SQUIDSIM, SQUID SIMULATOR, Version 1.1.
SC11 WP07

Ignacio Payá C., IFOP, Chile

septiembre 14, 2023

Table of Contents

SUMMARY

I. Payá (2019) writed the version 1.0 of the SQUIDSIM, a program to simulate individual, population and fishery components of Humboldt Squid stock in month scale. Two growth functions (exponential or VonBertalanffy) were included. Maturity was modelled as a logistic function. Two options for modelling stock-recruitment relationship (Ricker or Beverton and Holt) with steepness parameters and process errors were included. Three options (constant, exponential and sinusoidal) for seasonal recruitment patterns were allowed. The fishing component includes two fleets with selectivity patterns modelled as double half-normal functions. A length-age key is calculated based on the growth model in order to estimate the mantle length frequency in the population and in the commercial catches. This simulator was coded in R Mardown in R Studio, which allows to automatically knit text, R codes, tables and figures to produce a report in html, word and pdf formats. In order to run the simulation with different cases, the parameters must be input in an csv format file.

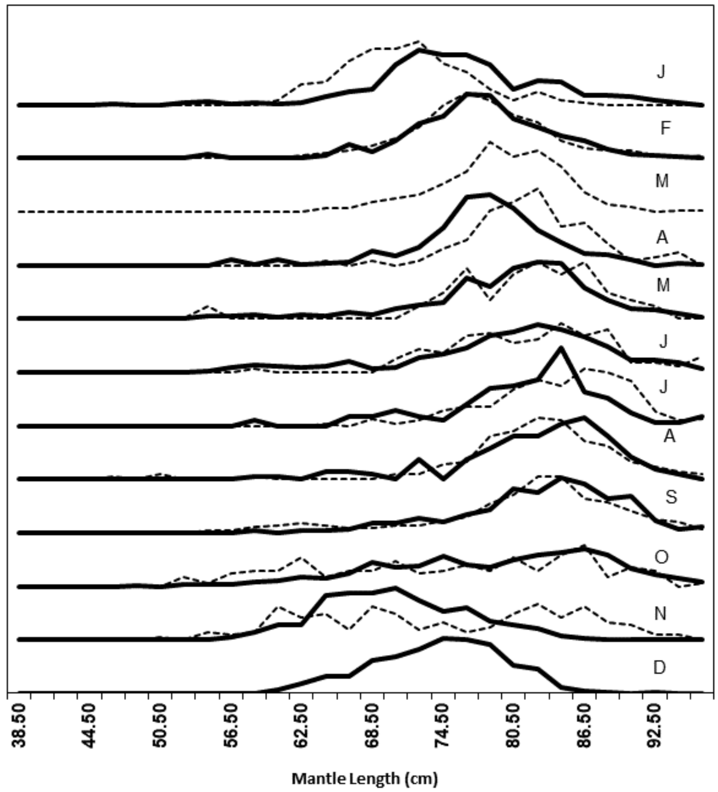
The current version 1.1, adds the simulation of four abundance indices: two CPUE (with hyperstability) and two acoustic biomass. Selectivities for acoustic surveys were modelled by length using double half-normal functions. Also, adds a new option for seasonal recruitment pattern, new charts and improvements to some others charts.

INTRODUCCTION

The Scientific Committee seems to agree that because of the short lifetime (1 -1.5 year) of Humbodlt squid, the stock assessment and management should be done in-season scale. However, the impact of not doing so and try to apply models with year scale, as the global production models, has not been formally evaluated.

Management strategy evaluation requires to build an operational model to test different stock assessment models and harvesting rules. The simulation of the stock dynamics and the fisheries is the first step in development an operational model. Therefore, this contribution offers a simulator of the population dynamic and fishery of Humboldt squid stock.

From the point of view of the local squid stock assessment in the EEZ of Chile, the simulator should be able to reproduce the mantle length frequencies observed by month in artisanal catches in 2015 (broken line) and 2016 (solid line)(I. Payá 2015, 2016).



These frequencies had a clear modal progression that suggests the arrival of large squids in November and the departure in October of the next year (I. Payá 2016). This mantle length data combined with abundance indices have been used in fitting successfully local depletion models (I. Payá 2015, 2016, 2017, 2019).

Therefore, this is a program to simulate the dynamic of Humboldt Squid population off Chilean waters. The time scale is month. The recruitments are modelled using a Ricker (1954) or a Beverton and Holt (1957) stock-recruitment relationship, with a steepness parameter (h) (Mace and Doonan 1988) and process errors (rsigma). Recruitment can also be multiply by a seasonal factor to generate a seasonal pattern. Seasonal pattern can be constant (no effect), exponential decreasing or sinusoidal.

The fishing component includes two fleets. The fishing selectivities are modelled using double half-normal functions.

This simulator is coded in R Mardown in R Studio (Allaire et al. 2018). The individual, population and fishery parameters are setting in a file named “HSquid_Par.csv”. The use of external parameter file allows to run the simulation with different set of parameters.

METHODS

The age and time variables are in units of years and they are divided by month. The bin is the fraction of the year for a month ($bin = 1/12$). The age i, $i = 1, \ldots, nags$, where $nags$ is numbers of months in the lifetime. The time j, $j = 1, \ldots.. nbtins$, where $nbtins$ is the whole numbers of months in the time series.

INDIVIDUAL FUNCTIONS

Growth models

There are two model options. If gm=1 the exponential model is used:

$$l_i = a_{expo} exp\left(b_{expo} t\right)$$

where l is the Mantle length (cm) and a_{expo} and b_{expo} are the parameters, which were taken from Argüelles et al. (2001) for large squid with hatching in spring.

If gm>1 the vonBertalanffy model is used:

$$l_i = loo(1 - exp\left(-r(t - t_0)\right)$$

where loo: Infinite length (cm); r: growth rate; t: age in years; $t0$: age in years at length zero;

Allometric growth

$$w_i = a l_i^b$$

where a and b are the allometric parameters and w is the whole weight.

The vonBertalanffy parameters and the allometric parameters were taken from Payá I. et al. (2014).

Maturity

$$pm_i = 1/(1 + exp(-log(19)(l_i - lm50)/lmrange))$$

where $lm50$ is the length at 50% of maturity and $lmrange$ is the amplitude of the function.

POPULATION FUNCTIONS

Natural Mortality (M)

$$M_{i,j} = M_{bin} + e_{i,j}^M$$

where $e^M \sim N(0, sd_M)$ and sd_M is the standard deviation of $Mbin$

N at the first month

The number at age 1 for the first month is R0, and for the older ages is the number of survivors of previous recruitments

The recruitment before the first year is vector of length equals to numbers of ages (nags)

$$predR_i = R0 \quad exp(e_i^0)$$

For i (age) = 1

$$N_{1,1} = B0 + e_i = predR_{nags} \quad exp(e_i^0)$$

For i (age)>1

$$N_{i,1} = predR_{nags-1-i} \quad exp\left(-M_{i-1,1}(i-1)\right) \quad exp(e_i^0)$$

$$e_i^0 \sim N(0, prevrsigma)$$

where $prevrsigma$ is the standard deviation of recruitments before the starting month.

Seasonal Recruitment Patterns

Constant pattern ($RSeason$=1):

$$inbinR = 1 \quad exp(e_1^s)$$

Exponential pattern ($RSeason$=2), with $inbinR_1 = 1$:

$$inbinR_i = exp\big(-0.20(i-1)\big) \quad exp(e_i^s) \qquad for \quad i = 2, \ldots, 12$$

Sinusoidal Pattern, two peaks in a year ($RSeason$=3):

$$inbinR_i = \sin(3+i) \quad exp(e_i^s) \qquad for \quad i = 1, \ldots, 12$$

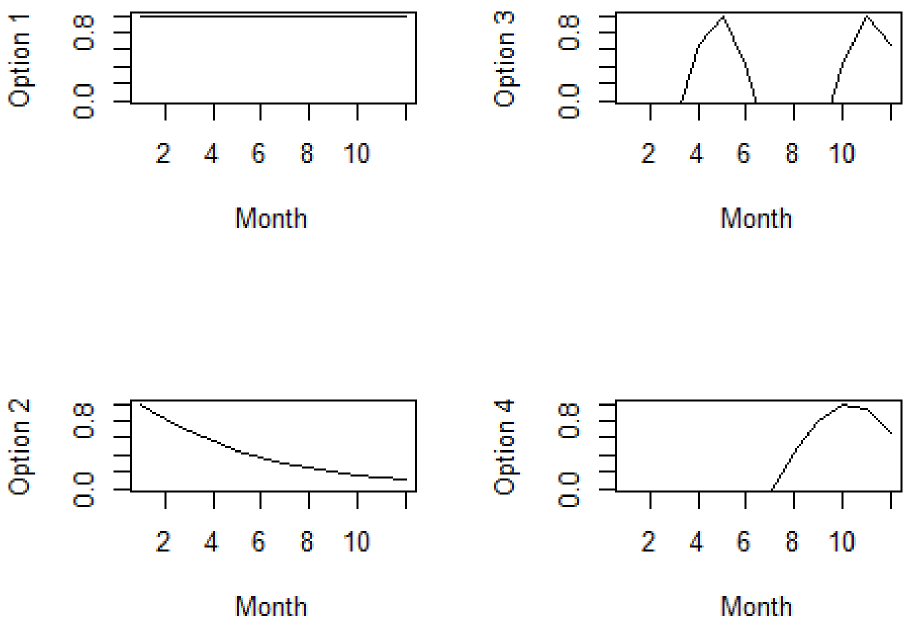
Sinusoidal Pattern, one peak in a year ($RSeason$=4):

$$inbinR_i = \sin(9+i/2) \quad exp(e_i^s) \qquad for \quad i = 1, \ldots, 12$$

$$e^s \sim N(0, SdSeason)$$

Non negative $inbinR_i$ were not allowed, so if $inbinR_i$<0 then $inbinR_i$=0.

Figure 0. Seasonal recruitment pattern options.



Equilibrium functions

The numbers per recruit ($Neq_1 = 1$), are :

$$Neq_i = Neq_{i-1}exp\left(-M_{i-1,1}\right) \qquad for \quad i = 2, \ldots, nags$$

The potential spawning biomass per recruit, $SPBR$, in tons:

$$SBPR = \sum_{i=1}^{nags} w_i \, pm_i Neq_i / 1000$$

For $SB0$ (in tons) $R0$ is:

$$R0 = SB0/SBPR$$

There are two options for the stock-recruitment model. If parameter SRModel= 1 then Ricker else Beverton-Holt.

The Ricker parameters are calculated based on the steepness parameter h are:

$$alpha = 1.25log(5 * h) - log(SBPR)$$

$$beta = 1.25log(5h)/SB0$$

The Beverton-Holt parameters based on steepness parameter h are:

$$alpha = (1 - h)/(4h) \quad SBPR$$

$$beta = (5h - 1)/(4h \quad SB0) \quad SBPR$$

The recruitment at the first month j=1, using Ricker model is calculated as:

$$R_1 = N_{1,1} = SB0exp(alpha - beta * SB0) \quad inbinR_j \quad exp\left(e_j^r - rsigma^2/2\right)$$

while with Beverton-Holt model as:

$$R_1 = N_{1,1} = SB0/(alpha + betaSB0) \quad inbinR_j \quad exp\left(e_j^r - rsigma^2/2\right)$$

where e_j^r is:

$$e_j^r \sim N(0, rsigma)$$

Population after the first month (j>1)

The number $N_{i,j}$ are:

$$N_{i,j} = N_{i-1,j-1}exp\left(-M_{i,j}\right)$$

The whole number by mnonth, NT(tons), is:

$$NT_j = \sum_{i=1}^{nags} N_{i,j}$$

The whole biomass by mnonth, BT(tons), is:

$$BT_j = \sum_{i=1}^{nags} N_{i,j}\, w_i/1000$$

The whole spawning biomass, SBT(tons), is:

$$SBT_j = \sum_{i=1}^{nags} N_{i,j}\, pm_? w_i/1000$$

The recruitment, R_j, with Ricker model is:

$$R_j = N_{1,j} = SBT_{j-1}exp\left(alpha - betaSBT_{j-1}\right) \quad inbinR_j \quad exp\left(e_j^r - rsigma^2/2\right)$$

while with Beverton-Holt is:

$$R_j = N_{1,j} = SBT_{j-1}/\left(alpha + betaSBT_{j-1}\right) \quad inbinR_j \quad exp\left(e_j^r - rsigma^2/2\right)$$

To estimate the length frequency an age-length key,$alkey$, is calculated assuming a normal distribution of length at age:

$$alkey_{i,j} = \frac{1}{\sigma_i\sqrt{2\pi}} e^{-\left(ls_j - l_i\right)^2/2\sigma_i^2} \quad for \quad i = 1,\ldots,nags; \quad j = 1,\ldots,nls$$

where ls_i is the mean length at age and σ_i is the standardt deviation at age. σ_i = ls_i*$CVGrowth$

The number at length (k) and month (j), $N_{k,j}$, is calculated as:

$$N_{k,j} = \sum_{i=1}^{nags} \left(N_{i,j} \quad * \quad alkey_{k,i}\right)$$

FISHERY FUNCTIONS

Selectivity and Fishing mortality.

Selectivty, S, are modelled by fleet (f) using double half-normal functions:

$$S_i^f = exp(-0.5(i - bs^f)^2)/as^{f^2}) \qquad for \quad i < sb^f.$$

$$S_i^f = exp(-0.5(i - bs^f)^2)/cs^{f^2}) \qquad for \quad i => sb^f.$$

where as, bs and cs are parameters. bs is the age of maximun selectivity ($S_{bs}^f = 1$)

The fishing mortality,F, by fleet (f) at age and month is calculated as:

$$F_{i,j}^f = F_{ref}^f bin \quad S_i^f$$

The whole fishing mortality is:

$$F_{i,j} = \sum F_{i,j}^f$$

Catch

Catch, C, by fleet (f) in numbers at age (i) and month (j):

$$C_{i,j}^f = F_{i,j}^f/\left(F_{i,j} + M_{i,j}\right)N_{i,j}\left(1 - exp\left(-M_{i,j} - F_{i,j}\right)\right)$$

Catch in number by fleet (f) at length (k) and month (j) is calculated as:

$$C_{k,j}^f = \sum_{i=1}^{nags} \left(C_{i,j}^f \quad * \quad alkey_{k,i}\right)$$

The whole catches in numbers are:

$$C_{i,j} = \sum C_{i,j}^f \qquad ; \quad C_{k,j} = \sum C_{k,j}^f$$

The catch (tons) by fleet, YT^f (tons), is:

$$YT_j^f = \sum_{i=1}^{nags} C_{i,j}^f \, w_i/1000$$

The whole catch (tons) is:

$$YT_{i,j} = \sum YT_{i,j}^f$$

ABUNDANCE INDICES

CPUE

$CPUE$ by fleet (f) and month (j) is:

$$CPUE_j^f = q^f \left(\sum_{i=1}^{nags} \left(C_{i,j}^f w_i/1000 \right) / F_{i,j}^f \right)^{hyp}$$

Acoustic Selectivities.

Acoustic selectivities (S) by length (l) are modelled by survey (f) using double half-normal functions:

$$S_l^f = exp(-0.5(l - bs^f)^2)/as^{f^2}) \qquad for \quad l < sb^f.$$

$$S_l^f = exp(-0.5(l - bs^f)^2)/cs^{f^2}) \qquad for \quad l => sb^f.$$

where as, bs and cs are parameters. bs is the length at the maximun selectivity $(S_{bs}^f = 1)$

Acoustic Biomass

Acoustic Biomass $(Bacous)$ by survey (f) and month (j) is:

$$Bacous_j^f = qacous_j^f \sum_{i=1}^{nls} S_{l,j}^f \, N_{l,j} w_l/1000$$

RESULTS

The results are presented in graphs and then the parameters in tables.

INDIVIDUAL FUNCTIONS

Figure 1. Growth at size and age.

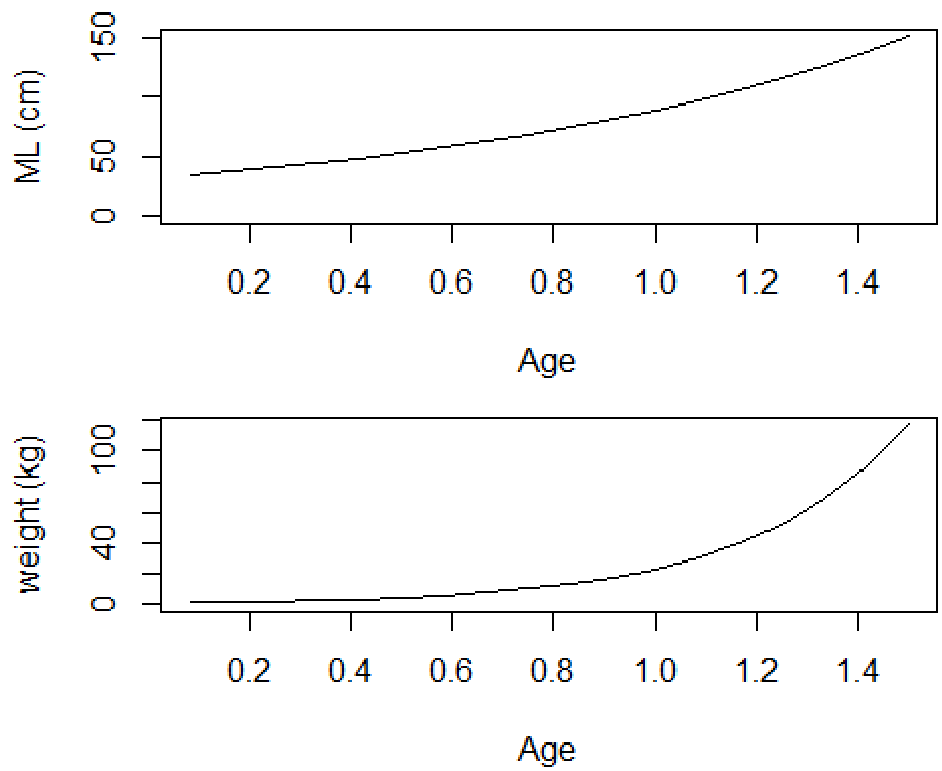
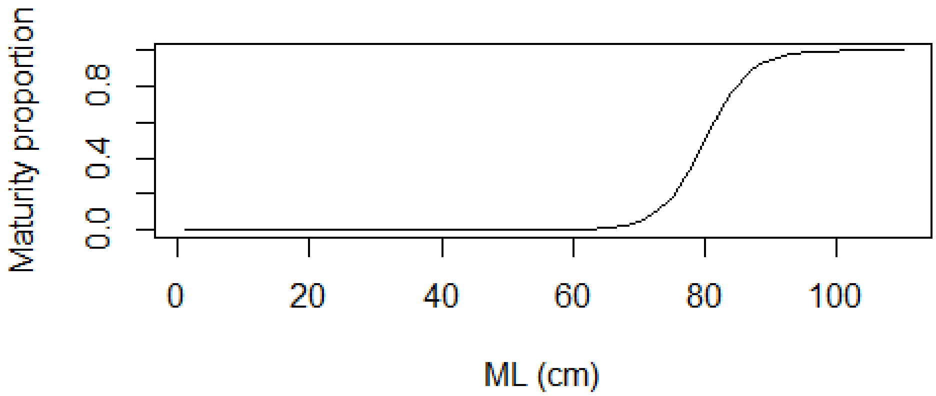


Figure 2. Maturity at size and age.



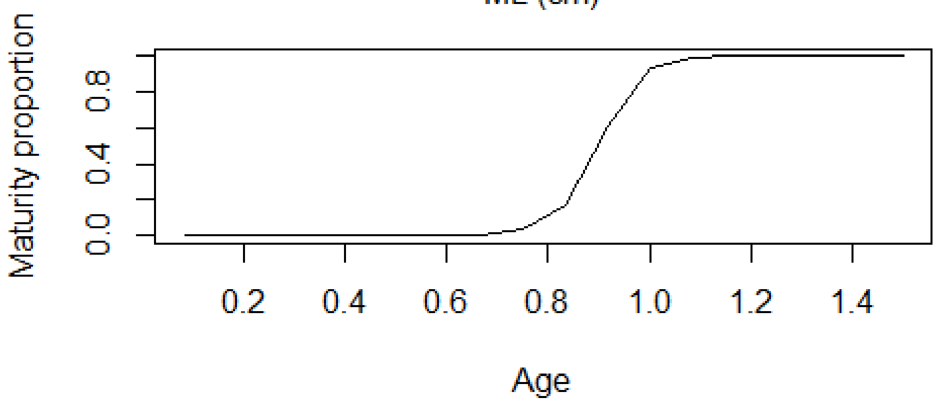


Table 1. Individual Parameters

Growth Parameters

a_expo	b_expo	a	b
309.11	0.0029	2.31e-05	3.077

Maturity Parameters

lm50	lmrange
80	10

POPULATION FUNCTIONS

Figure 3. M by age and YEAR.MONTH (if M is constant then one color).

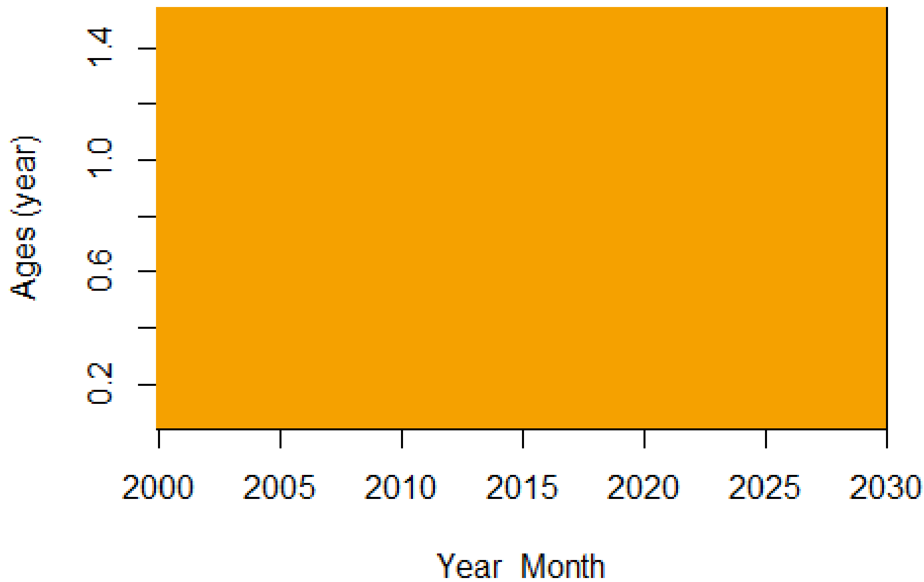


Figure 4. Recruitment before the starting time.

