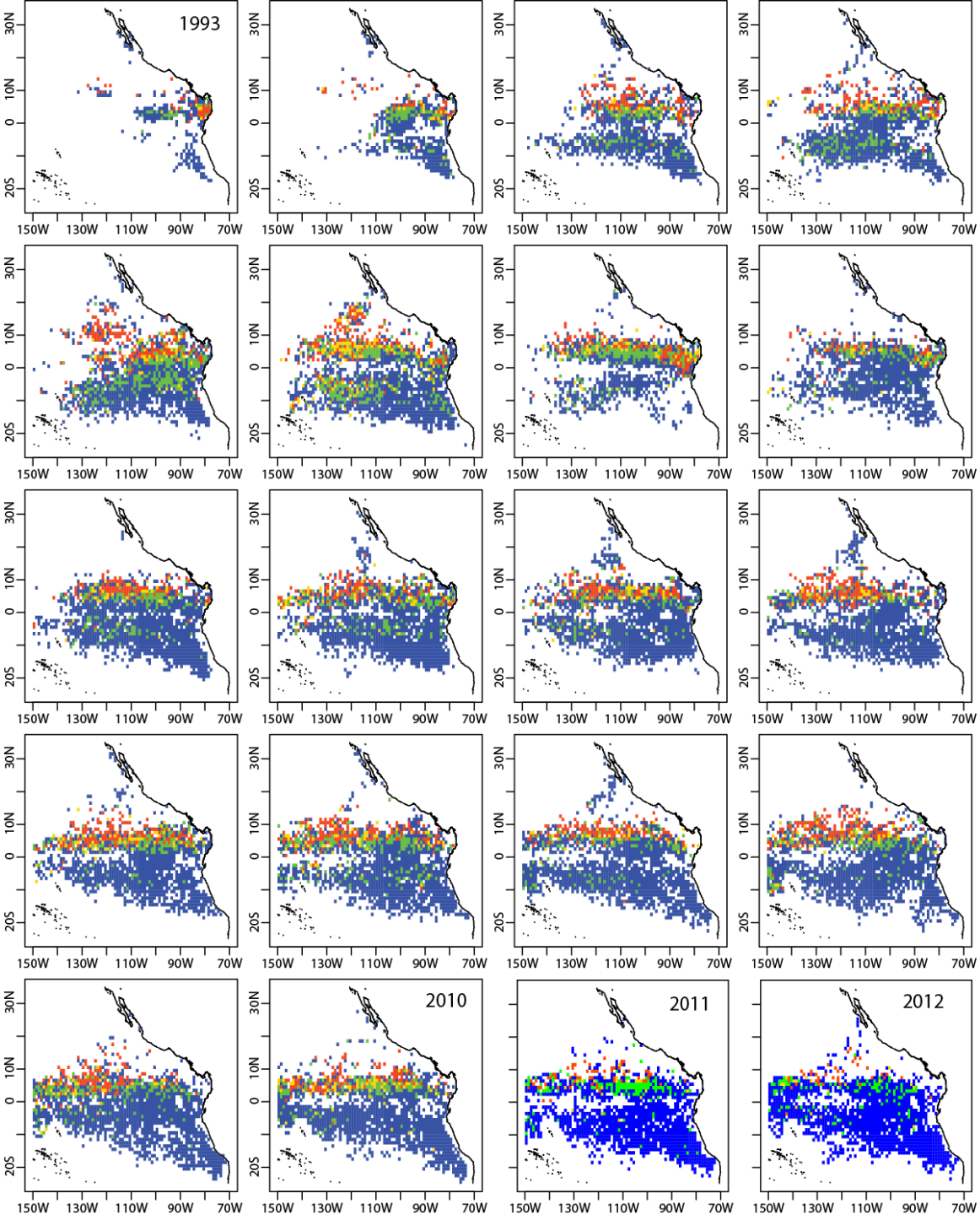
Presence/absence silky bycatch (total+live release; nominal)
1994-2012

All IATTC sets
raw shark data file



Fltobj sets
small silky
IATTC only

Color scale:
blue: 0 bps
green: <= 1 silky/set
yellow: 1-2 silky/set
red: > 2 silky/set



