SQUIDSIM, SQUID SIMULATOR, Version 1.2, SPRFMO SC12

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Table of Contents

SUMMARY

I. Payá (2019) wrote 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 modeled as a logistic function. Two options for modeling 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 modeled 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 a csv format file.

The version 1.1 (I. Payá 2023) added to the simulation: two CPUE indices (with hyperstability); two acoustic biomasses indices. The selectivity curves of the acoustic surveys were modeled by length using double half-normal functions. Also, added a new option for seasonal recruitment pattern, new charts and improvements to some others charts.

The current version 1.2, adds 1) the longevity and the fecundity parameters to estimate the natural mortality using gnomonic method Caddy (1996), 1) a third commercial fishery.

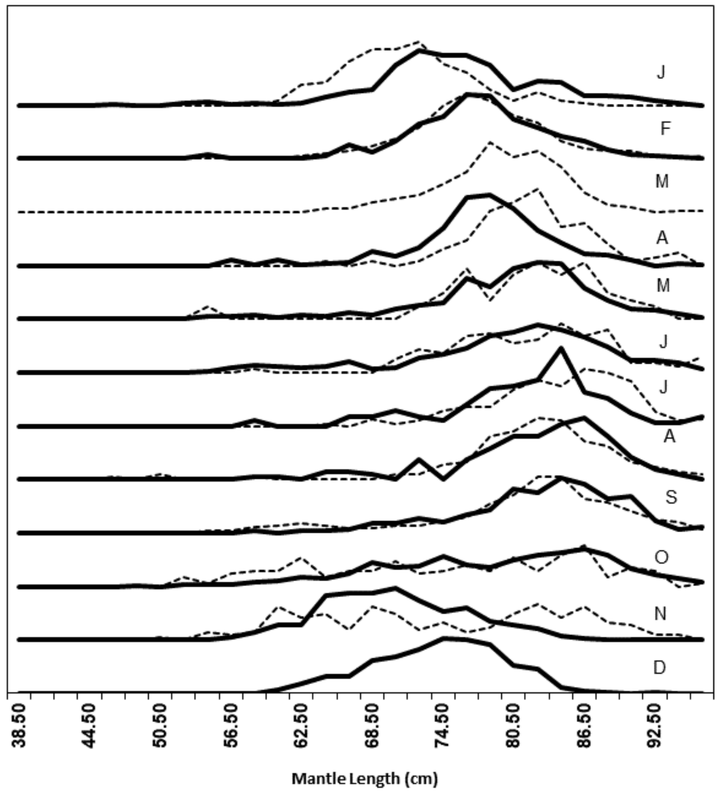
INTRODUCCTION

The Scientific Committee seems to agree that because of the short lifetime (1 -2 year) of Humboldt 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 as the ones 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).

The version 1.0 (I. Payá 2019) was design to simulate the dynamic of Humboldt Squid population in 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 multiplied 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 selectivity functions are modelled using double half-normal functions.

The version 1.1 (I. Payá 2023) extended the squid simulator to the FAO area 87. It added four abundance indices: two CPUE indices (with or without hyperstability) and two acoustic biomasses. Selectivity curves of the 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.

The current version 1.2, adds 1) the longevity and the fecundity parameters to estimate the natural mortality using gnomonic method Caddy (1996), 1) a third commercial fishery.

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, $j = 1, \ldots\ldots nbtins$, 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 is estimated using the gnomonic method Caddy (1996) and the R package gnomonicM of Torrejon-Magallanes (2021). Following to Martínez-Aguilar et al. (2010), the number of gnomonic intervals is fixed to 5 and the duration of the first interval (egg) is fixed to 6 days, while longevity and fecundity are input parameters. M is equal to adult mortality.

$$M_{i,j} = M_{bin} + e^M_{i,j}$$

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

N at the first month

The recruitment before the first year is a vector of length equals to numbers of ages -1 (nags-1)

$$predR_i = R0 \quad exp(e^0_i)$$

$$e^0_i \sim N(0, prevrsigma)$$

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

The number at age 1 at the first month is R1

$$N_{1,1} = R1$$

and for the older ages (i>2) is the number of survivors of previous recruitments

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

Seasonal Recruitment Patterns

Constant pattern ($RSeason$=1):

$$inbinR = 1 \quad exp(e^s_1)$$

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

$$inbinR_i = exp\big(-0.20(i-1)\big) \quad exp(e^s_i) \qquad for \quad i = 2, \dots, 12$$

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

$$inbinR_i = \sin(3+i) \quad exp(e^s_i) \qquad for \quad i = 1, \dots, 12$$

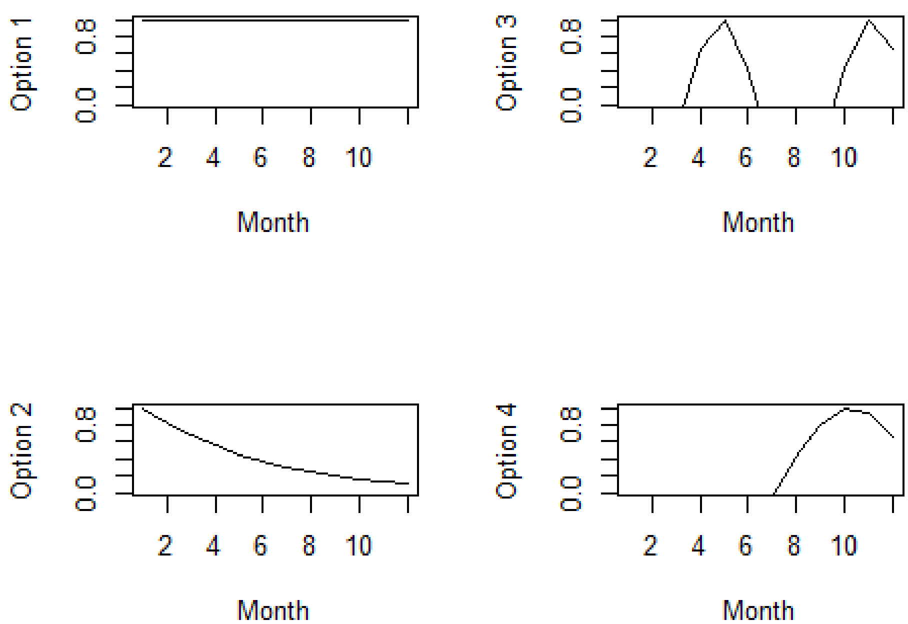
Sinusoidal Pattern, one peak in a year ($RSeason$=4):

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

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

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

Figure 1. 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:

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

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

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

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

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

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

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

where, mat_i is the maturity at age.

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:

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

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.

Selectivity, 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:

$$YT_j = \sum_{f=1}^{nf} Y\,T_j^f$$

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 Selectivity.

Acoustic selectivity (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 2. Growth at size and age.

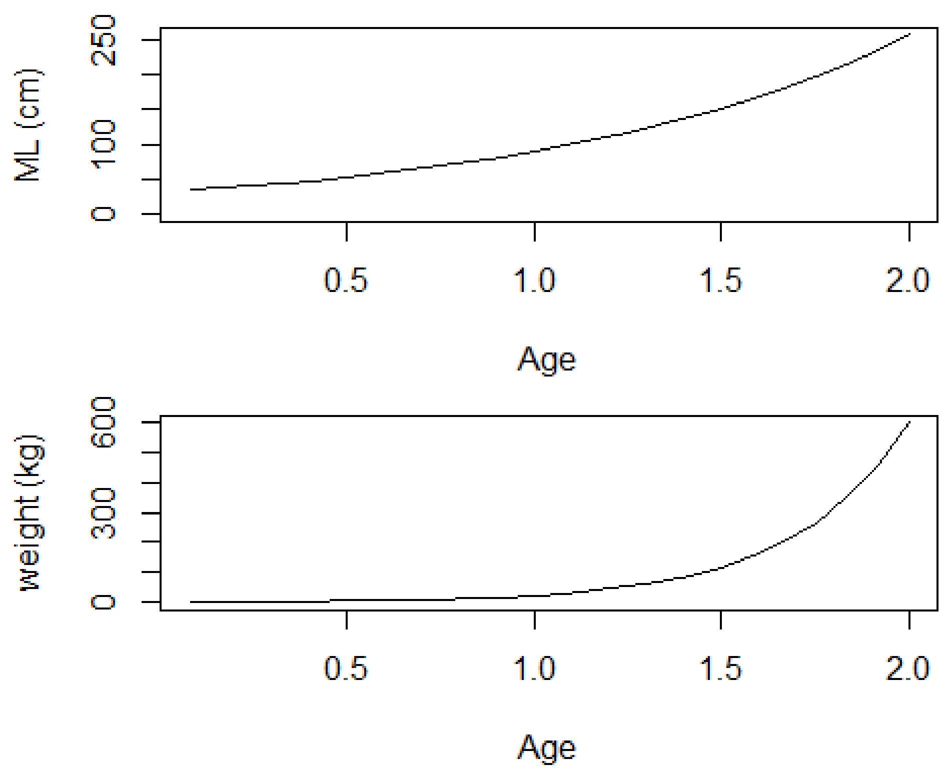


Figure 3. Maturity at size and age.

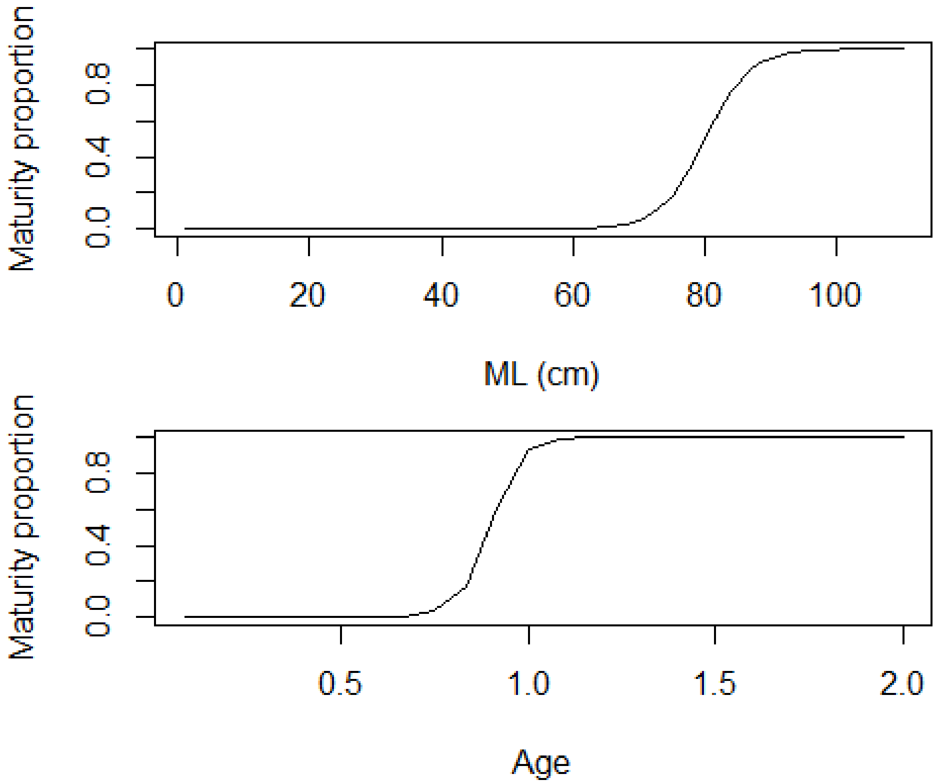


Table 1. Individual Parameters

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

```
## -------------------------------------------------------
##
## No additional information. You are only considering the egg stage
duration = 6
##
## -------------------------------------------------------
```

Figure 4. M by age and YEAR.MONTH (if M is constant then one color).