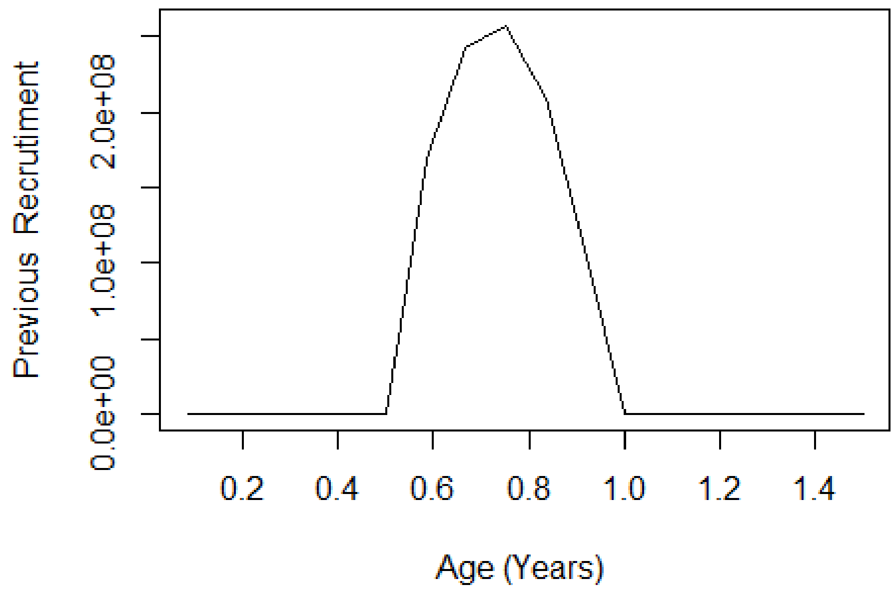


Figure 5. N at the first year.

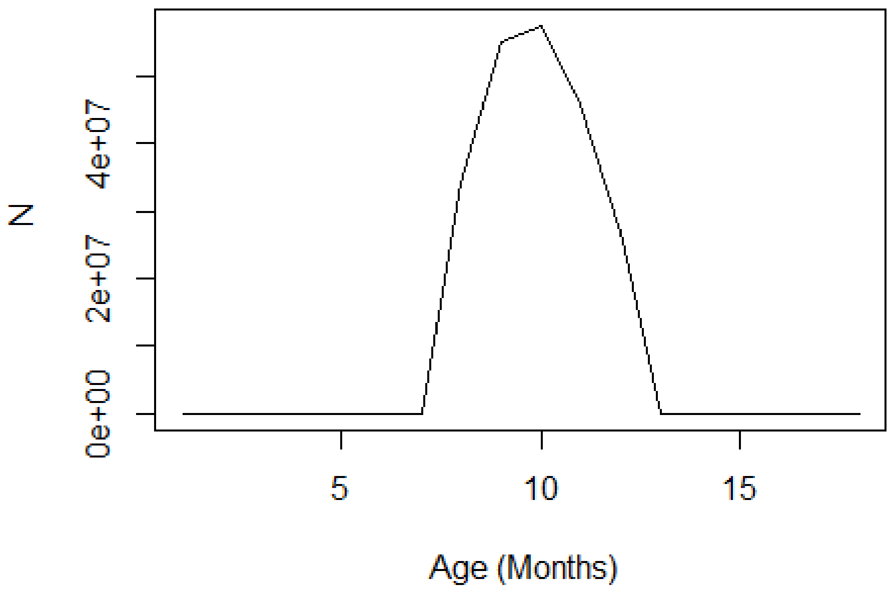


Figure 6. Seasonal recruitment patterns.

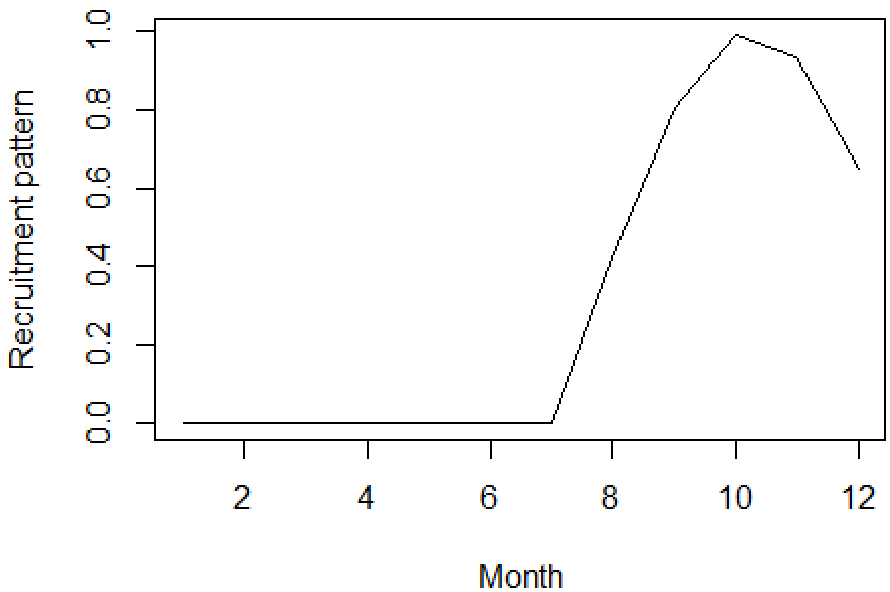


Figure 7. Fishing Selectivity by fleet.

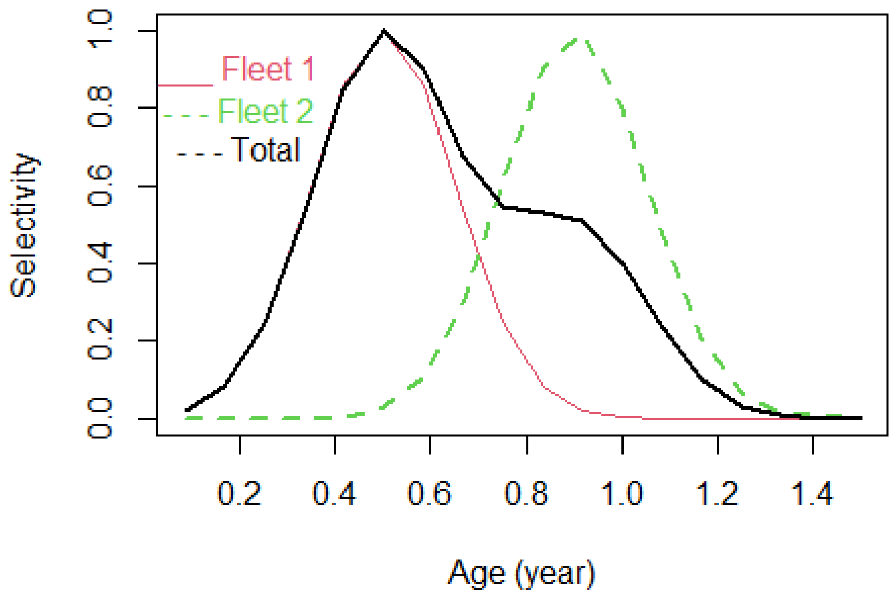


Figure 8. Spawning Biomass and Recruitment.

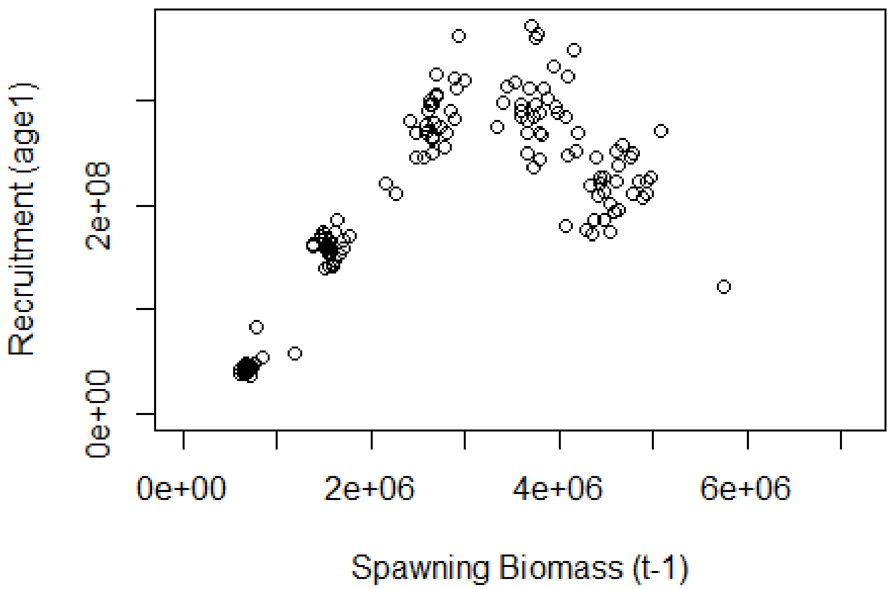


Figure 9. Seasonal Pattern of recruitment and Number at the begginning.

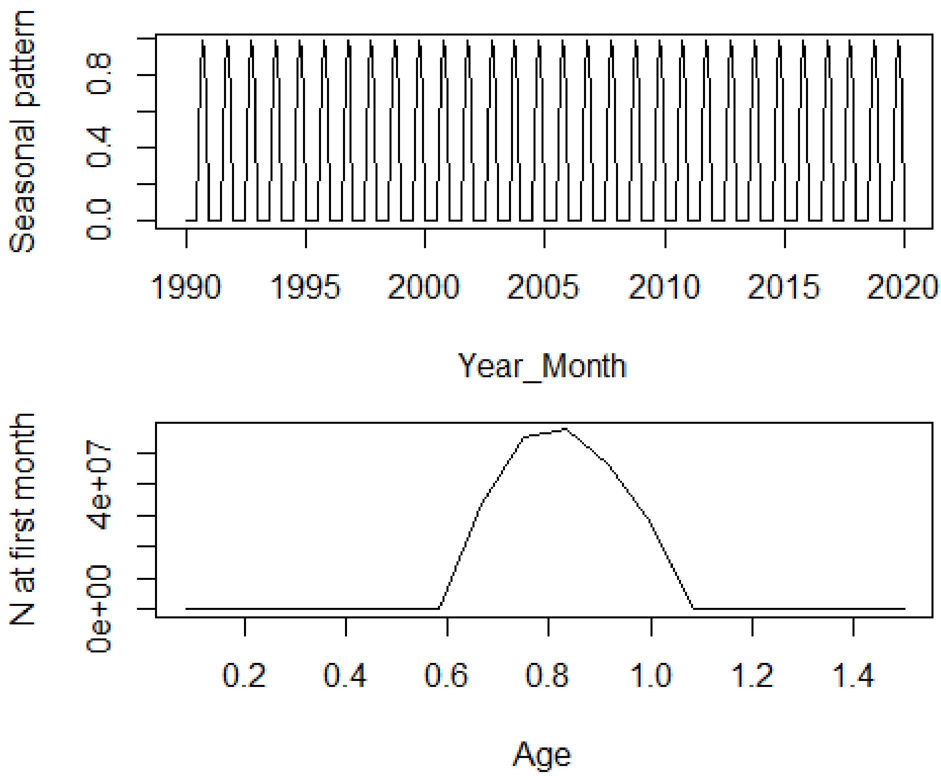
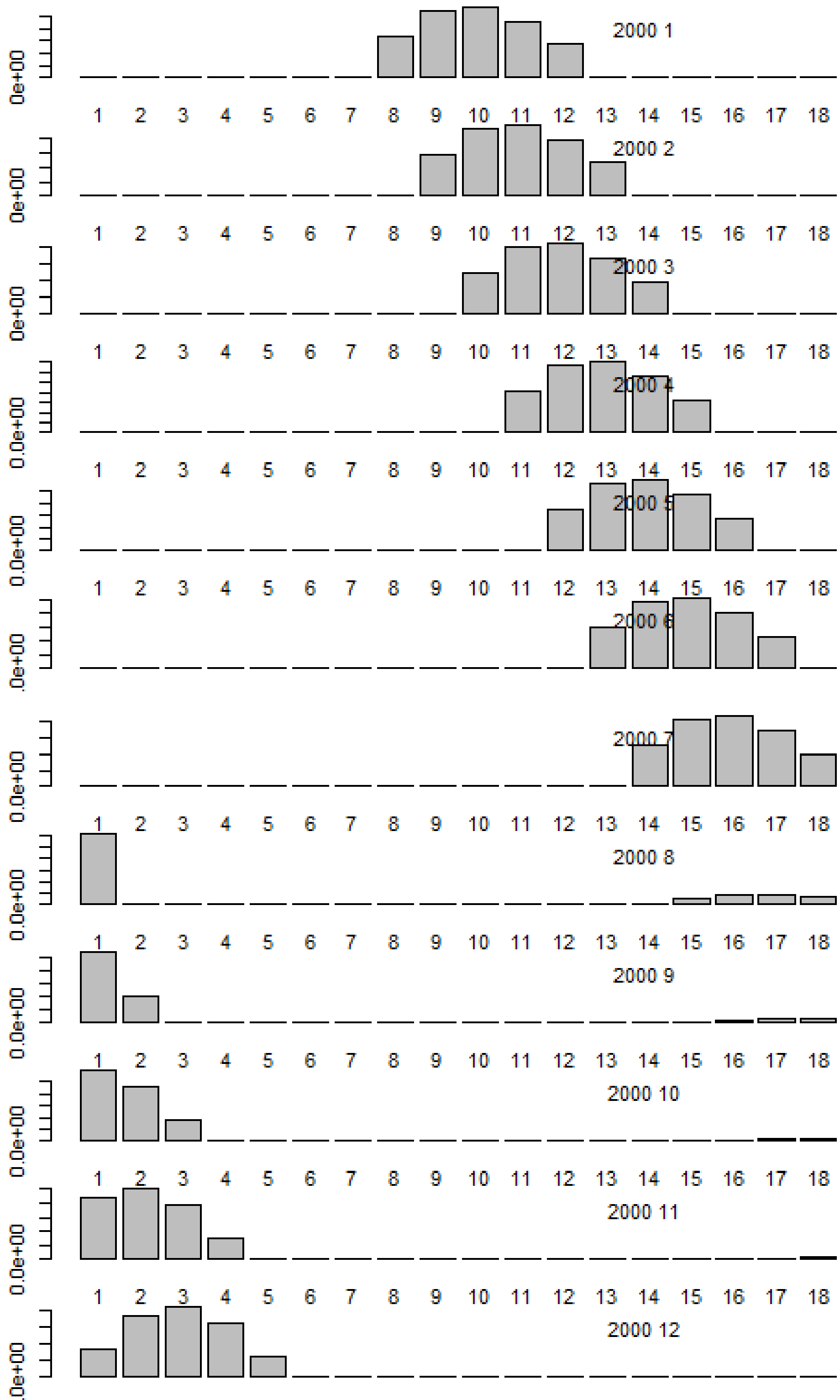
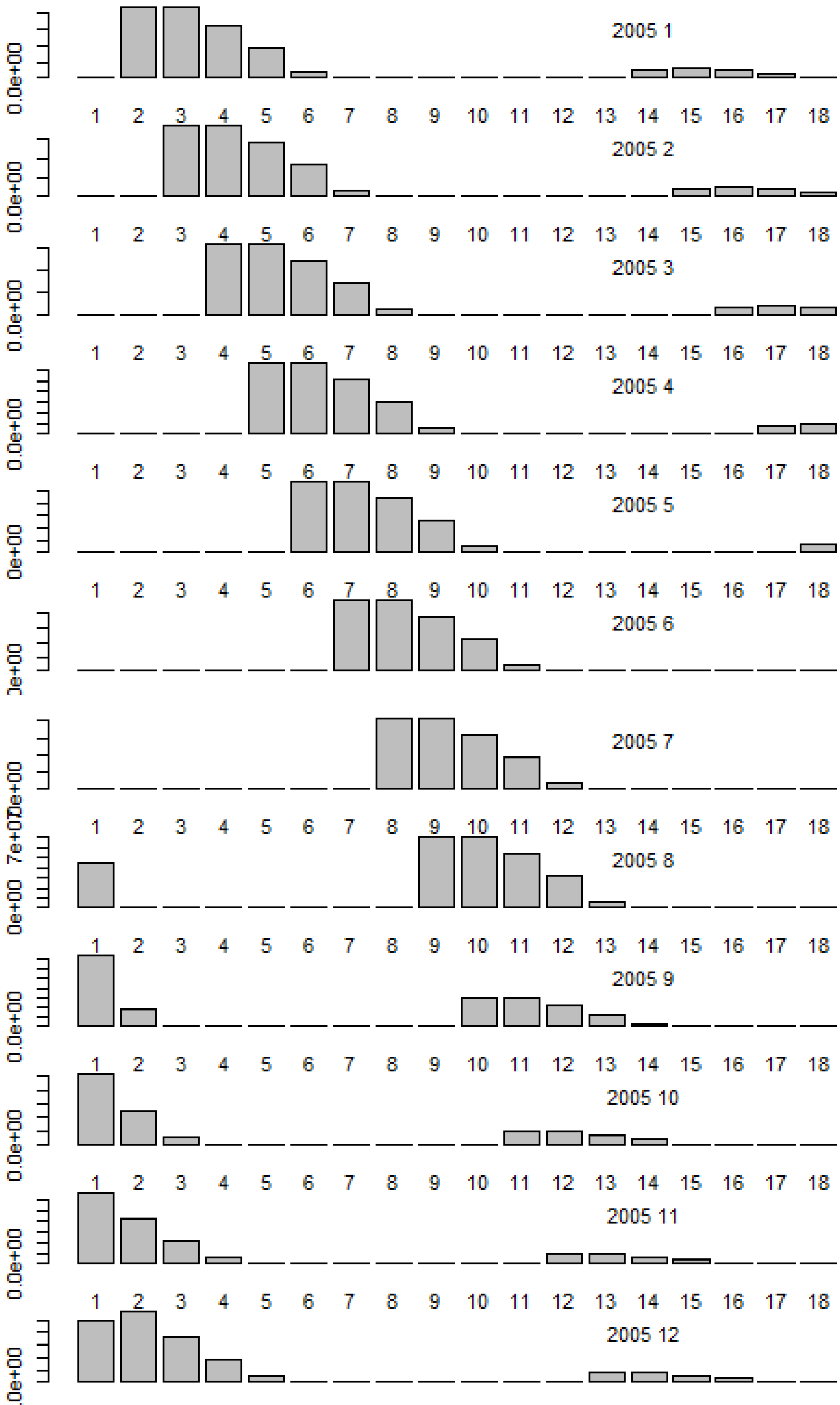
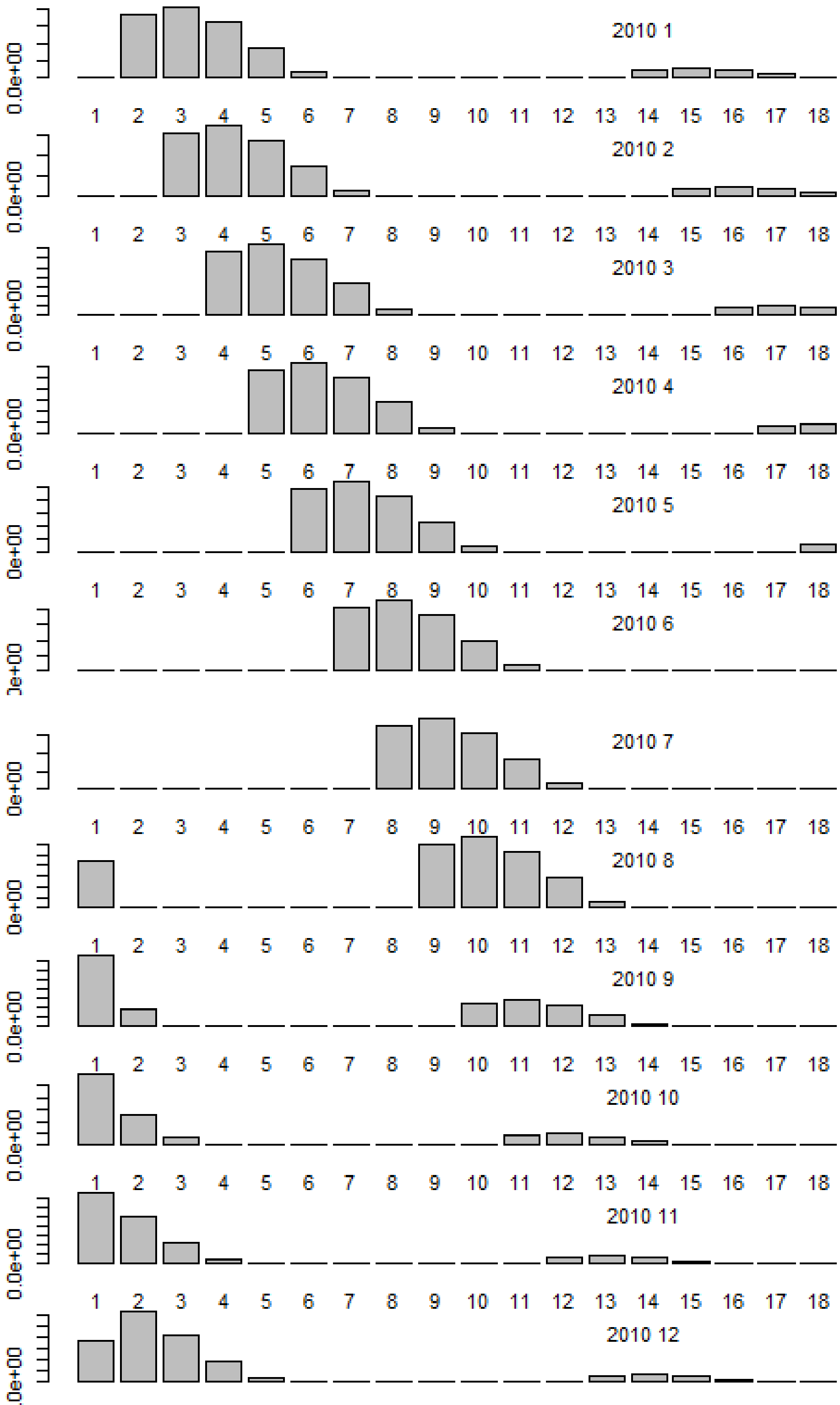
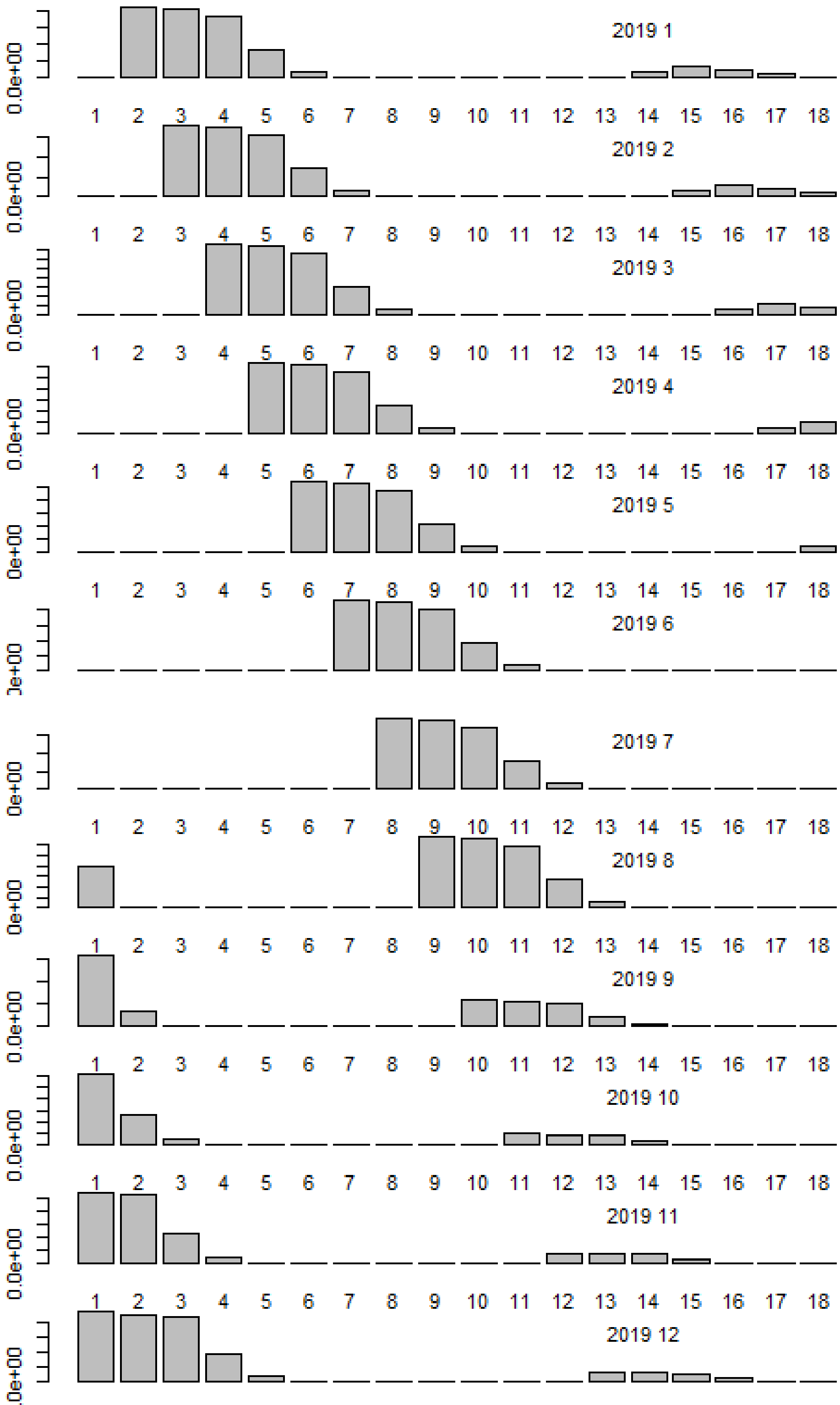


Figure 10. Number at age by YEAR.MONTH.