1993-1996

1997-2000

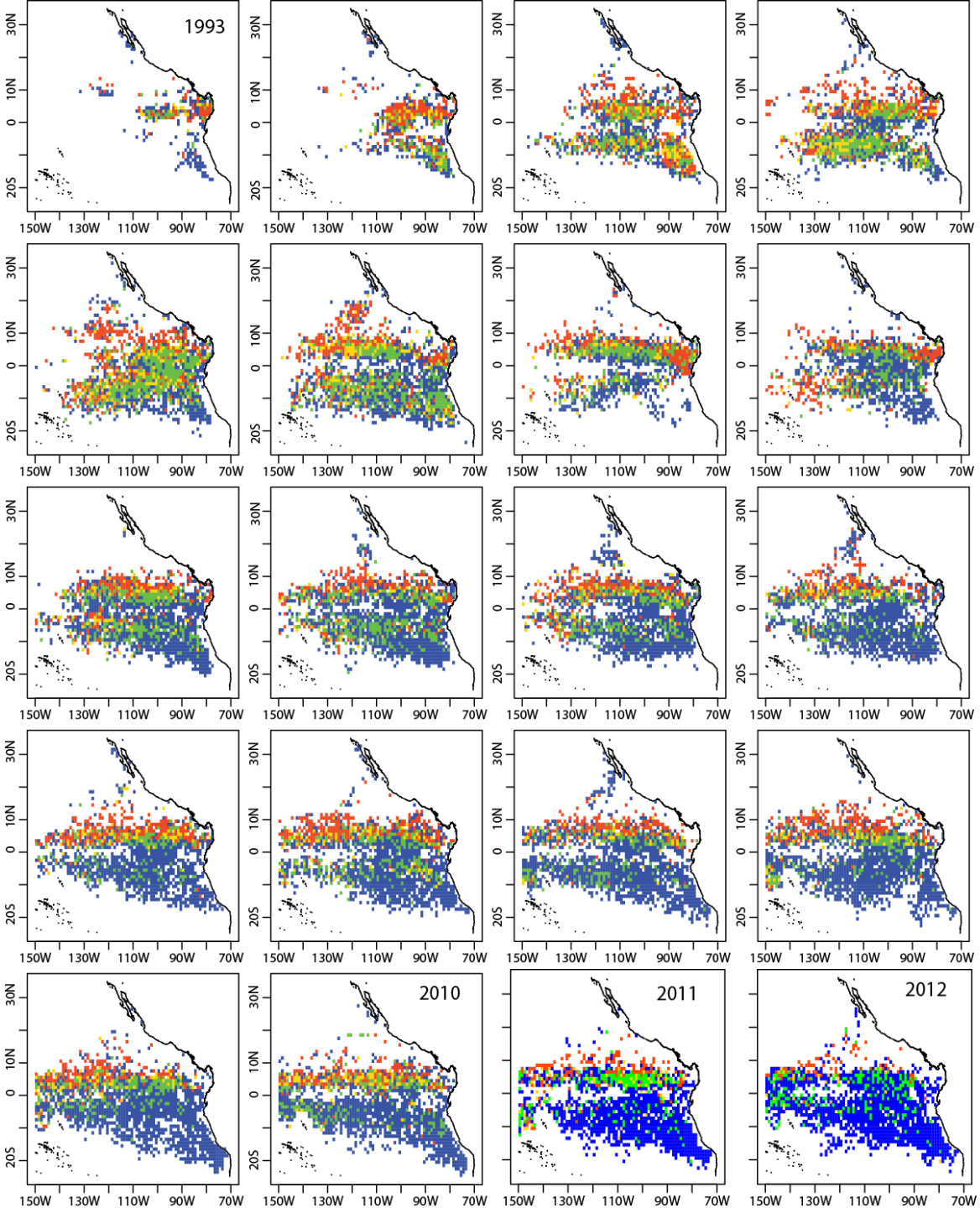
2001-2004

2005-2008

2009-2012

Fltobj sets
medium silky
IATTC only

Color scale:
blue: 0 bps
green: <= 1 silky/set
yellow: 1-2 silky/set
red: > 2 silky/set



