Stock assessment of Southwest Pacific blue shark

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Introduction

- Blue sharks (*Prionace glauca*) landed in longline fisheries globally between 50^{o}N and 50^{o}S
- Relatively productive: fast growth and high fecundity (for a shark)
- Reported catch records since the 1990s
- North and south Pacific stocks treated as separate stocks, no cross-equator movement in tagged animals.
- Potentially large catch in Southwest Pacific albacore fisheries in the late 1980s (incl. by driftnets).

Introduction (Contd.)

- First attempt at south-west Pacific blue shark assessment in 2016 (SC12; Takeuchi et al. 2016), using MULTIFAN-CL.
- Assessment was considered work in progress; conflicting trends in CPUE depending on data source considered.
- North Pacific stock has been assessed (ISC 2018): stock has recovered from low biomass and high fishing mortality in the 1990s; currently considered not to be overfished and overfishing is not taking place.
- Present assessment attempted to:
  1. Resolve data conflicts
  2. Update catch reconstruction
  3. Combine advances from south- and north Pacific assessments

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Summary

Inputs

- LF data from observer measurements (all LFs in FL)
- Catch reconstructed from extrapolated observer-recorded catch-rates.
- CPUE from:
  1. SPC-held observer data (not used in assessment)
  2. Groomed log-sheet data (used for NZ/EU fleets)
  3. JP operational logsheet data (high-seas)
  4. Chinese-Taipei observer CPUE

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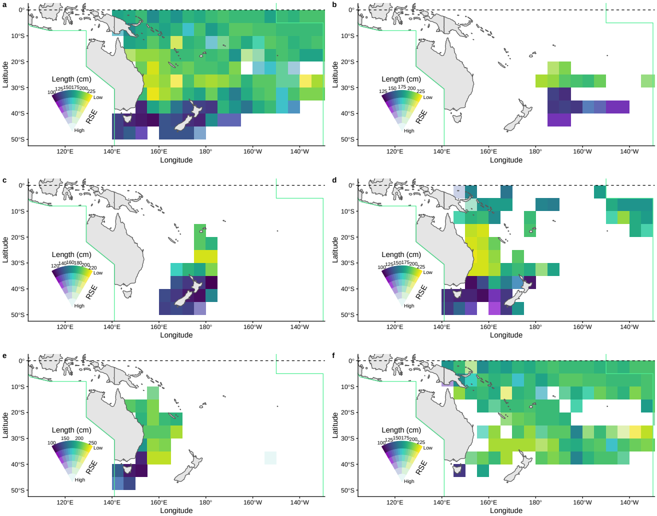
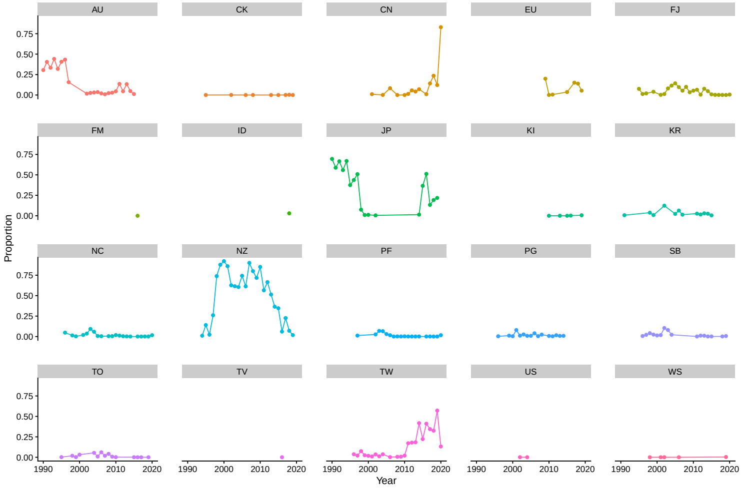
Length frequencies

Spatial LFs by flag



Length frequencies

Temporal LFs by flag



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Length frequencies

Overview

- Good spatial coverage
- Temporal coverage biased towards AU (early/mid 1990s) -> NZ (late 1990s–2010) -> JP/TW/CN (2010–2020).
- LFs used to derive fleet selectivity, then down-weighted in assessment (using Francis 2011).
- Clear signal of smaller individuals south of 35 degrees South, suggests nursery areas in high latitudes.
- Growth (5y Manning & Francis) applied to high latitude samples suggests low- to high latitude movement.

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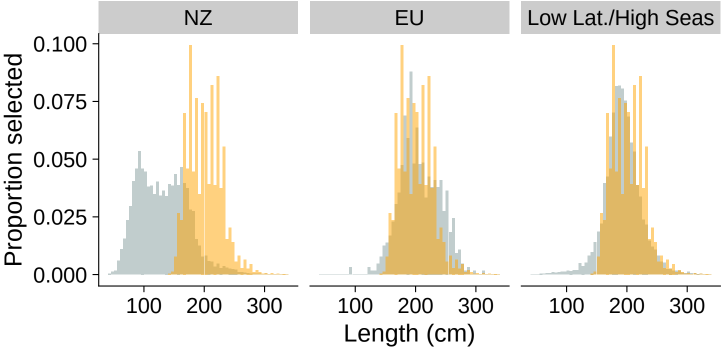
Length frequencies

Lagged LFs by model fleet

Growth applied to high latitude samples (orange) suggests low- to high latitude movement.