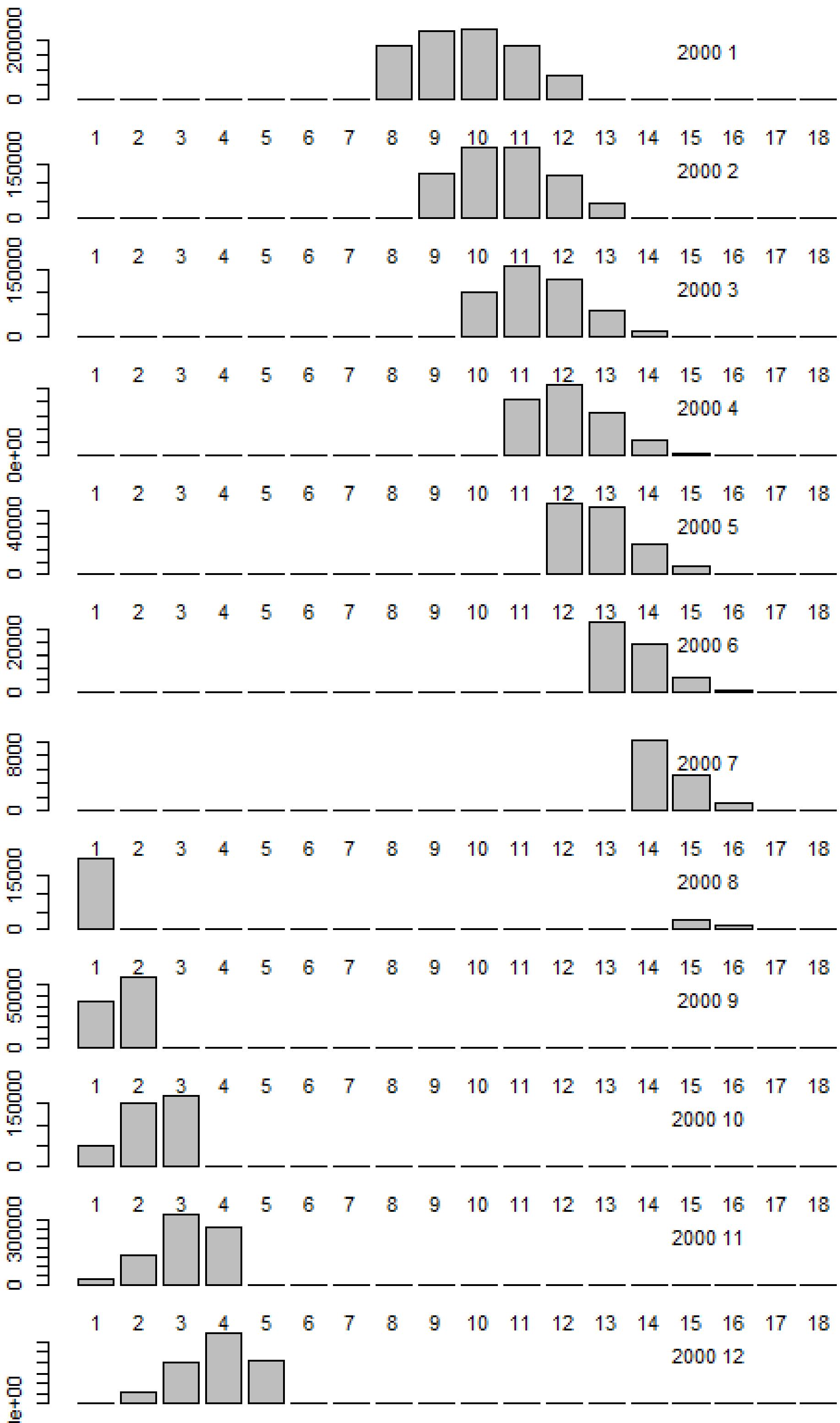

2005 1
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0.0e+00

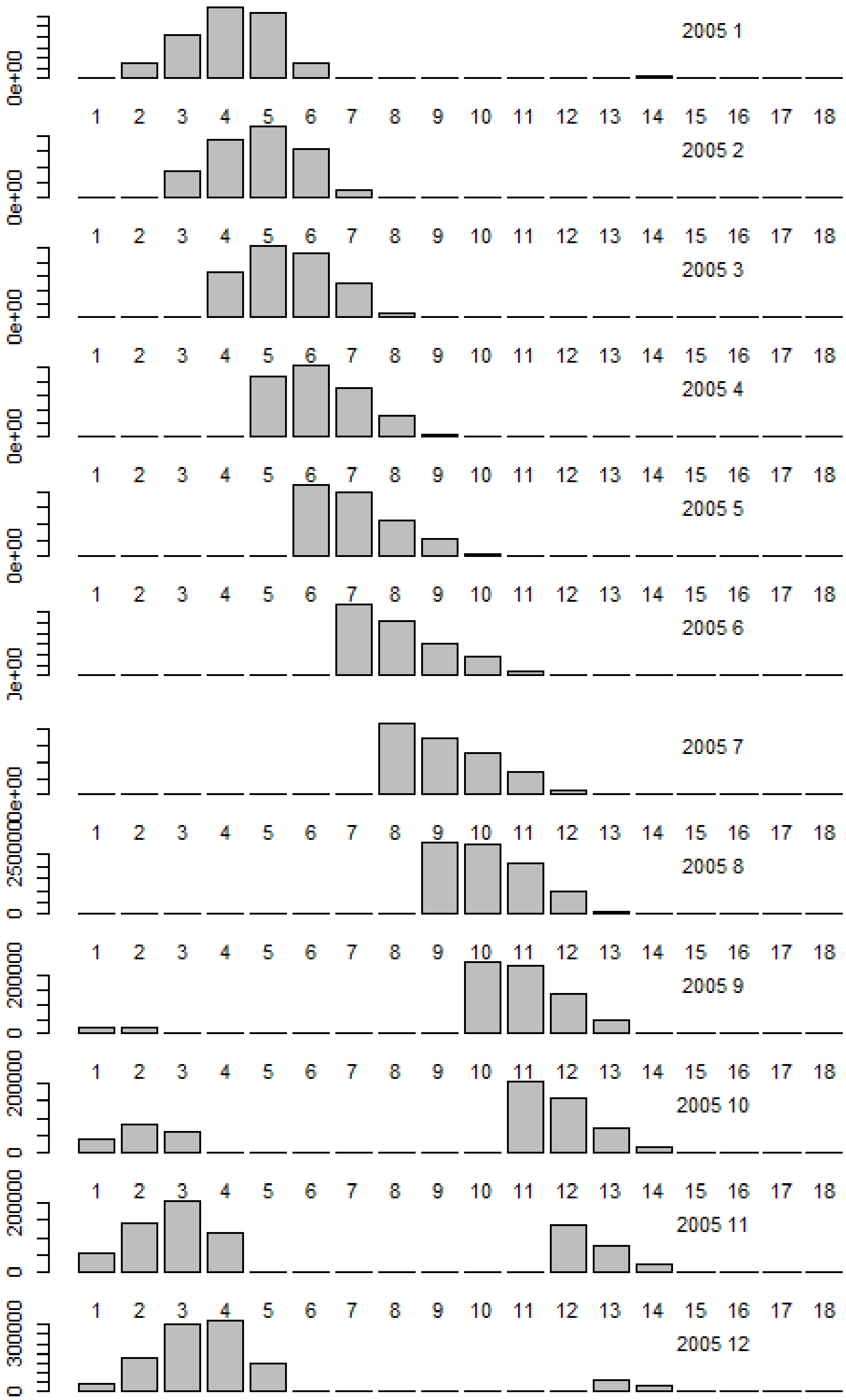

0.0e+00
2010 1
2010 2
2010 3
2010 4
2010 5
2010 6
2010 7
2010 8
2010 9
2010 10
2010 11
2010 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

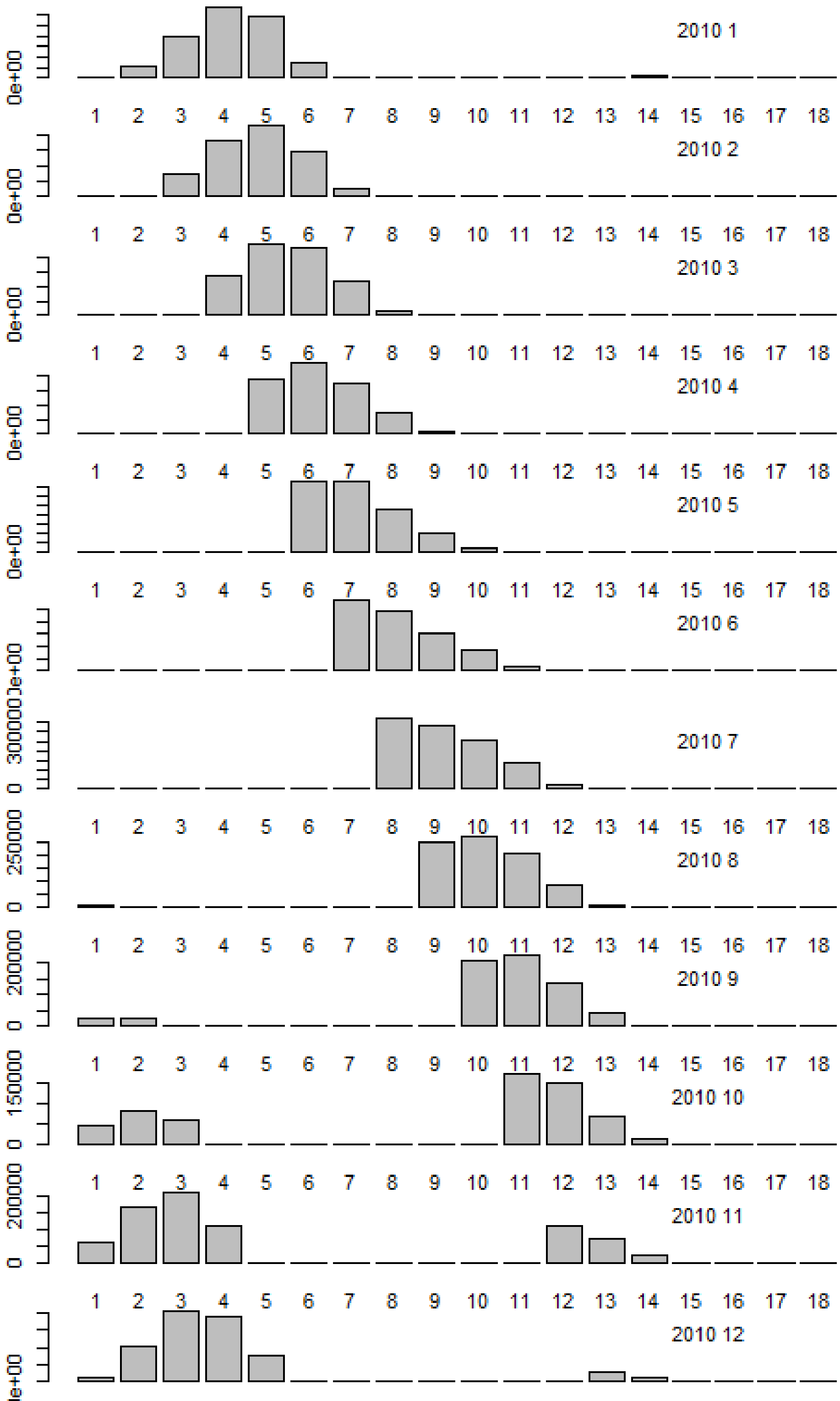

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
0.0e+00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

FISHERY

Figure 11. Whole Catch in number at age by YEAR.MONTH.




2005 1
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0e+00
0
250000
200000
300000


2010 1
2010 2
2010 3
2010 4
2010 5
2010 6
2010 7
2010 8
2010 9
2010 10
2010 11
2010 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

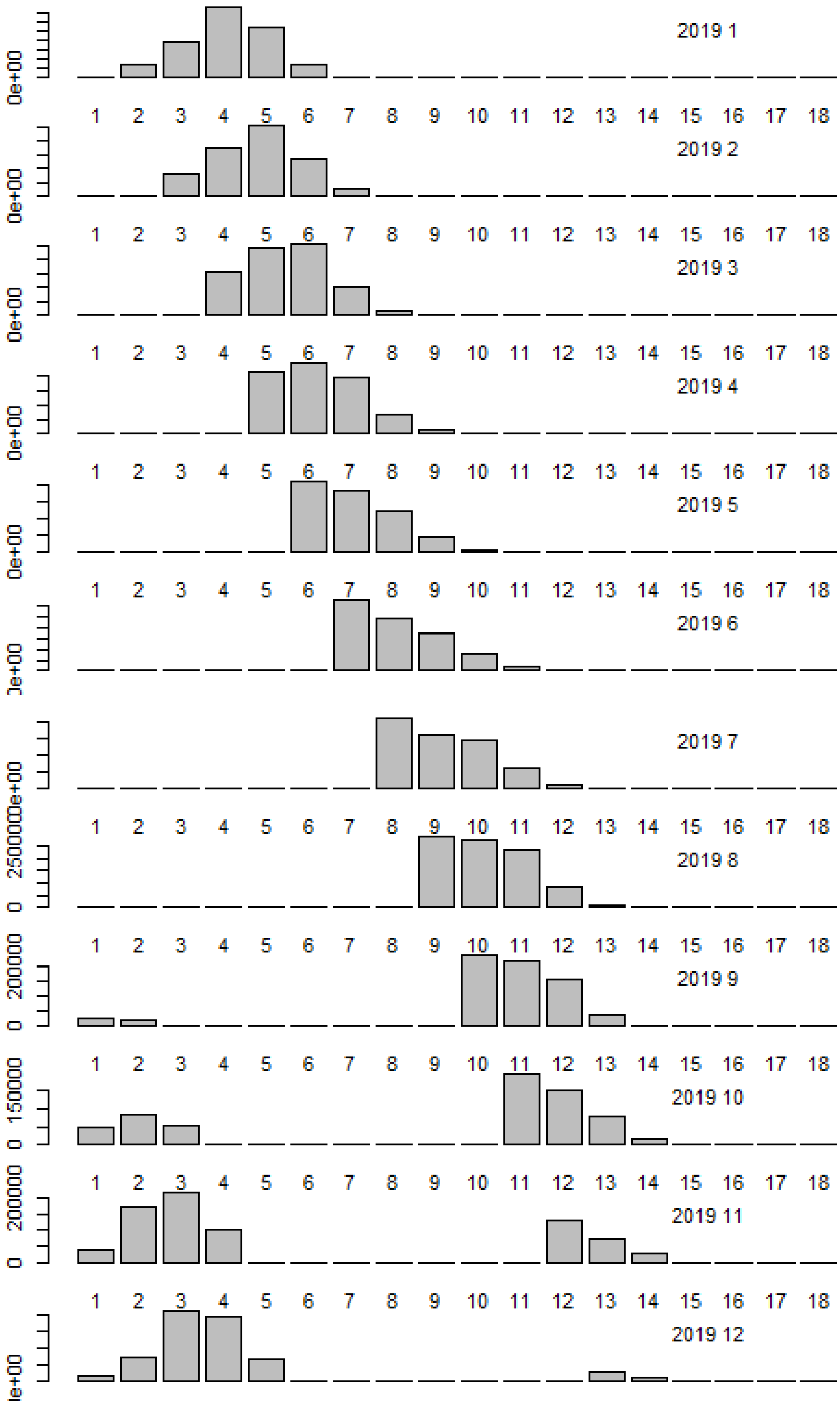
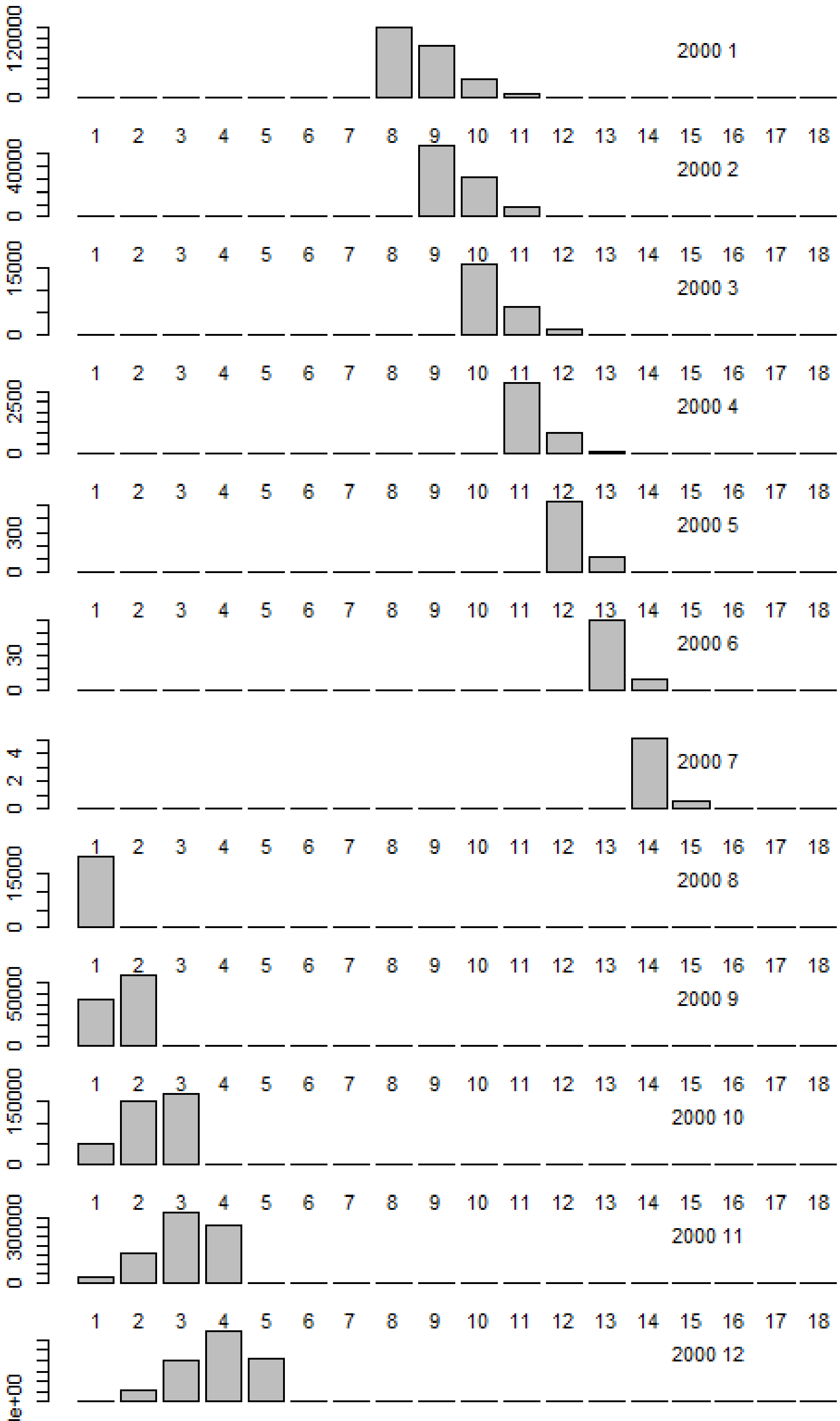
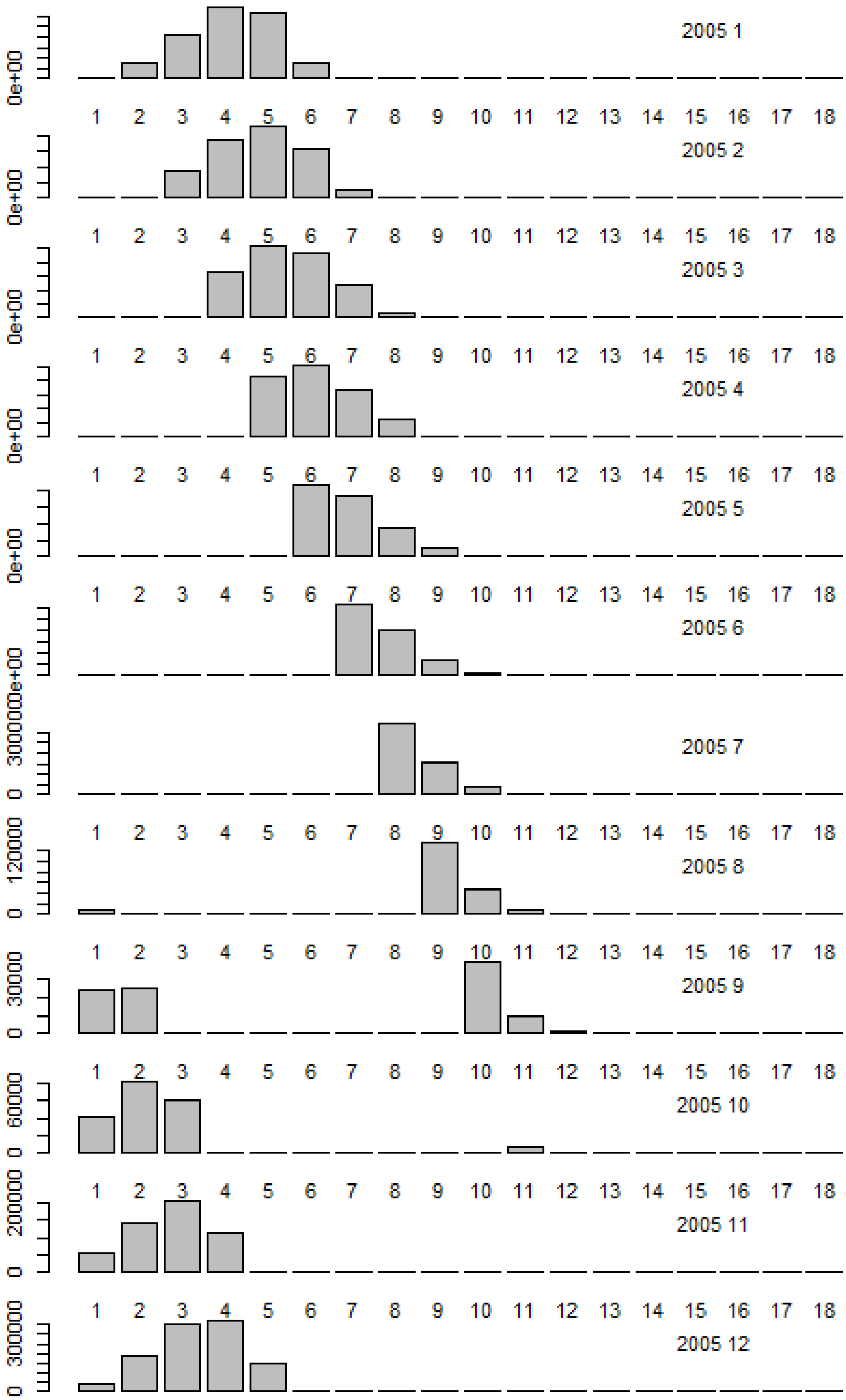
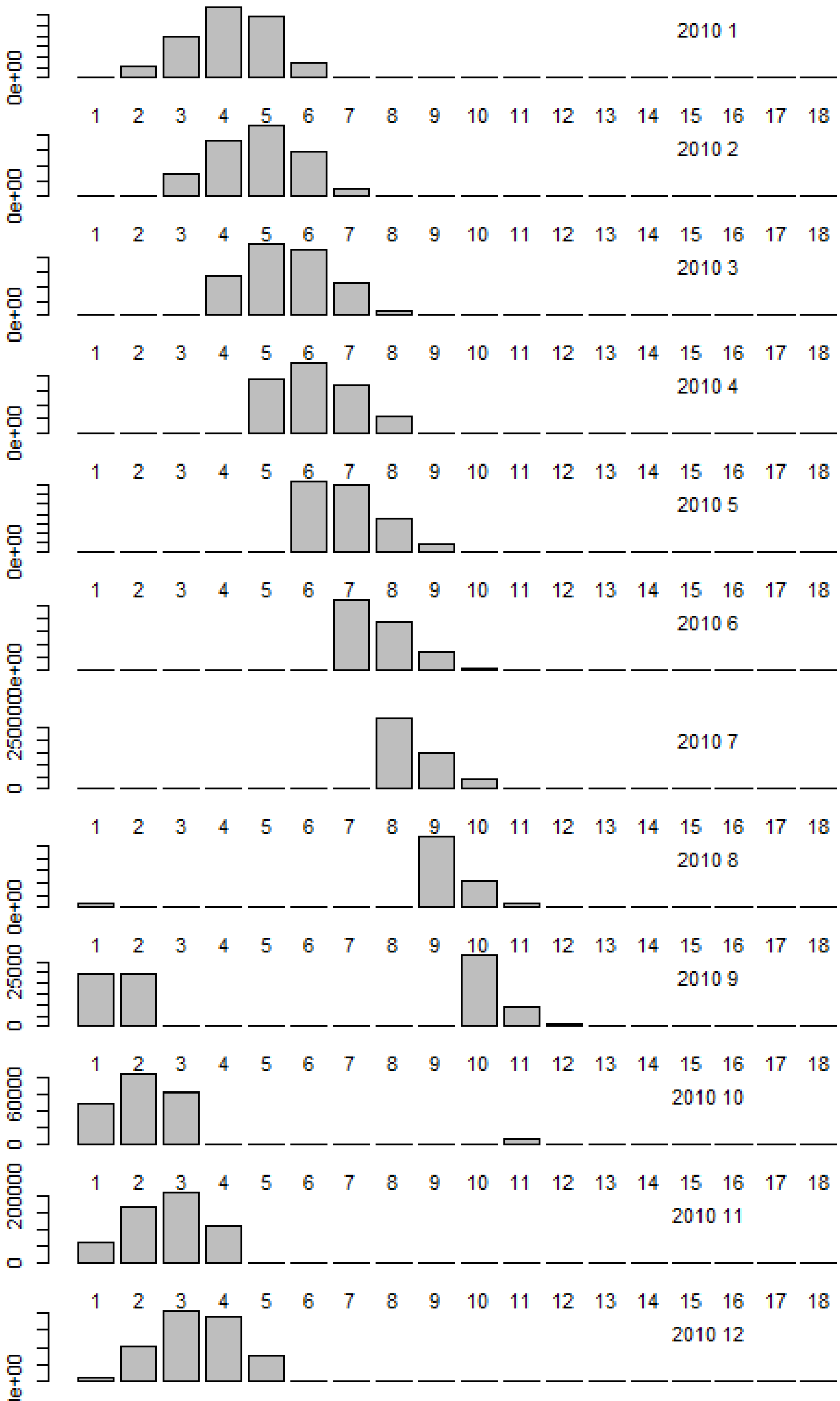

