



Introduction of a Statistical Age-structured Model Used for Southern Bluefin Tuna in CCSBT

Hiroyuki Kurota & Yukio Takeuchi
National Research Institution of Far Seas Fisheries,
Shimizu, Shizuoka, Japan



Today I'd like to talk about a statistical age-structured model used for southern bluefin tuna in CCSBT.

I think this model is much simpler than other models reviewed yesterday, but it is enough complicated for entomologists.

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Hiro's Stormy Life

Before



After



First let me tell you about myself.

I'm Hiroyuki Kurota.

I originally studied population dynamics of a small beetle for my PhD.

However, five years ago I started to study southern bluefin tuna, or SBT, by some accident.

As you know, SBT issues are kind of political.

So I want to run away from it, but my bosses don't allow me.

Please help me.

(click)



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MP development in CCSBT

(Commission for the Conservation of Southern Bluefin Tuna)



- CCSBT started **Management Procedure (MP)** development in 2002.
 - a decision rule which sets TAC based on available data
- A MP (developed by Butterworth & Mori) was selected in September 2005 after competition among several dozen of candidates.
 - My MP was the second winner. 

Before I explain about this model, I'll tell you some backgrounds of it.

The commission for the conservation of southern bluefin tuna, or CCSBT, started development of management procedure, or MP, in 2002.

In this case, MP means a decision rule which sets TACs based on available data.

We worked very hard.

This September a single MP developed by Butterworth and Mori was selected after competition among several dozen of candidates.

Unfortunately, my MP was the second winner.

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Operating Model for MP evaluation

- **Operating Model** was constructed to evaluate MP performance by SC.
 - To imitate actual SBT dynamics and fishing process with enough uncertainty
 - To be fitted to historical data to estimate parameters like stock assessment models.
 - To originate from a **stock assessment model** for the SBT by Butterworth et al. (2003)

For this MP evaluation, the Scientific Committee, or SC, constructed an operating model specific to SBT.

This operating model imitates actual SBT dynamics and fishing process with enough uncertainty.

Therefore, it is fitted to historical data to estimate parameters like common stock assessment models.

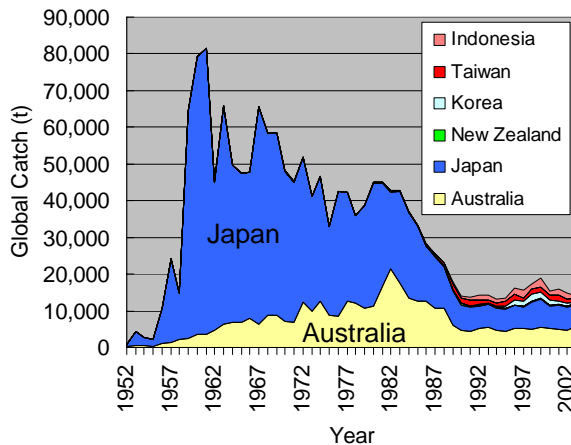
Actually this model originates from a stock assessment model for the SBT by Butterworth, Ianelli and Hilborn.

And it is also used as one of stock assessment models in the CCSBT.

So today I'll explain this operating model as a stock assessment model.

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Global catch of SBT



- Global catch remains at about 15,000 t after 1990.

Next let's talk about SBT fisheries briefly.

Historically, Australia and Japan are two main fishing countries.

Fisheries started in the 1950s and they caught 80,000 tons at their peak.

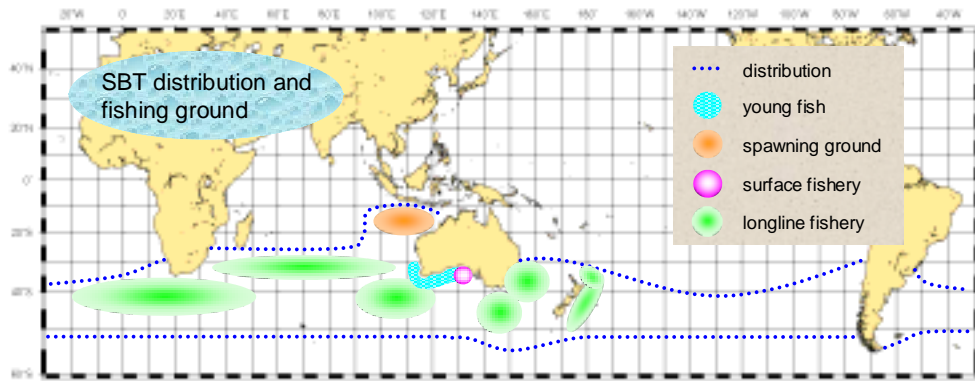
However, the catch continued to decrease and the global catch has remained at about 15,000 tons after 1990.