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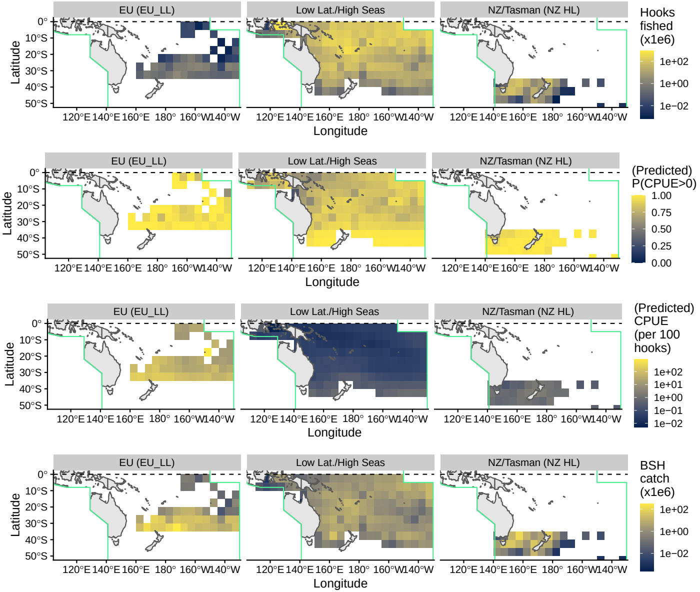
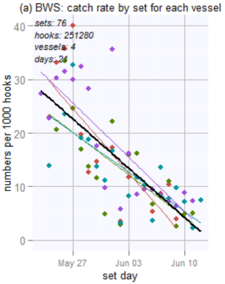
Fleet definition



Catch reconstruction

Methods

- Previous assessment attempted three different catch reconstructions strategies.
- Predictions from observer-reported catch rates to over-all effort appeared most robust. Also applied for OCS in 2019 (Tremblay-Boyer et al. 2019).
- Same strategy applied here, but some model developments:
  1. Log-normal model used over negative binomial - NB gave poor diagnostics, however, results nearly the same.
  2. Indication of local fishing out of blue sharks on temporal and spatial scale of the model (month-5x5degree) strata.
  3. Smooth term for total effort in cell



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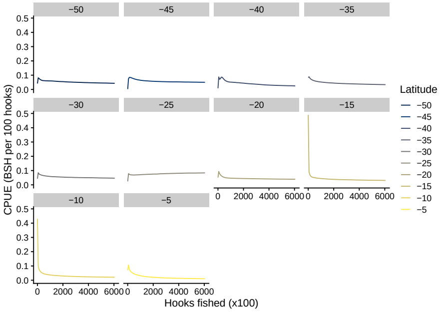
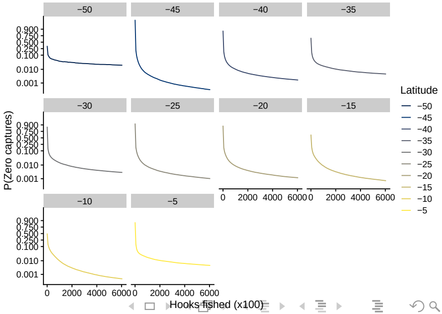
Catch reconstruction

Results

- Models with non-linear effort term provide better predictive accuracy (LOO-CV).
- They also predict a lower (posterior mean) of total captures than previous estimates.
- Large uncertainty includes previous trends in late 1990s and early 2000s.
- Stronger decline in catch since early 2000s than previous predictions.





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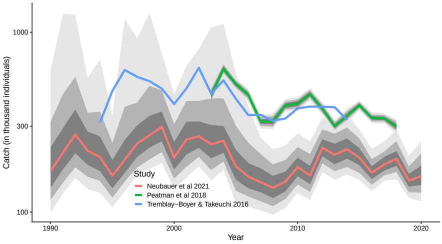
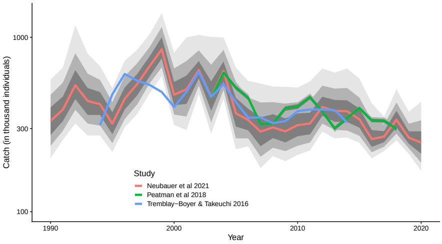
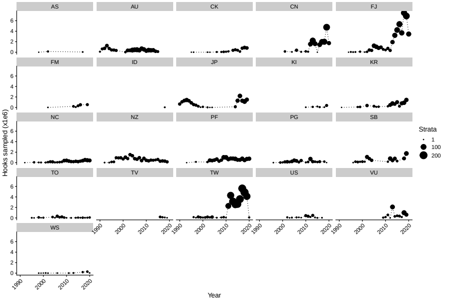




Catch reconstruction

Caveats

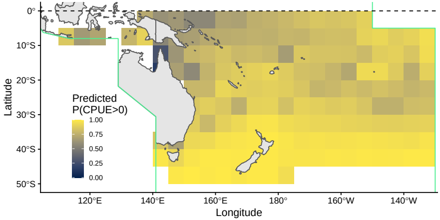
- Clear spatio-temporal bias in observer coverage
- NZ/AU High Lat Region well observed in 1990s, but shifting coverage.
- Early low-lat/high-seas CPUE derived from very little data. Not used for assessment.