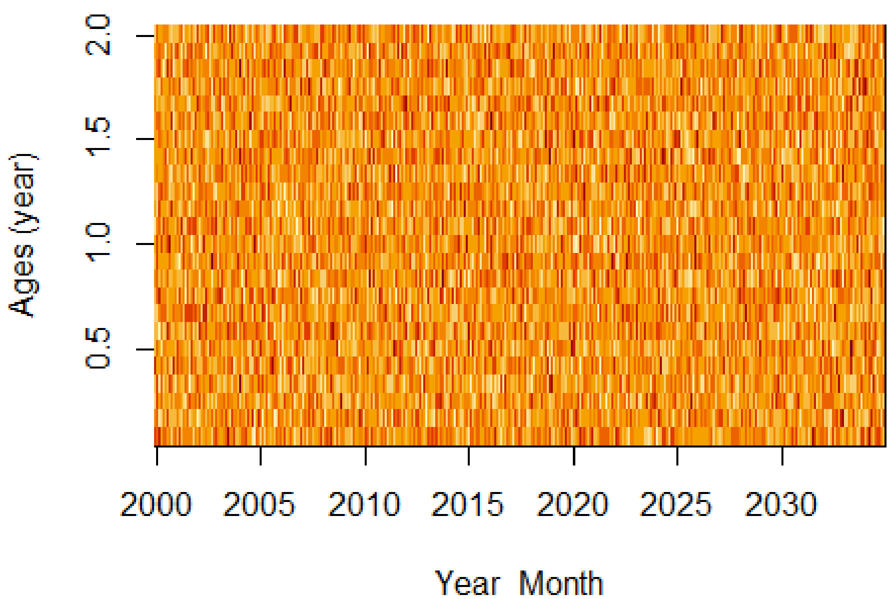


Figure 5. Recruitment before the starting time.

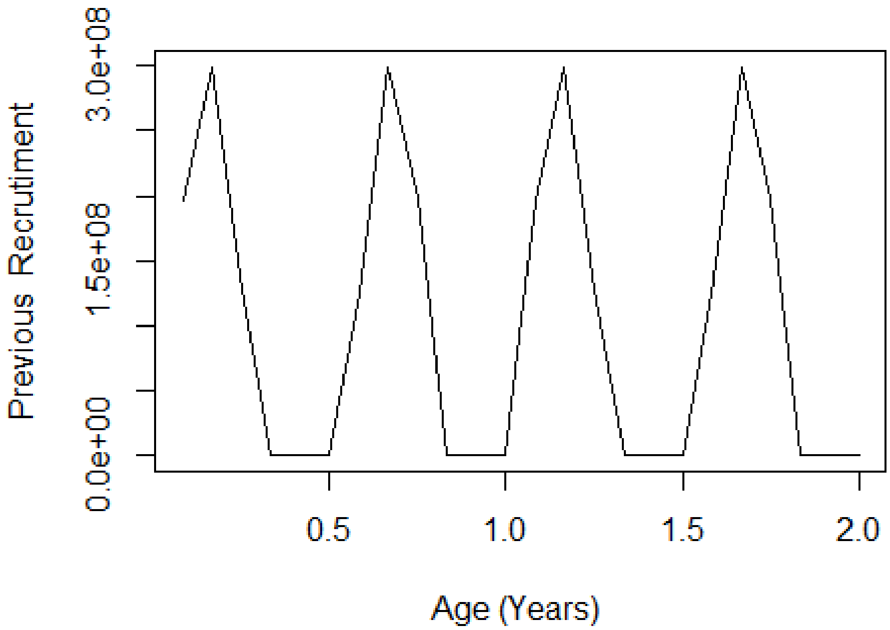


Figure 6. N at the first year.

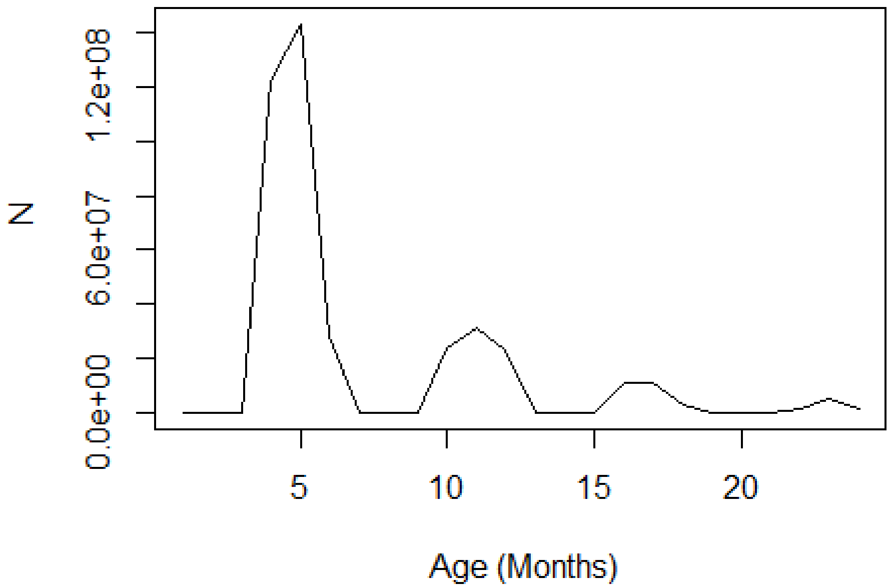


Figure 7. Seasonal recruitment patterns.

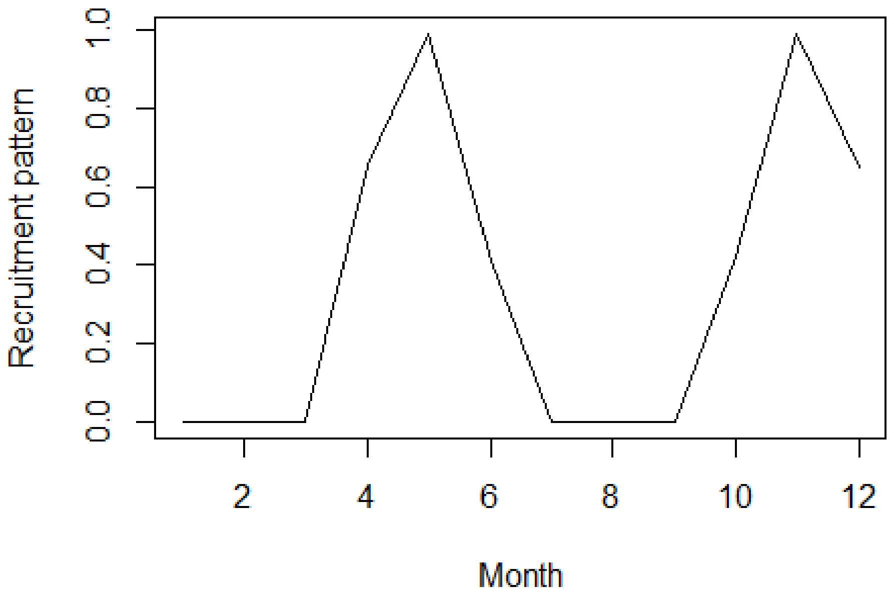


Figure 8. Fishing Selectivity by fleet.

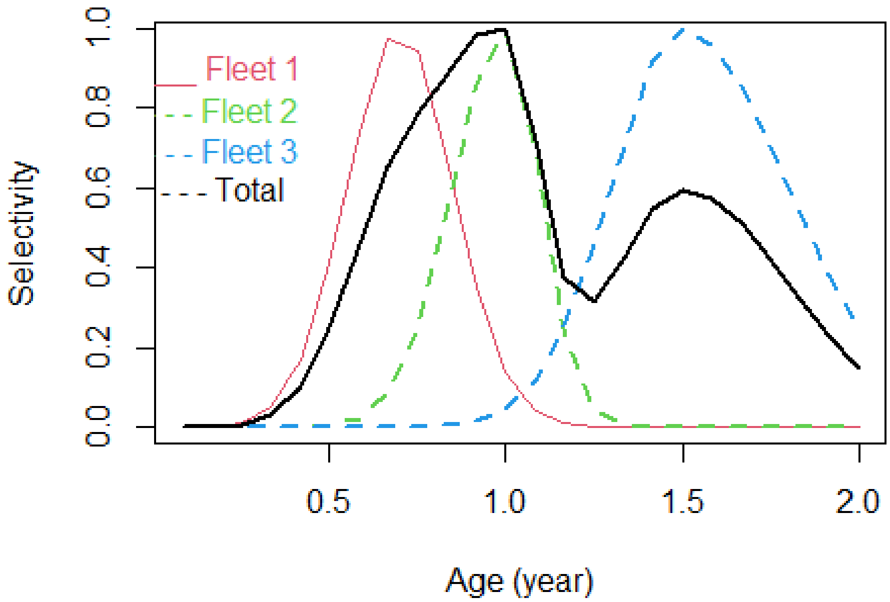


Figure 9. Spawning Biomass and Recruitment.

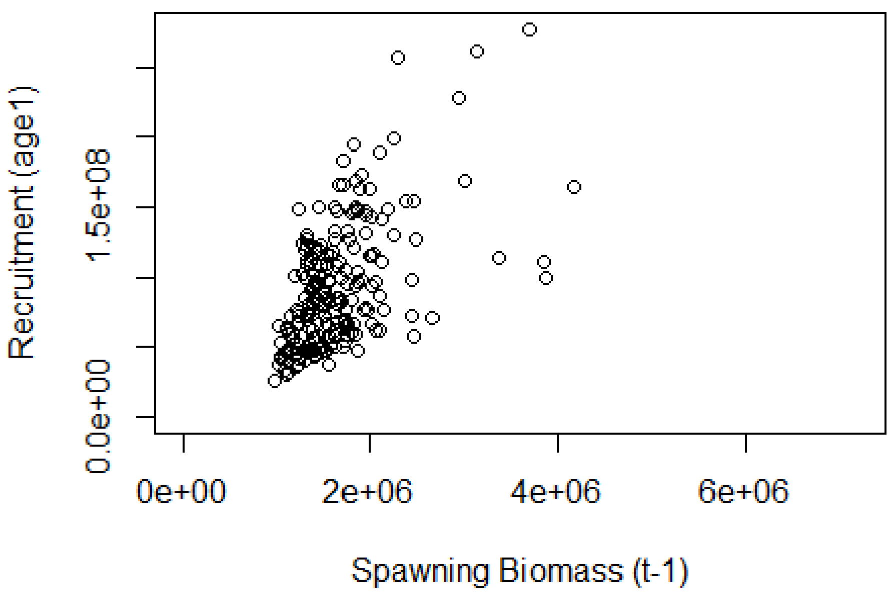


Figure 10. Seasonal Pattern of recruitment and Number at the begginning.

