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

2nd Meeting (May 2011)
- Identify silky shark data sources available

3rd 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

Silky shark
*C. falciformis*

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

Small: < 90cm TL
Medium: 90-150cm TL
Large: > 150 cm TL
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
Age and growth of the silky shark *Carcharhinus falciformis* from the Pacific Ocean

Shungo Oshitani, Hideki Nakano, and Sho Tanaka

**Length-weight relationship**

\[ BW = 0.0000273 \times PCL^{2.86} \]

\[ n = 322 \]

Fig. 1 Locations of sampling during the research cruise.
Length-weight relationship

MALES (n=552)
- Mexico - Colima (n= 83)
- Mexico - Chiapas (n=437)
- Ecuador (n=32)

FEMALES (n=634)
- Mexico - Colima (n= 58)
- Mexico - Chiapas (n=538)
- Ecuador (n=38)

SEXES COMBINED (n=1,186)
- Mexico - Colima (n= 141)
- Mexico - Chiapas (n=975)
- Ecuador (n=70)
Length-weight relationship

- This study - females
- This study - males
- This study - sexes combined
- Branstetter (1987) - GOM
- Joung et al (2008) - Taiwan
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

**Mexico (Santana, N=141)**

\[ y = 1.5603x - 1.6561 \]
\[ R^2 = 0.9743 \]

**Ecuador (Martinez, N=10)**

\[ y = 1.7011x - 0.8369 \]
\[ R^2 = 0.9874 \]
Age and growth of the silky shark *Carcharhinus falciformis* from the Pacific Ocean

Shungo Oshitani,¹ Hideki Nakano² and Sho Tanaka¹

\[ L_t = 216.4 (1 - e^{-0.148 (t + 1.76)}) \]
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

![Graph](image)
Age and growth (cont.)

Birth: 65-75 cm

Age_max

L_max

L_max

Oshitani (2003)
Sanchez-de Ita (2011)
Variability of length-at-age

Ending year expected growth

Length (cm, middle of the year)

Age (yr)
Maturity-at-length

CHIAPAS (Soriano-Castillo)

N=11,094

N=11,354
Maturity-at-length

L50 = 182 cm

Proportion gravid

- Maturity
- Pregnancy

Length (cm)

Proportion

Age (years)

Proportion gravid
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.

Pregnant Female Size / number of embryos

Pregnancy x fecundity

Relative fecundity (pregnancy x fecundity)

Age (years)
Natural mortality (M)

Frisk et al. (2001)
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

NORTH
- Adjusted for shallow
- Original

SOUTH
- Adjusted for shallow
- Original

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

- **CA - non-coastal nations (estimated)**
- **CA - coastal nations**

**Chart Description:**
- The chart displays landings (total weight, tons) for non-coastal nations and coastal nations in Central America from 1993 to 2010.
- The y-axis represents the landings in tons, ranging from 0 to 10,000.
- The x-axis represents the years from 1993 to 2010.
- The chart uses different colors to distinguish between non-coastal nations and coastal nations.
Catches – Ecuador

Expert opinion:
Ecuadorian scientists
Catch - “missing” coastal nations
Catch Northern stock

Silky shark catches - Northern stock

CA-non-coastal
CA-coastal
Ecuador
Mexico
LL-tuna
PS-tuna

Year

Catch (tons)
0 2,000 4,000 6,000 8,000 10,000 12,000 14,000 16,000 18,000 20,000
Catch Southern stock

Silky shark catches - Northern stock

Silky shark catches - Southern stock

Year

CA-non-coastal
CA-coastal
Ecuador
Mexico
LL-tuna
PS-tuna

Catch (tons)

LL-tuna
PS-tuna
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
2009-2010

Average bycatch-per-set, floating-object sets
Small silky sharks, 1993-2010
Fltobj sets  
medium silky  
IATTC only  

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

1993-1996  
1997-2000  
2001-2004  
2005-2008  
2009-2010  

Average bycatch-per-set, floating-object sets  
Medium silky sharks, 1993-2010
Fltobj sets
large silky
IATTC only

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

1993-1996
1997-2000
2001-2004
2005-2008
2009-2010

Average bycatch-per-set, floating-object sets
Large silky sharks, 1993-2010
Purse-seine standardized trends: floating-object sets

North

South

Black = All
Aqua = All + live release
Red = Large
Green = Medium
Blue = Small

Number of sharks per set

1995  2000  2005  2010

1995  2000  2005  2010
Purse-seine Standardized trends: dolphin and unassociated sets

Dolphin sets

North

Unassociated sets

North

South

South

Presence/absence-based index

Year

Black = All
Red = Large
All indices
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

Index S2-OBJ-CL6-LRG_F16

LARGE

Index S3-OBJ-CL6-MED_F17

MEDIUM

Index S4-OBJ-CL6-SML_F18

SMALL
Model fits to CPUE data – NOA & DEL

Index S5-NOA-CL6-ALL_F19

Index S7-DEL-CL6-ALL_F21
Fits to length comps - OBJ

size comps, female, whole catch, aggregated

size comps, male, whole catch, aggregated

Proportion

Length (cm)

F1-OBJ-CL6

F3-DEL-CL6

F2-NOA-CL6

F3-DEL-CL6

CIAT
IATTC
Fits to size comps - OBJ

size comps, sexes combined, whole cat

F1-OBJ-CL6

F3-DEL-CL6

F2-NOA-CL6

Length (cm)

Proportion
Fits to length comps – Mexico

size comps, sexes combined, whole catx

Proportion

Length (cm)
Fits to length comps – Ecuador

size comps, female, whole catch,

size comps, male, whole catch, $a_\xi$

Proportion

F13-ECU-LL

F14-ECU-GN

Proportion

F13-ECU-LL

F14-ECU-GN

Length (cm)

Length (cm)
Fits to length comps – OSPESCA

size comps, female, whole catch, aggre

S20-CA-OSPESCA_F34

Length (cm)

Proportion

size comps, male, whole catch, aggre:

S20-CA-OSPESCA_F34

Length (cm)

Proportion
Fits to length comps – OSPESCA

size comps, female, whole catch, aggregate

size comps, male, whole catch, aggregate
Fits to length comps – WWF

Size comps, female, whole catch, aggregate

Length (cm)

Proportion

Size comps, male, whole catch, aggregate

Length (cm)

Proportion

CIAT
IATTC
Total biomass

Total biomass (mt) with forecast

Year

Total biomass (mt)
Spawning depletion

Spawning depletion with forecast

Year

Spawning depletion

Stock-recruitment
Stock-recruitment

Equilibrium yield (mt) vs. Relative depletion
Surplus production model

• Model fits (CPUE)
Surplus production model

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

(A2) \[ \frac{B_{MSY}}{B_0} = \left( \frac{1}{m^{m-1}} \right) \]

(A3) \[ r = \frac{MSY}{B_{MSY}} \]
Surplus production model

Increase productivity ($r$)
Surplus production model

Estimate catch

Year

CPUE

Obs  r=0.1  r=0.3

Catch

r=0.1  r=0.3
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 North fltobj 1994-2012
black: large
blue: medium
green: small
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
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
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
MEXICO

S20-MEX-SinMA-NC_N

S21-MEX-ColMA-NC_N

S22-MEX-ColA-NC_N

S23-MEX-ChiArt-S_N
size comps, sexes combined, whole catc

Proportion

Length (cm)
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?