1993-1996

1997-2000

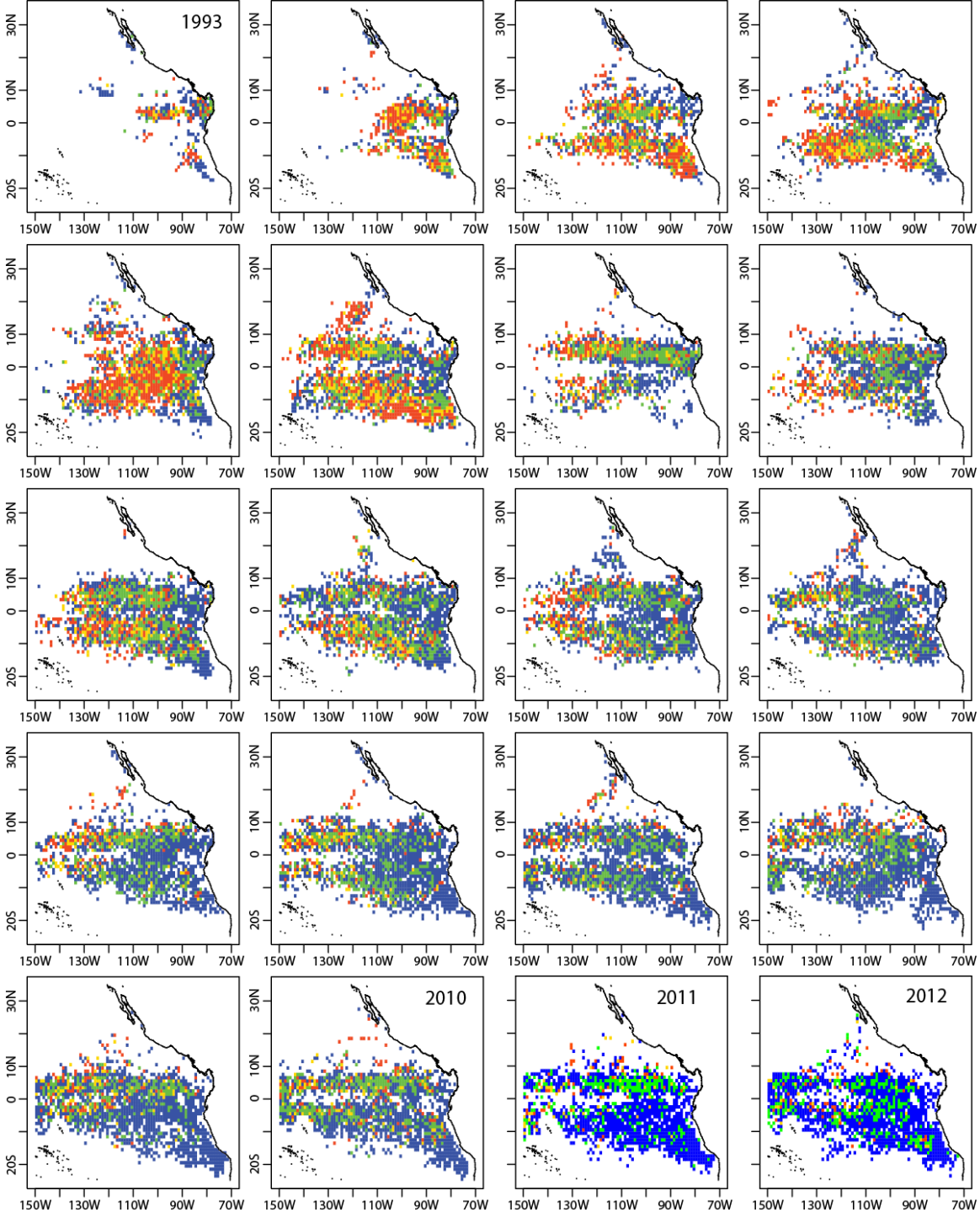
2001-2004

2005-2008

2009-2012

Fltobj sets
large silky
IATTC only

Color scale:
blue: 0 bps
green: <= 1 silky/set
yellow: 1-2 silky/set
red: > 2 silky/set