This is because stock abundance declined and a quota system was introduced in 1985.

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SBT Distribution & Fisheries



- Surface (purse seine) fishery
 - Australia (age 2-4: farming)

- Longline fishery
 - Japan, Taiwan, Korea, NZ (age 4-10)
 - Indonesia (age >10)

Now Australian surface fishery catches juveniles for farming (in the Great Australian Bight).

Japan, Taiwan, Korea, and New Zealand catch older juveniles and adults in ocean waters by longline.

Indonesia also catches spawning adults un-intentionally.

And each fishing occurs in a specific season.

So, as to SBT fisheries, different countries catch fish at different ages by different ways in different seasons.

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Main cast – CCSBT SC

■ National scientists

- Australia - [T.Pollachek](#), M.Bason, D.Kolody
- Japan - S.Tsuji, [D.Butterworth](#), H.Kurota
- New Zealand, Korea, Taiwan



■ Advisory panels

- R.Hilborn, J.Pope, J.Ianelli, A.Parma (MP coordinator)



■ MP consultant

- V.Haist, T.Branch

Pictures thanks to K.Hiramatsu

Let me introduce the SC members here.

What I tell you today is the achievement made by all of us.

The SC consists of national scientists, advisory panels and consultants.

Advisory panels were established (in 1999) to facilitate consensus among member countries.

Current members are Ray Hilborn, John Pope, Jim Ianelli, and Ana Parma.

Their contribution is very important in the CCSBT.

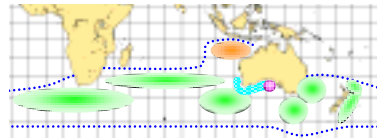
(click)

By the way, 90% of the meeting time is spent by listening to these two men fighting.

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Model Structure

- **statistical age-structured model**
 - convert age into length by a growth curve with variability
- **single stock (no spatial dynamics)**
- **two fishing seasons per year (events)**
- **5 fisheries**
 - longline 1-3 (1st season)
 - surface, spawning ground (2nd season)



Well, let's look at the model specification.

If my explanation is not clear, you can also refer to our document, particularly Appendices.

I can't believe my English.

The SBT model is a common age-structured population dynamics model.

We assume a single stock structure without spatial dynamics.

Also fishing and natural mortality are treated as discrete events, and two fishing seasons are modeled for each year.

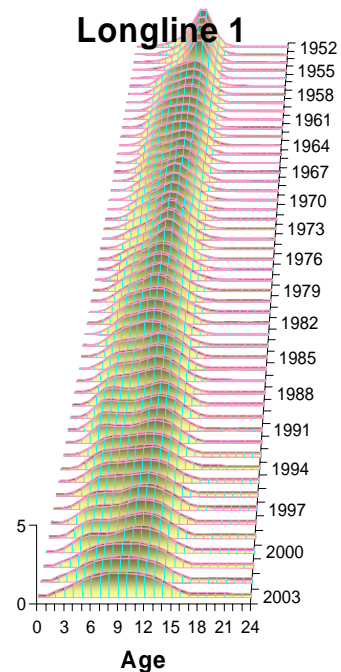
We classify fishing fleets into five based on selectivity differences.

Each fishery occurs in either season.

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Model Structure (cont.)

- fishing mortality
 - Pope's approximation
- natural mortality
 - fixed age specific vectors ("grid" axis)
- selectivity (age-based)
 - smoothness penalties
 - temporal variability
- catchability
 - linear increase (0.5% per year)



This model uses Pope's approximation as fishing mortality modeling.