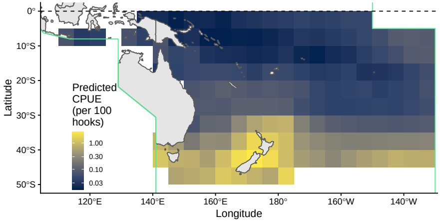


Catch reconstruction

Caveats

- Clear spatio-temporal bias in observer coverage
- NZ/AU High Lat Region well observed in 1990s, but shifting coverage.
- Early trends dominated by AU/JP/NZ effort in high latitudes, later trends dominated by high-seas effort.
- Early low-lat/high-seas CPUE derived from very little data. Not used for assessment.





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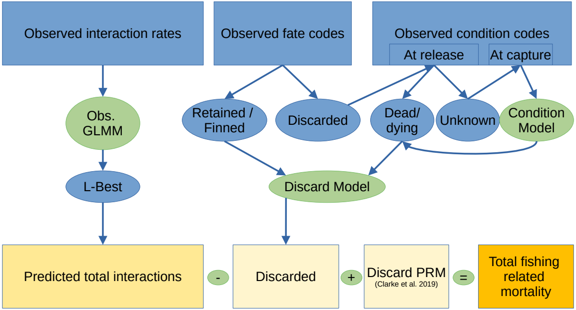
Discards

Concept

Fishing mortality determined by total interactions (catch), discard , and discard mortality rate.



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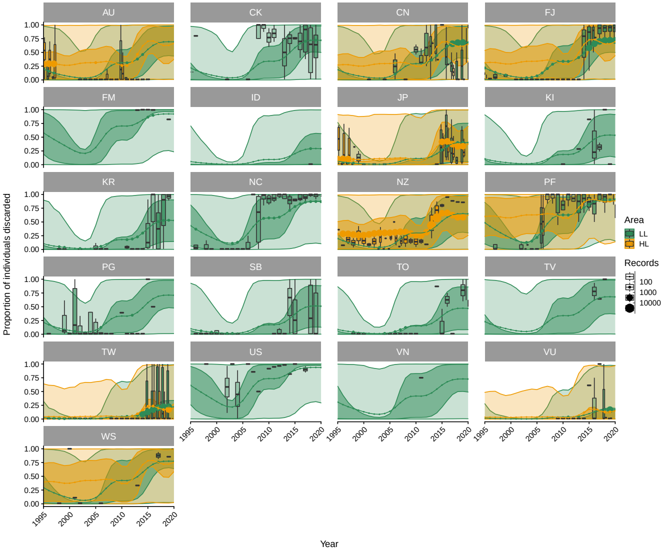
Discards

Trends

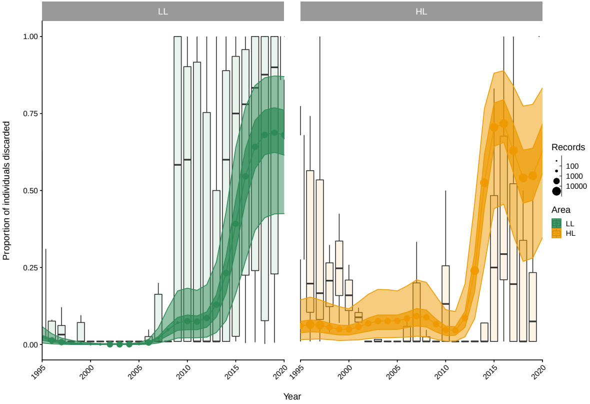


Discards

Trends

Clear increase in proportions discarded since 2010.

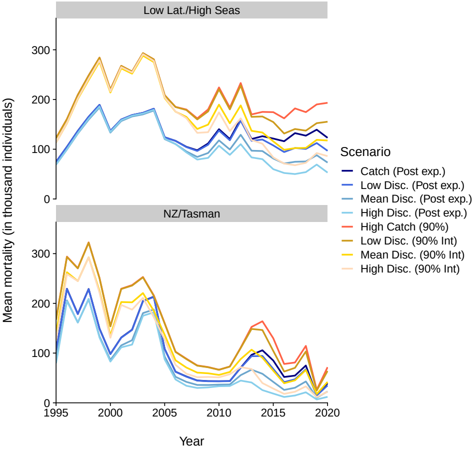
Most blue shark are discarded since ~2015.



Assumed catch time-series

Final catch considers:

1. Catch (interactions): posterior median and 90^{th} percentile
2. Discards (alive): low (25%), mean, high (75%).
3. Post-release mortality: 17% (Clarke et al. 2019)



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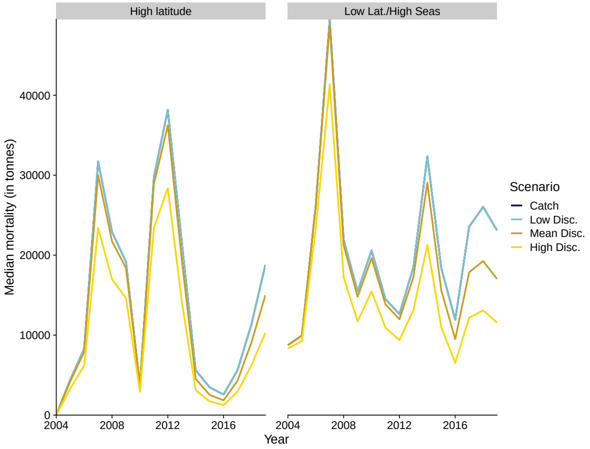

