Quick and dirty introduction of R

At IOTC-WPNT workshop on data-limited stock assessment

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Contents


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## Warning: package 'knitr' was built under R version 3.5.3
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Production model

Theoretical background in brief

The concept of "surplus production"

The change in a population biomass
(Ass. no immigration and emigration)

(Next year's biomass)

= (current biomass) + (Recruitment) + (Growth) – (Natural mortality) – (Catch)

= (current biomass) + (Surplus) – (Catch)

Equation 12

$$B_{t+1} = B_t + g(B_t) - C_t$$

The concept of "sustainable yield"

$$B_{t+1} = B_t + g(B_t) - C_t$$

$$C_t = g(B_t) \Longrightarrow B_{t+1} = B_t$$

This is the amount of catch which can be taken to maintain the biomass at a constant level

Therefore, it is called "sustainable yield"

The maximum value of among possible values of "sustainable yield" is called "maximum sustainable yield (MSY)", and the biomass attaining MSY is called "MSY level (MSYL)"

A simple relationship between stock biomass and surplus production

Logistic model

Equation 13

$$B_{t+1} - B_t = \boxed{r} B_t \left(1 - \frac{B_t}{\boxed{K}}\right)$$

Intrinsic rate of natural increase

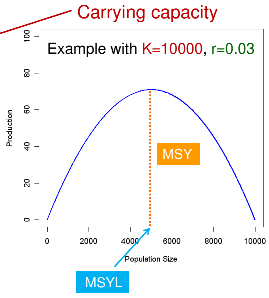
Carrying capacity

$$B_{t+1} - B_t = 0$$

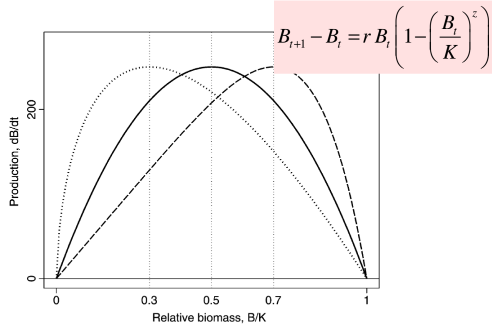
$$C_t = r B_t \left(1 - \frac{B_t}{K}\right)$$

$$MSY = \frac{rK}{4}$$

$$MSYL = \frac{K}{2}$$



Other functions



From Prager (2002)

Use of MSY as a reference point

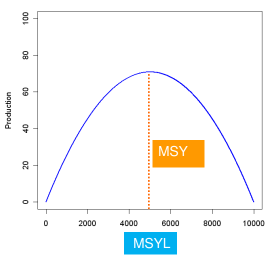
- MSY or MSYL
- FMSY

$$C = qEB = FB = F\frac{K}{2}$$

$$C = \frac{rK}{4}$$

$$F_{MSY} = \frac{r}{2}$$

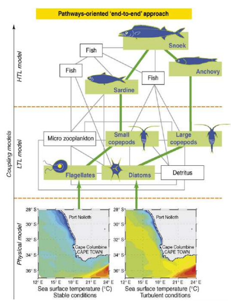
If the fishery is operated with FMSY level, then the stock level is approaching to its MSY level.



Concerns about MSY approaches

- Environmental variability
  (Are the carrying capacity and intrinsic rate of natural increase constant? Habitat quality might be influenced by environmental factors)
- Ecosystem perspective
  (e.g. Competition to other stocks may change carrying capacity)

$$C = \frac{rK}{4},\ F_{MSY} = \frac{r}{2}$$



From Curry et al. (2008)

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Concerns about MSY approaches

- Environmental variability
- Ecosystem perspective
- Behavior of fishermen

The Tragedy of the Commons

The population problem has no technical solution;
it requires a fundamental extension in morality.

Garrett Hardin

At the end of a thoughtful article on the future of nuclear war, Wiesner and York (*1*) concluded that: "Both sides in the arms race are . . . confronted by the dilemma of steadily increasing military power and steadily decreasing national security. *It is our considered professional judgment that this dilemma has no technical solution.* If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

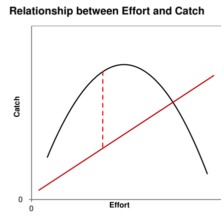
sional judgment. . . ." Whether they were right or not is not the concern of the present article. Rather, the concern here is with the important concept of a class of human problems which can be called "no technical solution problems," and, more specifically, with the identification and discussion of one of these.