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0e+00
0 250000
0 200000
0 150000
0 200000

Figure 12. Fleet 1 Catch in number at age by YEAR.MONTH.




2005 1
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0e+00
0 300000
0 120000
0 30000
0 60000
0 200000
0 300000


2010 1
2010 2
2010 3
2010 4
2010 5
2010 6
2010 7
2010 8
2010 9
2010 10
2010 11
2010 12
0e+00
0 250000
0 25000
0 60000
0 200000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

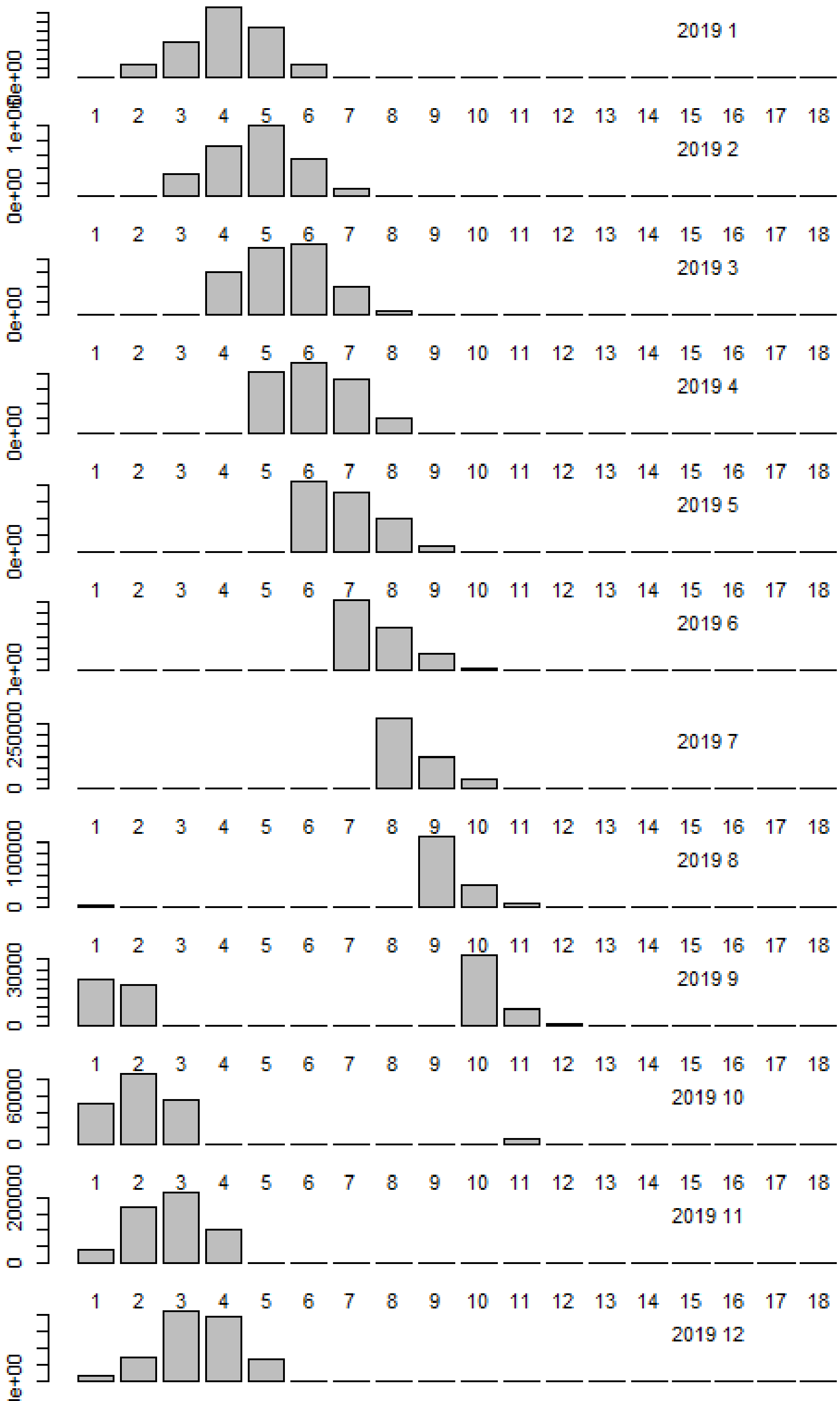
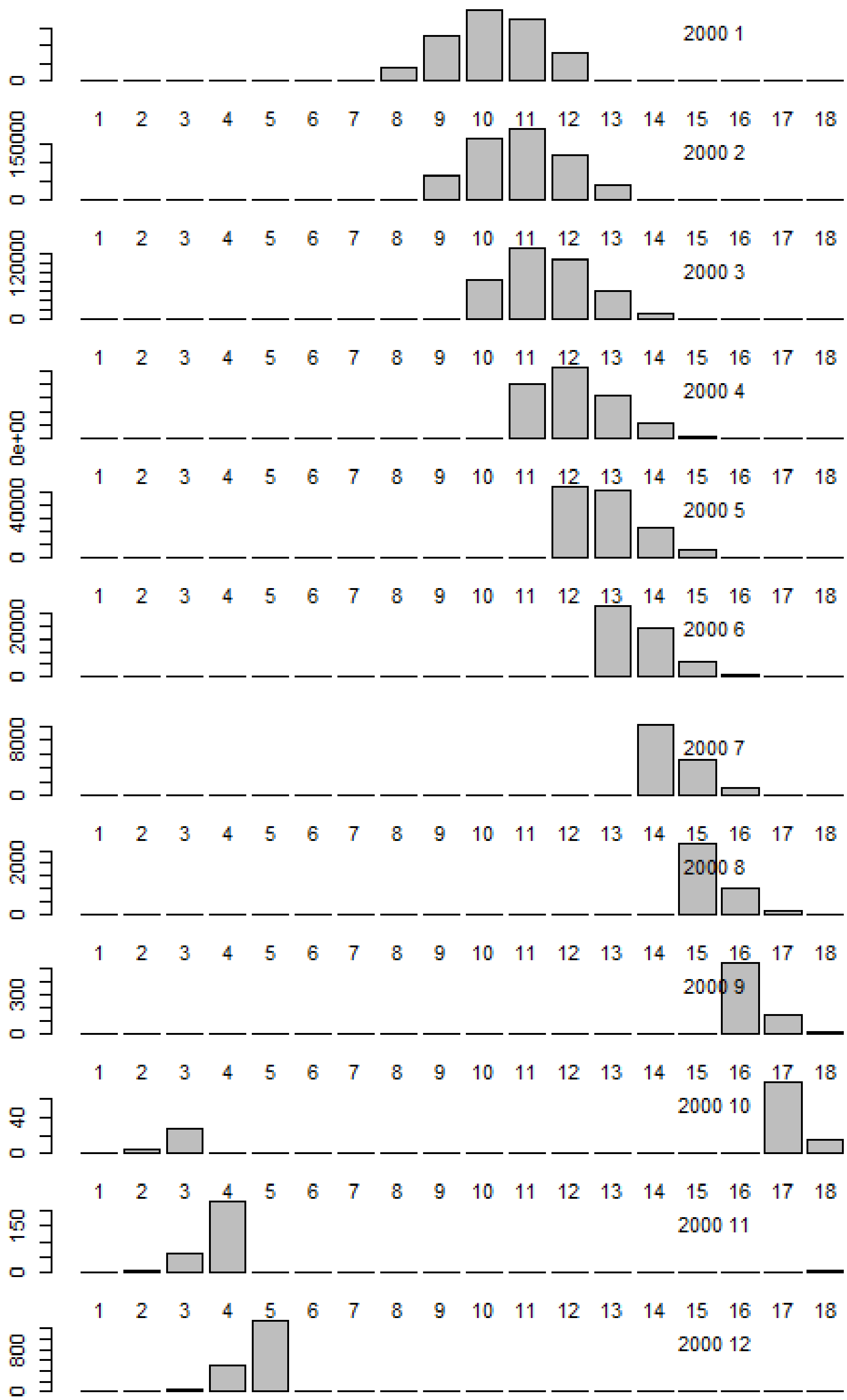
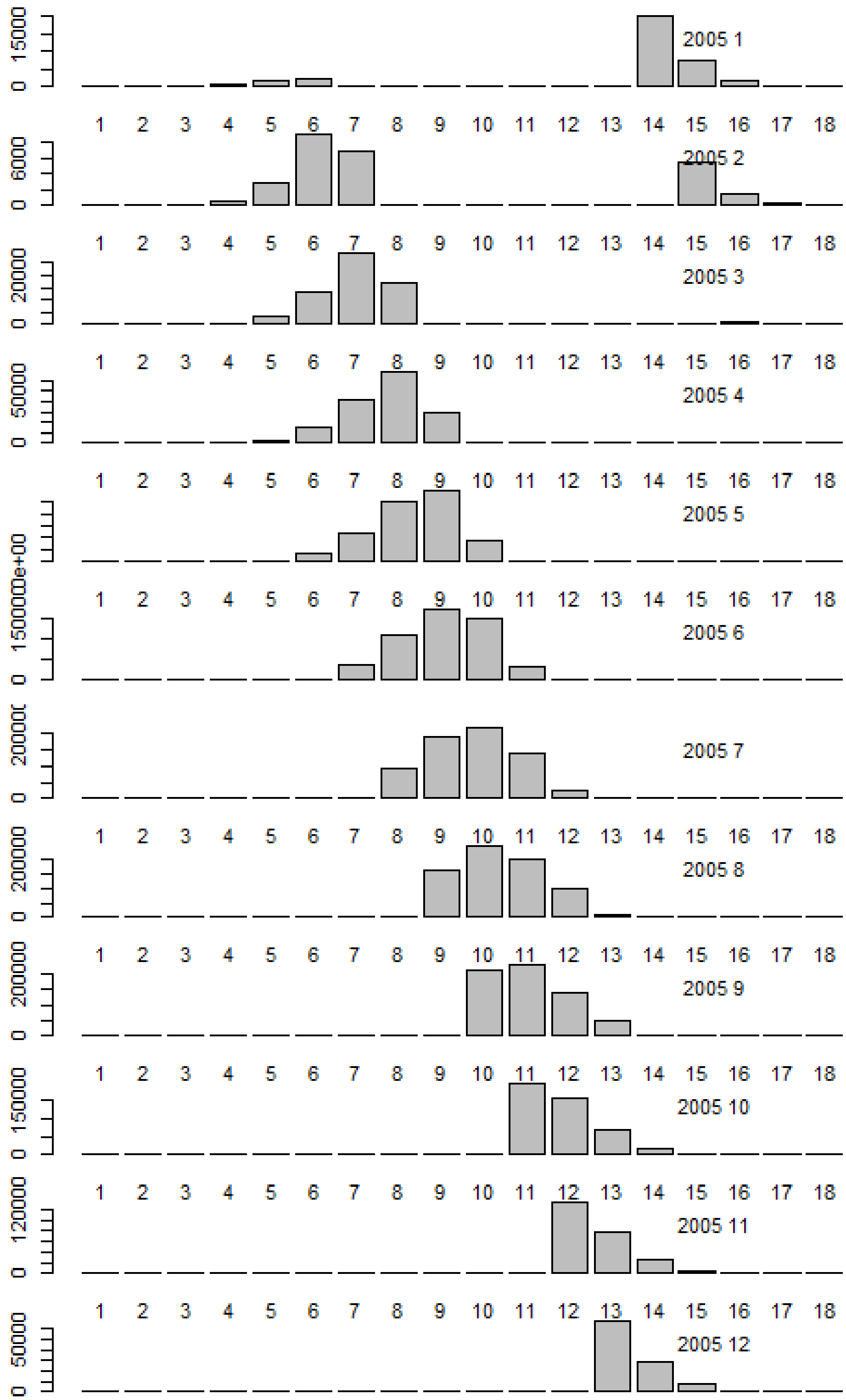
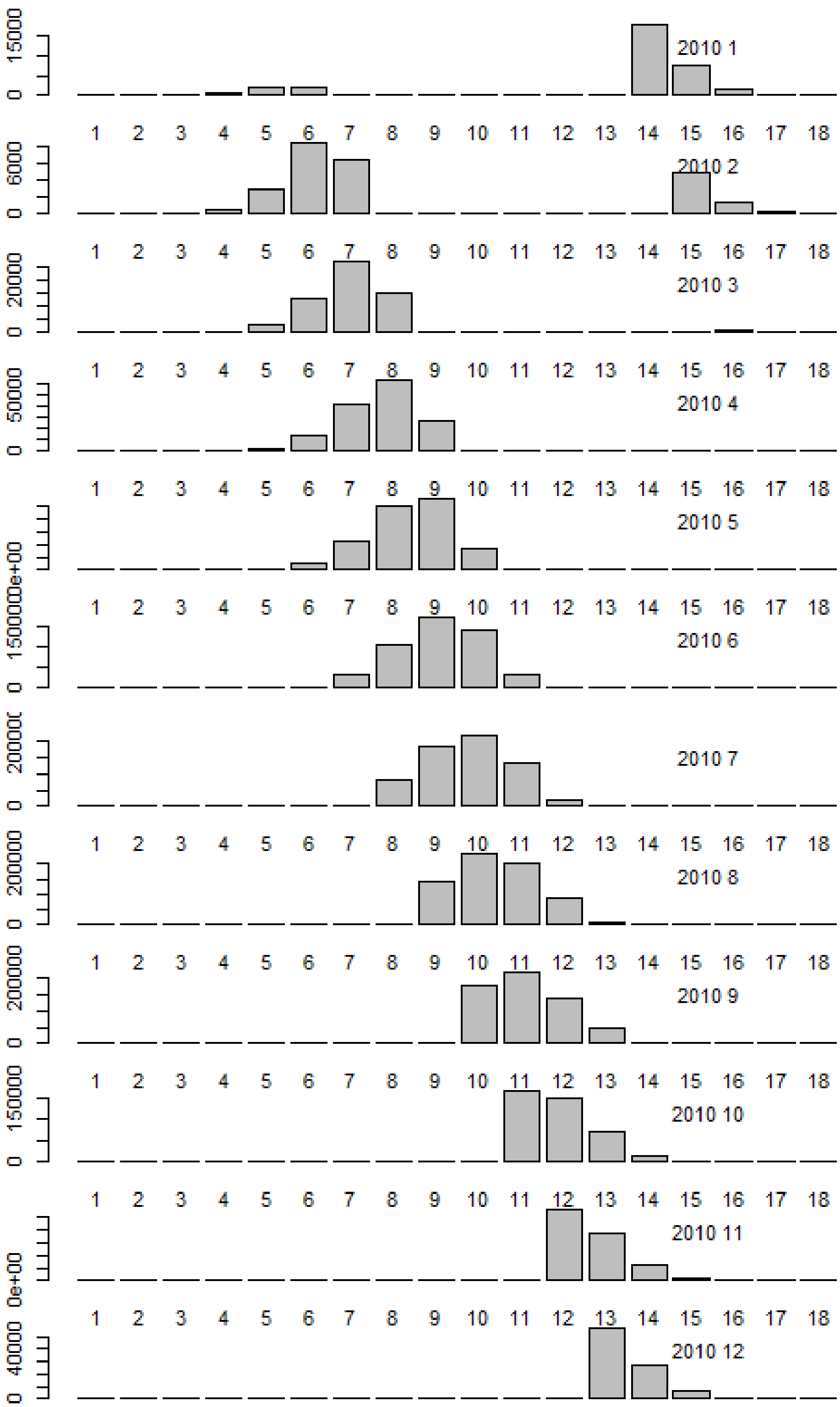

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0e+00
1e+06
250000
100000
30000
60000
200000
0

Figure 13. Fleet 2 Catch in number at age by YEAR.MONTH.




