Management strategy evaluation for the Indian Ocean tuna fishery : development of an operating model

IOTC Working Party on Methods
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Development process

- **Iterative development** of operating model
  1. Development and documentation of model
  2. Conditioning (i.e. fitting to data) and evaluation of model realism, fits and ability to evaluate alternative HCRs
  3. Repeat 1 & 2
- Currently in **step 1 of first cycle**; expect to complete first cycle by early 2014
- Model **implemented in C++** but intend to provide an **R package** and/or binary executables
- Code and documentation repository:
  - https://github.com/trophia/ioskj
- Documentation published at:
  - Text and equations: http://trophia.github.io/ioskj/
  - Code: http://trophia.github.io/ioskj/doxygen/html/index.html

Model dimensions

- Quarterly **time step**:
  - 1950-2013 (conditioning model to observed data)
  - 2014-2038 (evaluating alternative harvest control rules)
- Three **regions:**
  - Western
  - Maldives
  - Eastern
- Five **methods**: Purse seine (PS), Pole and line (PL), Gillnet (GN), Line (LI), Other (OT)
- Twenty four quarterly **ages**: 0-23
- Forty 2mm **size bins**: 0-2, 2-4, ..., 78-80mm

Model complexity

- Given model dimensions the model can be parametrised to provide **alternative levels of complexity**:
  - Simple / uniform : e.g. mortality rate the same for all regions, ages and sizes
  - Complex / heterogeneous : e.g. mortality rate different in each region and/or by age
- Start relatively simple and **add complexity as deemed appropriate** to give sufficient realism.
- **Notes in documentation** indicating alternative formulations

Natural mortality

Natural mortality is modelled as a constant instantaeous rate that is uniform over all regions, ages and sizes. The survival in one quarter is,

$$D = e^{-0.25\nu}$$

Natural mortality could vary by region and/or age i.e. $\nu_{r,a}$ or size $\nu_{r,s}$ or even time.

Model parameter priors and sensitivity ranges

- **Prior probability distributions** – for use in generating posterior distributions via conditioning
- **Sensitivity ranges** – for robustness testing outside of range of posterior distributions

Table X: Prior probability distributions for model parameters. Distributions are indicated as follows: fixed $F(value)$, uniform $U(lower, upper)$, normal $N(mean, sd)$, lognormal $L(mean, sd)$, beta $B(\alpha, \beta)$, mesa $M(\min, lower, upper, \max)$

