# Hazard function models to estimate mortality rates affecting fish populations by maximum likelihood using age data, with application to the sea mullet (Mugil cephalus) fishery on the Queensland coast (Australia)

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## Background

Fisheries management agencies around the world collect age data for the purpose of assessing the status of natural resources in their jurisdiction. Estimates of mortality rates represent a key information to assess the sustainability of fish stocks exploitation. Contrary to medical research or manufacturing where survival analysis is routinely applied to estimate failure rates, survival analysis has seldom been applied in fisheries stock assessment despite similar purposes between these fields of applied statistics.

## Method

The likelihood function of a sample of age ($S_{k,l}$) was derived for each cohort ($k$) from the hazard function:

$$h_k(t,\theta) = M + q\ s(t)\ E(t) \tag{1}$$

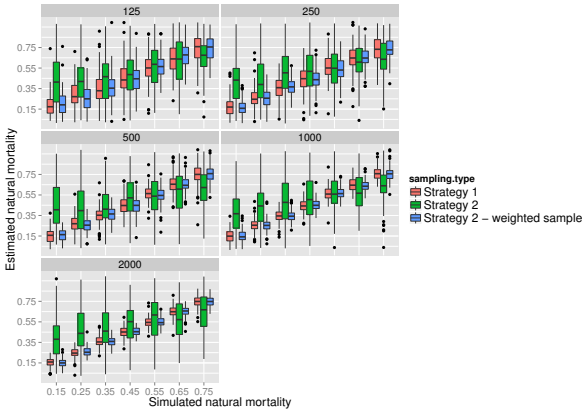
$$\mathcal{L} = \prod_{k=1}^{n+p-1} \prod_{l=1}^{r_k} \left( \int_{t=a_{k,l}}^{t=a_{k,l+1}} g_k(t;\theta)\ dt \right)^{S_{k,l}} \tag{2}$$

where

$$g_k(t;\theta) = \frac{q\ s(t)\ E(t) \times e^{-Mt - q\int_0^t s(t)\ E(t)\ dt}}{\sum_{l=1}^{r_k} \frac{q\ s_{k,l}\ E_{k,l}}{M+q\ s_{k,l}\ E_{k,l}} \left( e^{-M\ a_{k,l} - q\int_0^{a_{k,l}} s(t)\ E(t)\ dt} - e^{-M\ a_{k,l} - q\int_0^{a_{k,l+1}} s(t)\ E(t)\ dt} \right)} \tag{3}$$

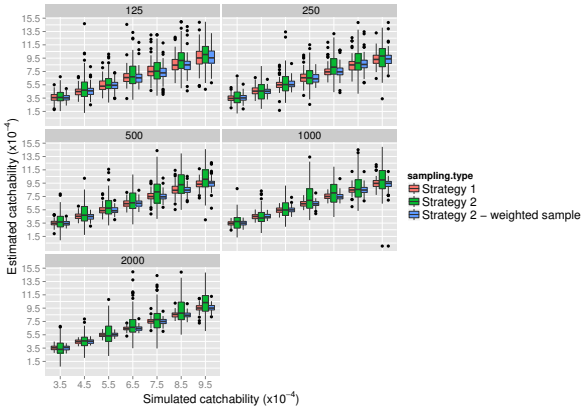
## Monte Carlo

The method was tested with Monte Carlo simulations to assess if it allowed to estimate natural mortality.




## Monte Carlo (cont.)

Estimates of catchability ($q$)




## Case study

The straddling sea mullet (*Mugil cephalus*) is caught along the east coast of Australia from Townsville to roughly the border between New South Wales and Victoria. Analyses of parasites concluded that the bulk of sea mullet caught in Queensland fishery is based on local fish populations and not migrating from New South Wales. A scientific survey samples this population in both estuaries and ocean habitats in order to provide representative description of the Queensland fishery. Mullet age in the samples varied between 0 and 16 years. Data collected between 2007 and 2014 were used to estimate, for the first time in Australia, the magnitude of natural mortality affecting this stock: it was estimated to equal $0.22 \pm 0.08$ year$^{-1}$.

## Conclusions

This likelihood method may well find its place into integrated stock assessment as it provided an efficient method to deal with samples of age data. Applications of survival analysis to fishery data could be expanded further, in particular to derive recruitment estimates using the probabilities estimated by survival analysis and total catch from the fishery.

## References

Kienzle, M. (2016).
Hazard function models to estimate mortality rates affecting fish populations with application to the sea mullet (*Mugil cephalus*) fishery on the Queensland Coast (Australia).
*Journal of Agricultural, Biological, and Environmental Statistics*, 21(1):76–91.