2005 1
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0 15000
0 6000
0 20000
0 50000
0 150000
0e+00
0 200000
0 200000
0 200000
0 150000
0 120000
0 50000


2010 1
2010 2
2010 3
2010 4
2010 5
2010 6
2010 7
2010 8
2010 9
2010 10
2010 11
2010 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

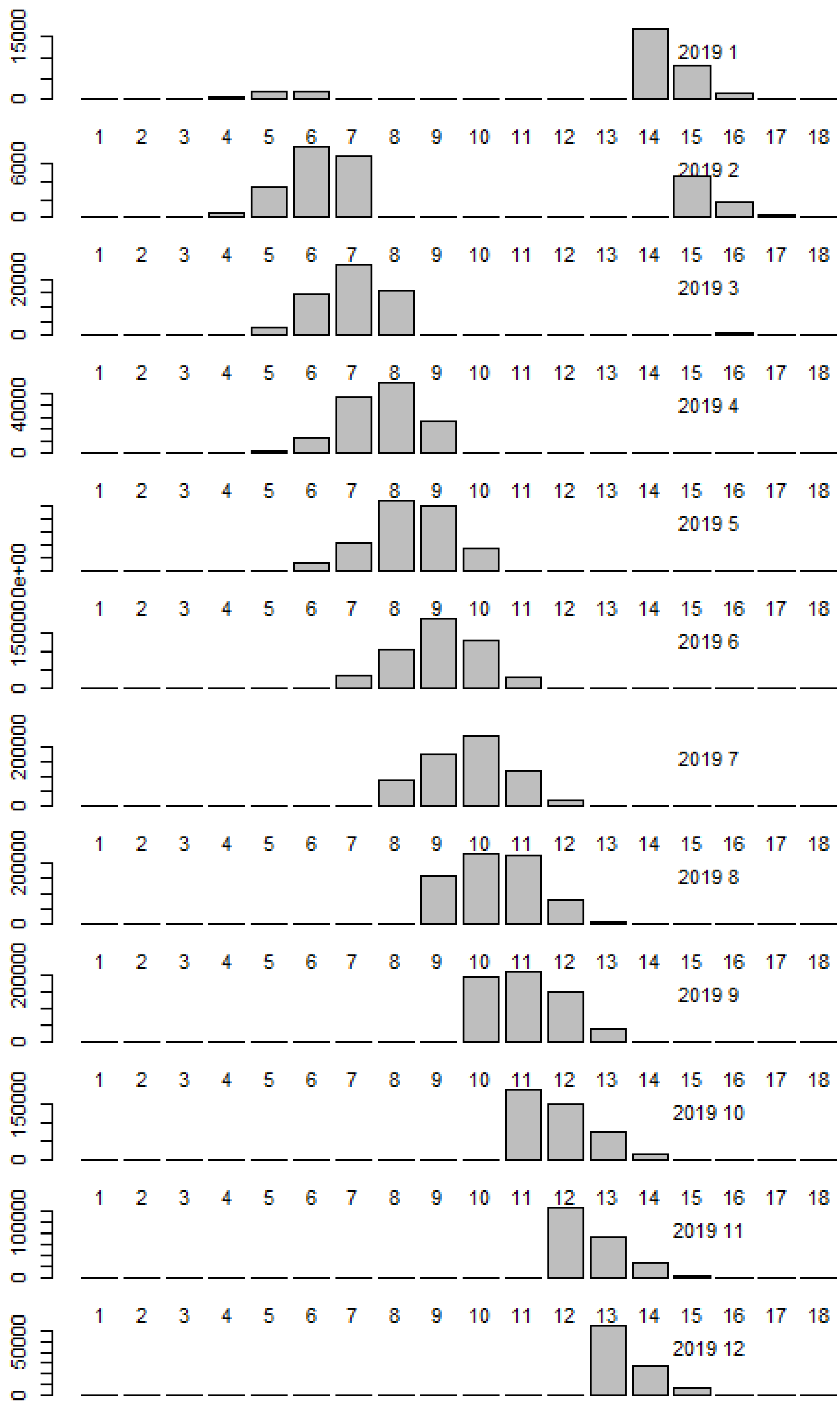

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
0
15000
6000
20000
40000
1500000e+00
200000
150000
100000
50000

Figure 14. Length-age key.

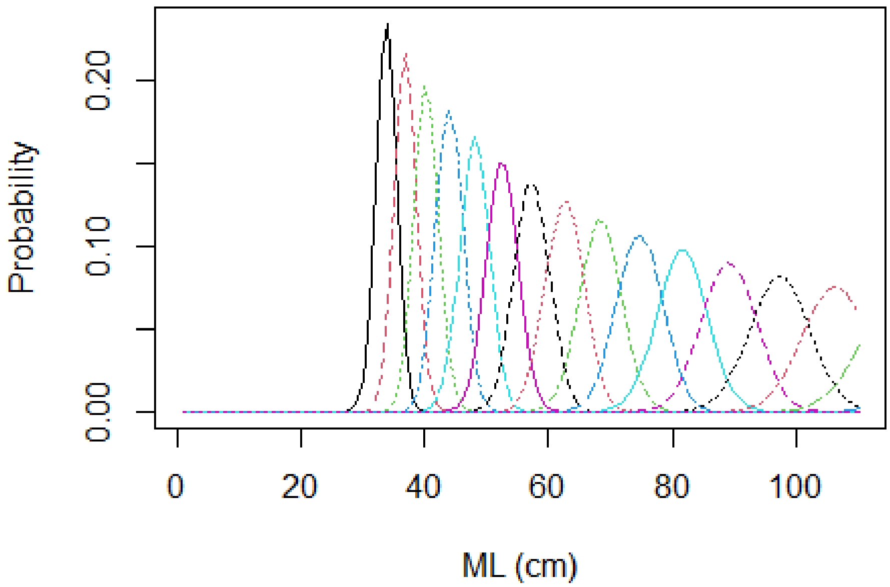
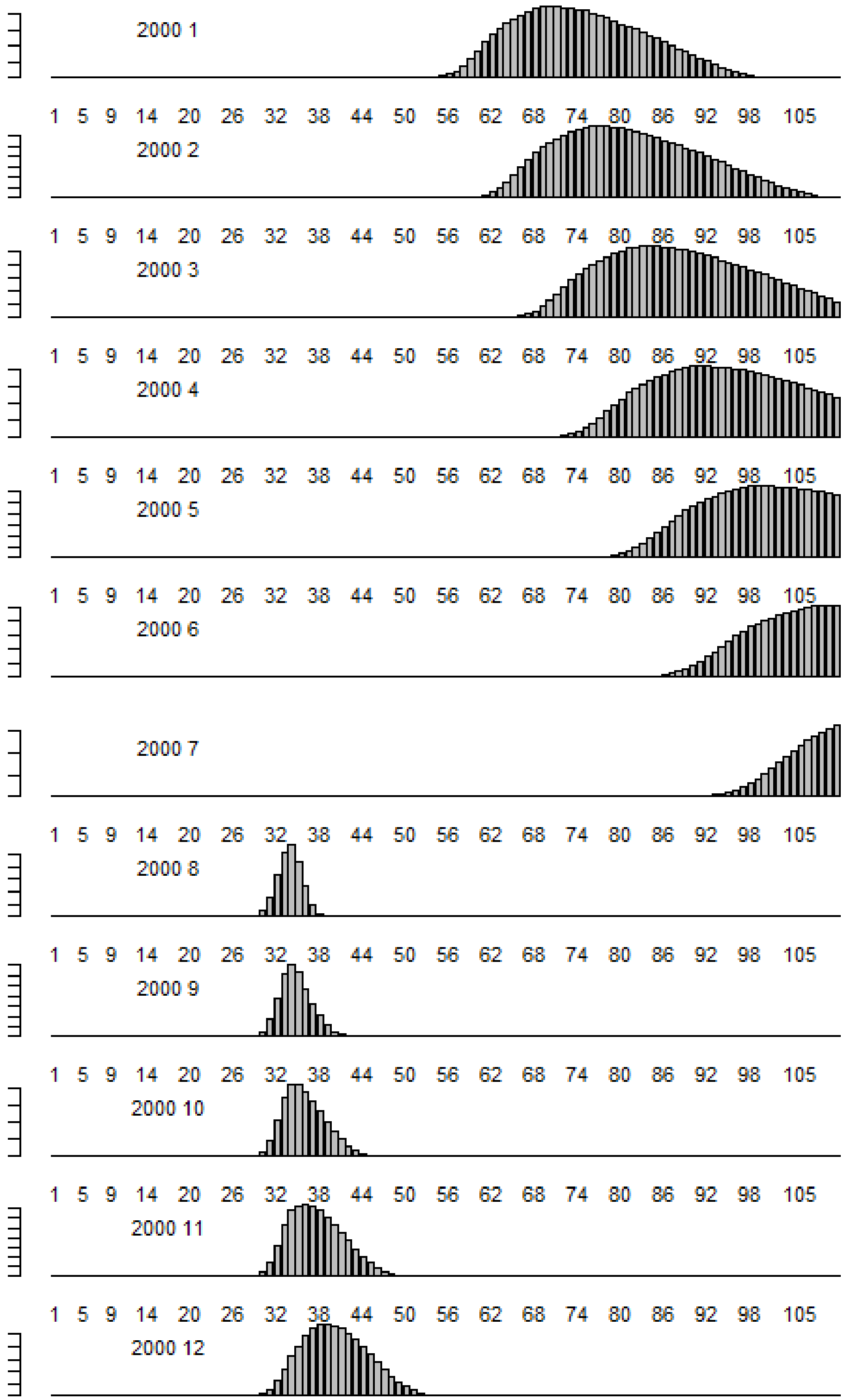
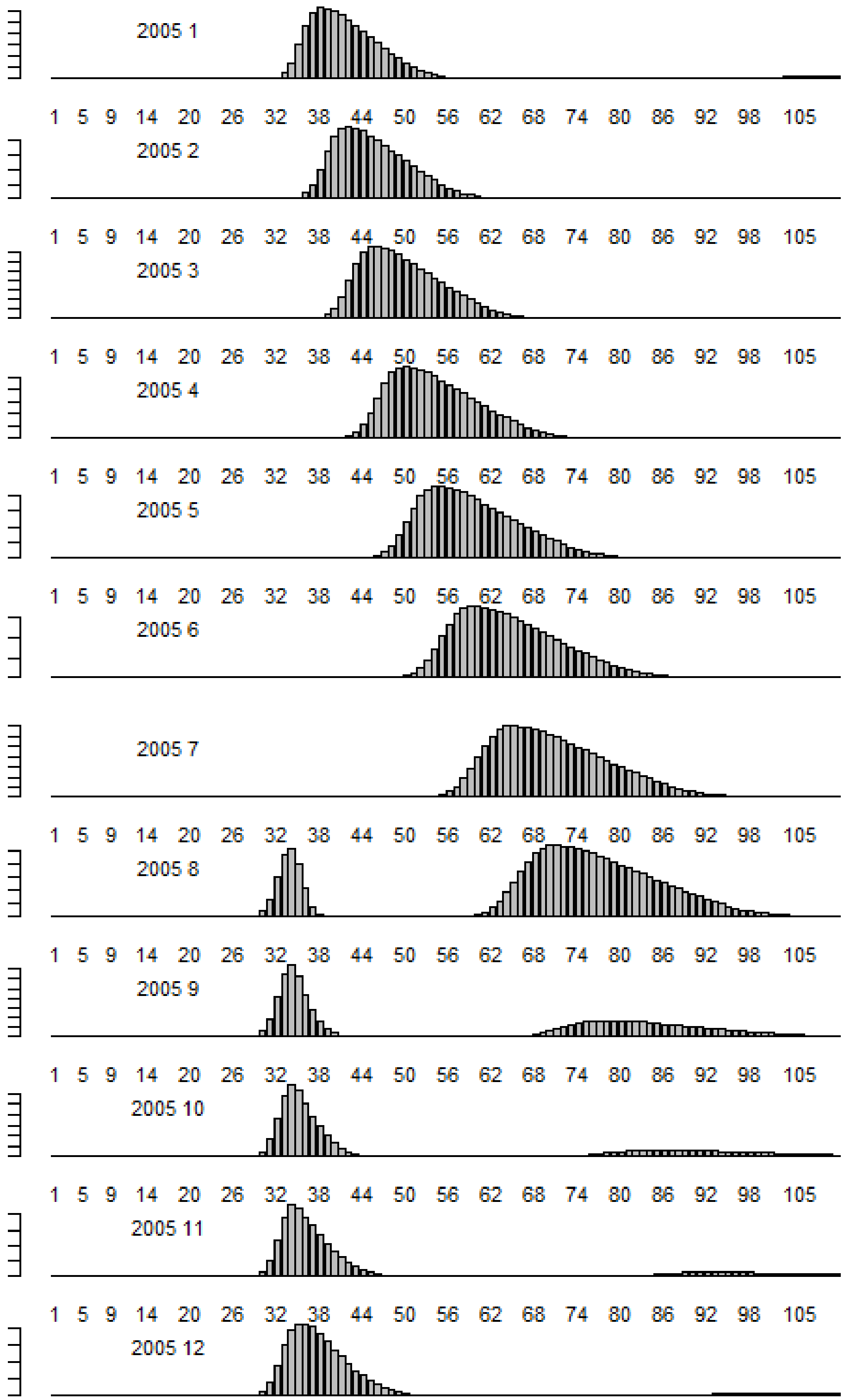
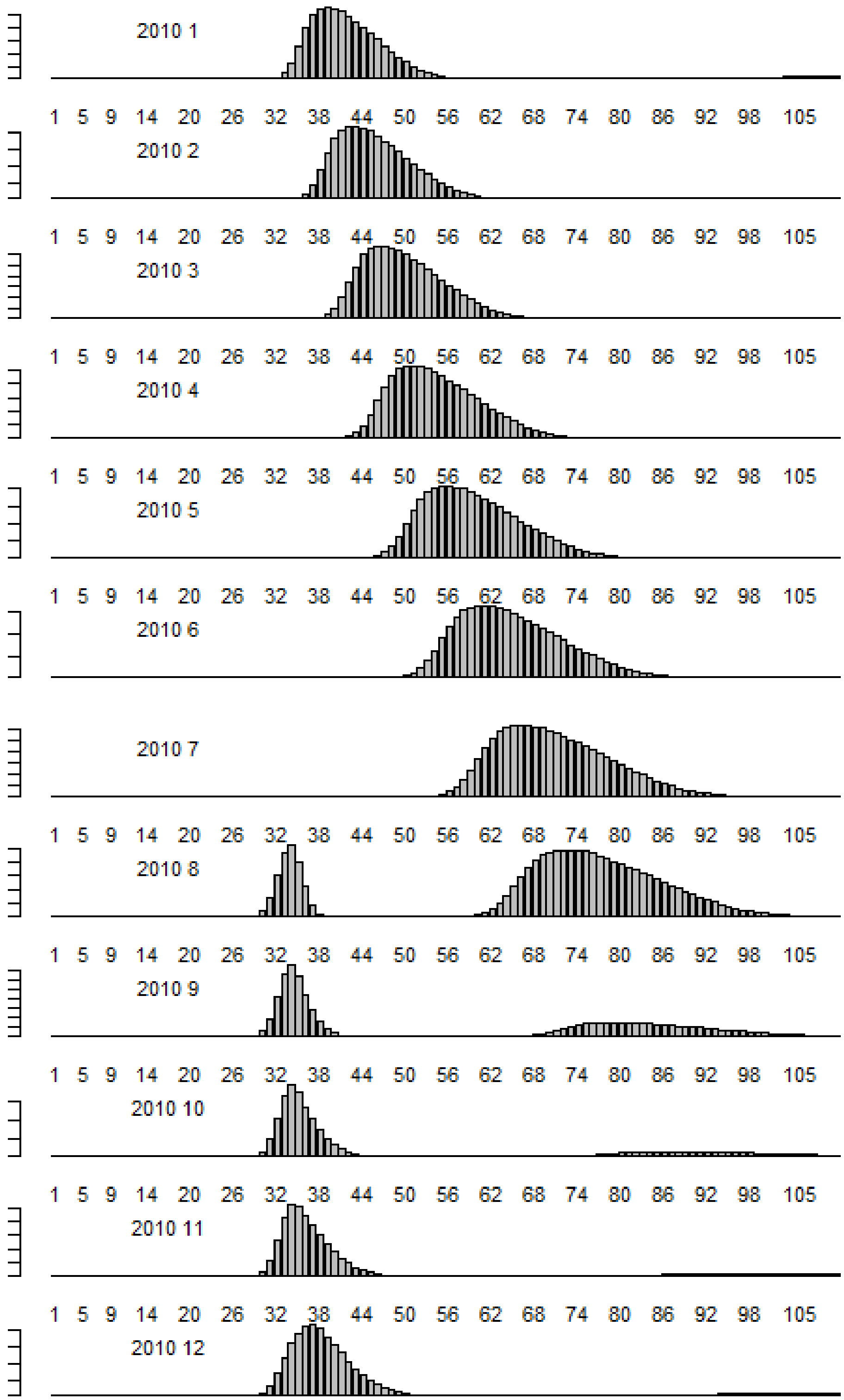


Figure 15. Length frequency by YEAR.MONTH.




2005 1
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105


2010 1
2010 2
2010 3
2010 4
2010 5
2010 6
2010 7
2010 8
2010 9
2010 10
2010 11
2010 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105