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CPUE

Summary

1. SPC-held observer data (not used in assessment)
2. Groomed log-sheet data (used for NZ/EU fleets)
3. JP operational logsheet data (high-seas)
4. Chinese-Taipei observer CPUE

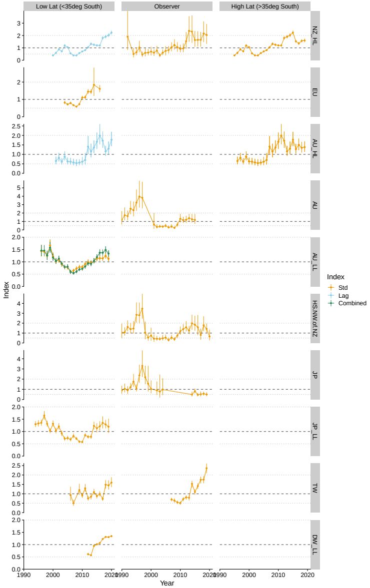
Grooming involved retaining only vessels that reported catch for at least three years (and at least 10 total events), and discarding vessel-years with no reported catch.

Hurdle-lognormal model used; negative binomial (ZI etc) tried but appeared to not perform as well. All indices except for AU low lat. used positive catch component only (ignoring the binomial model trend).

CPUE

Results

1. JP (base) and AU (north of 35°S) indices retained for low latitude/high seas (other than EU)
2. NZ index retained for high lat. fishery
3. EU index used for EU fleet.



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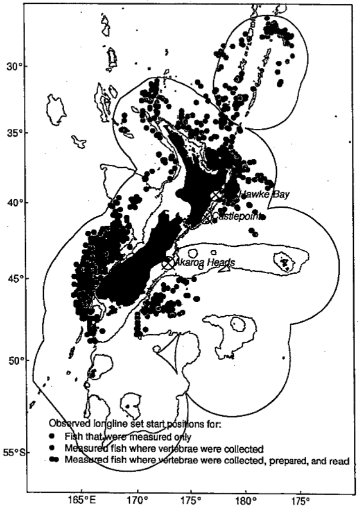
Growth

South Pacific

Manning & Francis 2005:

- Large sample (428 blue shark)
- Good age and length range
- Mainly from NZ and vicinity



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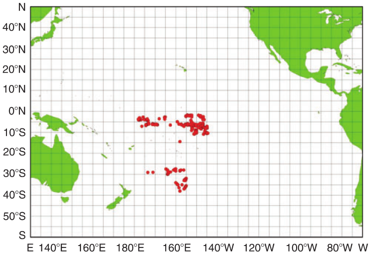
Growth

South Pacific

Joung et al. 2018:

- Smaller sample (259)
- Mainly mid-range ages and lengths (2.5-10 years)
- High seas North of NZ and near equator



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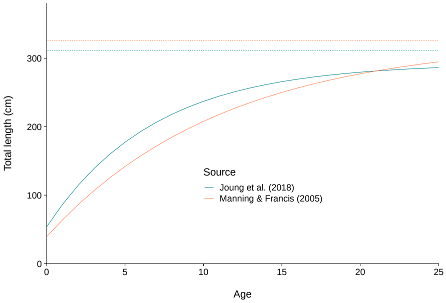

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Biological parameters

1. **Natural mortality** estimated using Hoenig's method - 0.2 (Manning & Francis 2005). More sophisticated approaches (e.g., Semba & Yokoi 2016 - M at age) available, but not explored for South Pacific at this stage.
2. **Stock-recruitment function** uses survival-based low-fecundity stock recruit function with parameters mirroring North Pacific. Again, more sophisticated approaches (e.g., simulations by Kai & Fujinami (2018) could be applied to South Pacific blue shark).
3. **Length at 50% maturity**: 180 cm fork-length
4. **Fecundity**: 35 pups annually (mean for both North and South Pacific).

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Assessment runs

- Run in Stock Synthesis (Version V3.30.17.01)
- CPUE data up to 2019
- Catch predictions up to 2020
- Model runs from 1995–2020;
- Note that reference to R0/B0 is with respect to average recruitment in model period; not long-term equilibrium. Proposal (in recommendations) to explore dynamic ref. points in future.

Assessment runs

- **Selectivity** estimated from run with high LF weight; then fixed. LFs down-weighted using Francis 2011.
- **Initial F**: Could not estimate initial F from data. Initial (equ) catch set to mean over predictions from 1990-1995 with high SD; initial F fixed at mean early (1995-2000) F from initial runs.
  - High initial F scenario explored - possibility of high F from setnet fishery pre 1990s. Also possibility that stock largely recovered between setnet fishing (pre-1990) and increase in longline effort.
- Equal weight for CPUE series in diagnostic case.