It is easy to show that the class is not a null class. Recall the game of tick-tack-toe. Consider the problem, "How can I win the game of tick-tack-toe?" It is well known that I cannot, if I as-

From Hardin (Science 1968)

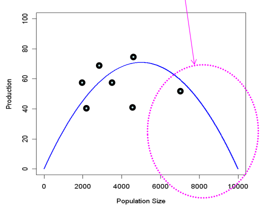
Concerns about MSY approaches

- Environmental variability
- Ecosystem perspective
- Behavior of fishermen
- Economical aspects
  (Cost should be taken into account -> MEY)



Concerns about MSY approaches

- Environmental variability
- Ecosystem perspective
- Behavior of fishermen
- Economical aspects
- Several uncertainties
  (in data, estimation, model etc.)



Concerns about MSY approaches

- Environmental variability
- Ecosystem perspective
- Behavior of fishermen
- Economical aspects
- Several uncertainties
- Age structures ?
- Stock (population) structures?

....

Estimation of surplus production

Equation 4

$$U_t = CPUE_t = \frac{C_t}{E_t} = q \times N_t$$

Equation 14

$$\Rightarrow U_t = CPUE_t = \frac{C_t}{E_t} = q \times B_t$$

Equation 13

$$B_{t+1} - B_t = r B_t \left(1 - \frac{B_t}{K}\right)$$

Equation 15

$$\Rightarrow B_t = B_{t-1} + r B_{t-1} \left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

Estimation of surplus production

Equation 14

$$U_t = CPUE_t = \frac{C_t}{E_t} = q \times B_t$$

Equation 15

$$B_t = B_{t-1} + r B_{t-1} \left(1 - \frac{B_{t-1}}{K}\right) - C_{t-1}$$

Equation 16

$$\Rightarrow \sum_t (\log U_t - \log qB_t)^2 \Rightarrow \min$$

Unknown parameters: K, r, q, B0

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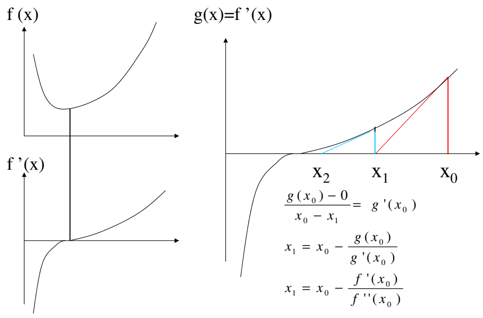
Data for yellowfin tuna in Eastern Pacific

Year	Catch	Effort	CPUE	Year	Catch	Effort	CPUE
1934	60913	5879	10361	1945	89194	9377	9512
1935	72294	6295	11484	1946	129701	13958	9292
1936	78353	6771	11572	1947	160134	20381	7857
1937	91522	8233	11116	1948	200340	23984	8353
1938	78288	6830	11462	1949	192458	23013	8363
1939	110417	10488	10528	1950	224810	31856	7057
1940	114590	10801	10609	1951	183685	18726	9809
1941	76841	9584	8018	1952	192234	31529	6097
1942	41965	5961	7040	1953	138918	36423	3814
1943	50085	5930	8446	1954	138623	24995	5546
1944	64094	6397	10019	1955	140581	17806	7895

- Catch (thousand pounds)
- Effort (standardized class 4 clipper days)
- CPUE(pounds/ standardized class 4 clipper days)

Data from Schaefer (1957)

Very simple illustration of Newton's method



$$\frac{g(x_0)-0}{x_0-x_1}=g'(x_0)$$

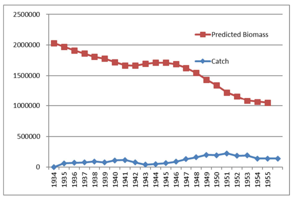
$$x_1=x_0-\frac{g(x_0)}{g'(x_0)}$$

$$x_1=x_0-\frac{f'(x_0)}{f''(x_0)}$$

Data for yellowfin tuna in Eastern Pacific

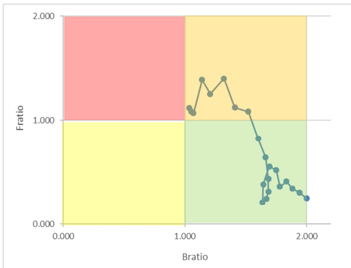
$$U_t=\frac{C_t}{E_t}=qB_t$$

$$B_t=B_{t-1}+r\,B_{t-1}\left(1-\frac{B_{t-1}}{K}\right)-C_{t-1}$$



Parameters	
K	2030950
r	0.239645
B1934	2030950
q	0.000006
Challengin cells	
logK	14.52401444
logr	−1.428598609
logq	−12.1065004
Sum of Squared errors	
	0.631
Bench Mark	
MSY	121677
BMSY	1015475
FMSY	0.120