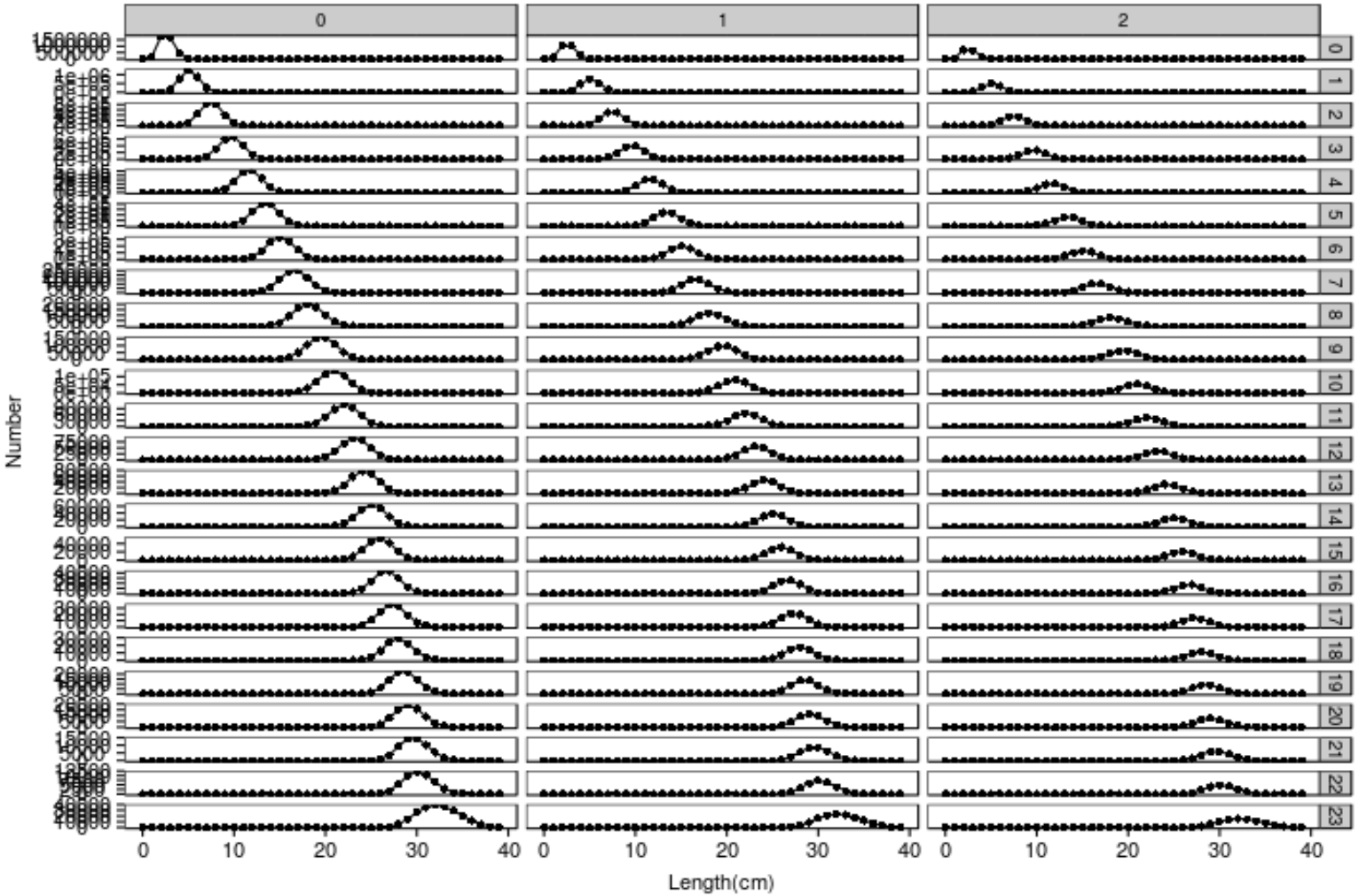
Symbol	Description	Units	Prior distribution	Sensitivity range	Notes
Weight					
α	Coefficient of the length-weight relationship	$t \cdot cm^{-3} \cdot 10^{-6}$	$N(5.32, 0.266)$	4-6	Sharma et al (2012) used $F(5.32)$ based on IOTC (2005). C.v. of 5%.
β	Exponent of the length-weight relationship	-	$N(3.35, 0.1675)$	3.0-3.6	Sharma et al (2012) used $F(3.35)$ based on IOTC (2005). C.v. of 5%.
Maturity					
τ	Inflection point of the maturity ogive	cm	$N(40, 2)$	35-55	Grande (2013) estimated a value of 39.9cm. Sharma et al (2012) assumed 38cm based on Grande et al. (2010). C.v. of 5%.
υ	Steepness of the maturity ogive	cm	$N(5, 0.5)$		Grande (2013) Fig 7.3. C.v. of 10%.

Model conditioning

- Propose to condition the model using similar data as used for assessment:
  - **Maldives** standardised **quarterly pole and line CPUE** 2004-2011 (Sharma et al 2013; IOTC-2013-WPTT15-32)
  - **Western** standardised **annual purse seine CPUE** 1982-2011 **(**Soto et al 2013; IOTC-2013-WPTT15-32)
  - Quarterly size frequencies by **region and method** as available
  - **Western** tagging-based Z estimates by quarter and size group 2005-2009 (Hillary & Everson in press)
- Condition model to generate posterior distributions using:
  - Sampling-importance-resampling (SIR) and/or
  - Markov Chain Monte Carlo (MCMC)