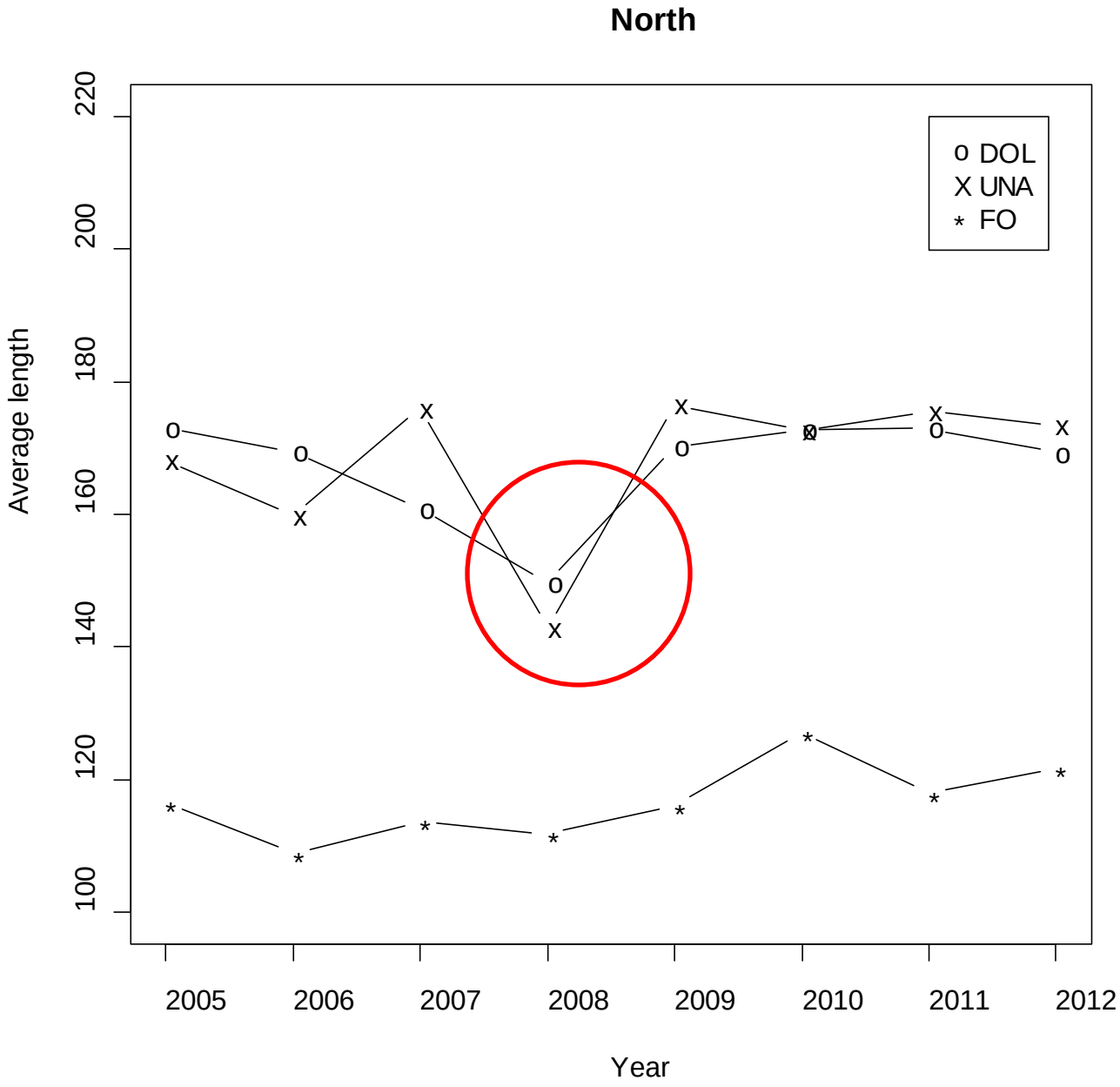
1993-1996

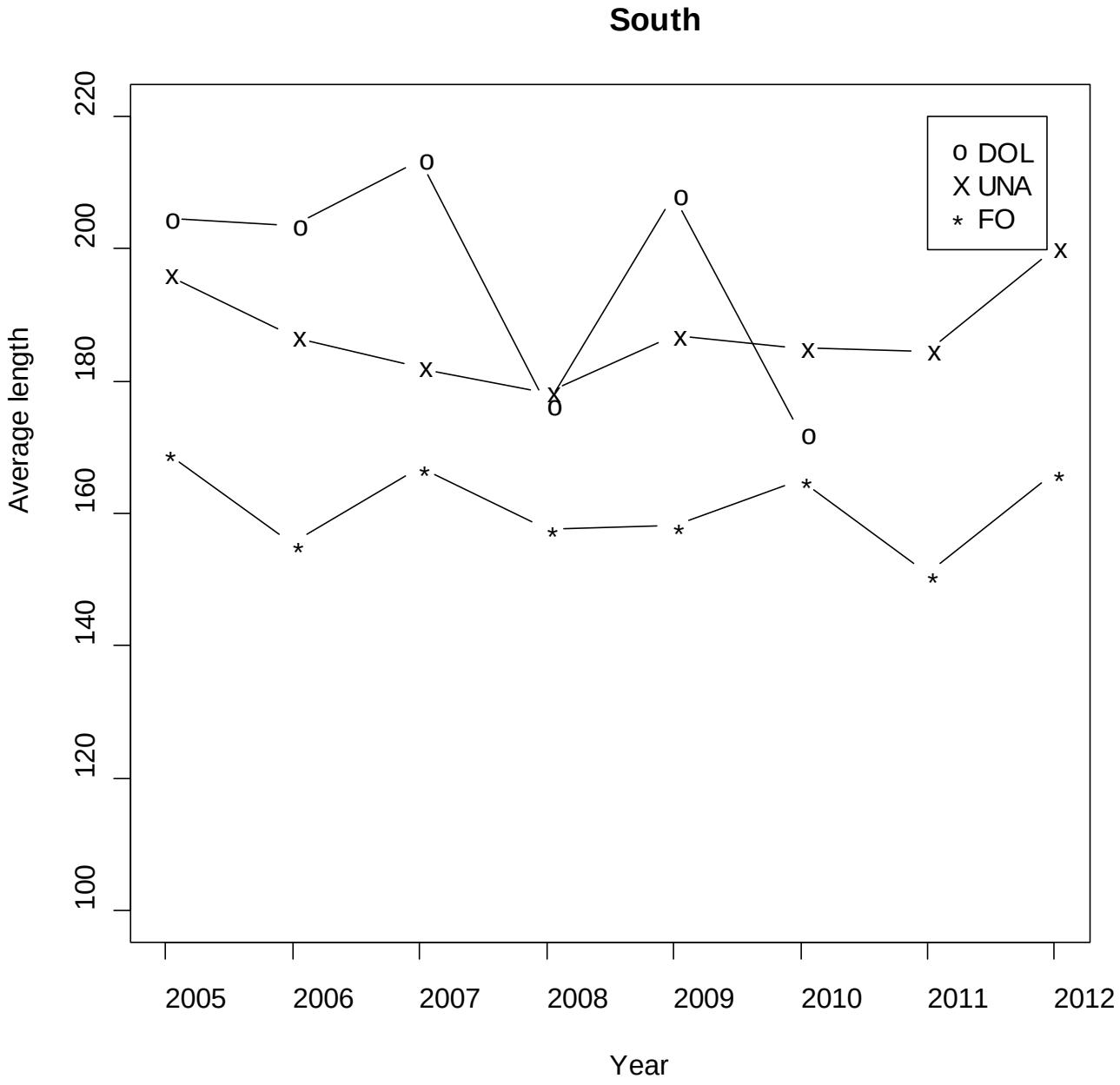
1997-2000

2001-2004

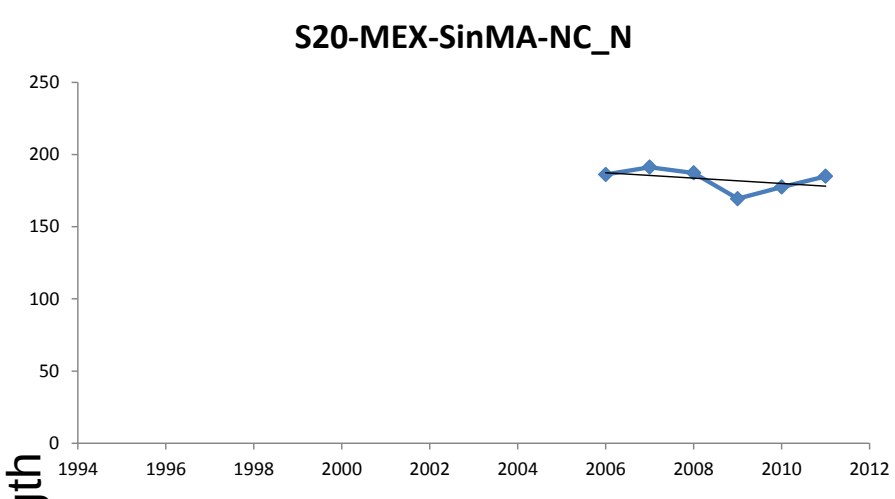
2005-2008