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Structural uncertainty grid

Axis	Description
Catch scenario	**Base**, high
Discard scenario	Low, **base**, high
Initial F	Low, **base**, high
Recruitment deviation (σ_R)	**Low (0.2)**, high (0.4)
High latitude CPUE	**Base**, low weight, - early New Zealand
Low latitude CPUE	**Japan**, Australia, remove EU CPUE
Natural mortality	**Base (0.2)**, low (0.16)
Survival fraction	**Base**, low, high
Growth	**Manning & Francis (2005)**, Joung et al. (2018)

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CPUE

- Prompted by conflicts in CPUE data about stock size
- Early NZ and EU trends favour high stock size
- Lots of changes in NZ prior to 2004: majority of the Japanese fleet left early 1990s, NZ fell + some JP charter took over (1990s). Then "fishing for quota" in early 2000s prior to QMS entry, followed by QMS fishery since 2004. Dropping data prior to 2004 deemed a sensible option (BUT CPUE aligns OK with observer CPUE globally.
- EU index may not accurately reflect abundance due to targeting.
- All other indices may be similarly affected to unknown degrees.

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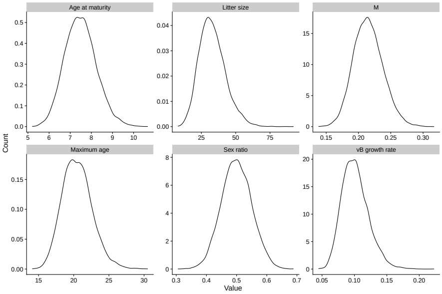
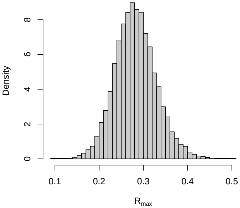
Surplus prod. model

Setup

- Dynamic (state-space) implementation, following Neubauer et al. 2019 OCS example.
- Priors for r and K derived from Monte-Carlo simulations.





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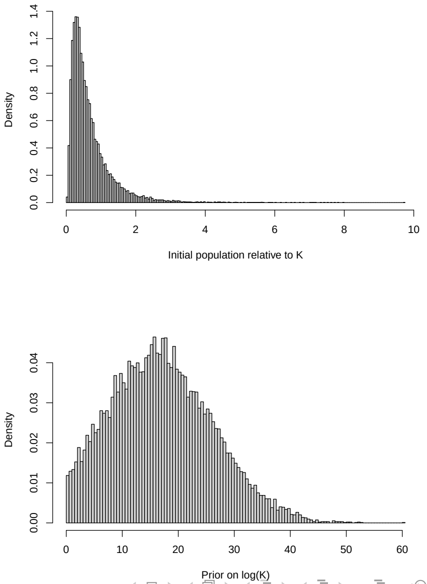
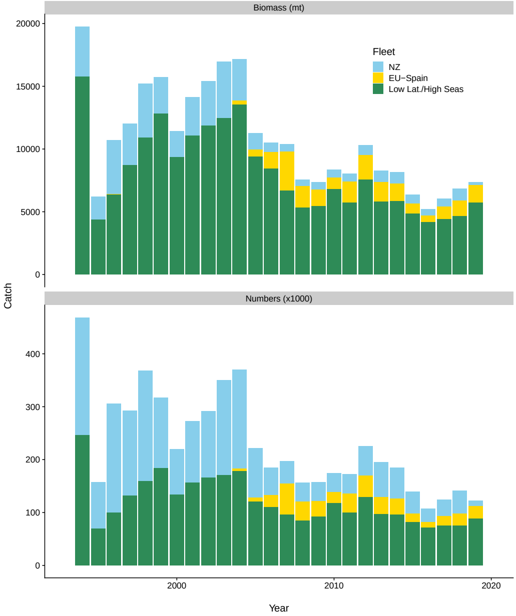


Catch (weight)

Although CPUE/catch in numbers is high(est) around NZ, given size-at-capture the biomass removed is far greater in low latitudes.



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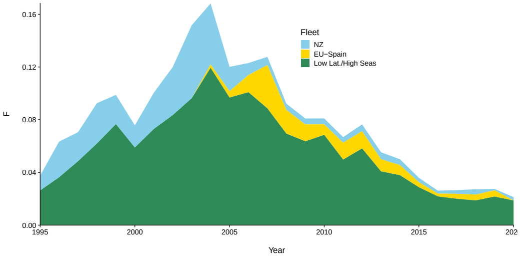
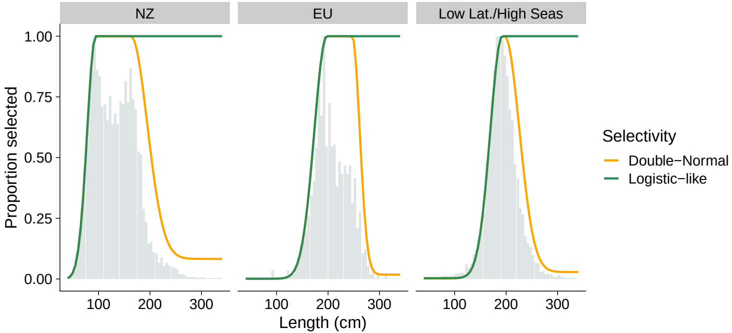
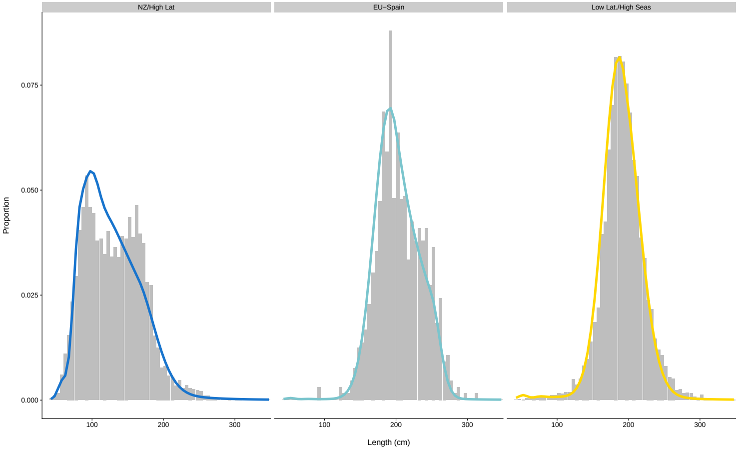