Natural mortality is fixed.

I'll explain later about the "grid" as an "uncertainty evaluation method".

This model relies on the separability assumption.

To represent selectivity, smoothness penalties are used like A-SCALA.

It also considers temporal changes in the selectivity.

This point is an important feature of this model.

This is an example of selectivity estimates for Japanese longline.

As you can see, selectivity is assumed to change every 4 years in this case.

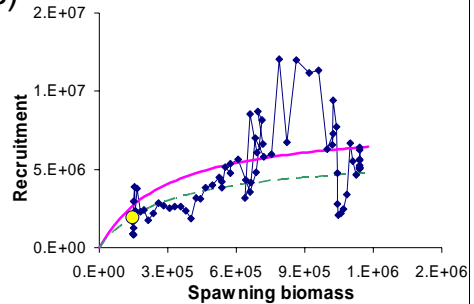
Catchability is assumed to increase linearly each year.

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Model Structure (cont.)

■ stock-recruitment

- Recruitment occurs once a year (1st season)
- stochastic Beverton-Holt model
 - sigmaR (fixed), R_0 (estimated)
 - steepness (fixed, grid axis)
- recruit autocorrelation
 - conditioning: no
 - projection: empirical



We use stochastic Beverton-Holt model as stock-recruitment relationship.

As you know, steepness, recruit autocorrelation, natural mortality, selectivity and so on have strong relationships.

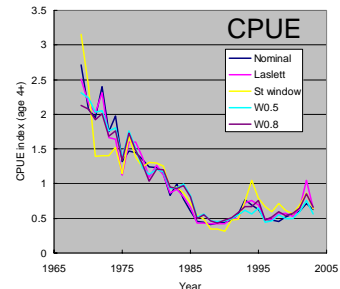
So actually, this stock-recruitment modeling was so difficult that we had to take a lot of trial and error.

Eventually we used these assumptions on key parameters.

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Data used

- catch-effort
 - standardized longline CPUE index (five series, grid)
- catch-at-age
 - for surface and spawning ground
- catch-at-length
 - for longline (Jpn since 1952)
- tag return data
 - Reporting rate is fixed.
- age-length
 - fixed growth curve



These data are used in this model as historical data.

This model uses Japanese longline CPUE series since 1969 as an abundance index.

(These are different in normalization methods.

They looked quite similar, but assessment results were significantly different.)

Either catch at age or catch at length is used for each fishery.

Also this model incorporates tag return data after 1990s.

Growth curve is fixed.

It is estimated from tagging data outside the model.

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likelihood components

- Japanese longline CPUE
 - **log-normal** likelihood function (The variance is estimated.)
- catch at age and length
 - **multinomial** likelihood function
 - Sample size is set for each fishery based on sampling intensity.
- tag return data
 - **Poisson** likelihood function (The variance is fixed.)
- penalties (treated as **fixed effects**.)
 - recruitment residuals
 - selectivity changes
- estimated parameters
 - B_0 , q , σ , I , recruit deviation, selectivity (571 parameters)

These are likelihood components.

This model is fitted to three kinds of data, and these likelihood functions are used.

Sample size for the multinomial likelihood function is set based on historical sampling intensity,

However, it was difficult to find proper values and there was considerable discussion on this topic.

Also such penalty terms are included in the objective function.

Under these assumptions, we estimated these 571 parameters.

Most of them are parameters related to selectivity.

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Bayesian approach

- MCMC had a convergence problem.
- A simpler method, **grid approach**, was used.
 - to assign weights to results under different assumptions based on prior and/or likelihood
- language: ADMB
- calculation time: over 40 hours

We use Bayesian approach to estimate uncertainty.

At first, we used the MCMC method with ADMB and it worked well.

However, MCMC had a convergence problem when some data were updated.

Probably I guess the model instability or something accounts for this problem, but there was little time to examine it.

We were required to finish the MP project soon.

Therefore, we moved to a simpler method called a grid approach as second best.

This approach assign weights to results under different assumptions based on prior and/or likelihood.