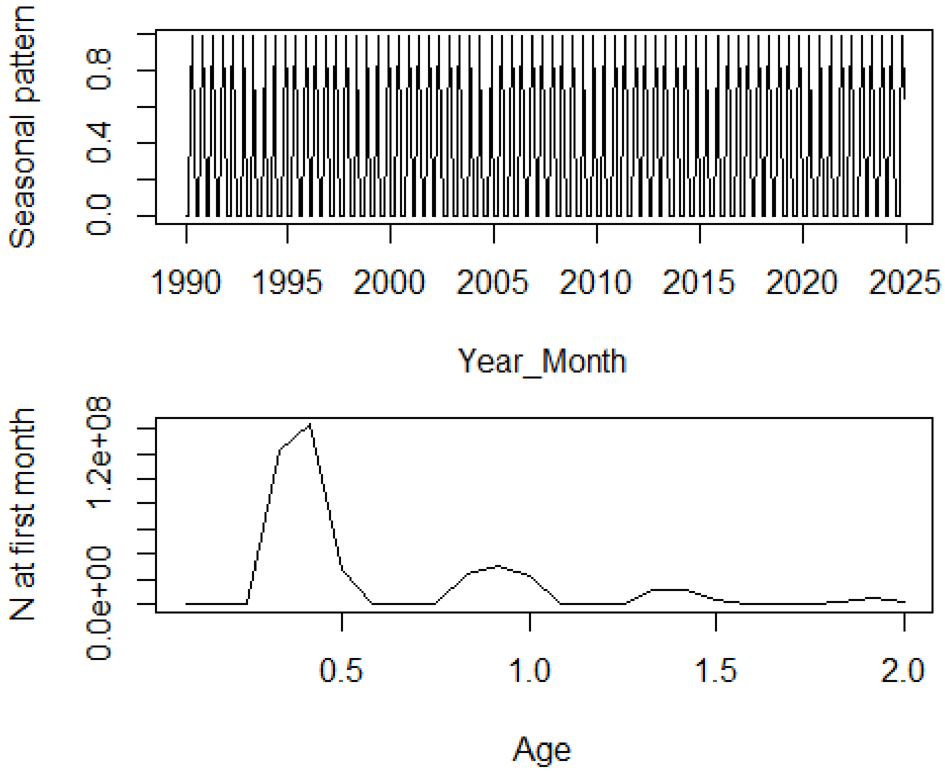
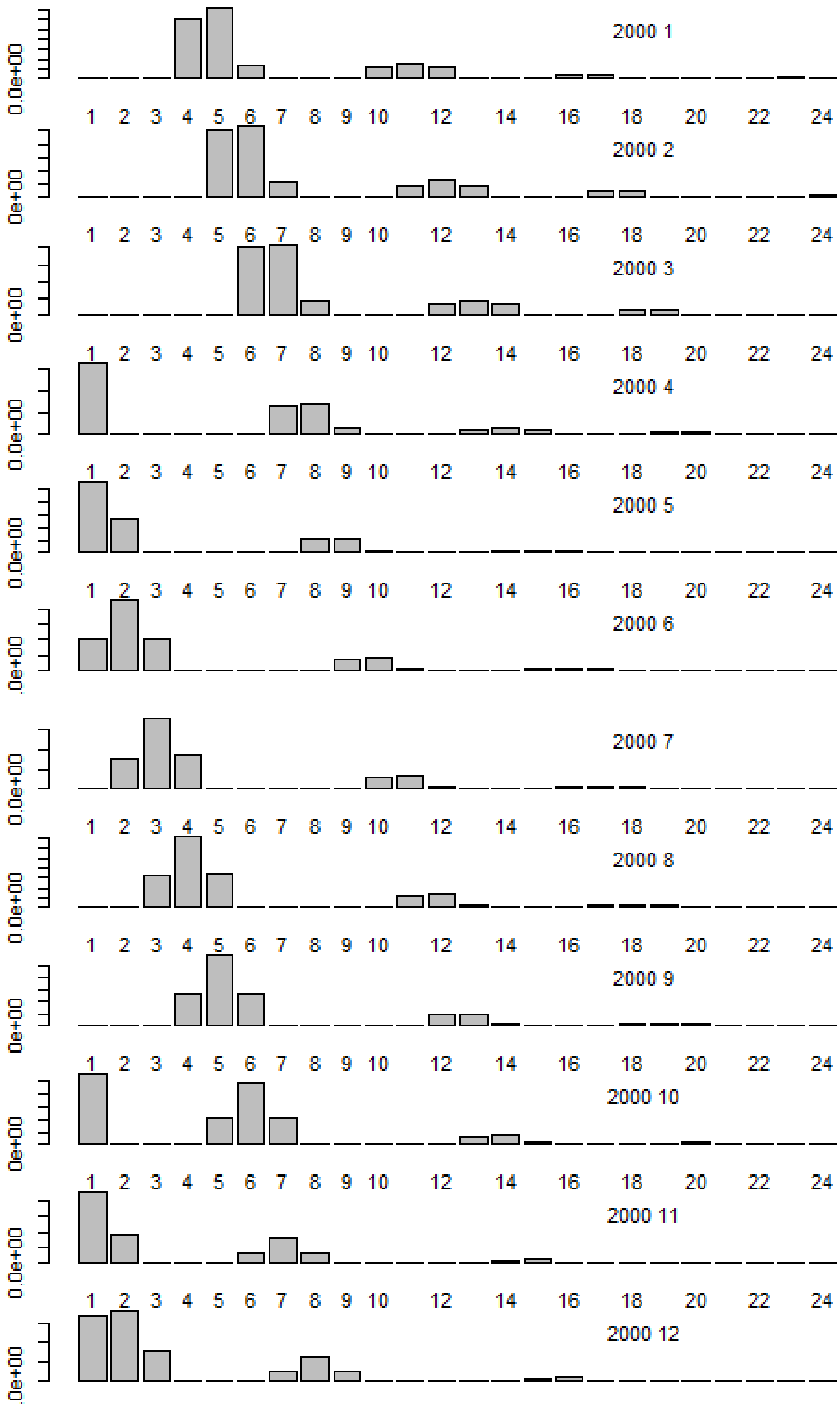
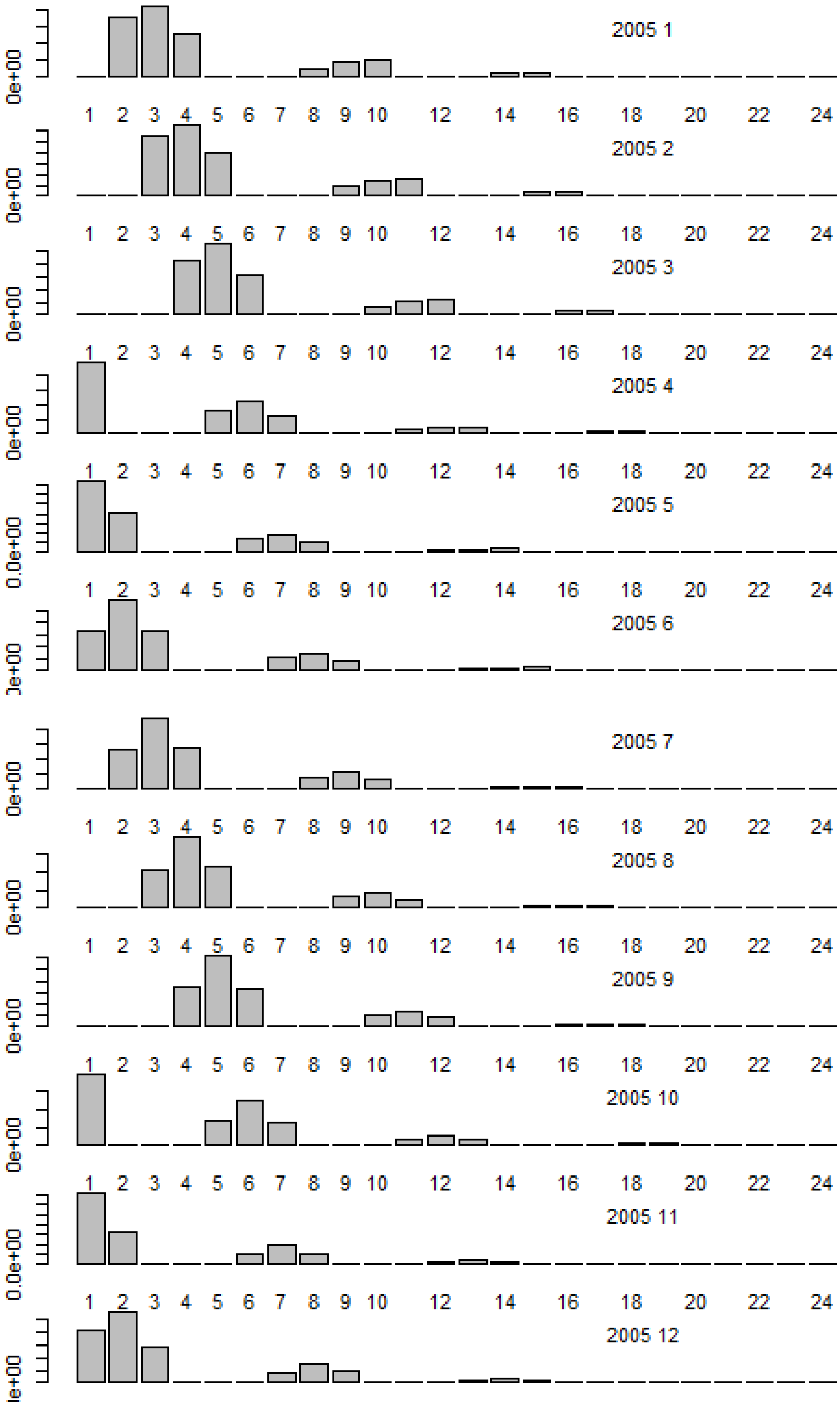


Figure 11. Number at age by YEAR.MONTH.