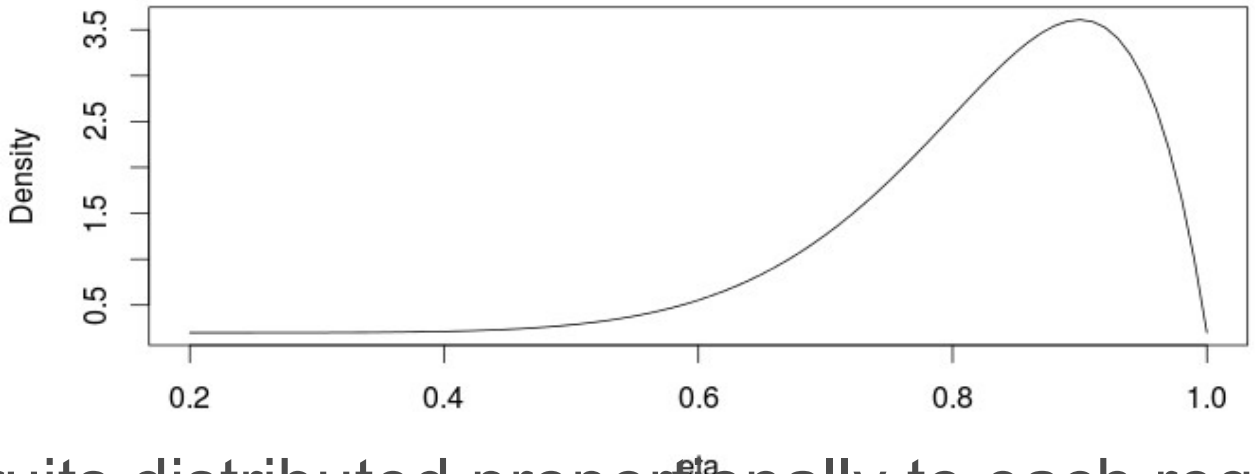
Fish : population structure

- Numbers by **region**, **age**, **size**
- Accounting for numbers-by-size (i.e. age x size matrix in each region): allows proper **modelling of size-based selectivity**; may provide advantages in simulating tagging programs



Fish : spawning and recruitment

- Seasonal spawning fraction:
  - Priors based on Grande (2013)
- Stock-recruitment relationship:
  - Beverton-Holt based on pooled, total spawning biomass
  - Prior on steepness : median 0.85, 0.64-0.87 5th percentiles; appropriate?



- Recruits distributed proportionally to each region and over sizes,

$$R_{r,s} = \overline{R} \cdot \chi_r \cdot A_s$$

Fish : growth

- Von Bertallanfy growth
- Variability in increments: **constant s.d. + c.v. on increment**
- Converted to a quarterly size transition matrix
- Priors based on Hillary (2011) based on tagging data

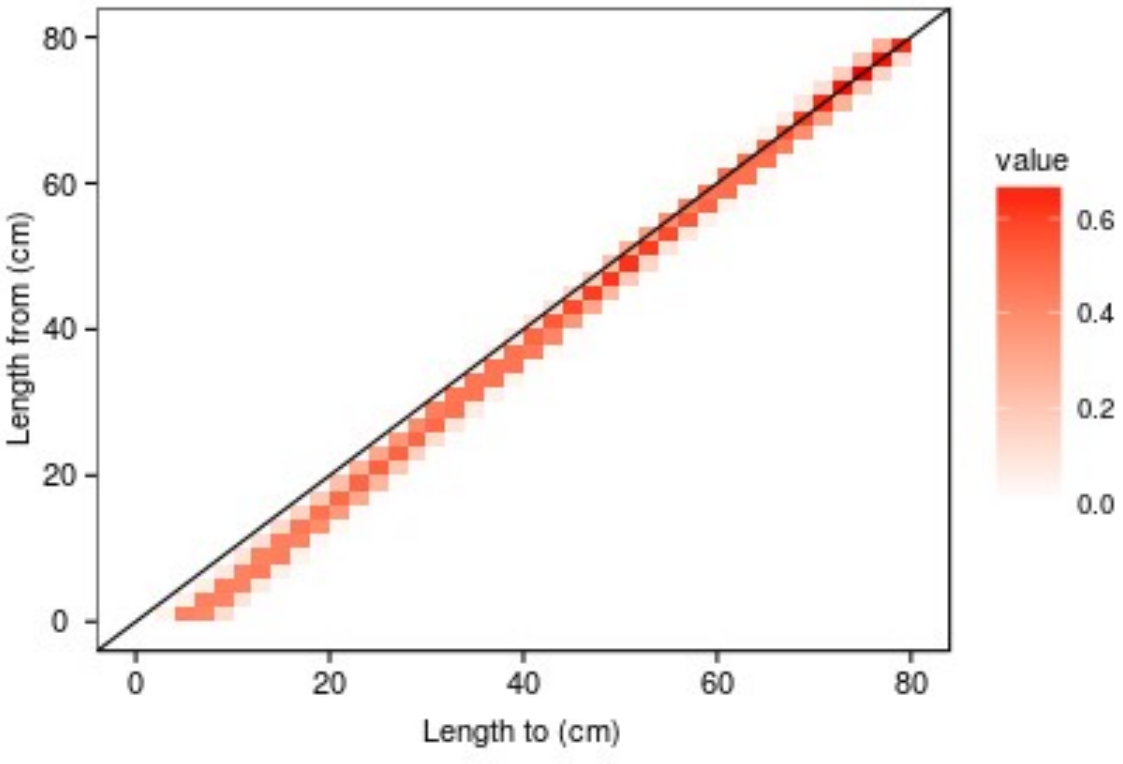
$$I_s = (\lambda - L_s)\left(1 - e^{-0.25\kappa}\right)$$