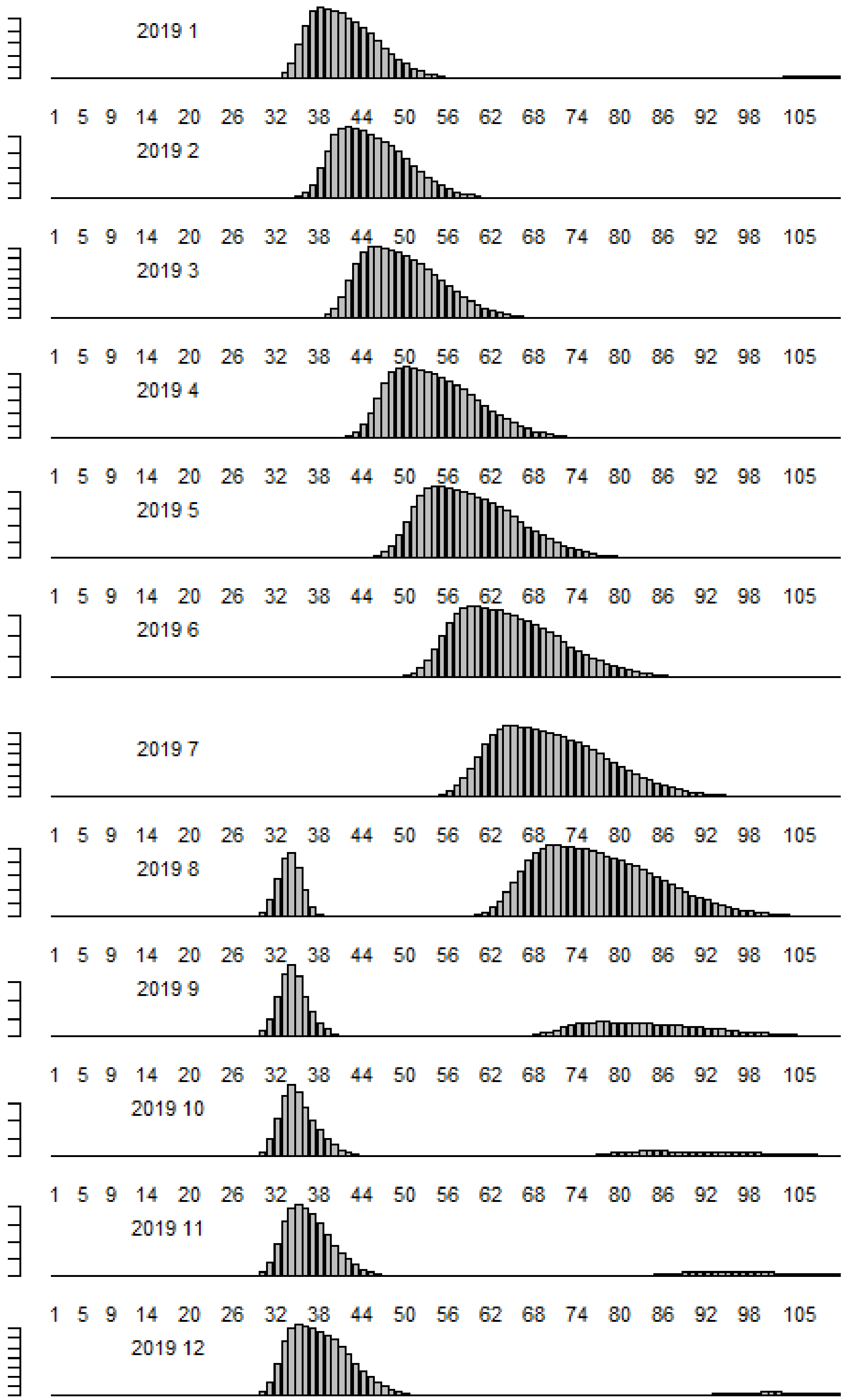
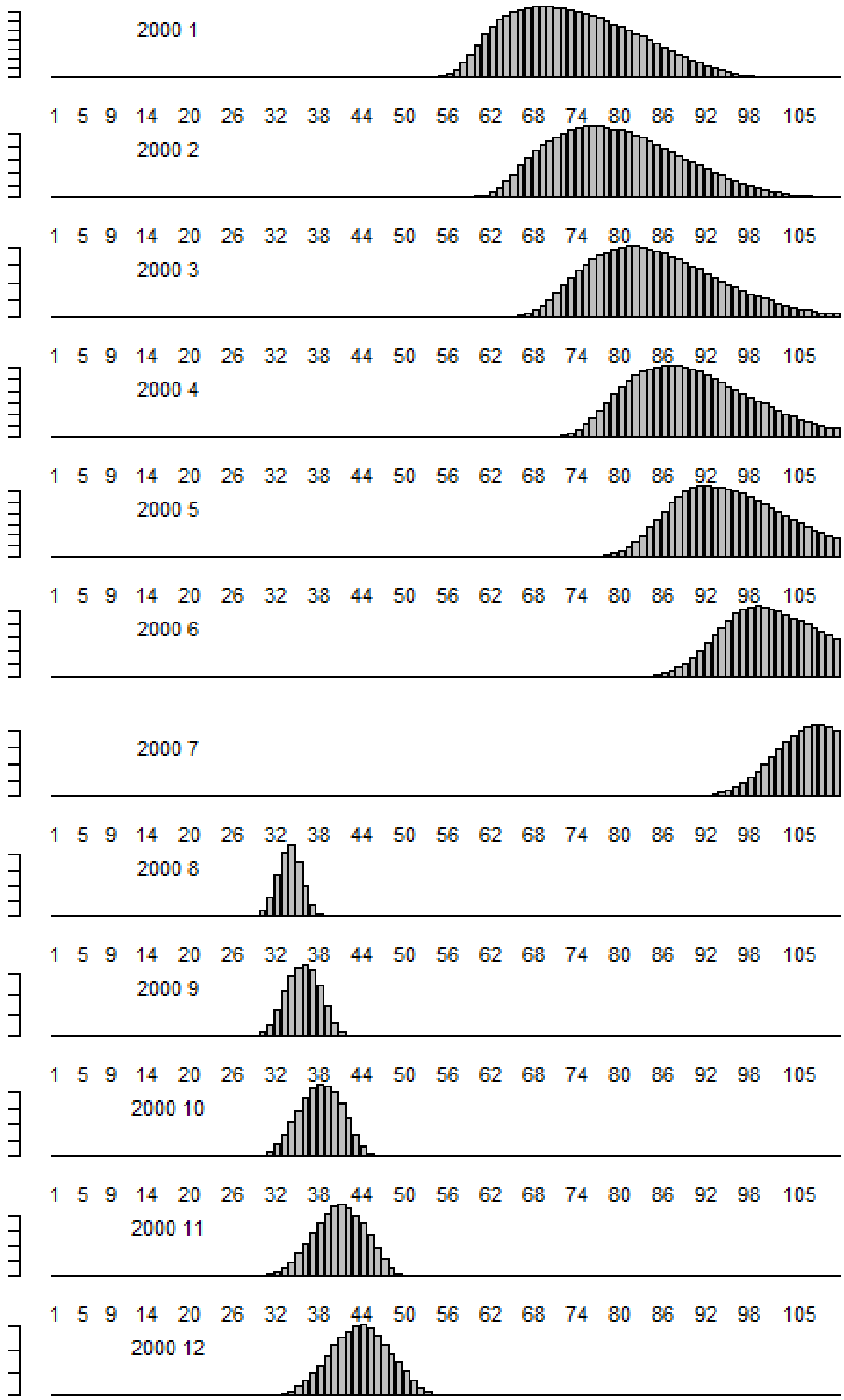
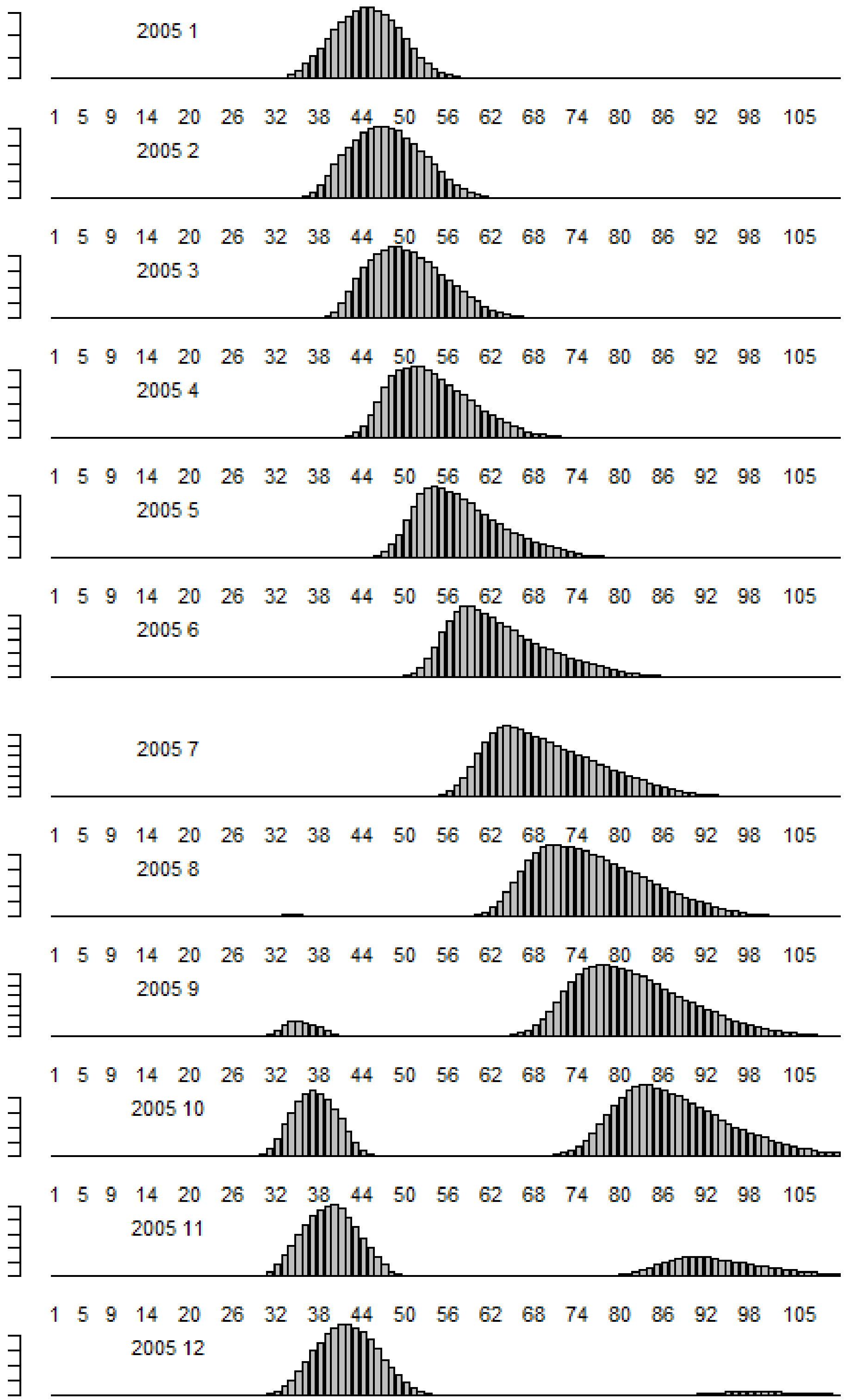
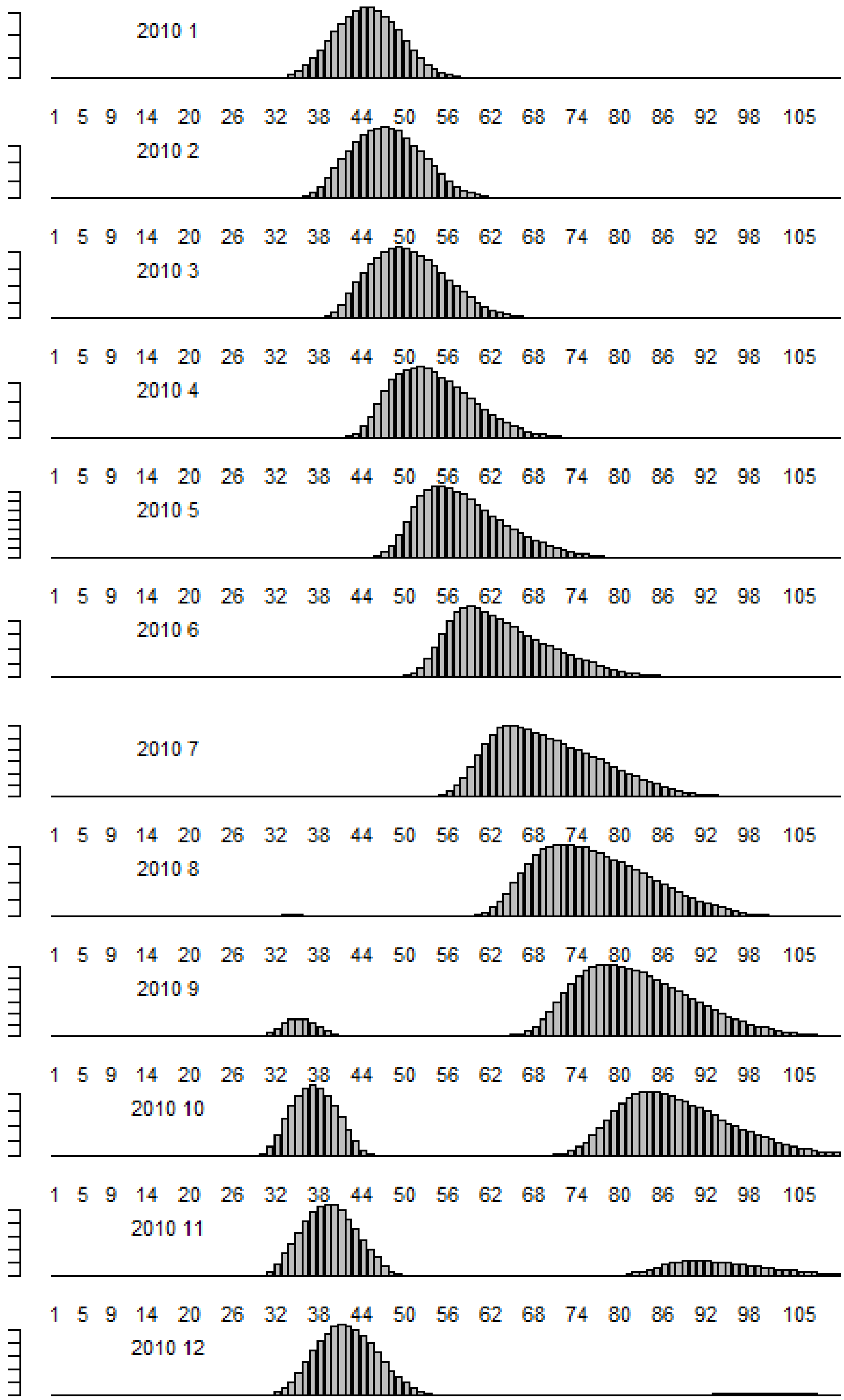

2019 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 6
2019 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 8
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 9
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 10
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 11
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 12

Figure 16. Whole Catch in number at length by YEAR.MONTH.




2005 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 6
2005 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 8
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 9
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 10
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 11
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 12


2010 1
2010 2
2010 3
2010 4
2010 5
2010 6
2010 7
2010 8
2010 9
2010 10
2010 11
2010 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105

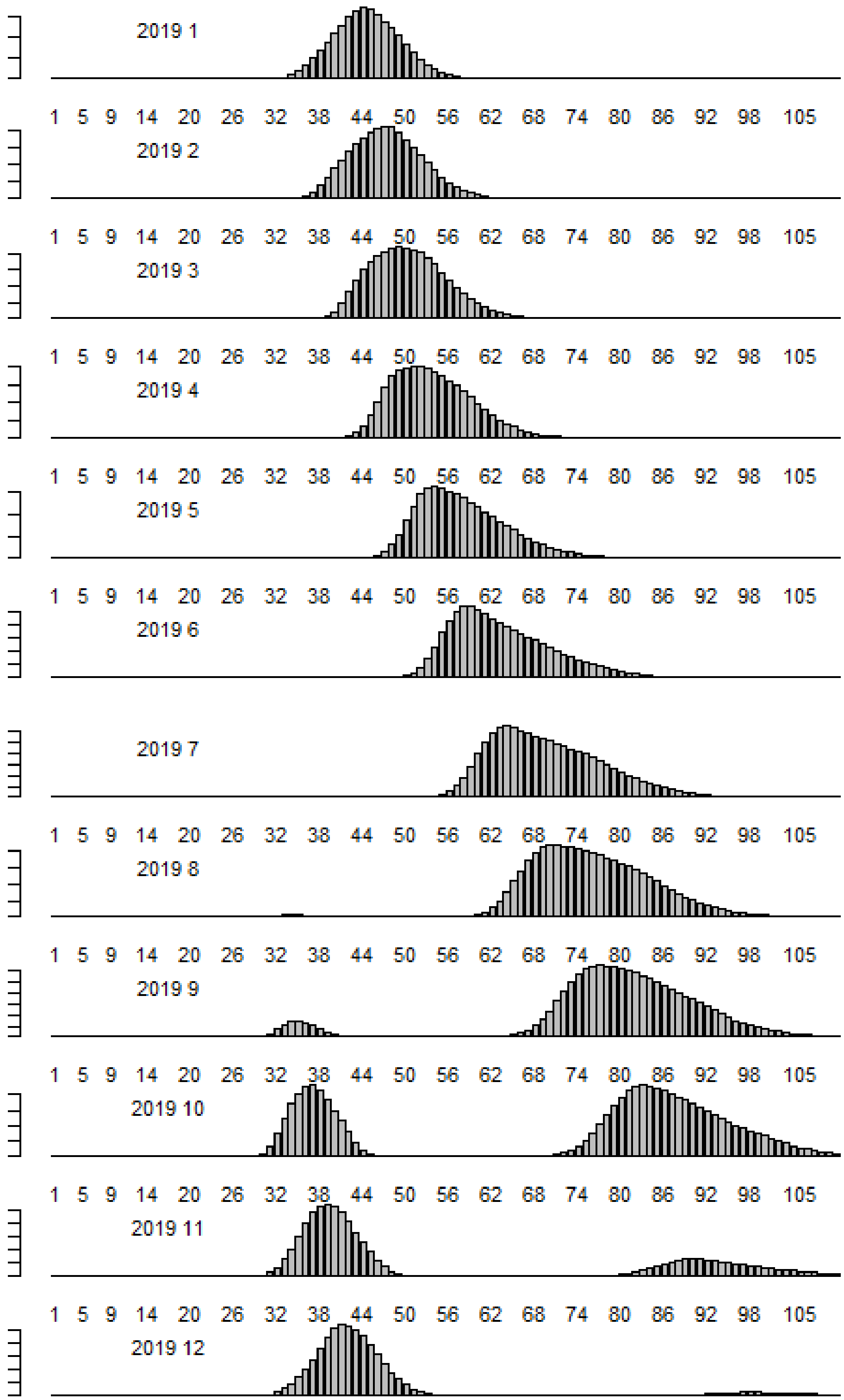
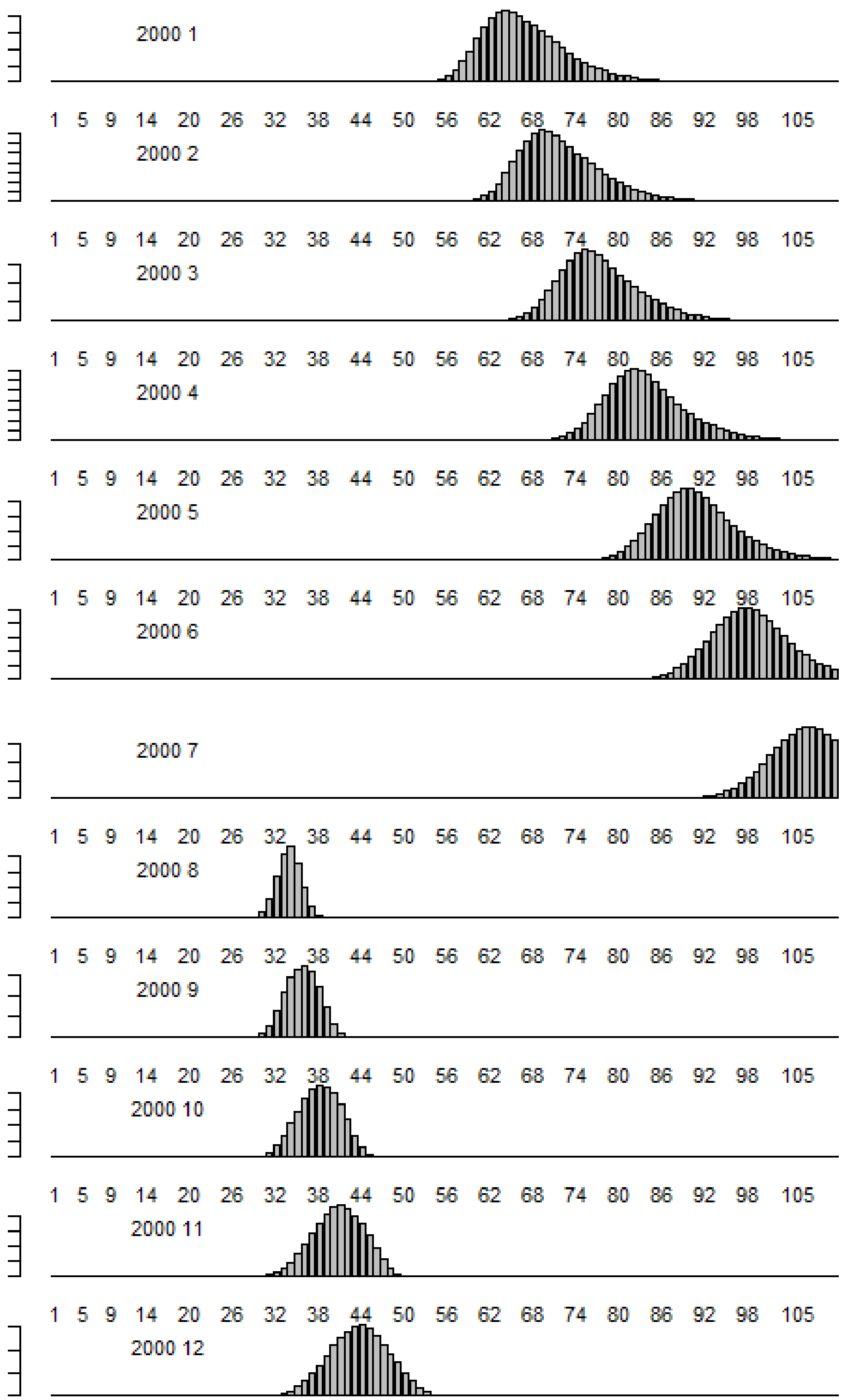
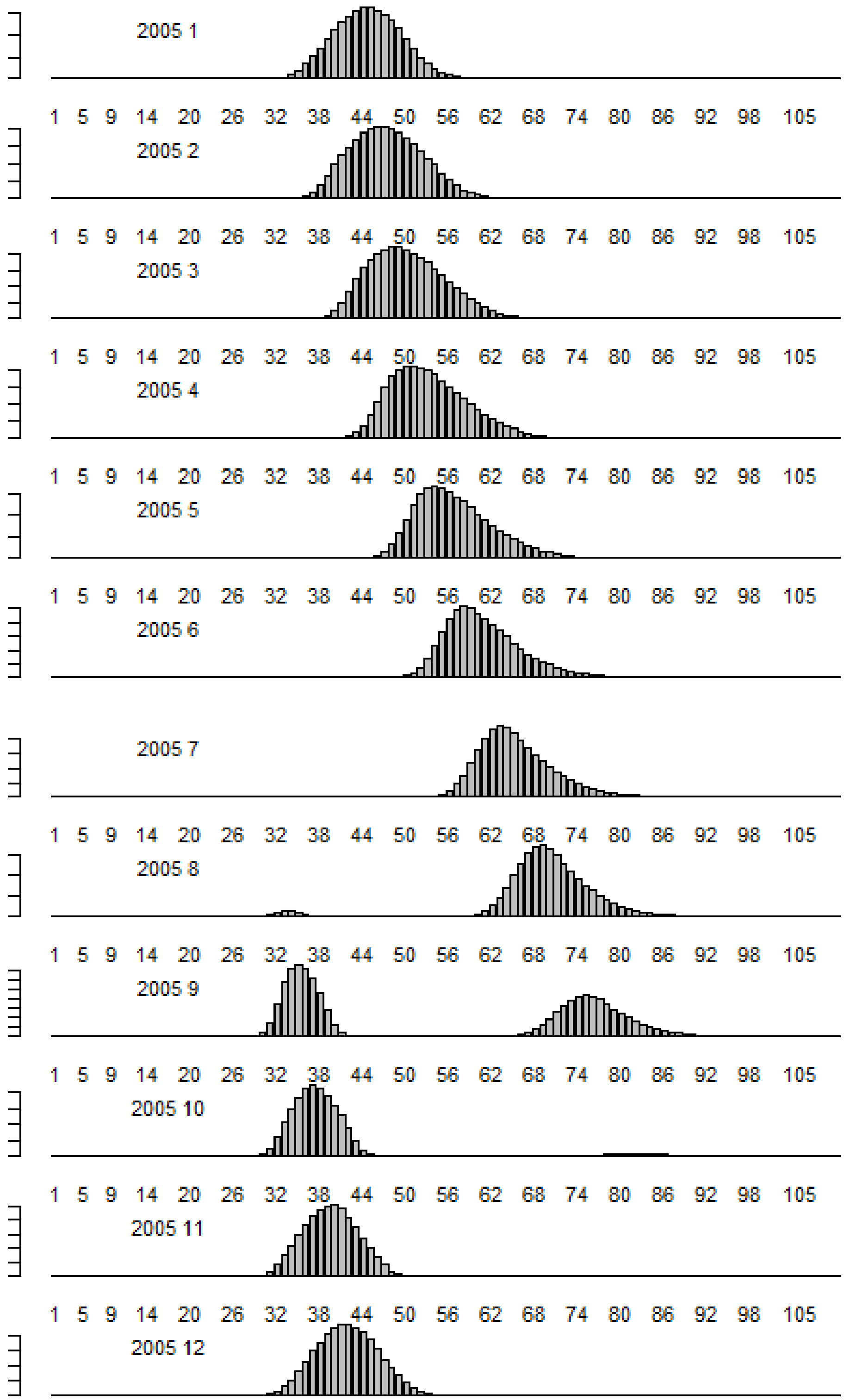
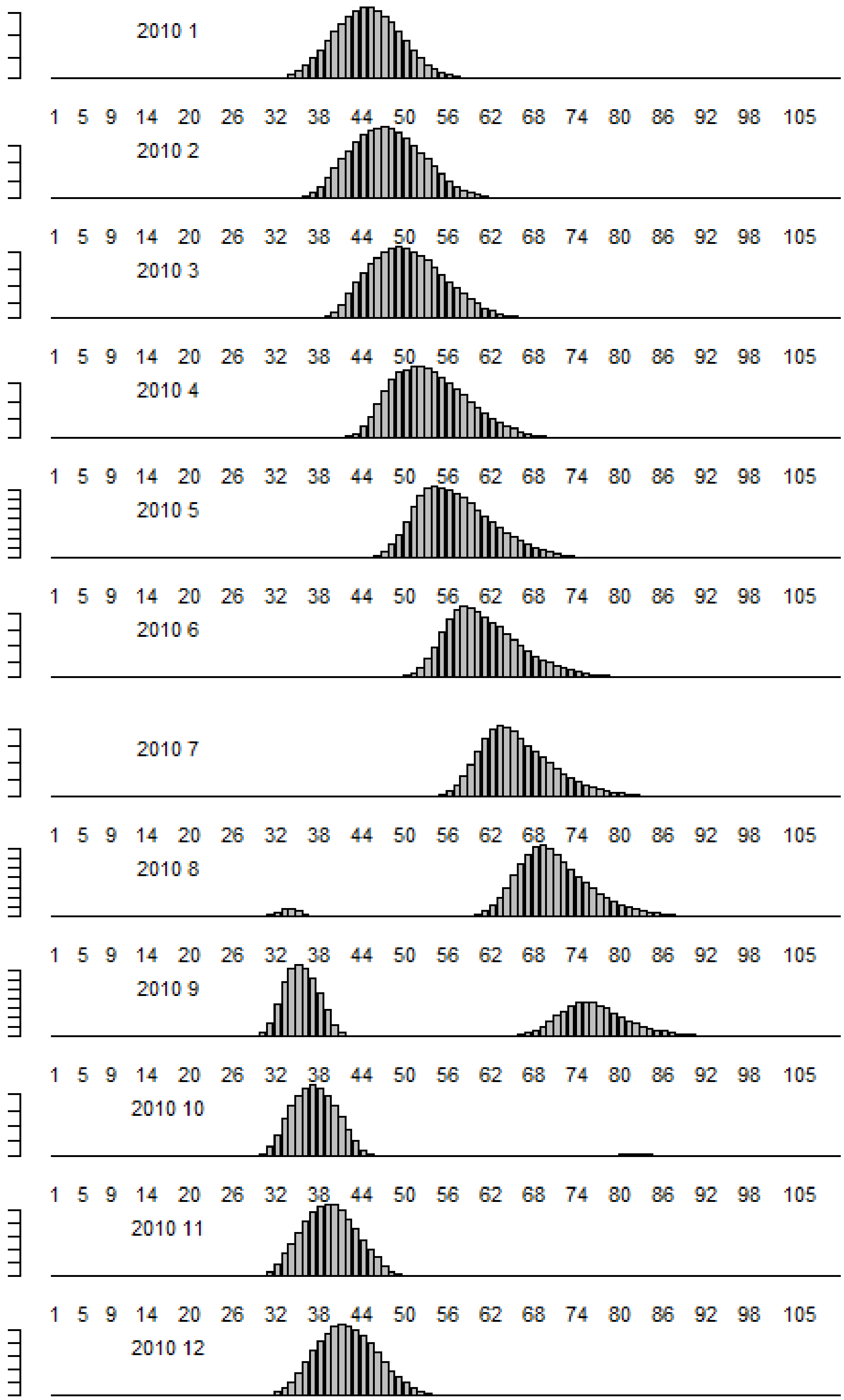

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105

Figure 17. Fleet 1 Catch in number at length by YEAR.MONTH.




