Potential methods for estimating fishing mortality

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Potential methods for estimating fishing mortality

- Traditional stock assessment
- **Area-based ERA methods**
- Age-based methods—catch curve
- Length-based methods

Traditional stock assessment

- Requires a range of data.
- Well accepted approaches.
- Avoids possible inconsistency between reference points and biological status because both refer to the same type of fish in terms of their age/size/sex composition.

Area-based ERA methods

- **Swept area** method (pope et al. 2000).
- **PSA** (Productivity and Susceptibility Analysis): the susceptibility axis (Hobday et al. 2011).
- **SAFE** (Sustainability Assessment for Fishing Effect): estimating F component (Zhou and Griffiths 2008, Zhou et al. 2011, Zhou et al. 2013).
- **SEFRA** (Spatially Explicit Fisheries Risk Assessment): impact ratio U (New Zealand).
- **EASI-Fish** (Ecological Assessment of Sustainable Impacts of Fisheries): estimating F (Griffiths et al. 2018).
- Sustainability risk assessment of Porbeagle shark and Bigeye thresher shark (Hoyle et al. 2017; Fu et al. 2018).

The concept

- $$= - \approx \frac{\sum \ | \ ,}{\ } \quad (1 - \ )$$

$$= \frac{\sum (\ | \ ,)}{\sum (\ ,)} \quad (1 - \ )$$

Fishing mortality is calculated as area overlap between fishing effort and species distribution, fine-tuned by density, gear efficiency, and post-discard survival.

C: catch;

: average biomass;

A_J: distribution range within the jurisdiction J;

$a_{s|AJ,t}$: gear affected area at fishing site *s;*

q_h: habitat-dependent encounterability;

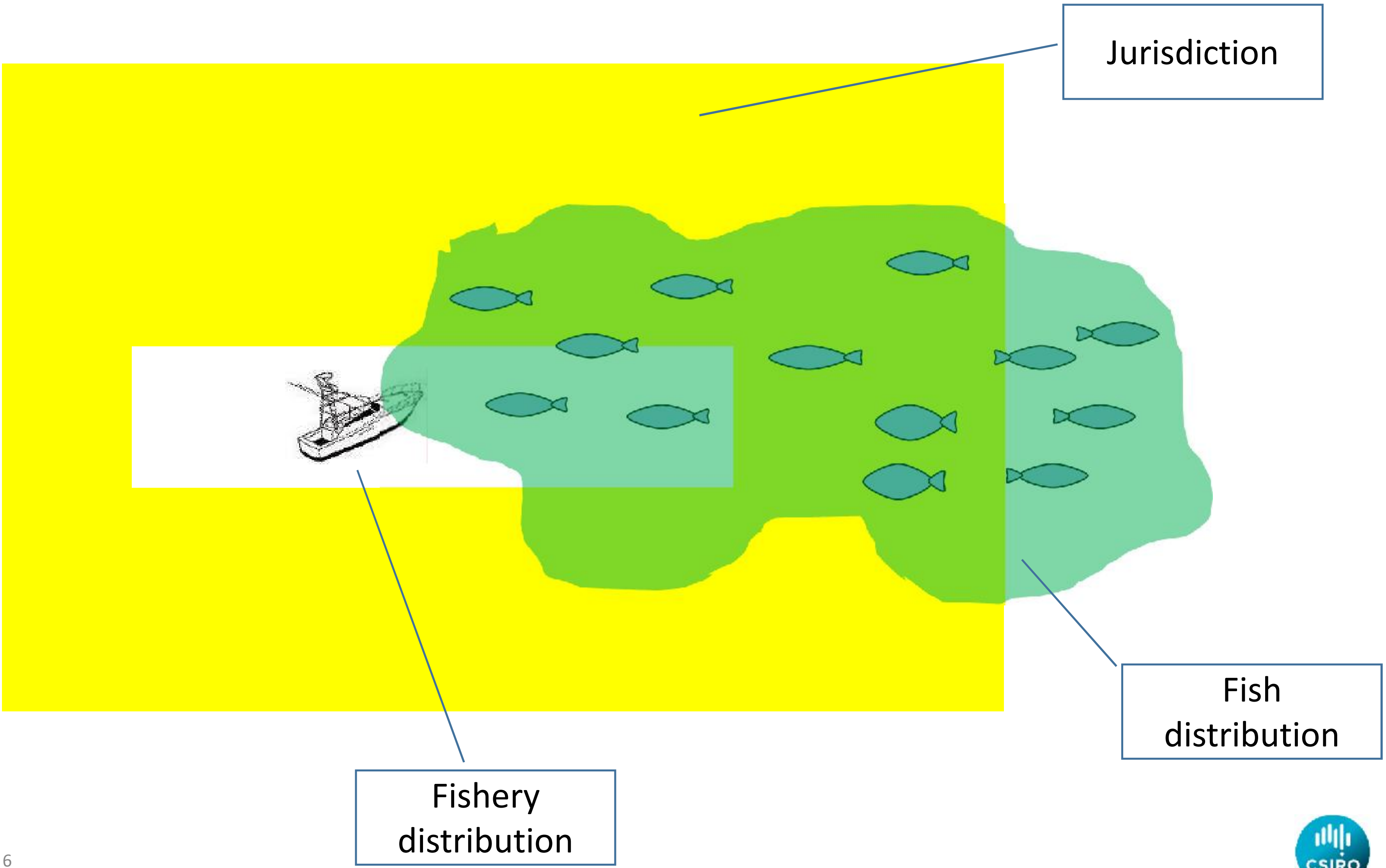
q_λ: size- and behaviour-dependent selectivity;