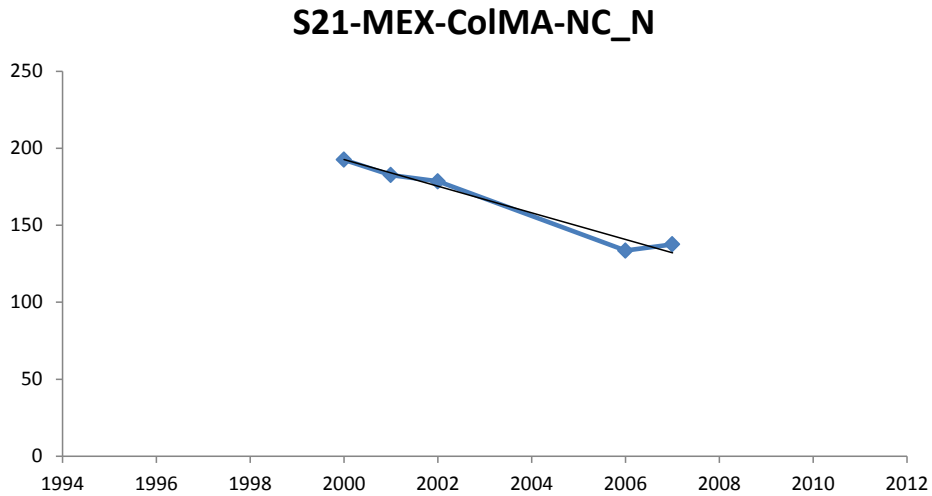
2009-2012

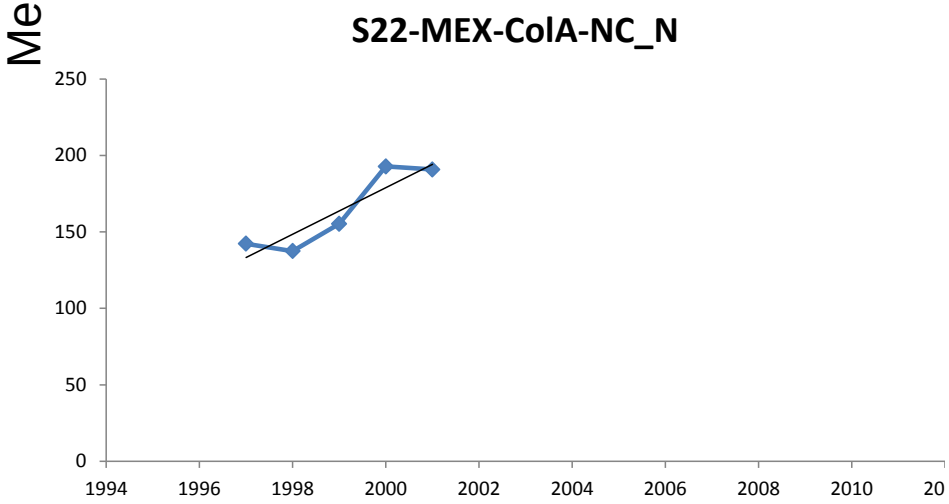

North
o DOL
X UNA
* FO
Average length
100
120
140
160
180
200
220
2005
2006
2007
2008
2009