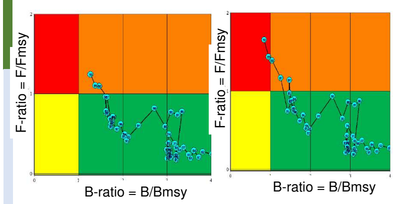
Data for yellowfin tuna in Eastern Pacific



What do you say about the population/fishery status?

What is your possible measure for this fishery?

KOBE 1 plots



B-ratio = B/Bmsy

B-ratio <1
or
B-ratio > 1 ?

F-ratio = F/Fmsy

F-ratio <1
or
F-ratio > 1 ?

What do you say about the population/fishery status?

What is your possible measure for this fishery?

Wrap-up discussion

- Do you think that this population is healthy or not?
- What do you think of the population status in terms of sustainable use?
- Is it possible to apply this method to your fisheries?

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$$B_{t+1} = B_t + rB_t\left\{1 - \left(\frac{B_t}{K}\right)^z\right\} - C_t$$

Assume that the CPUE is proportional to the population biomass as follows:

$$CPUE_t = qB_t.$$

Here q is a proportional coefficient called "catchability coefficient".

Let us assume the following time series model and try to estimate the parameters in the model.

$$\log CPUE_t = \log q + logB_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma^2)$$

Set-up of exercises for production model using ML estimation

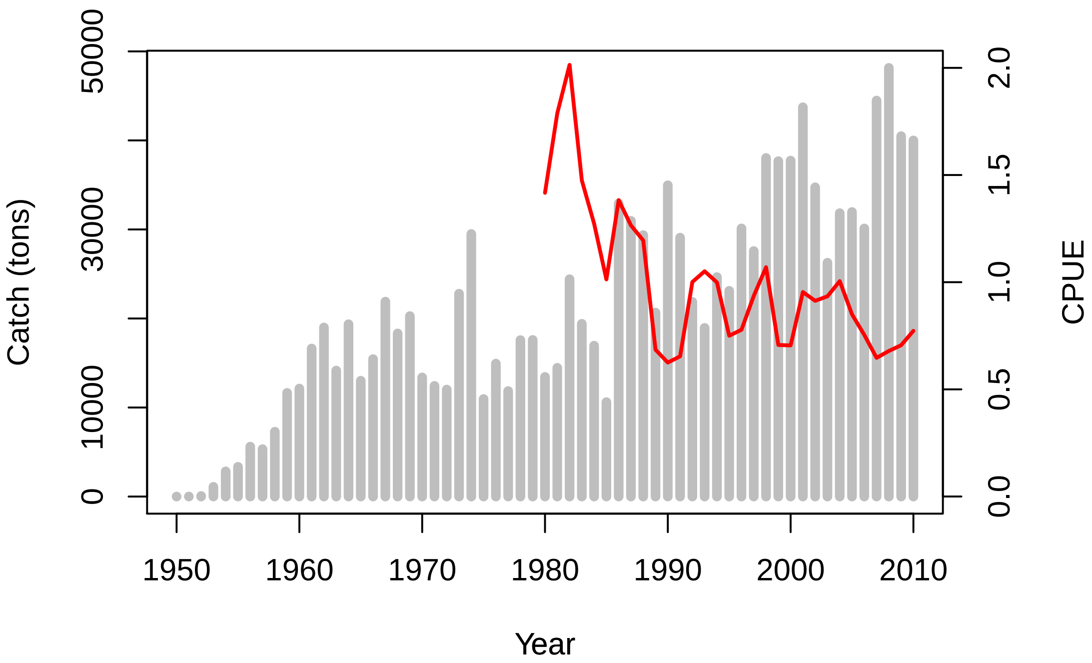
Reading the data

```
# Data for Indian Ocean albacore
Data <- read.csv("IO_Albacore.csv", header=T)
Year <- Data$Year
Catch <- Data$Catch
CPUE <- Data$CPUE
CV <- Data$CV
TT <- length(Year)

start.year <- min(Year)
final.year <- max(Year)
```