2005 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12


2010 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 6
2010 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 8
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 9
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 10
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 11
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 12

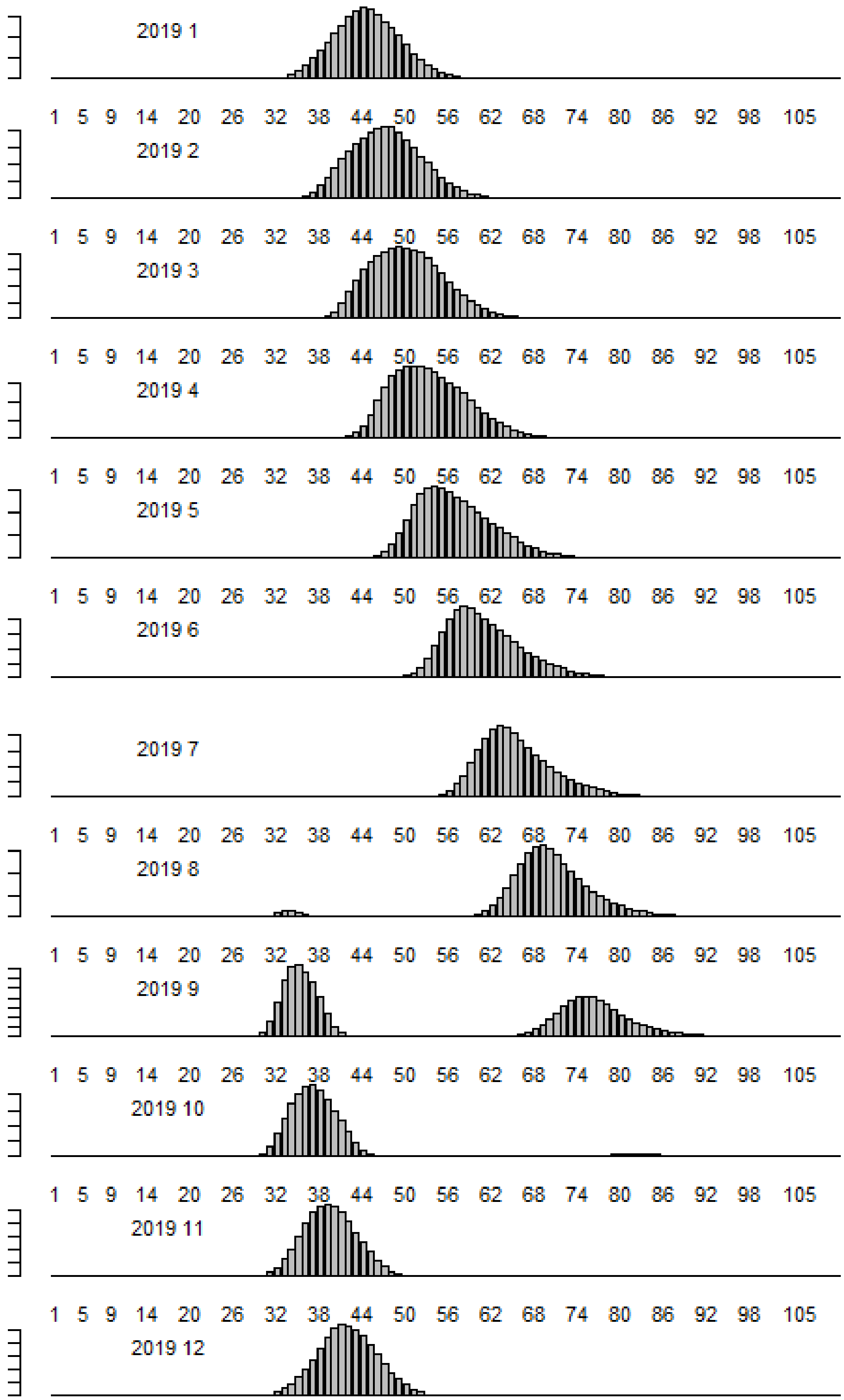
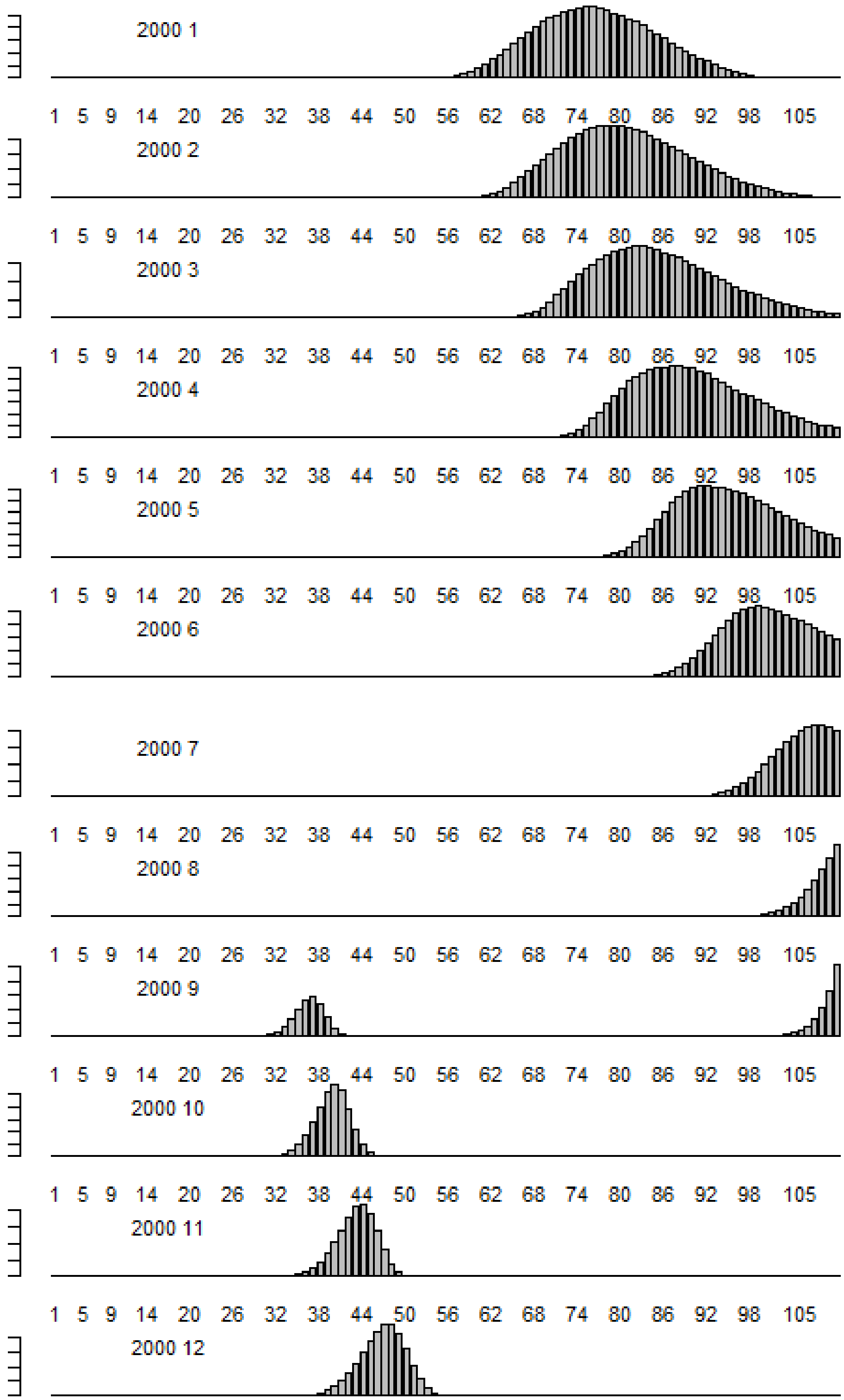
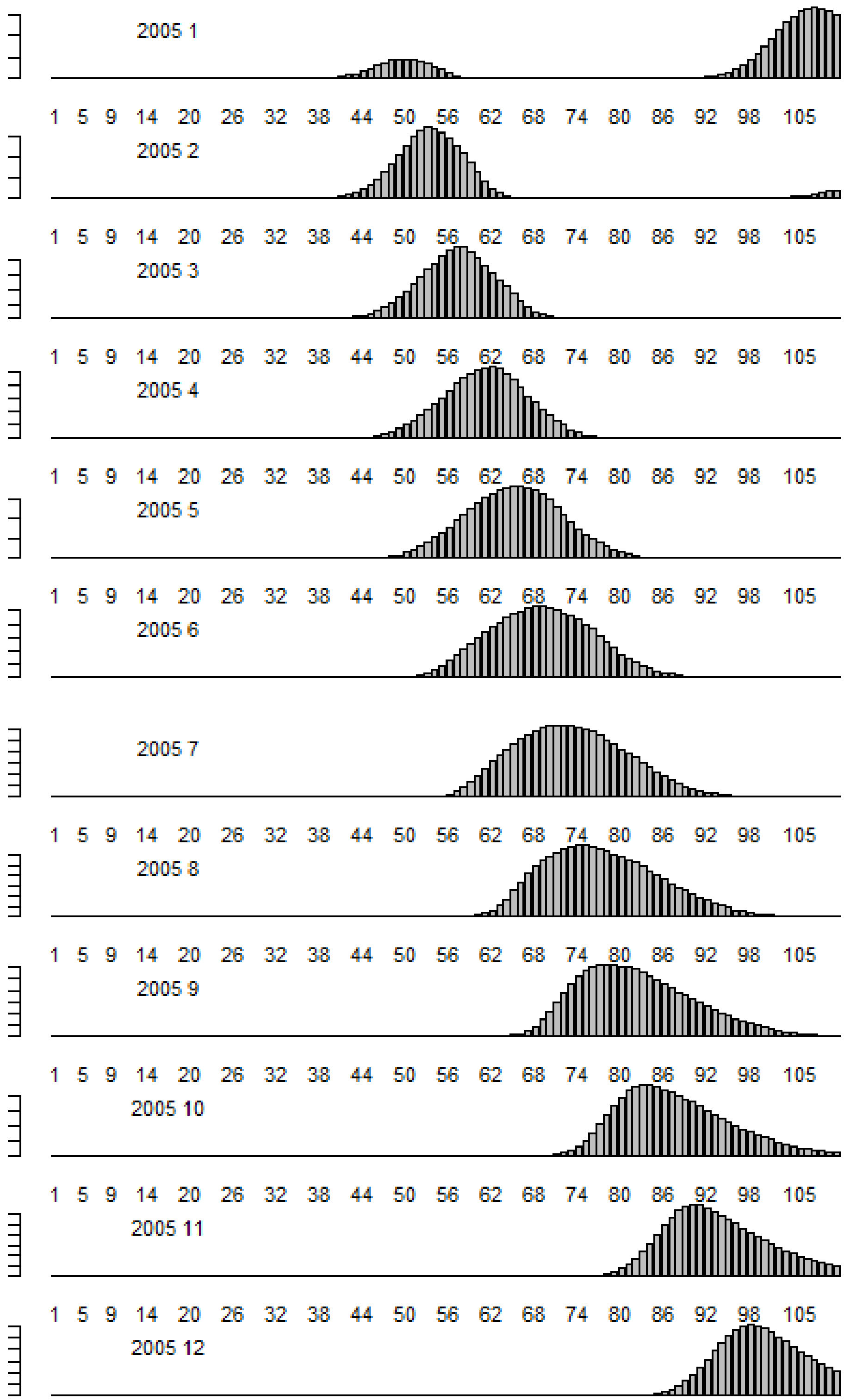
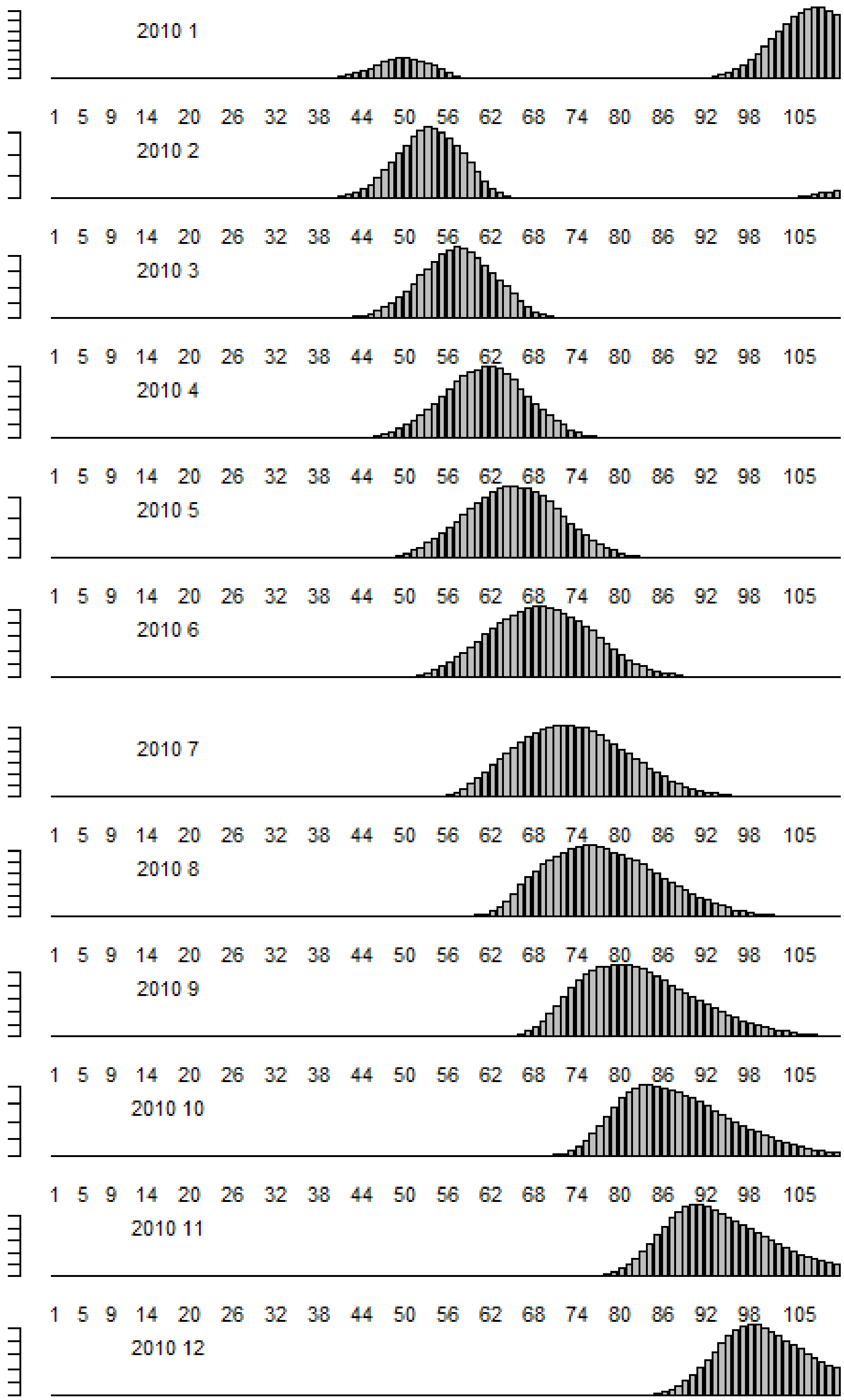

2019 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 6
2019 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 8
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 9
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 10
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 11
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 12

Figure 18. Fleet 2 Catch in number at length by YEAR.MONTH.




2005 1
2005 2
2005 3
2005 4
2005 5
2005 6
2005 7
2005 8
2005 9
2005 10
2005 11
2005 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105


2010 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 6
2010 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 8
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 9
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 10
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 11
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 12

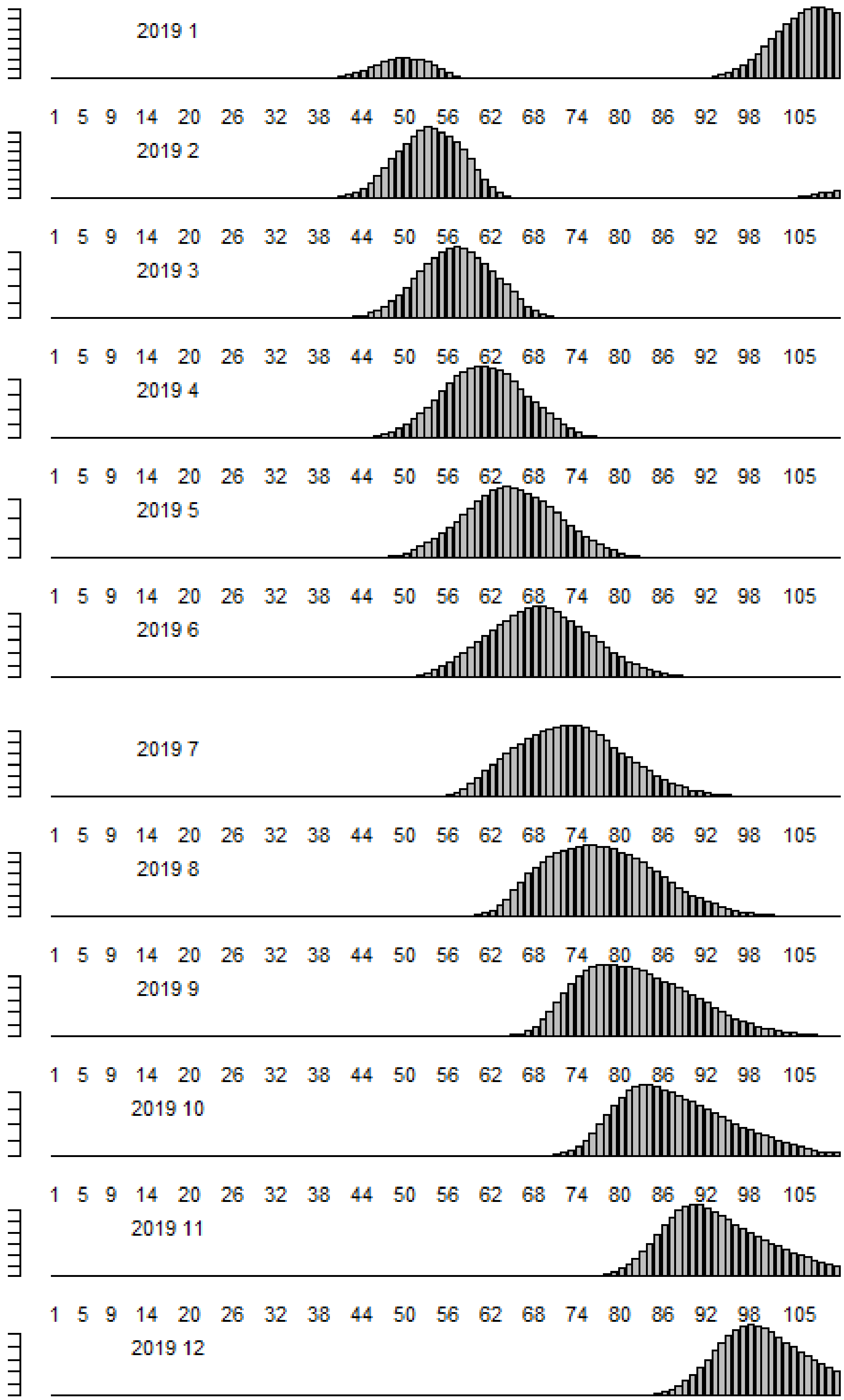

2019 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 6
2019 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 8
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 9
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 10
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 11
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 12

Figure 19. Number at age in the first Year and Recruitment by YEAR.MONTH.

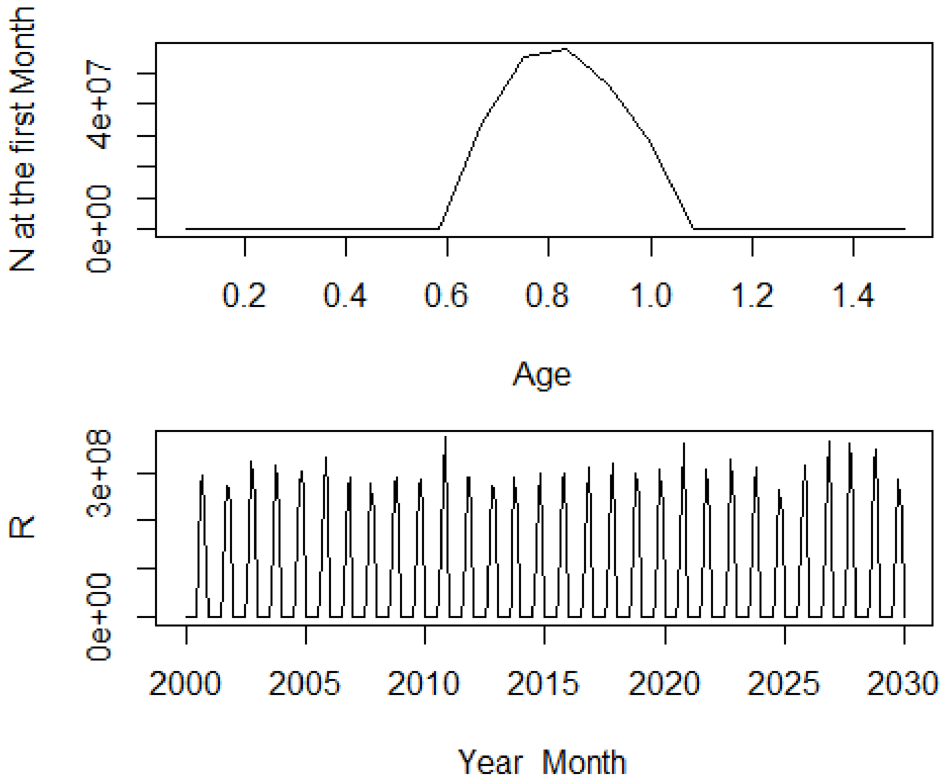


Figure 20. Whole number by YEAR.MONTH.