ormal distribution with a constant standard deviati
tion of the growth increment for a fish of size s is t

$$J_s = \sqrt{\varepsilon^2 + (\phi I_s)^2}$$

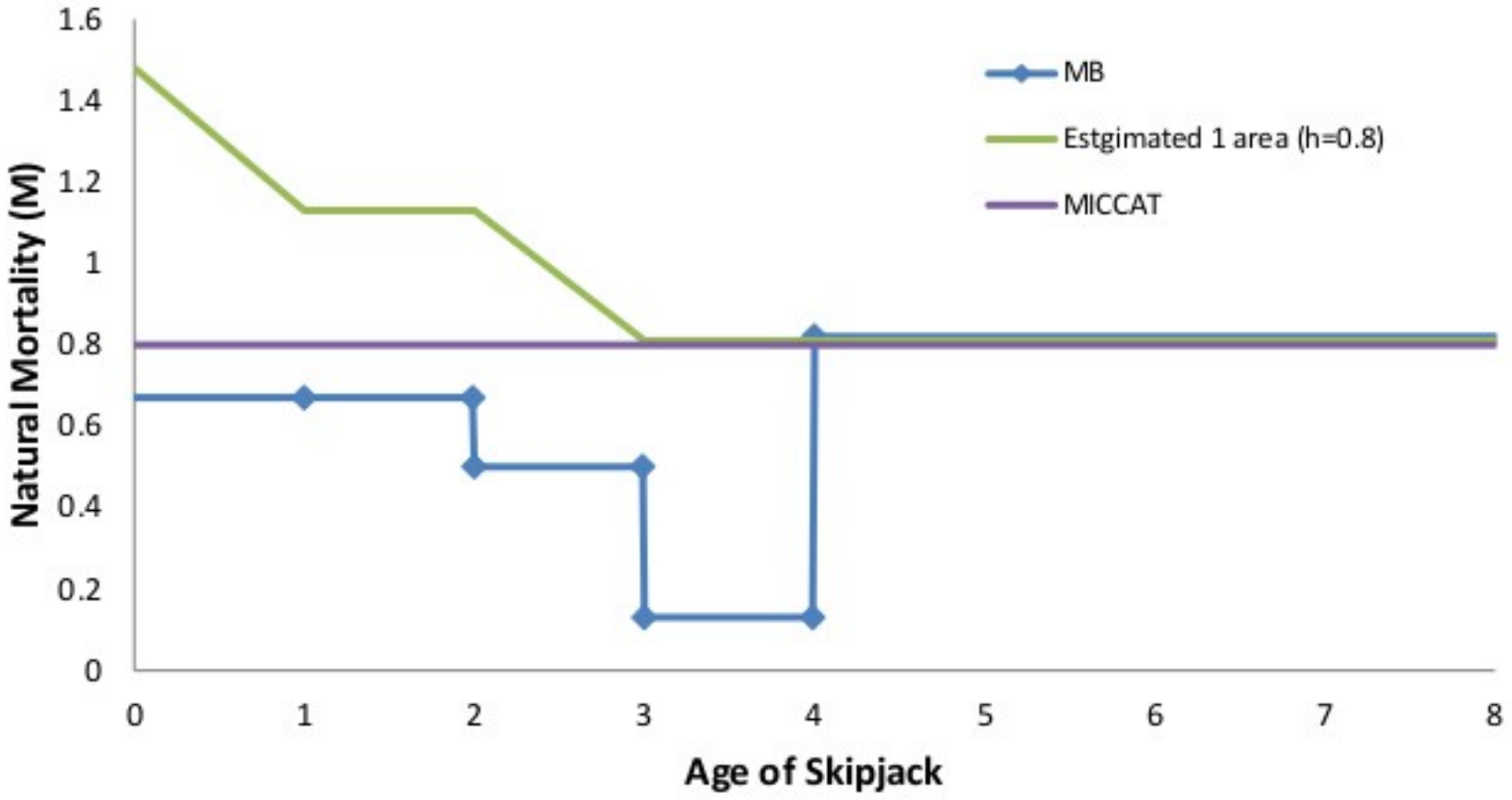
ze $\dot{s}$ to size s in one quarter is thus,