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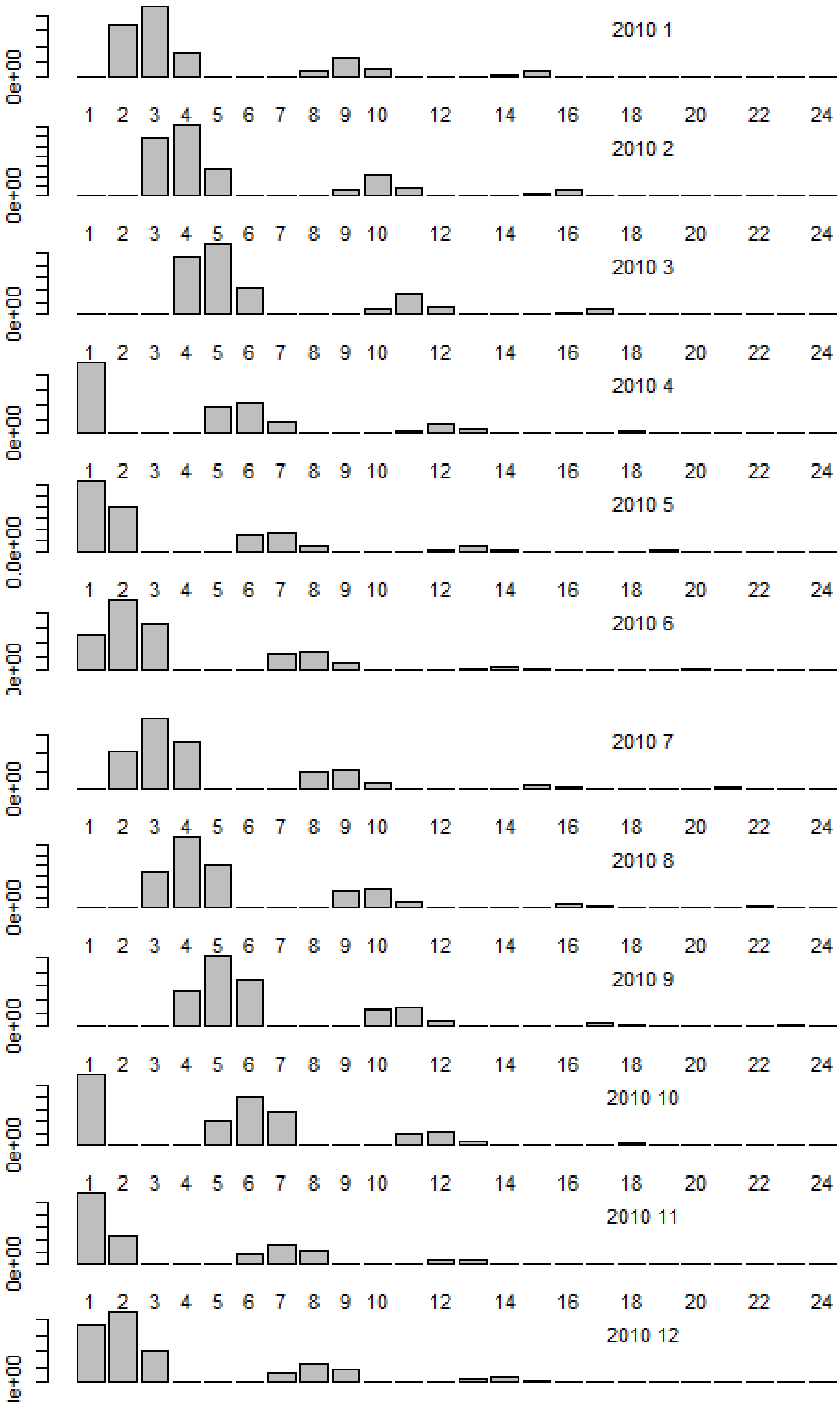
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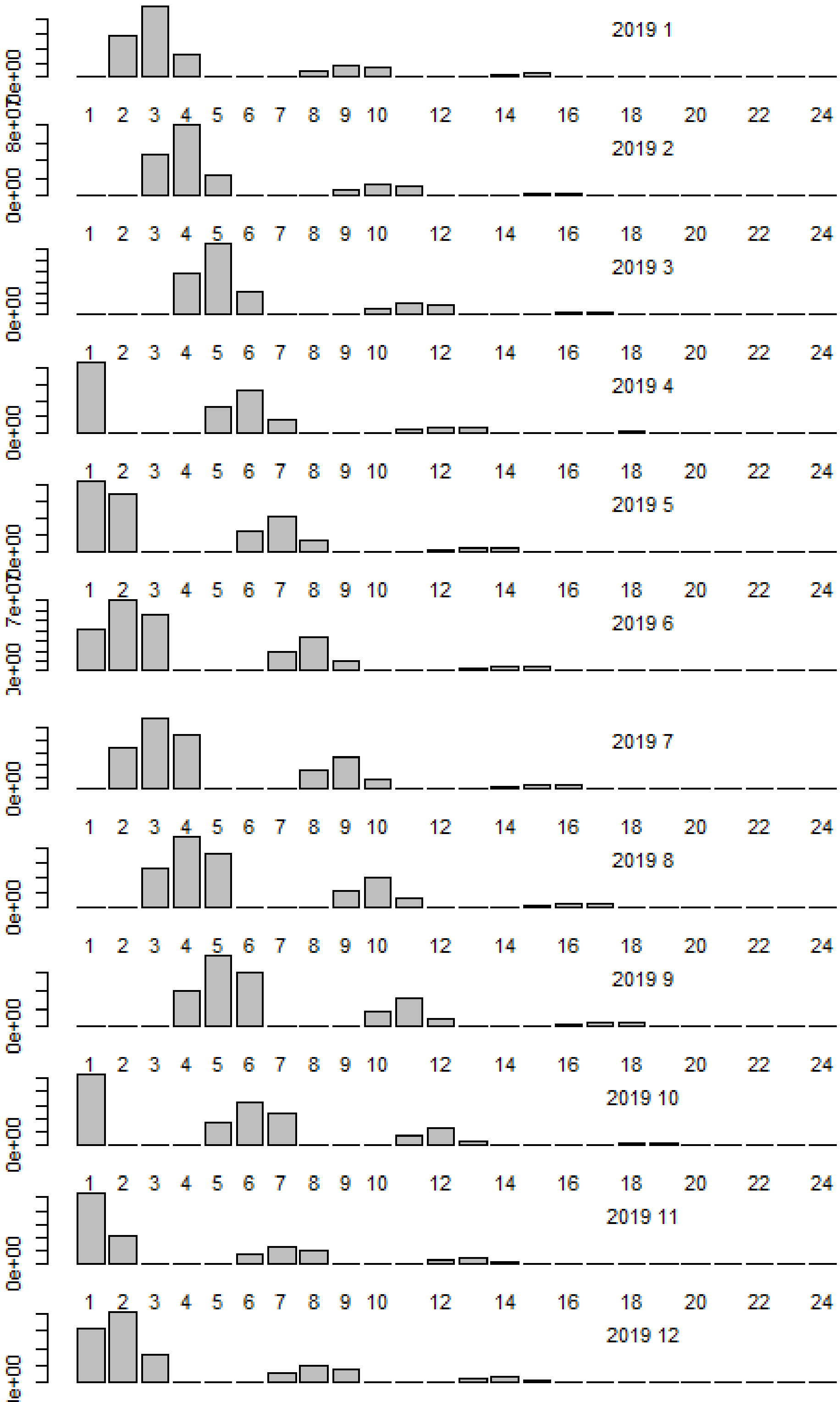
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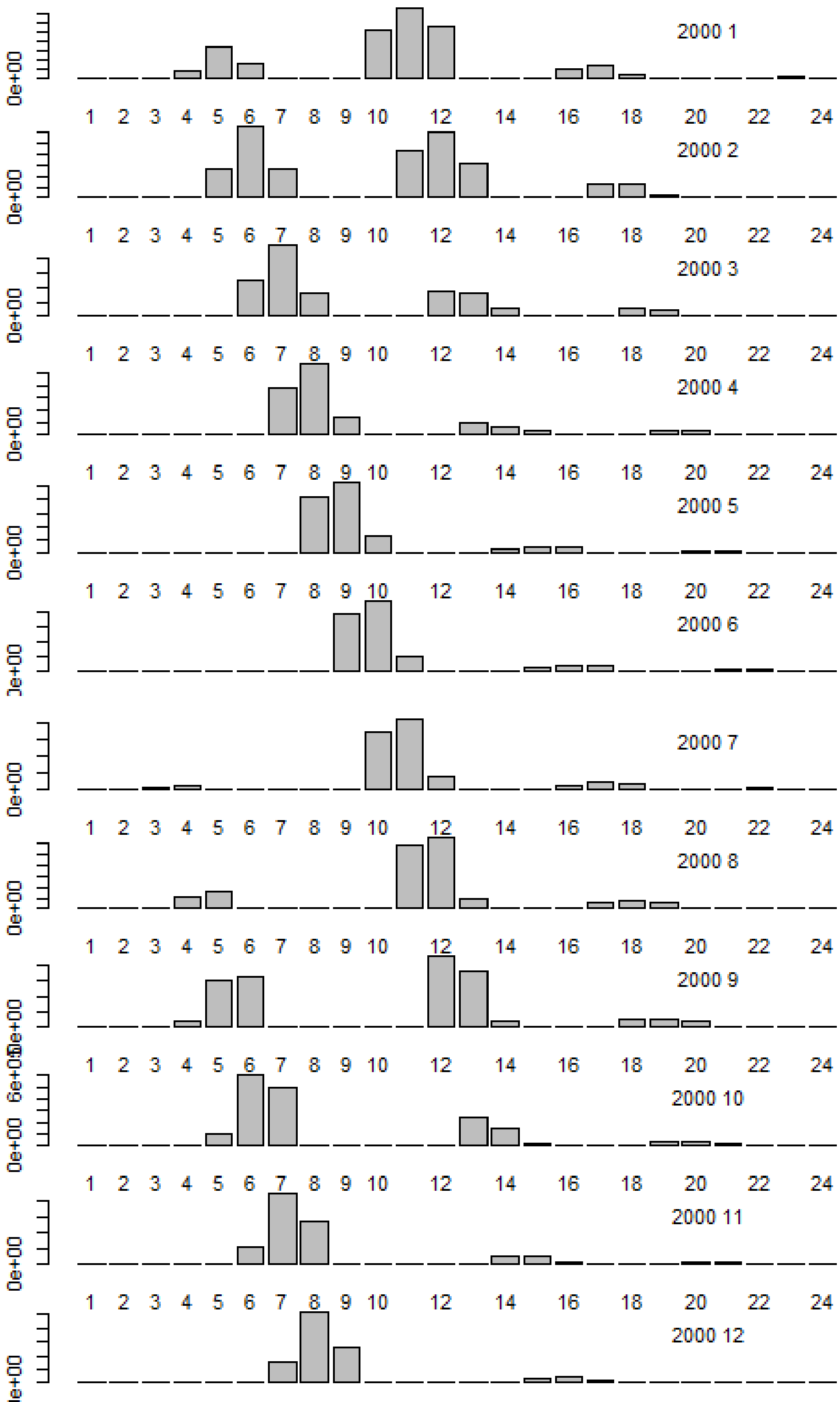
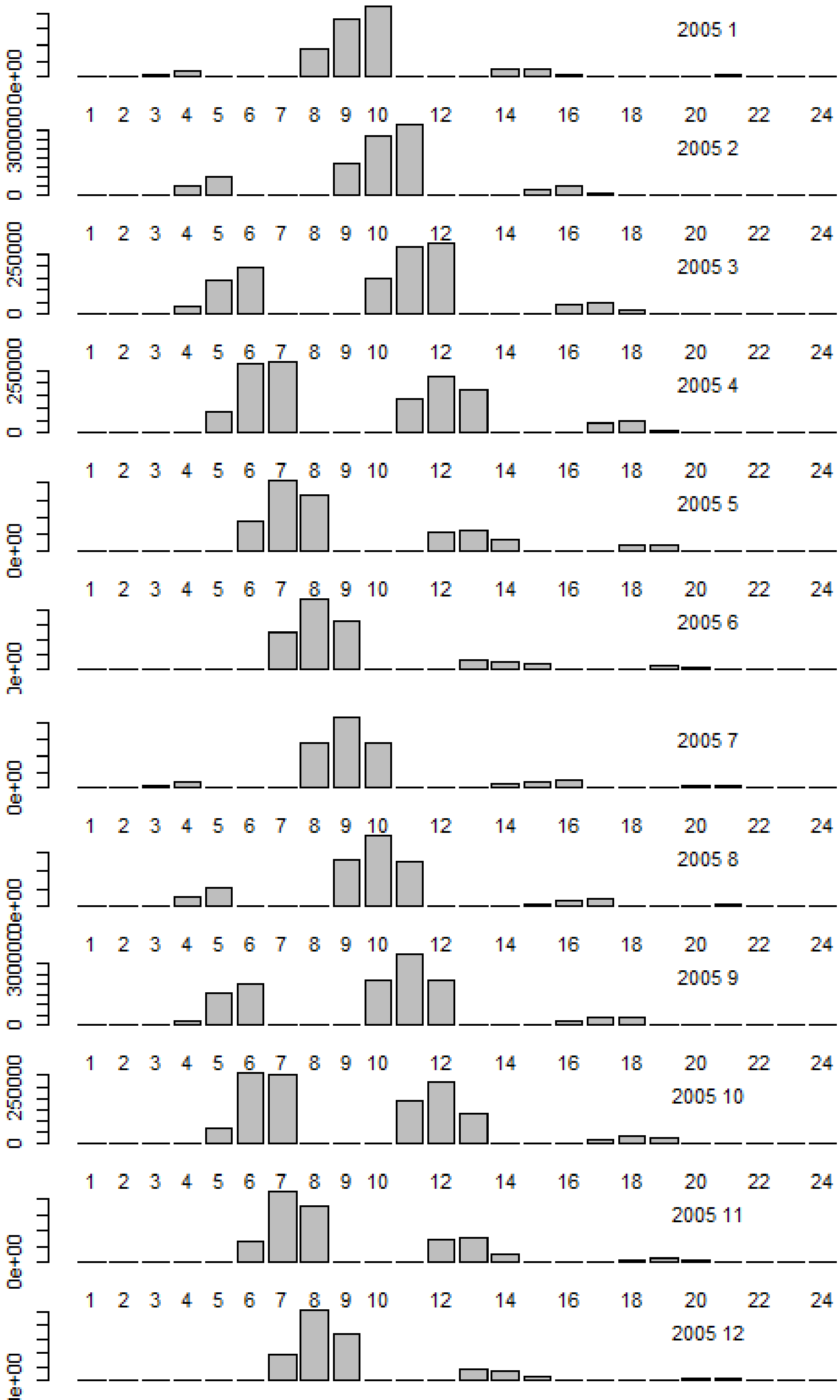
Figure 12. Whole Catch in number at age by YEAR.MONTH.