Visual presentation of data:

```
par(mai = c(1, 1.1, 1, 1.1))
plot(Year, Catch, type = "h", lwd=5, col="gray", ylab="Catch (tons)")
par(new =T)
plot(Year, CPUE, type="l", lwd=2, col="red", axes=FALSE,  ylab="", ylim=c(0,2))
axis(4); mtext("CPUE", side=4, line=3)
```



Definition of population dynamics:

```
PDM.PT<-function(r, K, z, B1, TT, Catch)
{
 TT <- TT
 B<-rep(NA,TT)
 B[1]<-B1
 for(t in 1:(TT-1))
 {
  tmp<-B[t]+r*B[t]*(1-(B[t]/K)^z)-Catch[t]
  B[t+1]<-max(tmp,0.001)
 }
 B
}
```

Definition of likelihood function (z=1; Schaefer model):

```
NLL.PT <- function(par,z)
{
 r<-exp(par[1])
 K<-exp(par[2])
 q<-exp(par[3])
 sigma <-exp(par[4])
 B<-PDM.PT(r, K, z, K, TT, Catch)

 yobs <- log(CPUE)
 mu <- log(q) + log(B)
```

```
  pdf <- dnorm(yobs, mu, sigma, log=T)
  loglike <- sum(pdf, na.rm=T)
  negloglike <- -loglike
  return(negloglike)
}
```

Estimation of parameters by maximum likelihood (ML) methods

Estimation

```
init.MSY <- 2*mean(Catch)
init.r <- 0.4
init.K <- 4*init.MSY/init.r

init<-log(c(init.r, init.K, 10^(-6), 1))
NLL.PT(init, z=1)
```

```
[1] 46.552
```

```
NLL.PT(2*init, z=1)
```

```
[1] 74.13025
```

```
res.SC<-optim(init, NLL.PT, z=1, method="BFGS", control=list(reltol=10^(-8)))
res <- res.SC; res
```

```
$par
[1]  -0.9788076  12.7297969 -12.4127161  -1.4274852

$value
[1] -0.2648306

$counts
function gradient
     172       51

$convergence
[1] 0

$message
NULL
```

```
r.est<-exp(res$par[1])
K.est<-exp(res$par[2])
q.est<-exp(res$par[3])
sigma.est<-exp(res$par[4])

MSY.est <- r.est*K.est/4
MSYL.est <- K.est/2

data.frame(r.est, K.est, q.est, sigma.est)
```

```
      r.est    K.est         q.est sigma.est
```

```
1 0.3757589 337660.7 4.066548e-06 0.2399115
```

```
Predicted <- PDM.PT(r.est, K.est, z=1, K.est, TT, Catch)
```