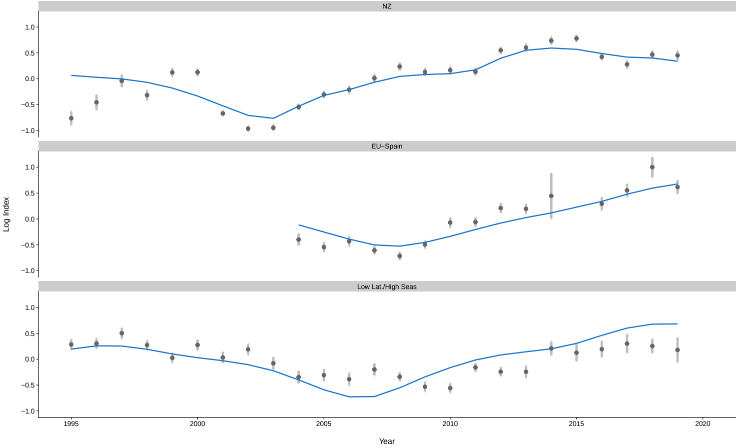
Selectivity



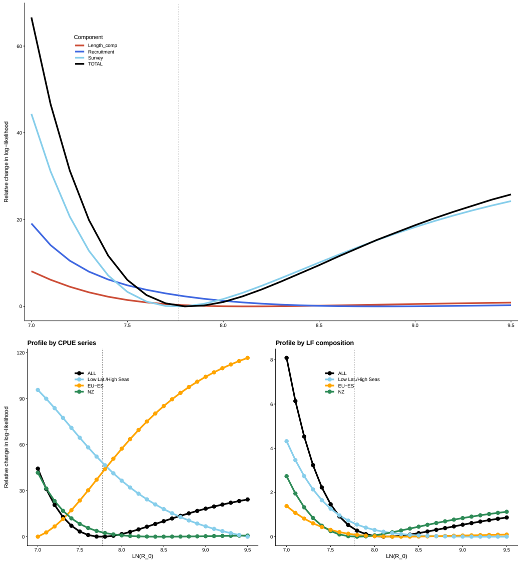
LF fits


NZ/High Lat
EU−Spain
Low Lat./High Seas
Proportion
0.000
0.025
0.050
0.075
100
200
300
Length (cm)

CPUE fits


NZ
EU–Spain
Low Lat./High Seas
Log Index
1.0
0.5
0.0
−0.5
−1.0
1995
2000
2005
2010
2015
2020
Year

CPUE fits


Component
Length_comp
Recruitment
Survey
TOTAL
Relative change in log−likelihood
Profile by CPUE series
ALL
Low Lat./High Seas
EU−ES
NZ
Profile by LF composition
LN(R_0)

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Diagnostic case

Summary

- Early CPUE dues not match between NZ/high lat and low Lat CPUE.
- Scale of increase also does not match, dominated by NZ CPUE.
- Creates conflict with regards to estimates of stock size.
- No *a priori* idea which is right; structural uncertainty grid encodes uncertainty.

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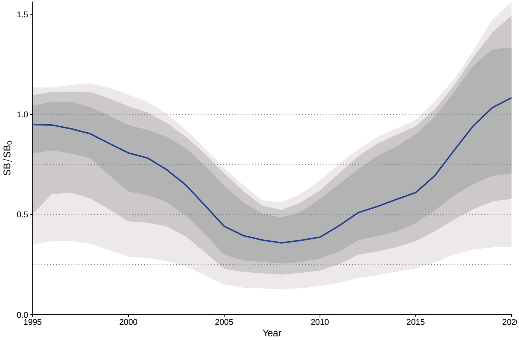
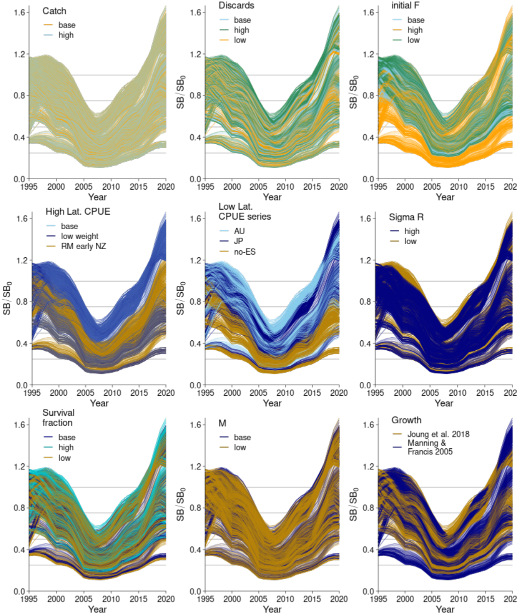
Structural uncertainty grid