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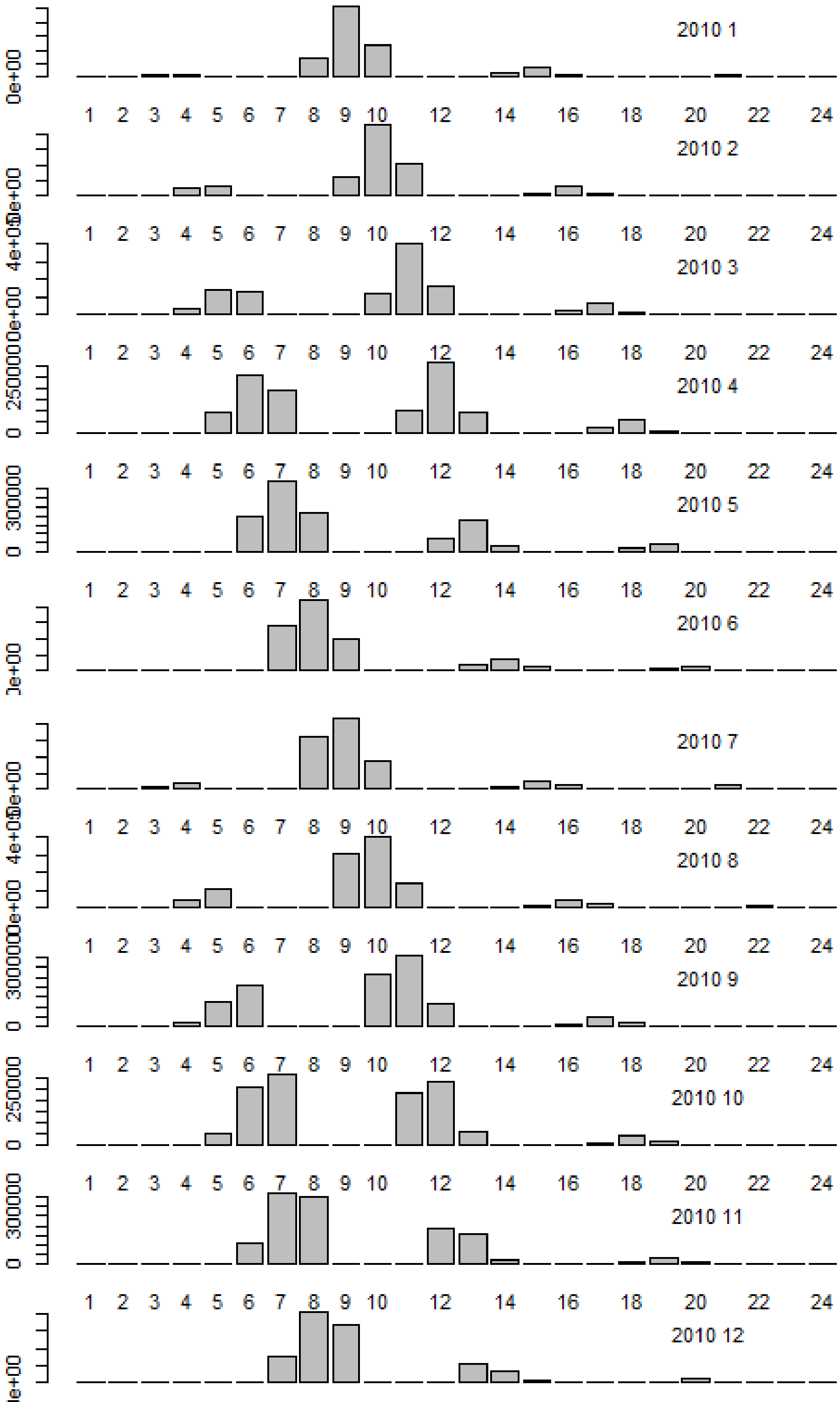
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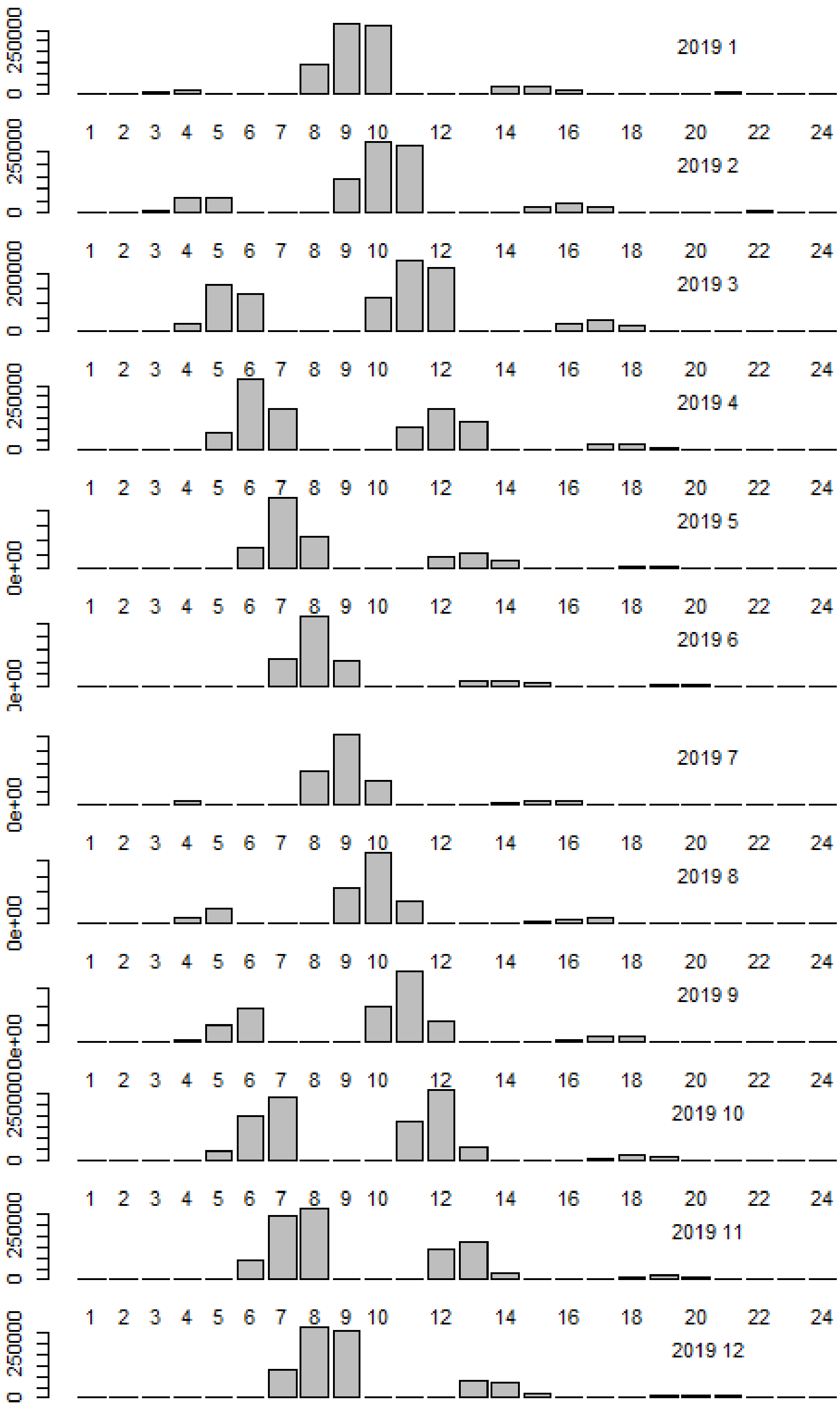
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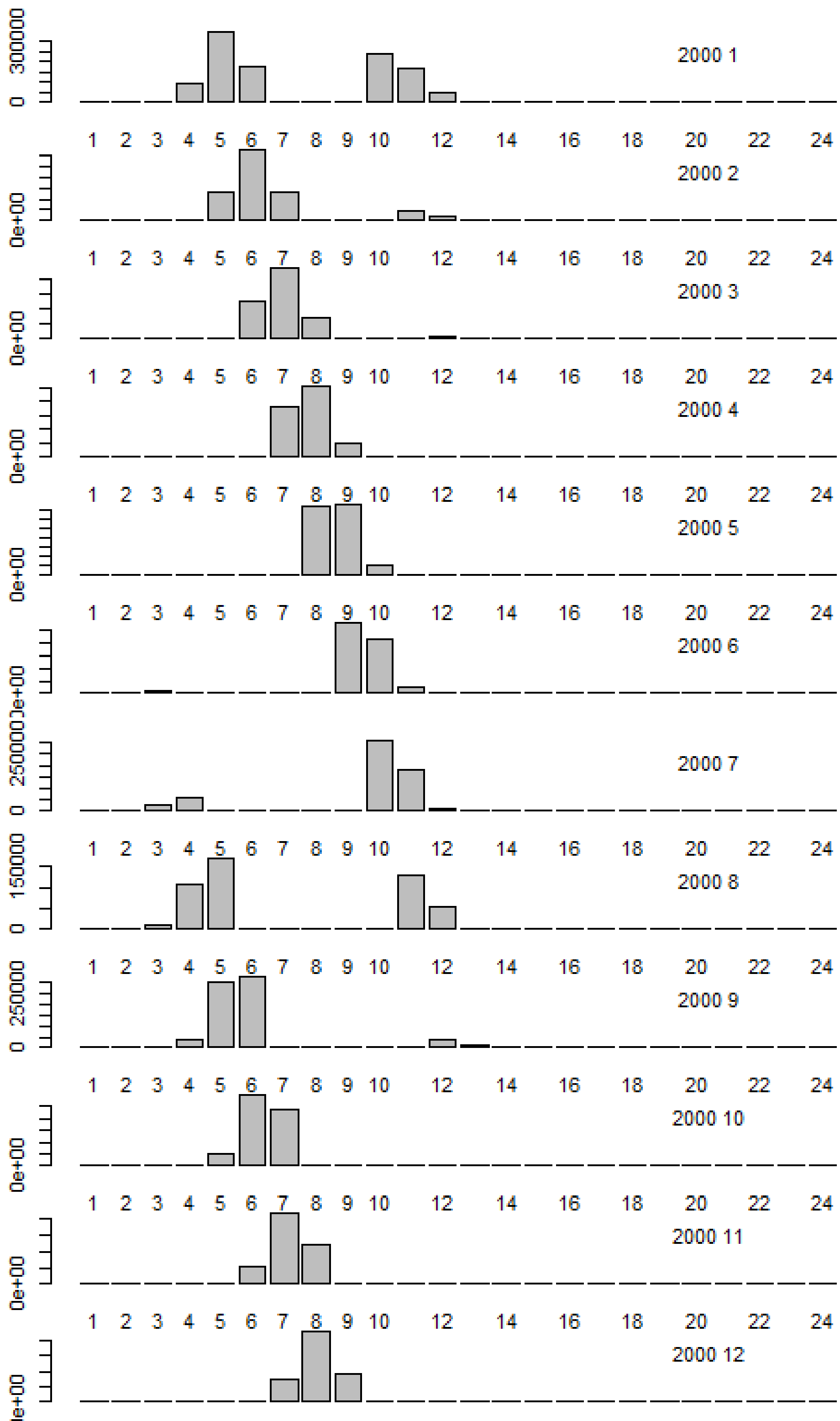
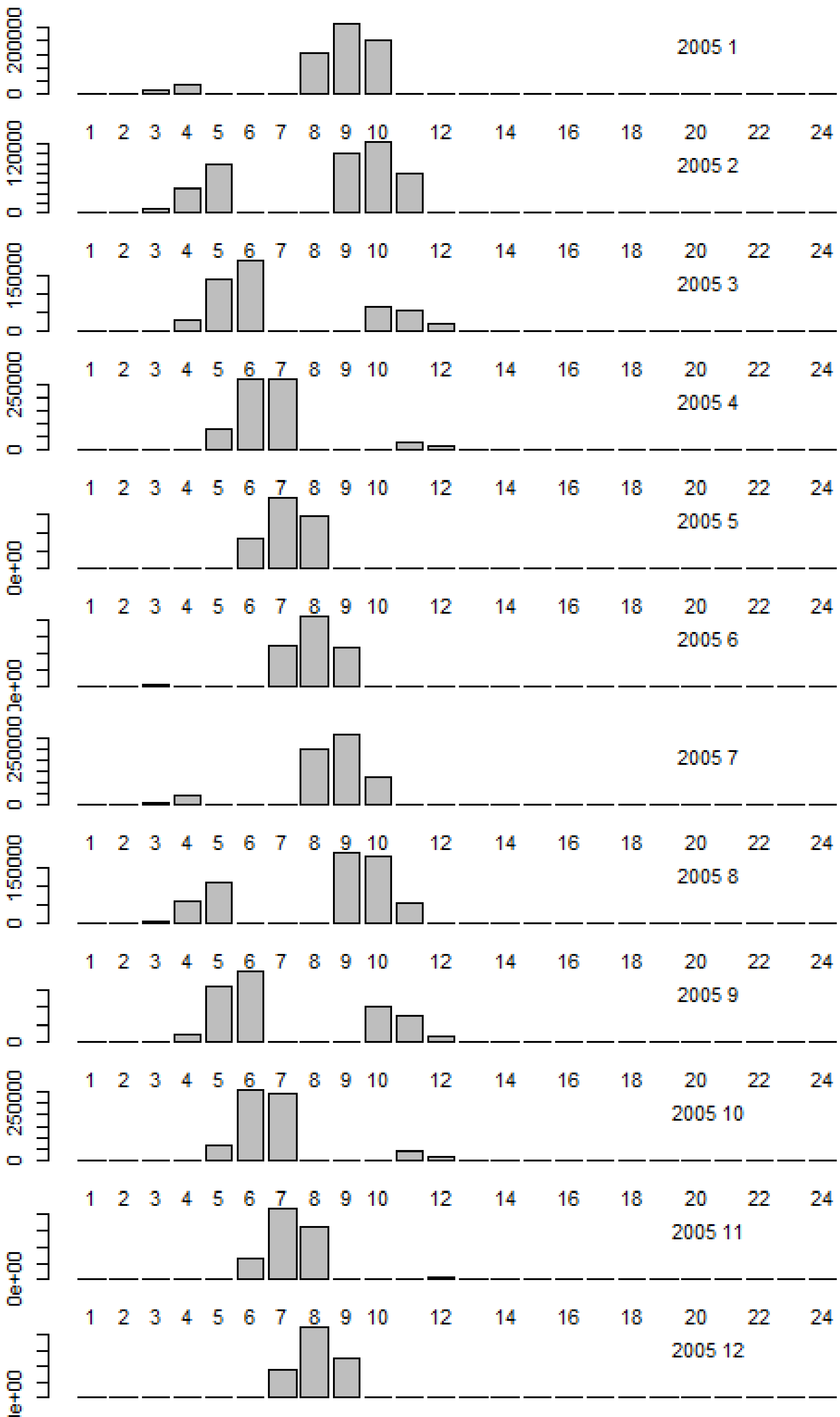
Figure 13. Fleet 1 Catch in number at age by YEAR.MONTH.