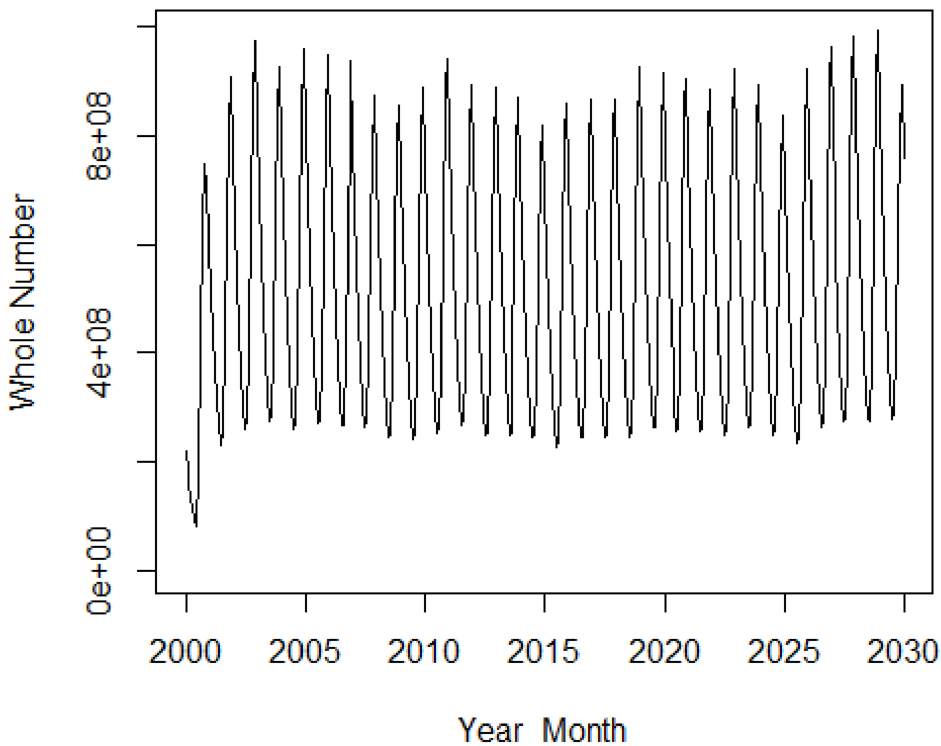


Figure 21. Catch (tons) by YEAR.MONTH.

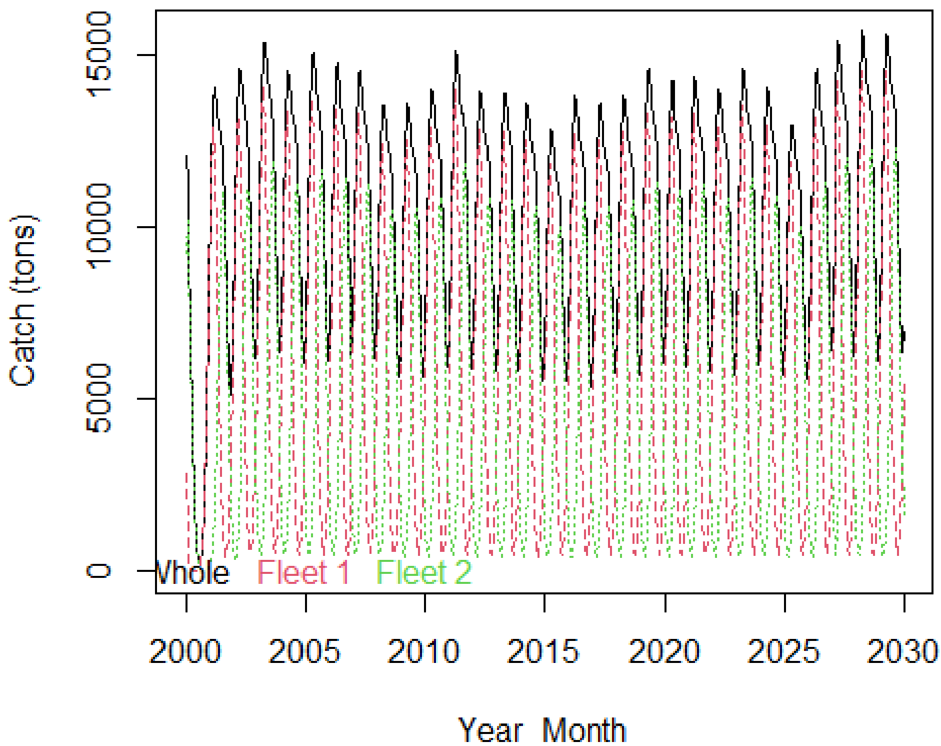


Figure 22. Whole number by YEAR.MONTH.

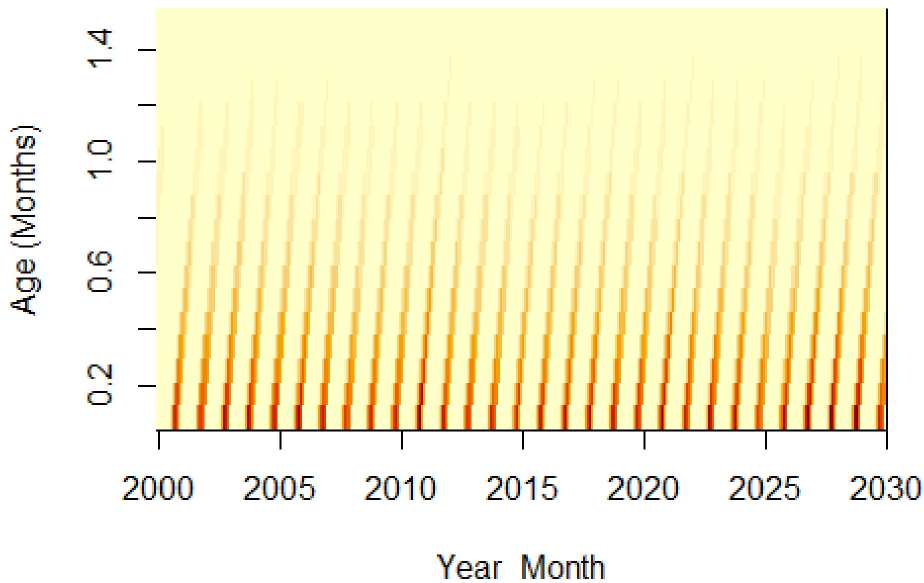


Figure 23. Biomass by YEAR.MONTH.

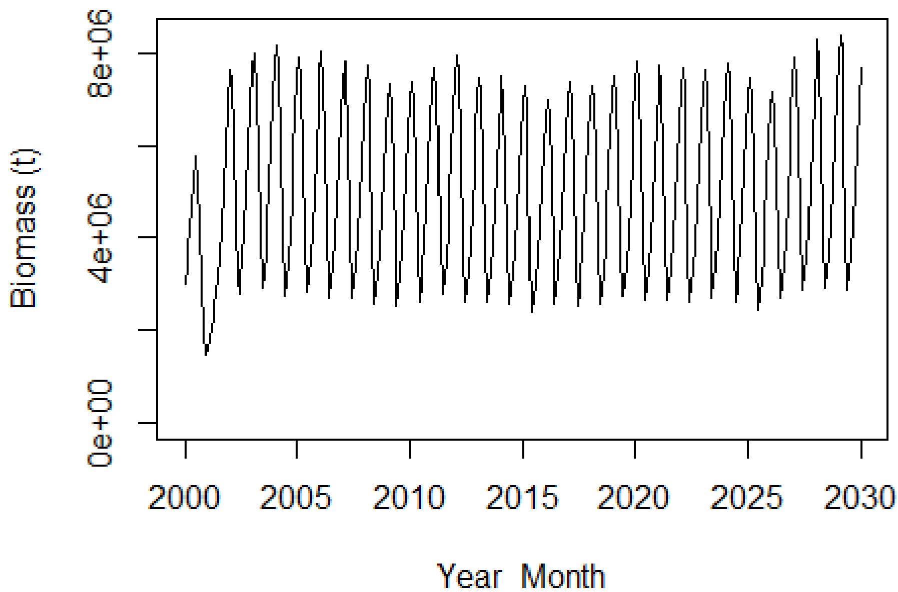
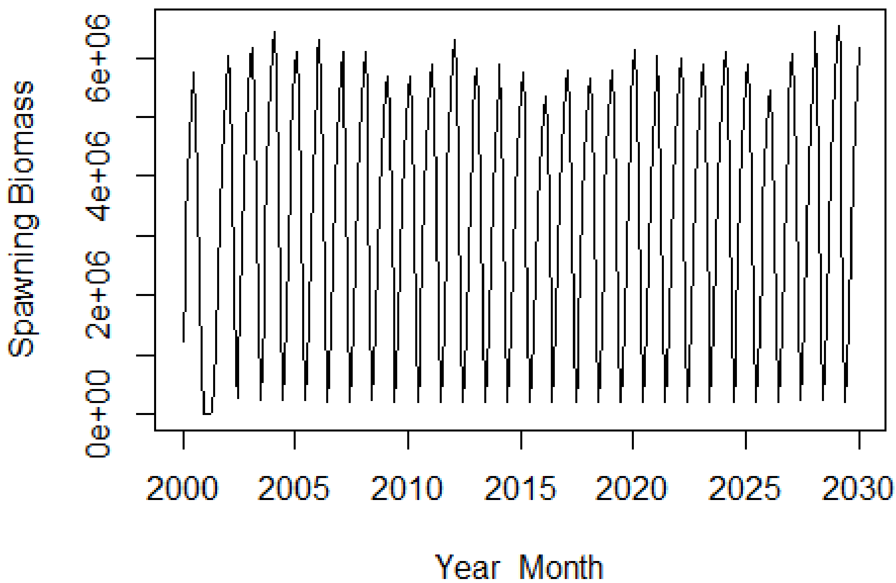


Figure 24. Spawning Biomass by YEAR.MONTH.



ABUNDANCE INDICES

Figure 25. Hyperstability.

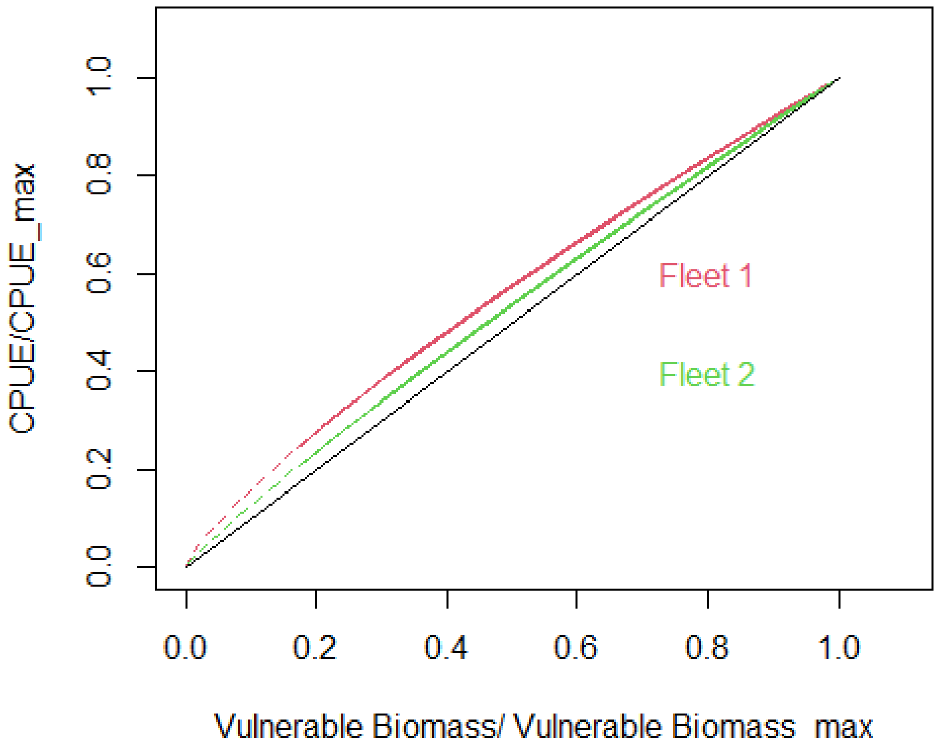


Figure 26. CPUE by YEAR.MONTH.

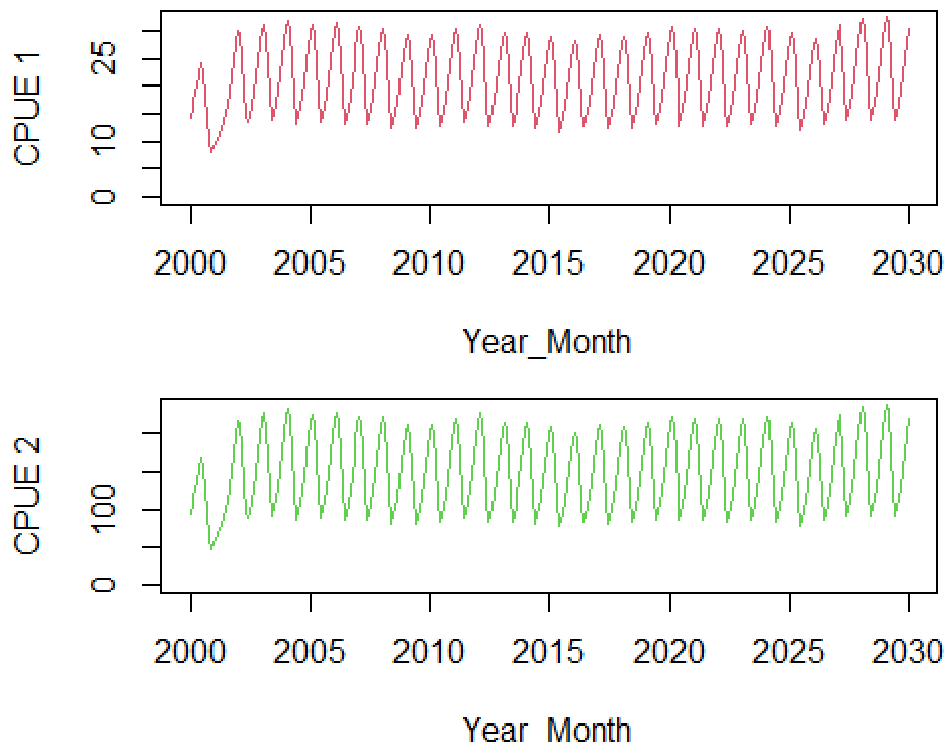


Figure 27. Examples of CPUE by month and fleet in two different years.

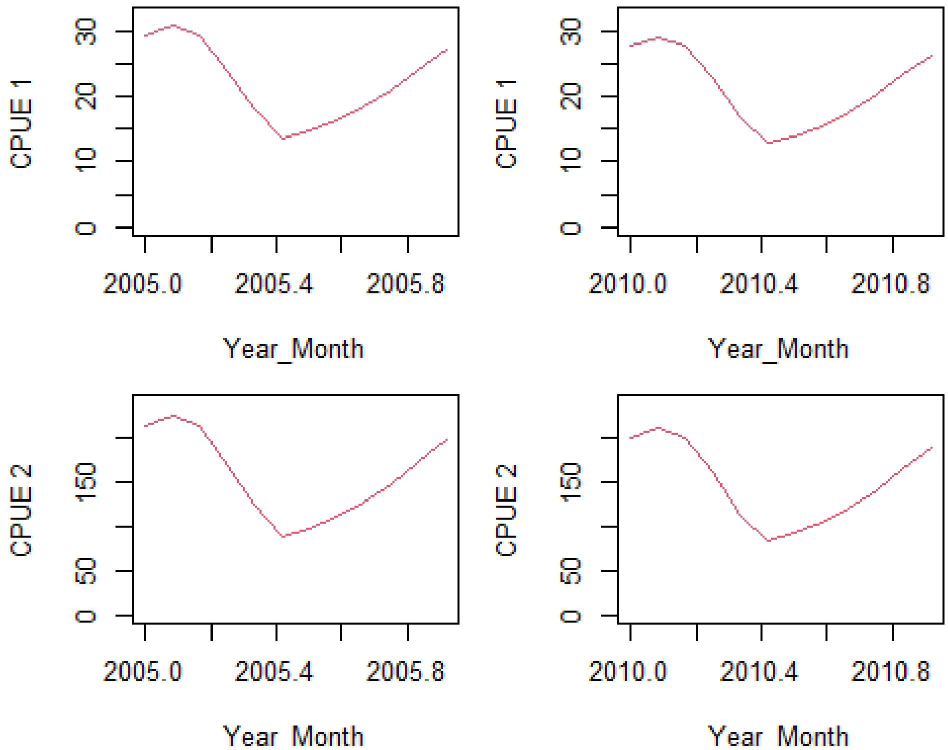


Figure 28. Acoustic Biomass by YEAR.MONTH.

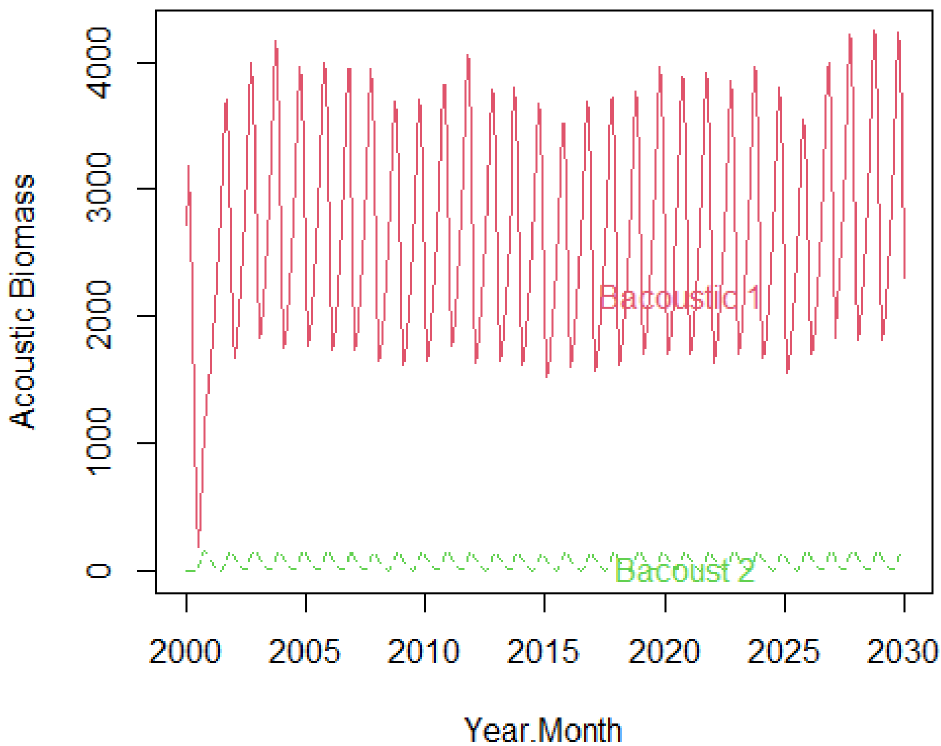


Figure 29. Acoustic Selectivities.

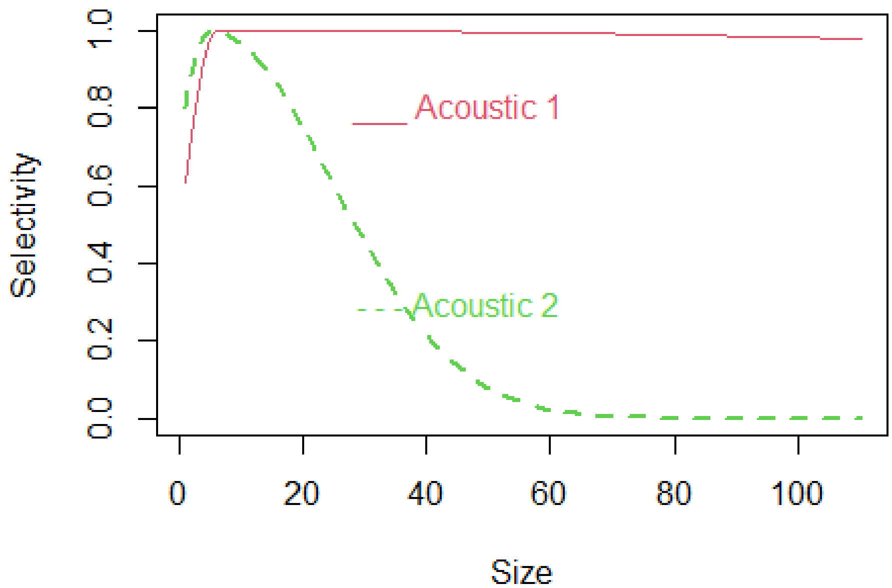


Table 2. Population, Fishery and Indices Parameters.

Recruitment Seasonal Parameters

RSeason	SdSeason
4	0

M and Stock Recruitment Parameters

M_Annual	M_bin	M_cv	SB0	SRModel	h	prev.rsigma	rsigma
2	0.1666667	0	1e+07	1	0.9	0	0.1

Fishery Parameters

Fref1	as1	bs1	cs1	Fref2	as2	bs2	cs2
0.1	0.15	0.5	0.15	0.05	0.15	0.9	0.15

Indices Parameters

q1	hyp 1	q2	hyp 2	as 3	bs 3	cs3	as 4	bs 4	cs 4	qacous 1	qacous 2	qMP H
1e-04	0.8	0.00015	0.9	5	6	500	6	5	20	0.9	0.5	0.9

REFERENCES

Allaire, JJ., Y. Xie, J. McPherson, and et. al. 2018. "R Markdown." Computer Program. https://rmarkdown.rstudio.com.

Argüelles, J., P. G. Rodhouse, P. Villegas, and G. Castillo. 2001. "Age, Growth and Population Structure of the Jumbo Flying Squid Dosidicus Gigas in Peruvian Waters." Fisheries Research 54:51-61.

Beverton, R., and S. J. Holt. 1957. "On the Dynamics of Exploited Fish Populations." FAO Fishery investigations serie II Volumen XIX 533 p.

Mace, P. M., and I. J. Doonan. 1988. "A Generalised Bioeconomic Simulation Model for Fish Population Dynamics." New Zealand Fisheries Assessment Research Document 88/4.Fisheries Research Centre, MAFFish, POB 297, Wellington, NZ.

Payá, I. 2015. "Estatus y Posibilidades de Explotación Biológicamente Sustentables de Los Principales Recursos Pesqueros Nacionales. Año 2016. Jibia." Instituto de Fomento Pesquero. Informe de Estatus y Cuota. 85 p + 4 annexes.

———. 2016. "Estatus y Posibilidades de Explotación Biológicamente Sustentables de Los Principales Recursos Pesqueros Nacionales. Año 2017. Jibia." Instituto de Fomento Pesquero. Informe de Estatus y Cuota. 95 p + 4 annexes.

———. 2017. "Estatus y Posibilidades de Explotación Biológicamente Sustentables de Los Principales Recursos Pesqueros Nacionales. Año 2018. Jibia." Instituto de Fomento Pesquero. Informe de Estatus y Cuota. 94 p + 3 annexes.

———. 2019. "SQUIDSIM, SQUID SIMULATOR, Version 1.0." Instituto de Fomento Pesquero. Anexo III en Estatus y posibilidades de explotación biológicamente sustentables de los principales recursos pesqueros nacionales. Jibia. Año 2019. 34 pp.

Payá, I., L. Caballero, A. Barraza, J. Cavieres, A. Yañez, and R. Tascheri. 2014. "Estatus y Posibilidades de Explotación Biológicamente Sustentables de Los Principales Recursos Pesqueros Nacionales. Año 2015. Jibia." Instituto de Fomento Pesquero. Informe de Estatus y Cuota. 83 p + 4 annexes.

Ricker, W. E. 1954. “Stock and Recruitment.” Journal of the Fisheries Research Board of Canada, 11(5): 559–623.