$$G_{\dot{s},s} = \int_{l=2s}^{l=2(s+1)} \frac{1}{\sqrt{2\pi}\, J_{\dot{s}}} \frac{e^{-\left(L_{\dot{s}} + I_{\dot{s}} - l\right)^2}}{2(J_{\dot{s}})^2}$$



Fish : mortality

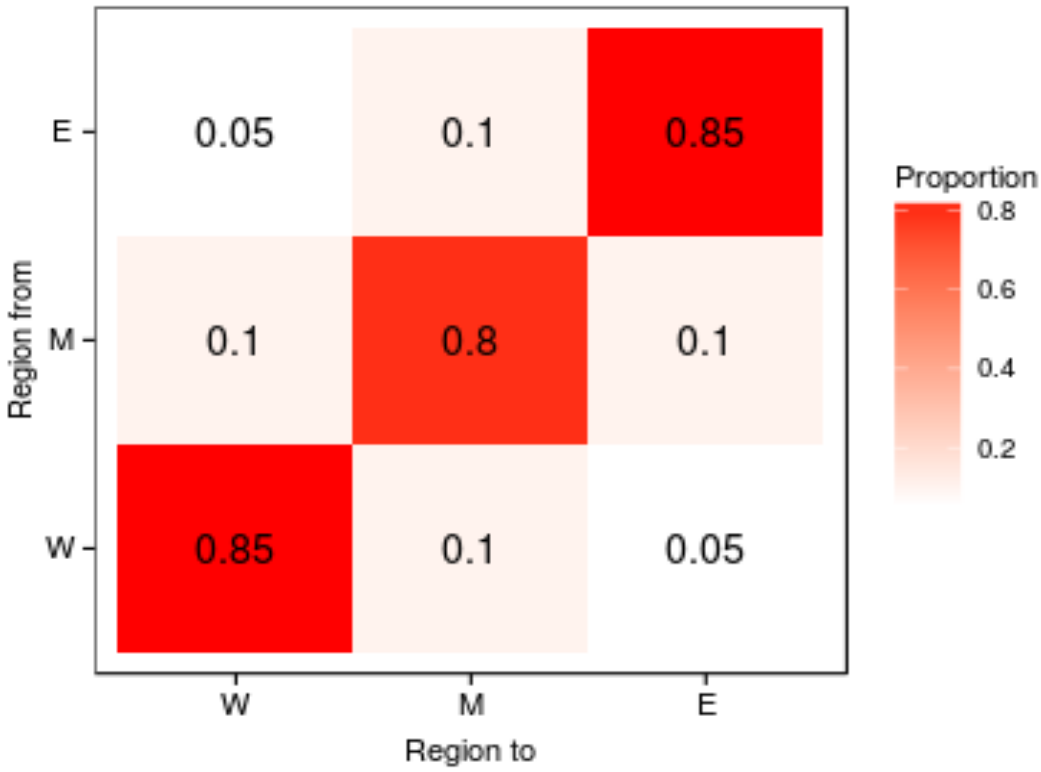
- Currently using **same M for all regions, ages and sizes**
- **Should M vary** by region, age or size?