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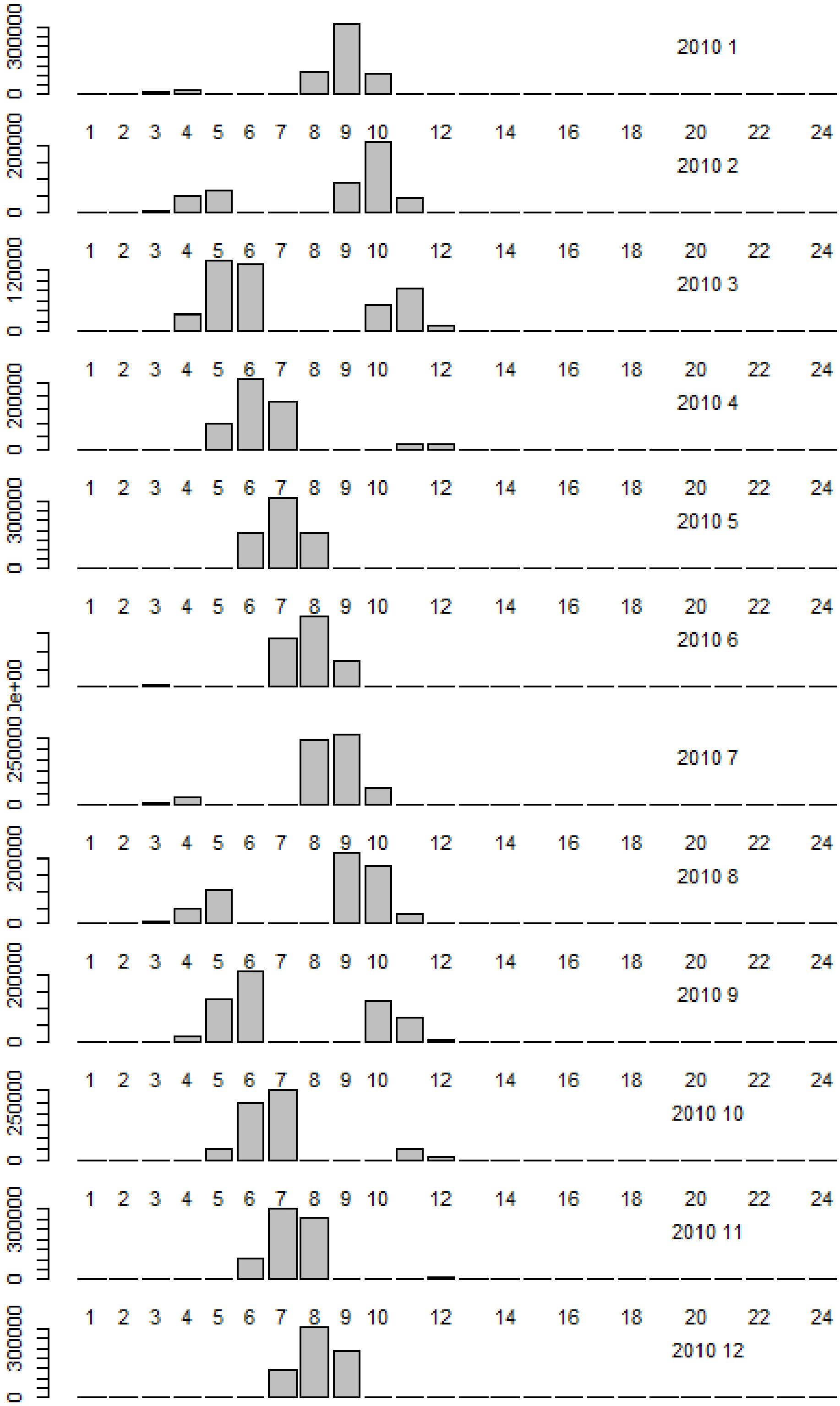
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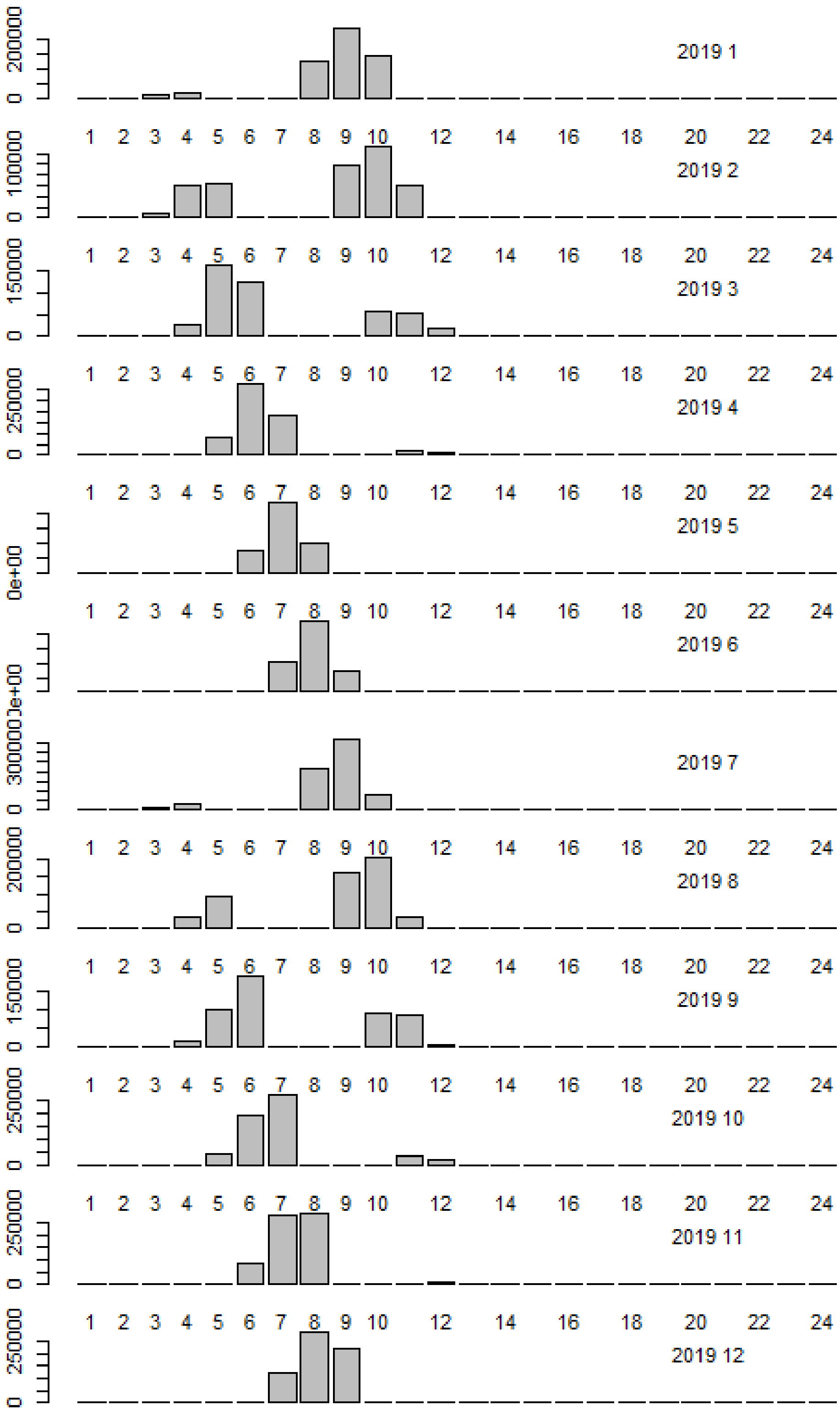
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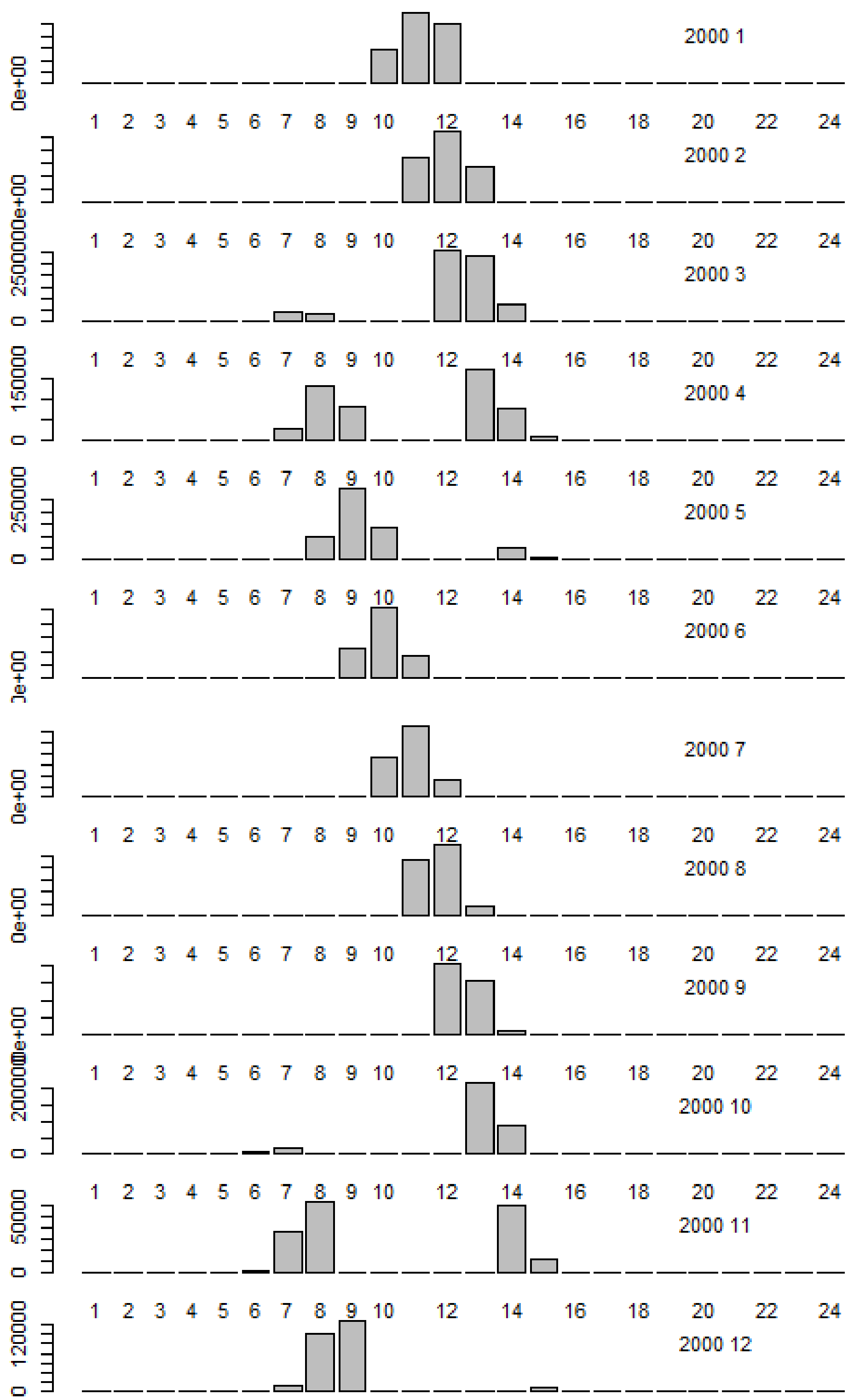
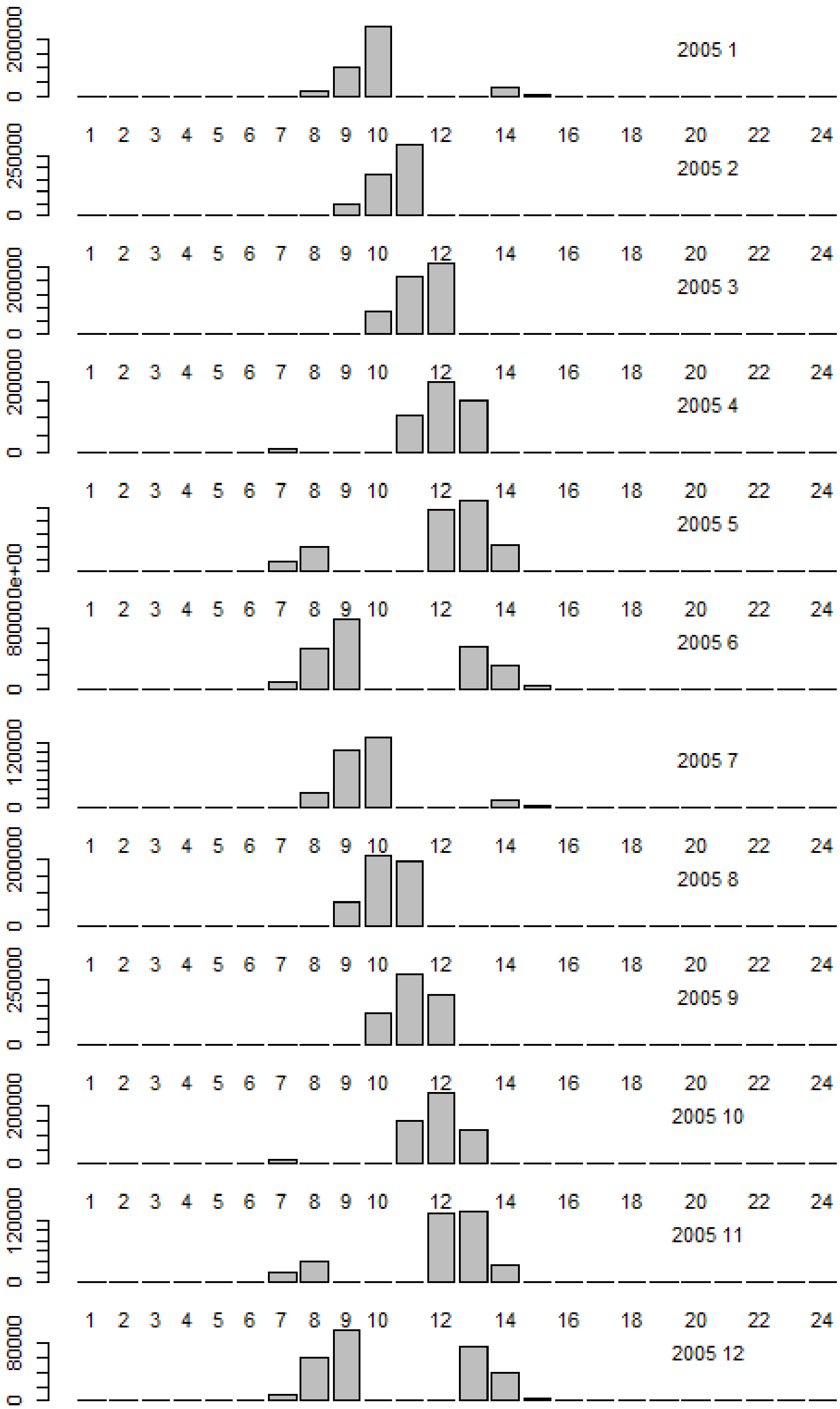
Figure 14. Fleet 2 Catch in number at age by YEAR.MONTH.