S: is the discard survival rate;

d_s: fish density;

Q: catch efficiency.

Area overlap between fishery and species distribution within jurisdiction



SAFE: fishing mortality

Density

Gear efficiency

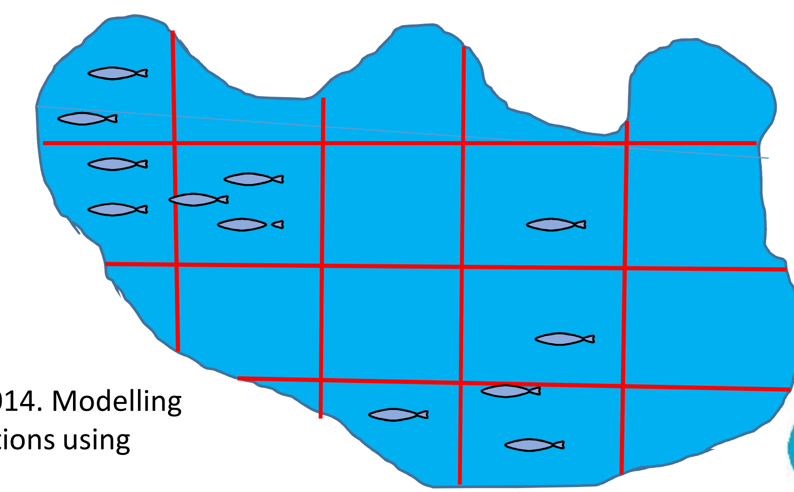
$$= \frac{\sum_{,}\left(\quad , | \quad , \right)}{\sum \left(\quad , \right)} \quad (1 - \quad)$$

Gear efficiency *Q*

- Assume Q = 1 or 0.5.
- Assume q_h and q_λ = 0.33, 0.67, 1 based on ecological and biological information.
- Estimate Q from survey, observer, or fishery data (not necessary time series) —N-mixture model.
- Estimate Q from time series of fishery data—Biomass dynamics model.