2010
2011
2012
Year

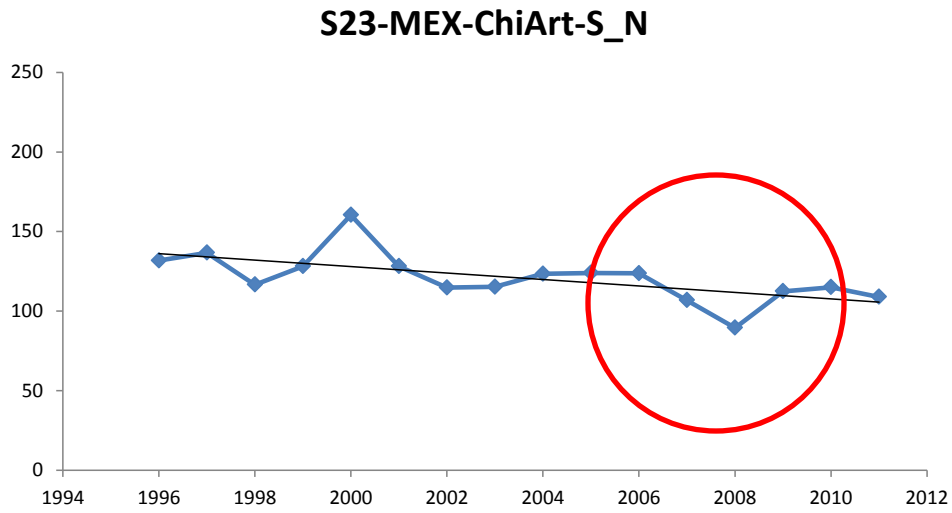

South
o DOL
X UNA
* FO
Average length
100
120
140
160
180
200
220
2005
2006
2007
2008
2009
2010
2011
2012
Year