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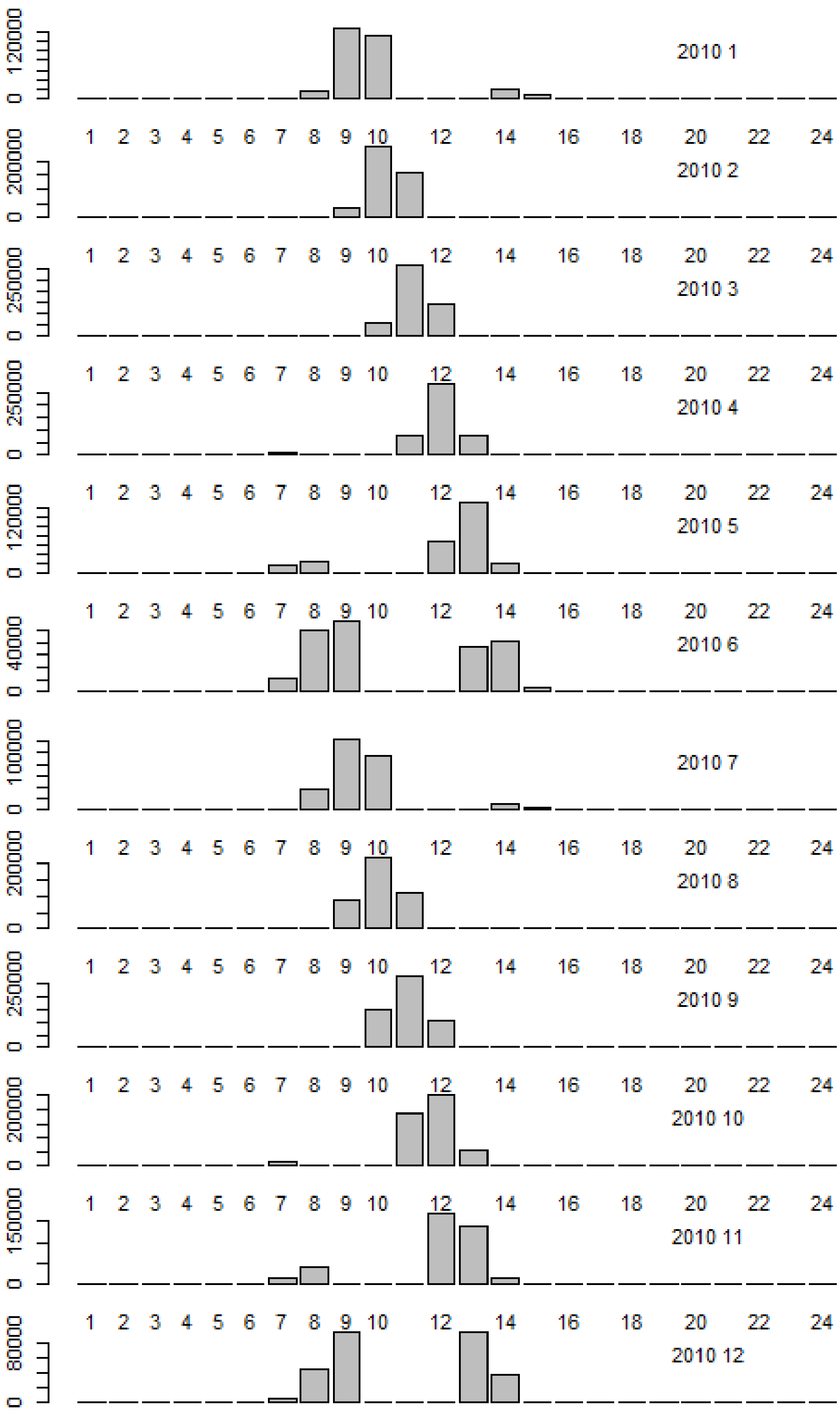
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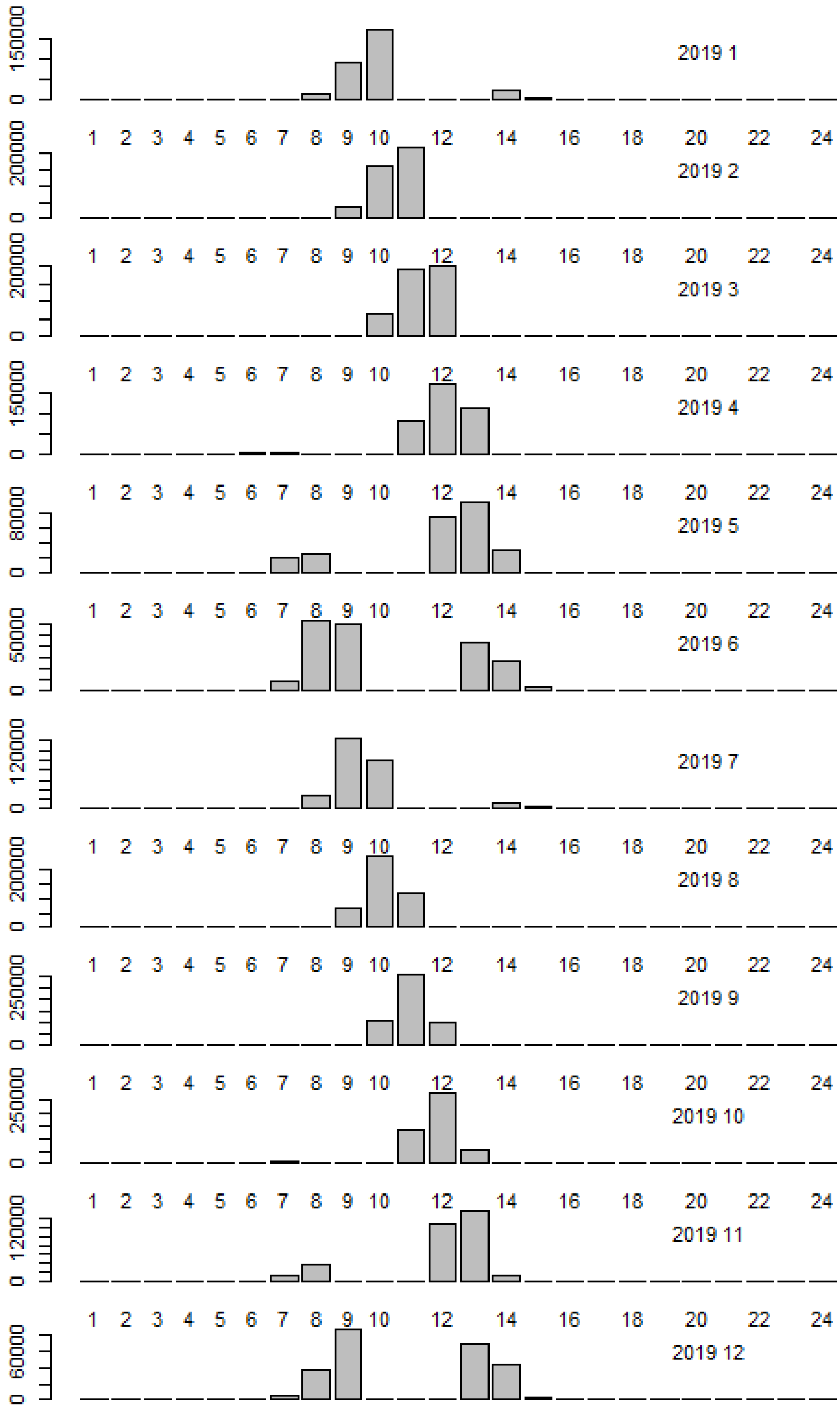