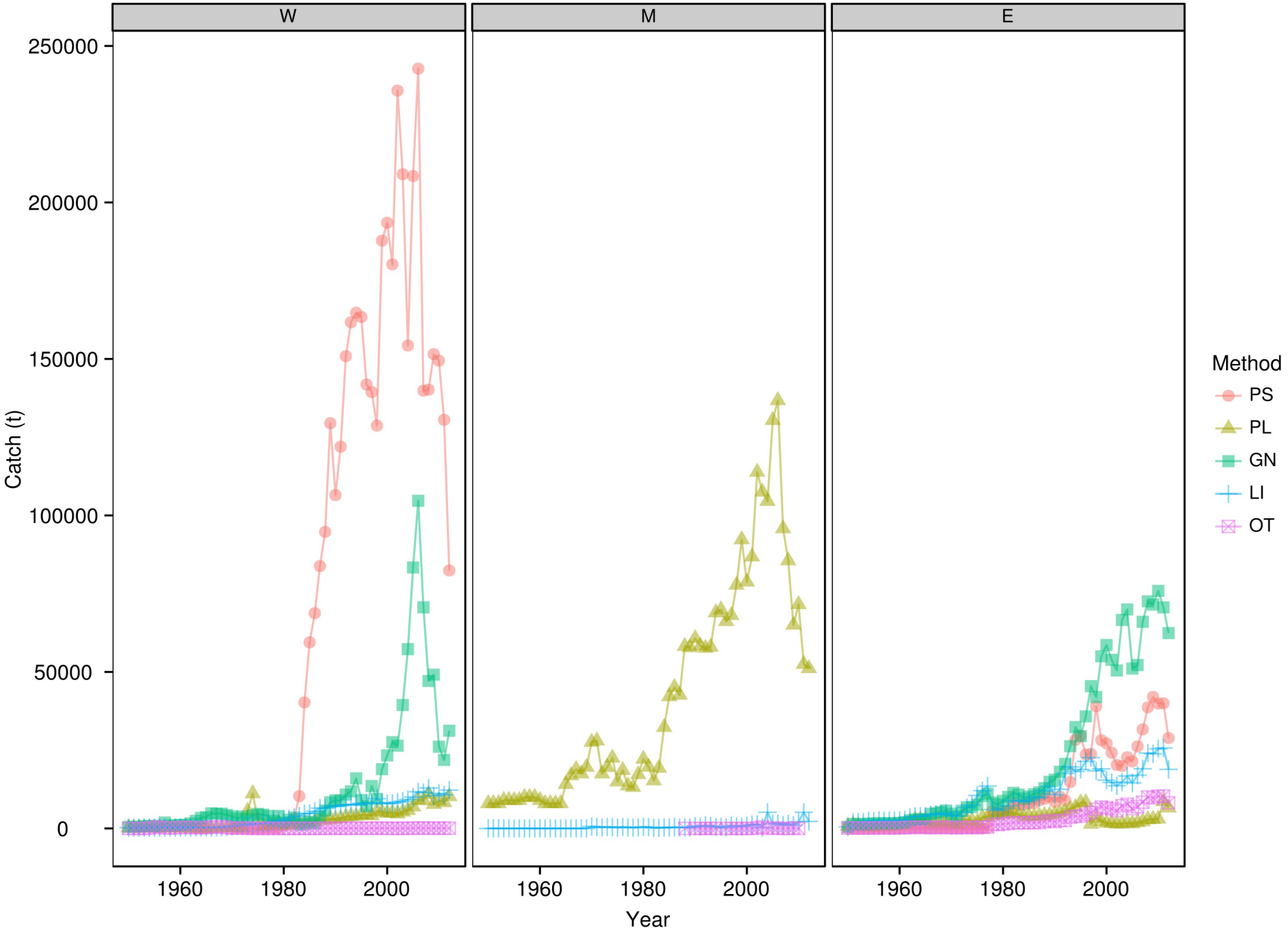
Sharma et al (2013)

Fish : movement

- Currently, movement between regions is **uniform across ages and sizes**
- Parameters represent **proportion of fish moving in a quarter**
- Unlikely to be information in conditioning data
- **How to set priors?**: use tagging data as a guide?