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Grid approach

- To select 7 critical axes of uncertainty and set a few values or assumptions in each axis.
- To calculate a point estimate for each combination (720 cells) and assign a weight on each result depending on prior and/or likelihood for each axis.
- To determine no. of replicates from each result by the weight to produce a total of 2000 replicates (a reference set).

Axis	Levels	Values		Prior	Simulation Weights	
Steepness	3	0.385	0.55	0.73	0.2, 0.6, 0.2	Prior
M0	3	0.3	0.4	0.5	Uniform	Posterior
M10	2		0.1	0.14	Uniform	Posterior
Omega	2		0.75	1	0.4, 0.6	Posterior
CPUE	5				Uniform	Prior
q Age-range	2		4-18	8-12	0.67, 0.33	Prior
Sample Size	2		Panel	Original/2	Uniform	Prior

Let me explain it in more detail based on our actual steps.

I'm sorry, it is difficult to explain in English. You can also refer to page 20 in our document.

First, we selected seven critical axes of uncertainty and set a few values or assumptions in each axis.

Then, we calculated a point estimate for each combination (720 cells) and assigned a weight on each result depending on prior and/or likelihood for each axis.

This weight determines the number of replicates to be simulated from each result to produce a total of 2000 replicates.

We call it "a reference set".

It takes over 40 hours to calculate all 720 cells to be integrated.

In other words, we can calculate each cell in a few minutes.

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Forward projection

- Specification was determined carefully to test MPs under realistic conditions.
- Uncertainty about the current status
 - the reference set (2000 replicates) integrated by the grid approach.
- Uncertainty about future conditions
 - recruitment variability & autocorrelation
 - sharp recruitment drop after 2000

Finally, let's look at future projection.

This model was developed to test MPs under realistic conditions.

So projection specification was determined carefully.

As to uncertainty about the current status, 2000 replicates of the reference set covers this kind of uncertainty.

On the other hand, as to uncertainty about future conditions, we assume recruitment variability as process error and autocorrelation.

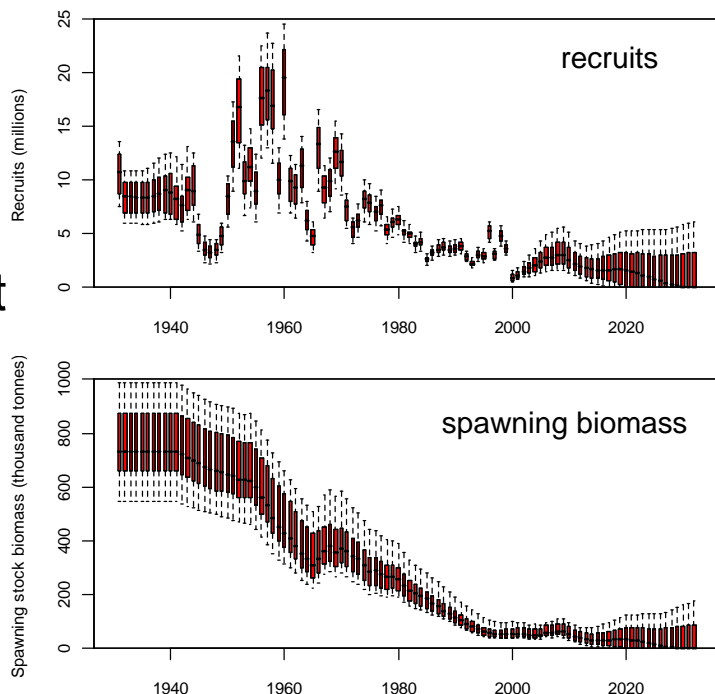
Particularly, the CCSBT is concerned about a sharp recruitment drop after 2000.

So, recent recruitments are modeled in detail to cover enough uncertainties.

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assessment and projection result for reference set

projection under
current constant
catch (15000 t).



This is the last slide.

These figures shows recruitment and spawning biomass for the reference set from 1931 to 2032.

Future projections were conducted under current catch levels.

As you can see, this result indicates that the stock biomass would further decline if nothing was done.

Therefore, the SC recommended significant quota reduction to the Commission before implementation of MP in 2008 or 9.

However, the Commission rejected it last month.

I'm afraid that the future of SBT may become darker.

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