MEXICO

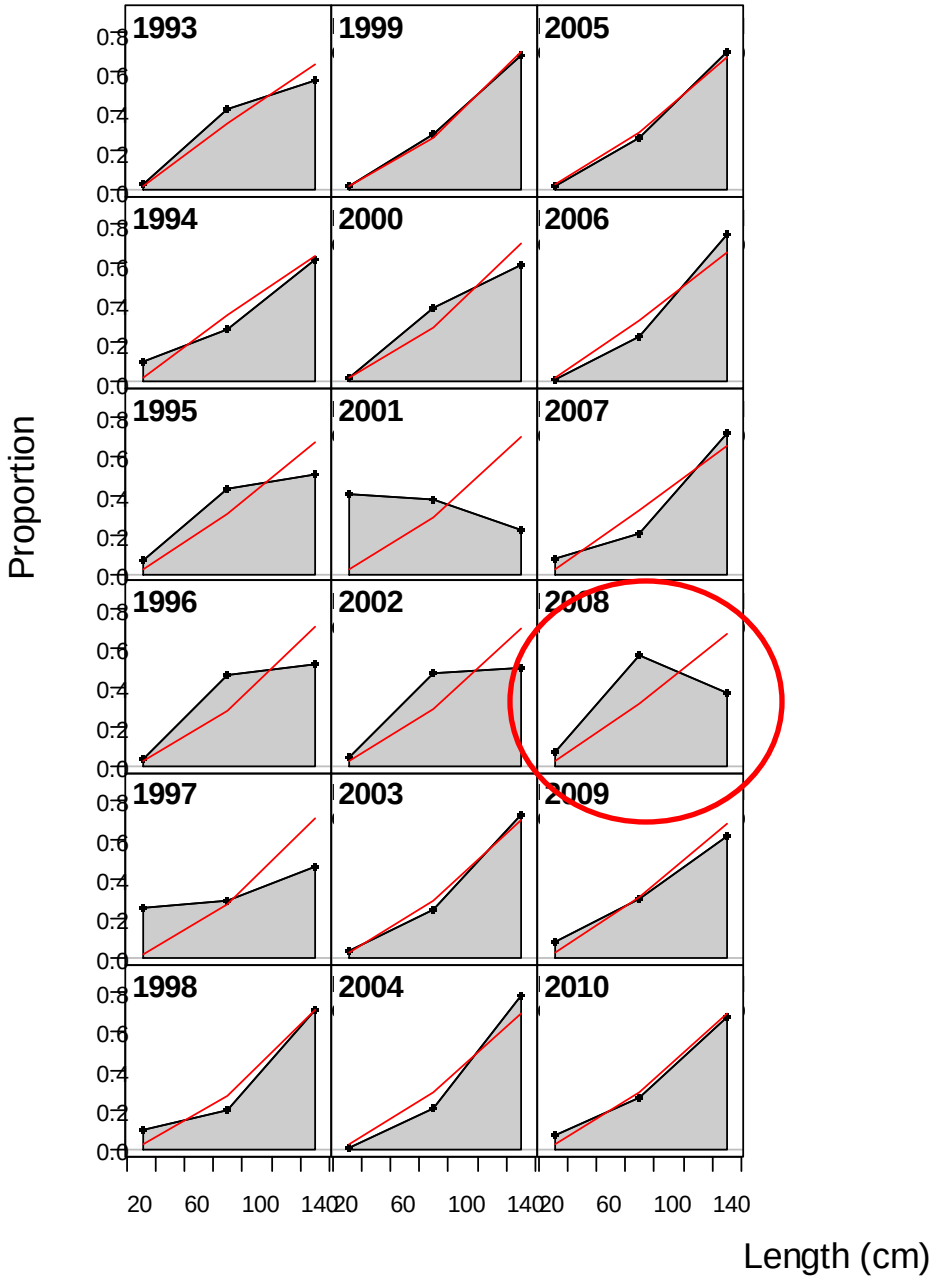

S20-MEX-SinMA-NC_N
Mean length
250
200
150
100
50
0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