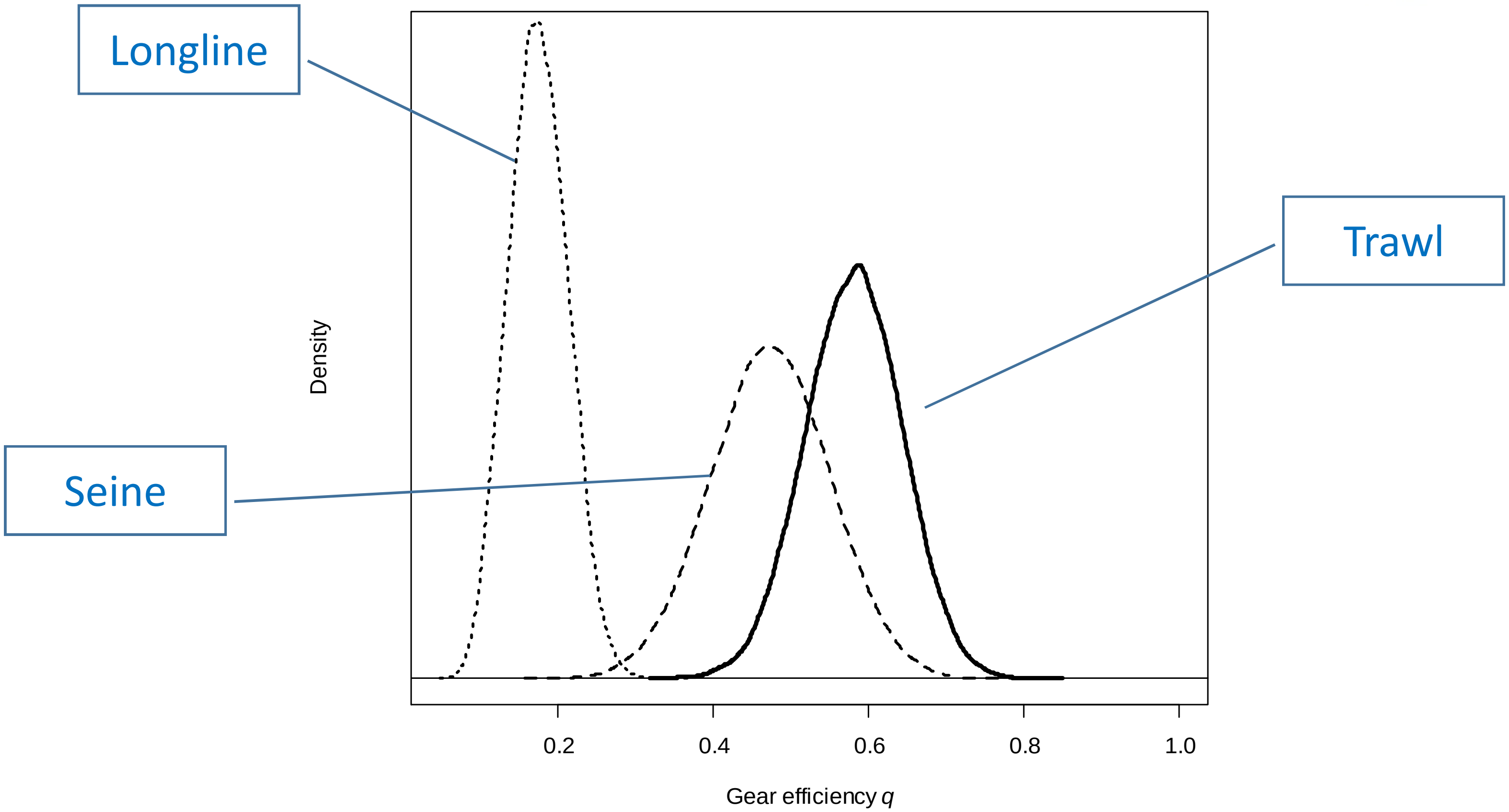
Estimating gear efficiency *Q* from survey, observer, or fishery data: Bayesian cross-sampling model

- Data required:
  - Shot-by-shot catch;
  - Repeated sampling within spatial and temporal strata;
  - Multiple gear types.
- Fish distribution:
  - Non-random aggregated between grids → $N_i \sim \text{negbin}(p, r)$;
  - Random within each grid → $N_{ij} \sim \text{pois}(N_i)$;
- Catch process: binomial distribution → $C_{ijk} \sim \text{binom}(Q_{ik}, N_{ij})$.
- Bayesian mixture model.



Zhou, S., Klaer, N.L., Daley, R.M., Zhu, Z., Fuller, M. and Smith, A.D.M. 2014. Modelling multiple fishing gear efficiencies and abundance for aggregated populations using fishery or survey data. *ICES Journal of Marine Science* 71: 2436-2447.

Gear efficiency for Bight Skate



Estimate *Q* from time series of fishery data

- Data required:
  - Select a calibration area A_{Ω} where time series data are credible and reliable;
  - Time series of catch history in A_{Ω};
  - Time series of standardised CPUE in A_{Ω}.
  - CPUE of various fishery groups.
- Modelling: estimate catchability q_{Ω} by Bayesian biomass dynamics model.
- Adjusting q_{Ω} by fishery groups and spatial scaling.

Fu, D., Rou, M.-J., Clarke, S., Francis, M., Dunn, A., Hoyle, S., and Edwards, C. 2018. Pacific-wide sustainability risk assessment of bigeye thresher shark (Alopias superciliosus). Prepared for Western and Central Pacific Fisheries Commission. NIWA, Wellington, April 2018. 102 pp.