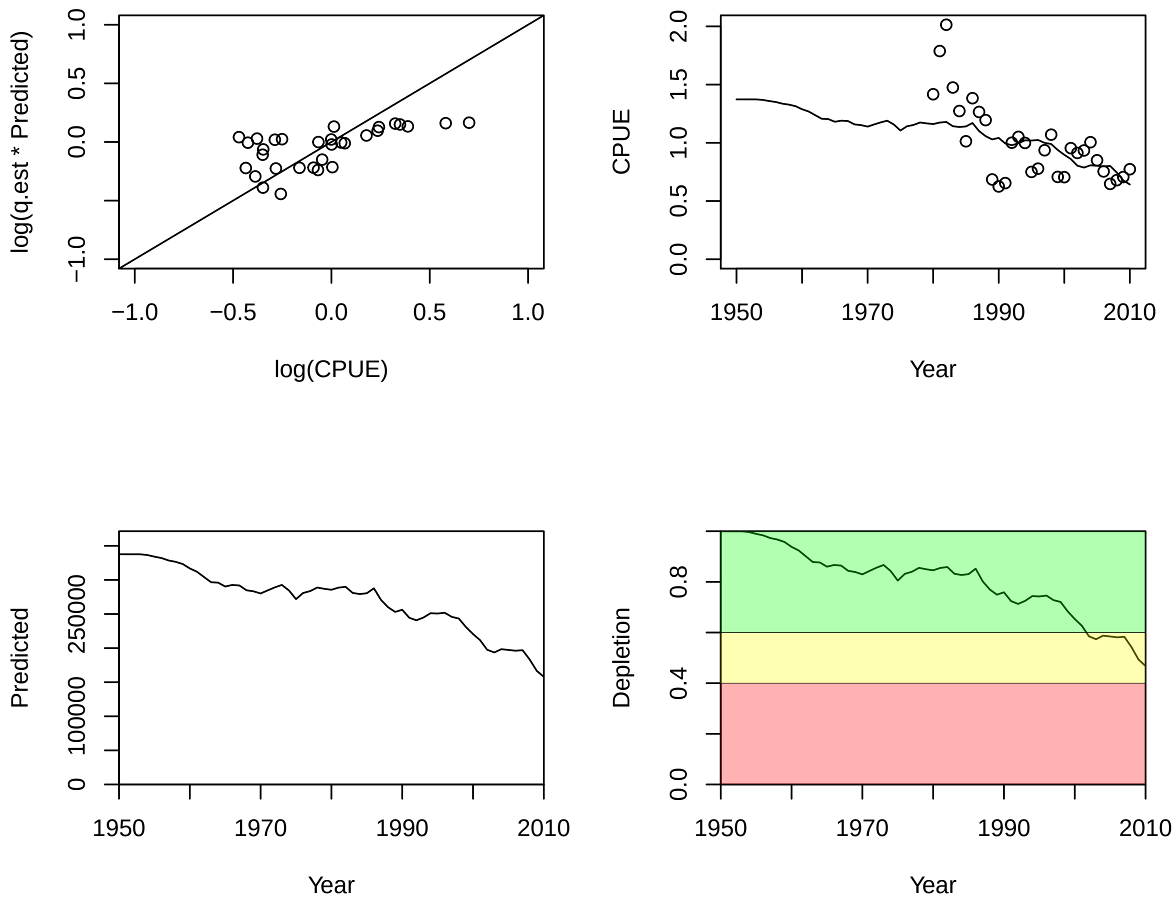
Visual presentation of outcomes (1)

```
# Fittness
par(mfrow=c(2,2))
plot(log(CPUE), log(q.est*Predicted), xlim=c(-1,1), ylim=c(-1,1)); abline(0,1)

# Time series plots for CPUE observation and its prediction by the model
plot(Year, CPUE, ylim=c(0, max(CPUE, na.rm=T)) )
points(Year, q.est*Predicted, type="l")

# Times series of estimated biomass
plot(Year, Predicted, type="l", ylim=c(0, 1.1*K.est), xaxs="i",yaxs="i")

# Times series of depletion level against the carrying capacity (B/K)
plot(Year, Predicted/K.est, type="l", ylim=c(0,1), xaxs="i",yaxs="i", ylab="Depletion")
rect(xleft=-1, ybottom=0, xright=2010, ytop=0.4, lwd=0, col=rgb(1,0,0,0.3))
rect(xleft=-1, ybottom=0.4, xright=2010, ytop=0.6, lwd=0, col=rgb(1,1,0,0.3))
rect(xleft=-1, ybottom=0.6, xright=2010, ytop=1, lwd=0, col=rgb(0,1,0, 0.3))
```



Visual presentation of outcomes (2)

```
# Definition of B-ratio and F-ratio
Bratio <- Predicted/MSYL.est
Fratio <- Catch/(MSY.est) #actually Hratio

plot(Bratio,Fratio,type="n",xlim=c(0,2),ylim=c(0,2),
     xlab="B/Bmsy",ylab="F/Fmsy", main="Kobe plot")
rect(xleft=0,ybottom=0,xright=1,ytop=1,lwd=0,col="#FEFF63FF")
rect(xleft=0,ybottom=1,xright=1,ytop=2,lwd=0,col="#FF4949FF")
rect(xleft=1,ybottom=1,xright=2,ytop=2,lwd=0,col="#FFBE7DFF")
rect(xleft=1,ybottom=0,xright=2,ytop=1,lwd=0,col="#85FF68FF")

points(Bratio,Fratio,type="l",lwd=1.8)
points(Bratio[1:(T-1)],Fratio[1:(T-1)],lwd=1,cex=3,pch=21,bg="skyblue")
points(Bratio[T],Fratio[T],lwd=1,cex=3,pch=21,bg="blue")
num <- c(seq((start.year-1900),99,1),seq(0,(final.year-2000),1))
text(Bratio,Fratio,labels=num,adj=0.5,cex=1, col="white")
```