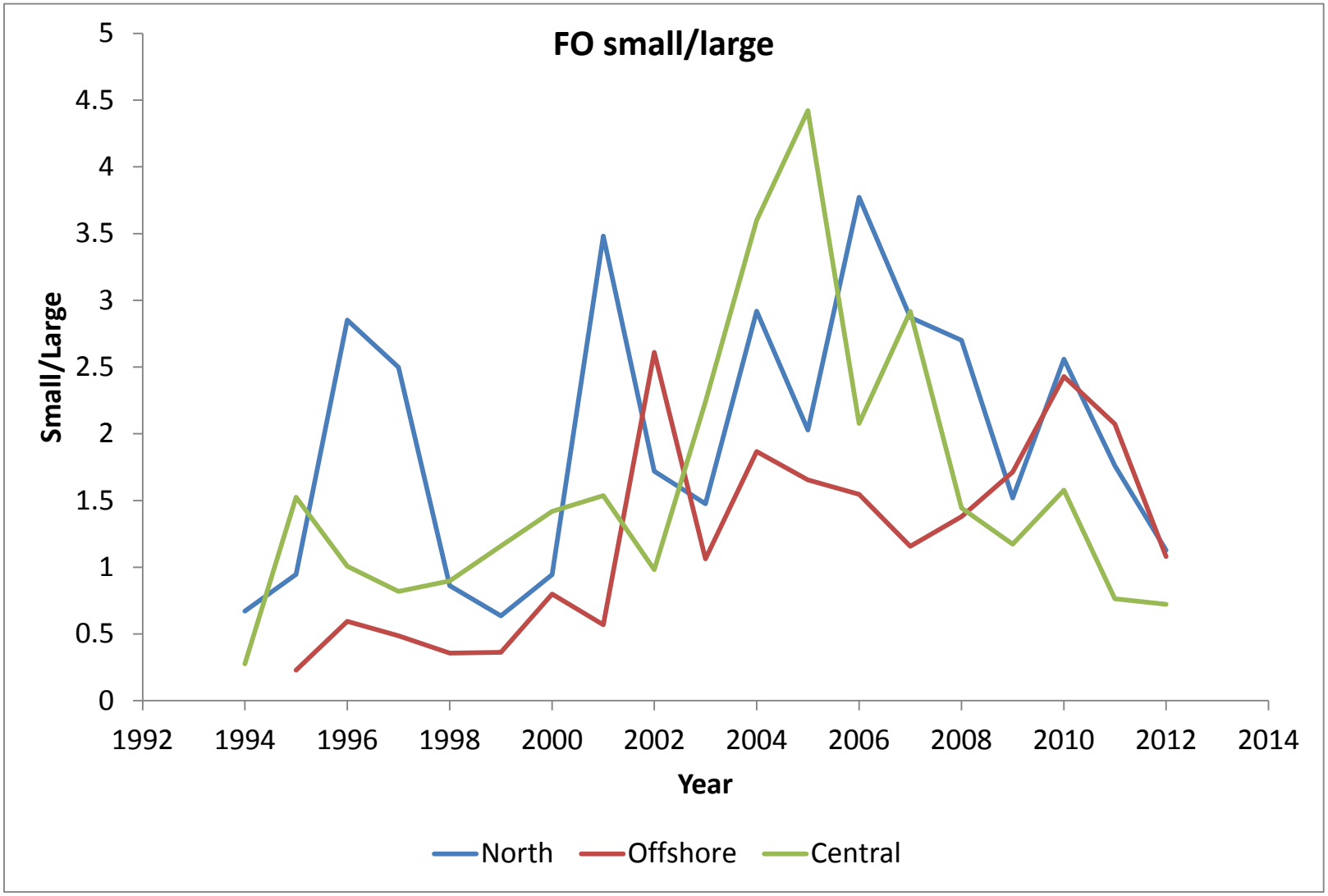

S21-MEX-ColMA-NC_N
250
200
150
100
50
0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012


S22-MEX-ColA-NC_N
250
200
150
100
50
0
1994
1996
1998
2000
2002
2004
2006
2008
2010
20


S23-MEX-ChiArt-S_N
250
200
150
100
50
0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

size comps, sexes combined, whole catc




FO small/large
Small/Large
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Year
North
Offshore
Central

Summary: recent indicators

- Updated purse-seine CPUE indices show:
  - declines in the last two years for all three set types, all sizes, and all areas, in the northern EPO;
  - no change trends in the southern EPO.
- There are no substantial changes in the recent purse-seine and Mexican time series of average length that correspond to the decline in CPUE.
- The recent CPUE decline occurred over the whole range of the floating object fishery north of the equator

Recommendations

- Data
  - Vital
    - Complete reporting of all silky shark catch
  - Useful
    - Catch, effort, size composition, sex composition, by spatial resolution
    - Improved growth estimates
    - Estimates of natural mortality
- Management
  - Limit fishing mortality rates to recent levels to allow further rebuilding

QUESTIONS?