Hoyle, S. D. S. D., Edwards, C. T. T., Roux, M.-J., Clarke, S. C., and Francis, M. P. 2017b. Southern hemisphere porbeagle shark (Lamna nasus) stock status assessment. NIWA Client Report, Prepared for Western and Central Pacific Fisheries Commission. WCPFC-SC13-2017/SA-WP-12. 65 pp.

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Estimate fish density d_s

- Assume homogeneous/random (bSAFE) (e.g. Zhou et al. 2011)
- Estimated from presence-absence data (e.g. Zhou and Griffiths 2008)
- Estimated from survey, observer, or fishery data (e.g. Zhou et al. 2013)
- Estimated from fishery CPUE and environmental data (SST) (e.g. Hoyle et al. 2017)

$$(catch/h \quad) \sim \quad + \quad + \quad (\quad , \quad) + (h \quad) + \quad + (\quad)$$

Estimating density and fishing mortality

Raw density:

$$d_y = \frac{c_y}{a_y \quad Q_k}$$

Smoothing GAM:

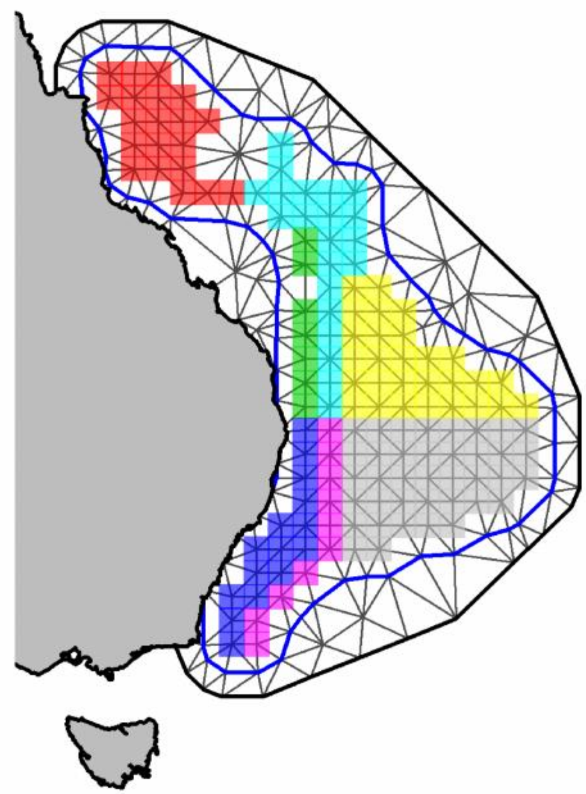
$$\log\left(d_{\mathrm{yij}}\right) = \beta_0 + f_1(lc \quad , lc \quad) + f_2(y \qquad) + f_3(m \qquad h)$$

Fishing mortality:

$$F_y = \frac{\sum_{\mathrm{g}} a_{y.} \quad \hat{d}_{\mathrm{yg}} \mathrm{Q_k}}{B_y} = \frac{\sum_{\mathrm{g}} a_{y.} \quad \hat{d}_{\mathrm{yg}} \mathrm{Q_k}}{\sum_{\mathrm{g}} \hat{d}_y \ A_g}$$

Geostatistical model

$$¦_i = {}_0 + {}_Y Y_i + {}_{HPF} HPF_i + {}_T T_i + {}_h \log(E_i) + f_s(s,t) + £_i$$