Over-all



Structural uncertainty grid

Trajectories by scenario



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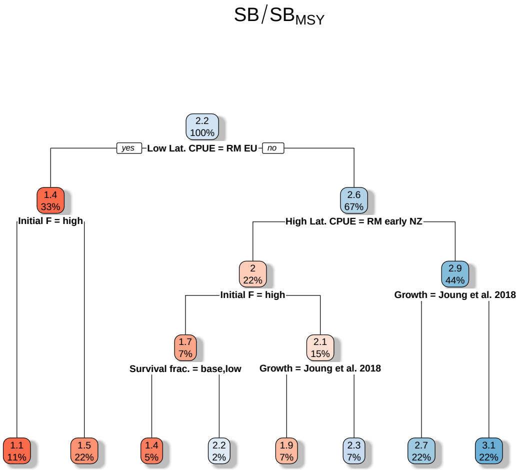
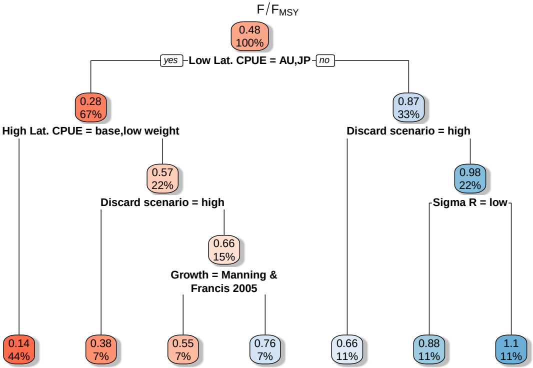
Determinants of status



Structural uncertainty grid

Determinants of overfishing status



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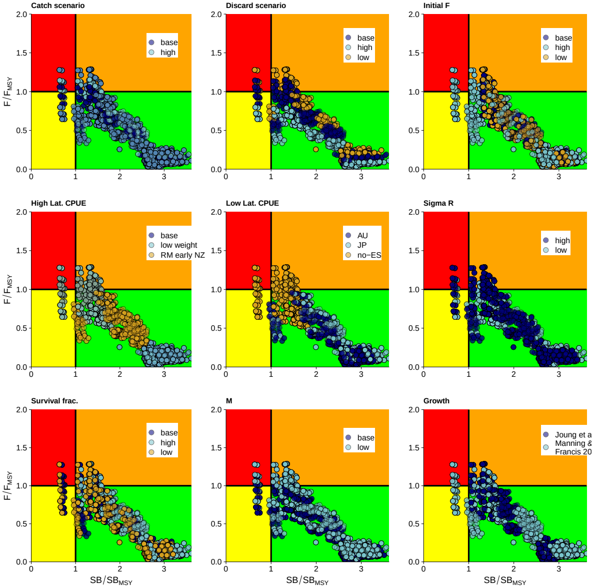
Status



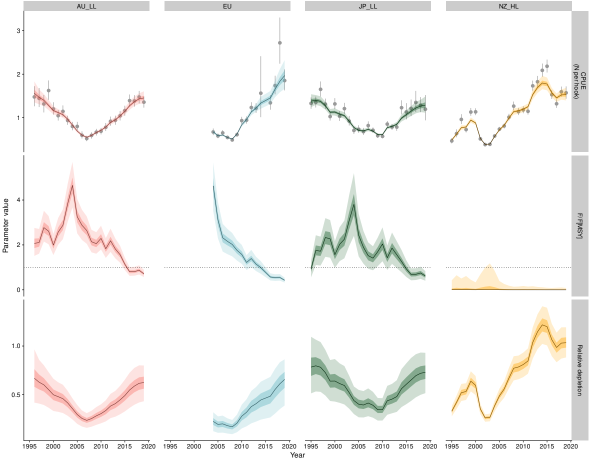
Structural uncertainty grid

Summary

- All runs show some level of recovery from low levels in mid 2000s.
- Pessimistic scenarios largely associated with assumptions of high initial F, removing EU CPUE and ignoring early CPUE from NZ.
- High recent stock status associated with runs that use both early NZ index and EU index.
- Uncertainty about data inputs (early catch, CPUE) dominates biological uncertainty.

Dynamic surplus production

Results



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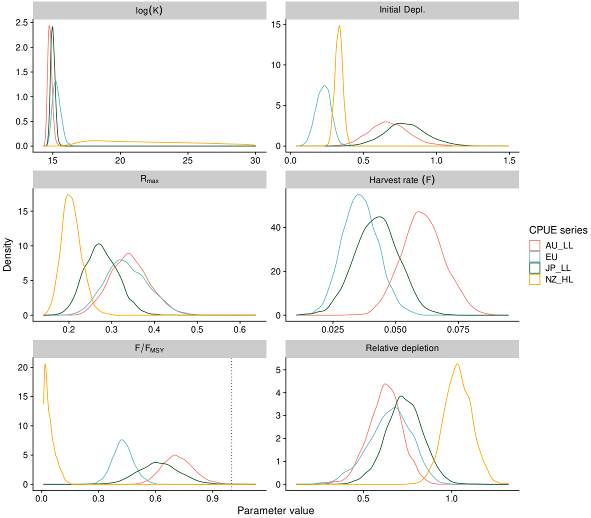
Results



Dynamic surplus production

Summary

- All runs except for NZ CPUE give reasonable results.
- Results variable among runs, but all point in same direction as the integrated assessment.