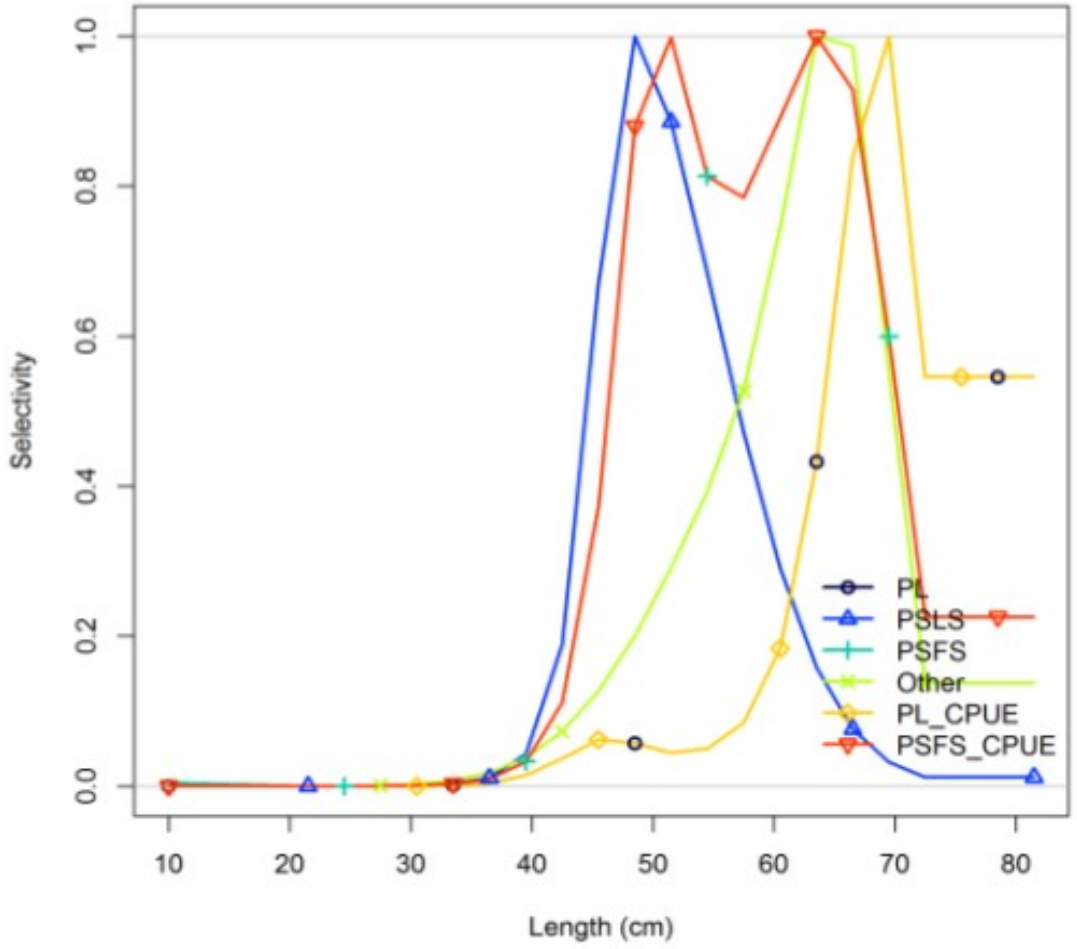


Fishing : catches by region and method



Fishing : selectivity

- Cubic spline for each **method**
- Currently no difference in selectivity between region
- Poor size frequency data for some methods (e.g. gillnet, line)



Sharma et al (2013)

Next steps

- Finalisation of first cycle of model development e.g.
  - Implementation of fishing selectivity functions
  - Likelihood functions and SIR/MCMC algorithms
  - Calculation of B_{MSY}
- Model conditioning
- Present completed model and conditioning results to IOTC working parties
- Preliminary MSE:
  - Definition of preliminary set of performance statistics
  - Development of preliminary set of simple management procedures/HCRs