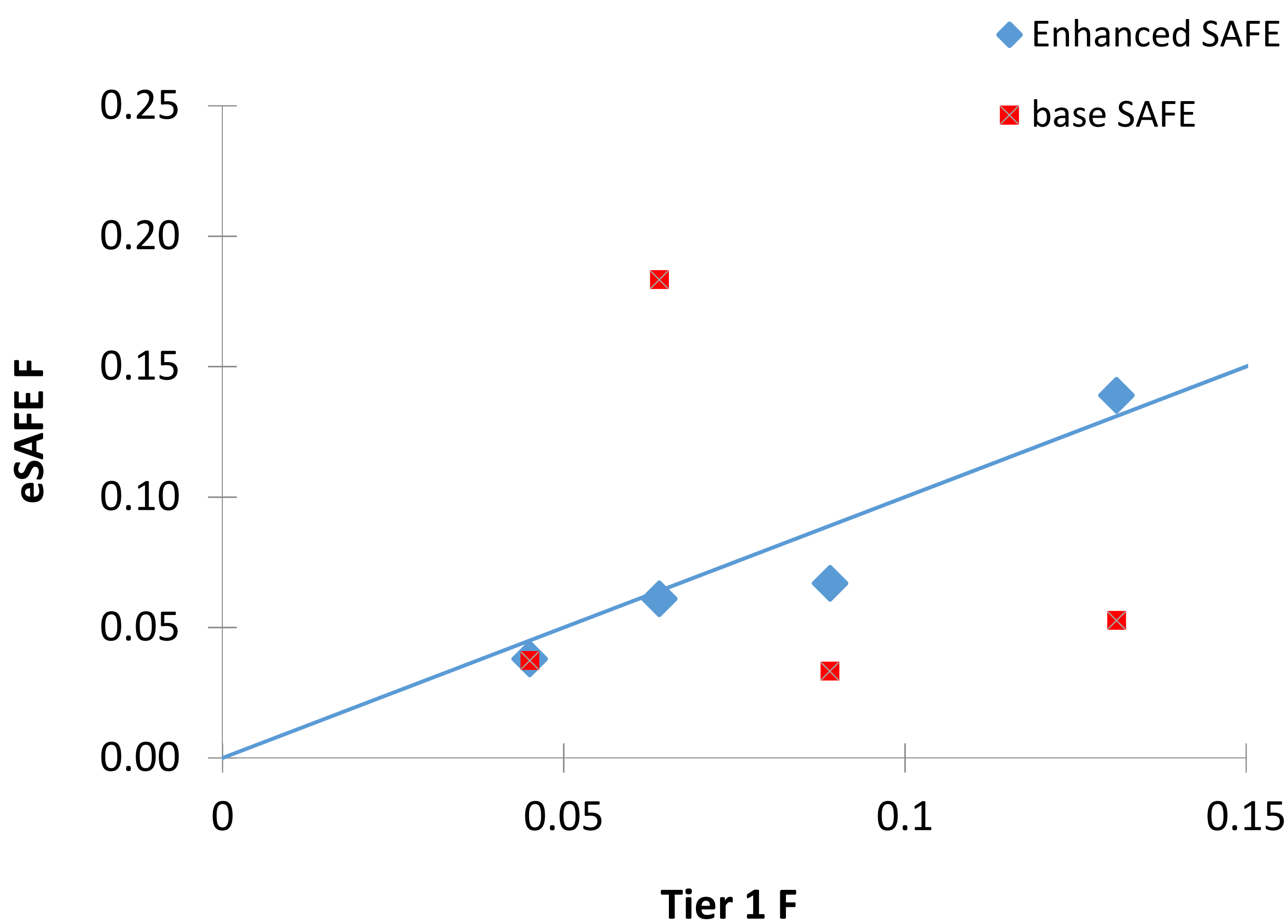


Instead of treating spatial and temporal information as discrete factors, model spatial and temporal data with a continuous Gaussian random field

Distribution range

- Habitat map
- Historical catch locations
- Additional information: museum records, surveys, anecdotal observations,

Compare Enhanced SAFE with Tier 1 stock assessment



Recommendations

- Modify area-based method to suit available data;
- Cross-validate methods for estimating Q;
- Consider using geostatistical modelling technique to estimate density.

Thank you

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Age-based methods—catch curve

- Estimated F is an average over several years;
- Generally requirements:
  - vulnerability to fishing gear is constant above the age when maximum catch occurs;
  - a constant recruitment for cohorts included in the analysis;
  - similar survival history for these cohorts;
  - **accurate aging**.

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Length-based methods

- Beverton-Holt “per-recruit” estimator (BHE)
- Length converted catch curve (LCCC)
- Length-based spawning potential ratio (LB-SPR)
- Length-based Integrated Mixed Effects (LIME)
- Length-based Bayesian biomass estimation method (LBB)

Length-based methods: general requirements

- Constant recruitment, growth, natural mortality, and fishing mortality;
- Length frequency data represent the size composition of the exploited size range of the stock;
- Combining length frequency data from multiple fisheries sampled at varying locations can be tricky.

Other potential management procedures

- Catch-rate (CPUE) approach
- Length-based methods
- Catch-only methods

- It may be worth to try these methods if the required data are available and satisfy the assumptions.