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Discussion

- Key uncertainties in relative biomass trends, as well as biological knowledge, addressed through extensive sensitivity model-runs.
- Large range of potential stock status outcomes, associated with affording high weight to a range of CPUE combinations.
- Other inputs also highly uncertain: early catch from longline and drifnets is not available - will likely remain a major uncertainty in future assessments.
- Consistent signals in the data of relatively rapid increases in biomass in the face of recent reductions in fishing mortality.

Conclusions

- The most influential axes of uncertainty was the weighting and inclusion of CPUE indices; high uncertainty remains in many model outputs across the sensitivity grid.
- The stock biomass was low throughout the region through the early 2000s following the expansion of longline fishing effort in the region.
- Estimates across the uncertainty grid largely indicated that the stock has recovered from lower biomass levels.
- 90% of model runs indicate that fishing mortality at the end of the assessment period was below F/F_{MSY} and 96% of model runs show that the biomass is above SB/SB_0, with high estimated spawning biomass levels near those expected under $F = 0$ and average recruitment across model runs, and minimum estimated SB of $0.3SB_0$.
- Fishing mortality has declined over the last decade and is currently relatively low. This is largely as a result of most sharks being released upon capture in the majority of longline fleets.
- Finally, considered against all conventional reference points the stock on average does not appear to be overfished and overfishing is not occurring.

Recommendations

The following recommendations are proposed for the SC to consider.

1. Increased effort to re-construct catch histories for sharks (and other bycatch species) from a range of sources. Our catch reconstruction models showed that model assumptions and formulation can have important implications for reconstructed catches. Additional data sources, such as log-sheet reported captures from reliably reporting vessels, may be incorporated into integrated catch-reconstruction models to fill gaps in observer coverage.
2. Dynamic/non-equilibrium reference points, such as $SB_{F=0}$ be investigated for shark stock status, as they may be more appropriate for fisheries with uncertain early exploitation history and strong environmental influences.
3. Additional tagging be carried out using satellite tags in a range of locations, especially known nursery grounds in South-East Australia and New Zealand, as well as high seas areas to the north and east of New Zealand, where catch-rates are high. Such tagging may help to resolve questions about the degree of natal homing and mixing of the stock.
4. Tagging may also help to obtain better estimates of natural mortality, if carried out in sufficient numbers. This could be taken up as part of the WCPFC Shark Research Plan to assess the feasibility and scale of such an analysis.

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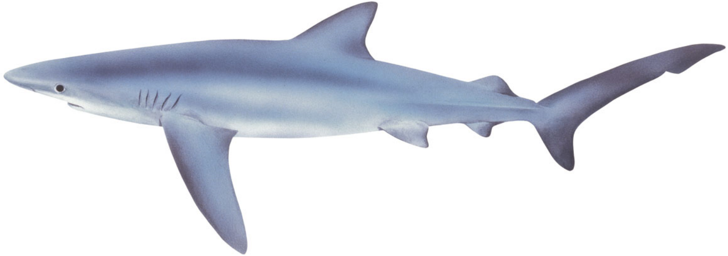
Recommendations continued

5. Additional growth studies from a range of locations could help build a better understanding of typical growth, as well as regional growth differences. Current growth data are conflicting, despite evidence that populations at locations of current tagging studies are likely connected or represent individuals from the same population.
6. Genetic/genomic studies could be undertaken to augment the tagging work to help resolve these stock/sub-stock structure patterns.

Recommendations from SA-IP-06

2. Aggregated data are submitted as annual totals for the WCPFC area only, making them uninformative for a stock specific assessment. Therefore, blue shark (and probably other Key Sharks) aggregated data should be reported by ocean area not simply as WCPO and, where possible, these data should be retrospectively corrected.
3. Observers (or the vessel) should record number of shark lines deployed or the number of floats with shark lines.

Thanks for listening



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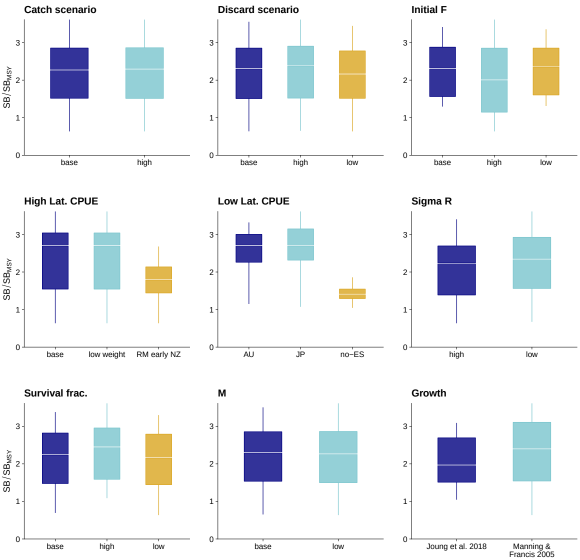
Structural uncertainty grid

Determinants of status



Structural uncertainty grid

Determinants of overfishing status