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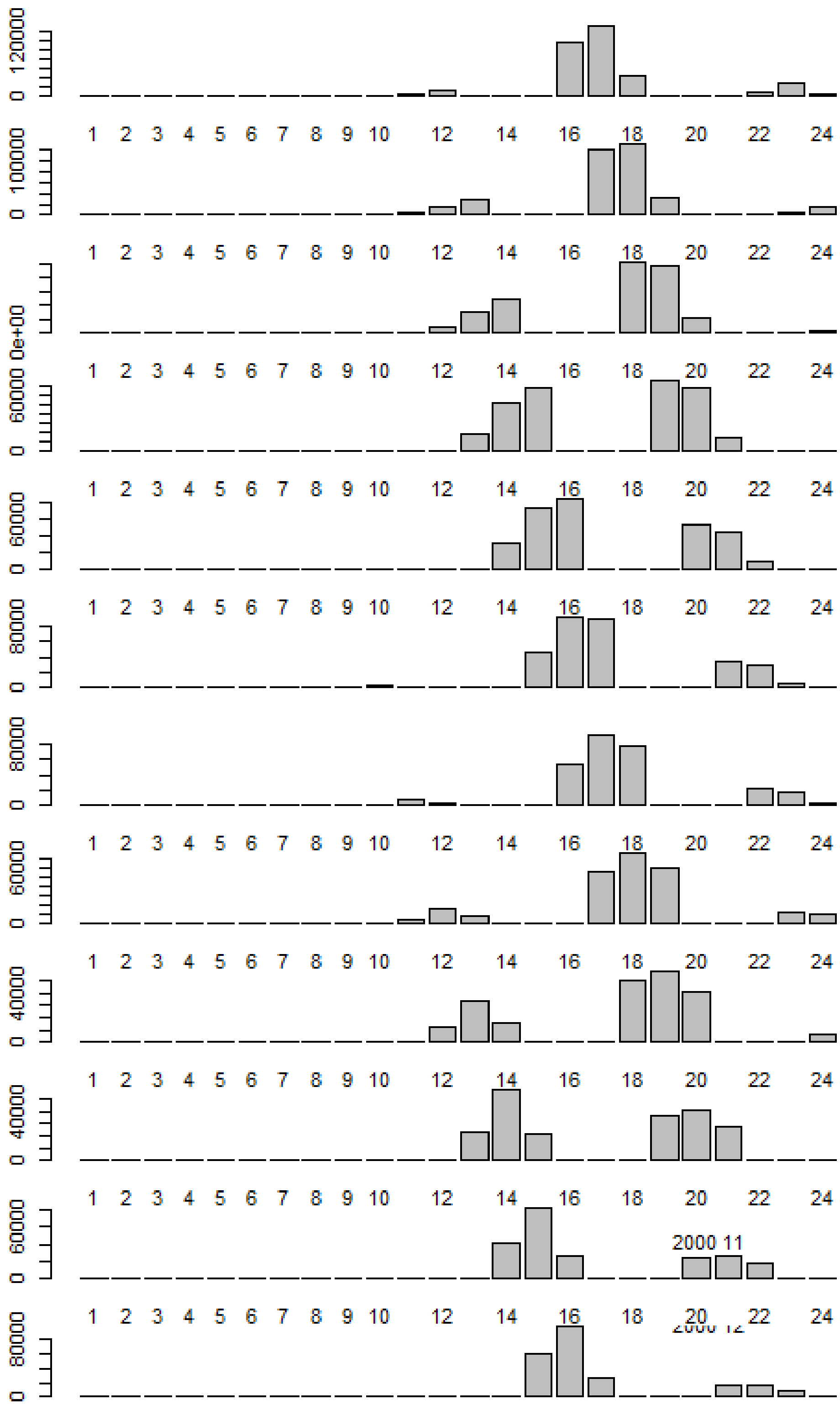
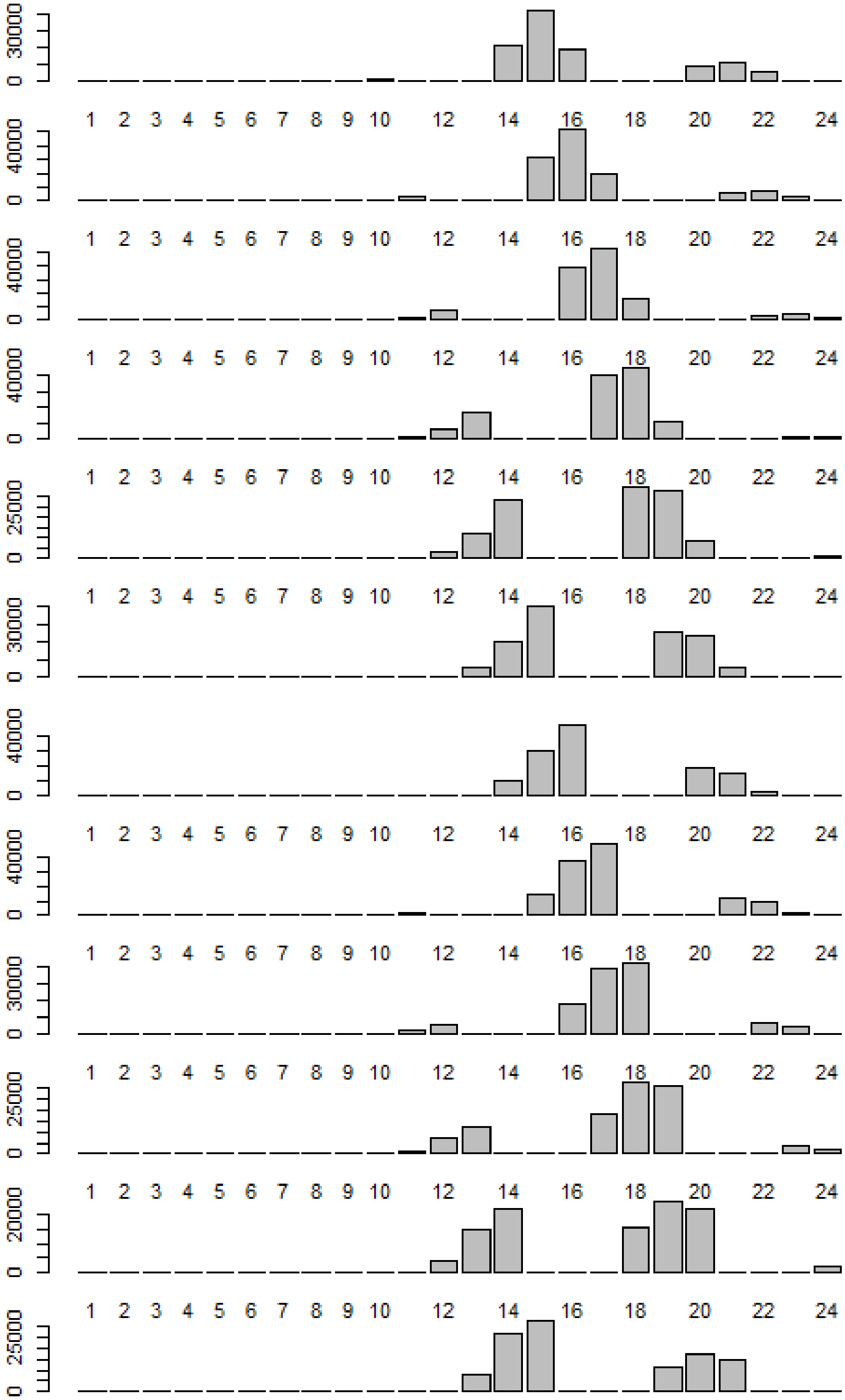
Figure 15. Fleet 3 Catch in number at age by YEAR.MONTH.

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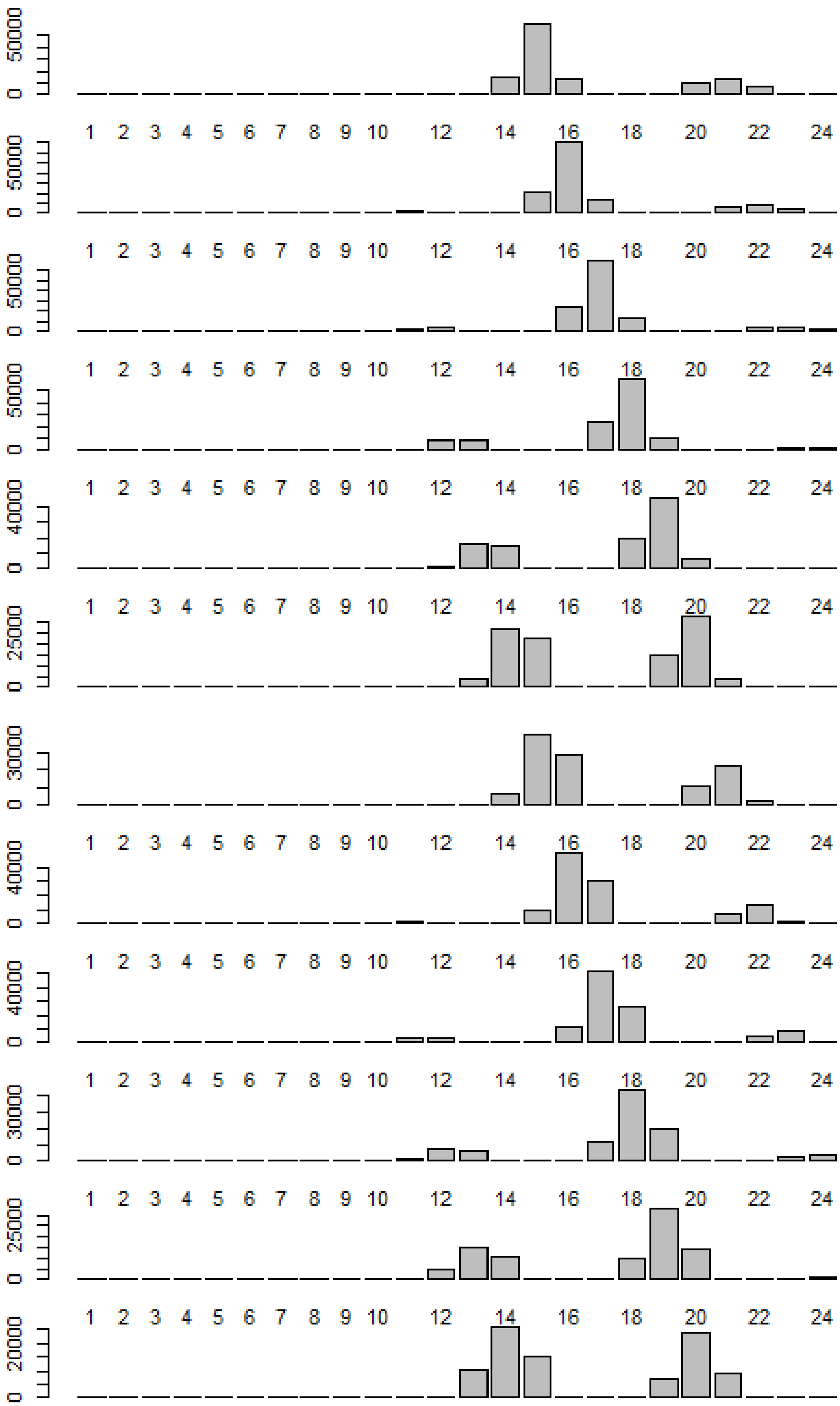
0 40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 30000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 30000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 20000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000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50000
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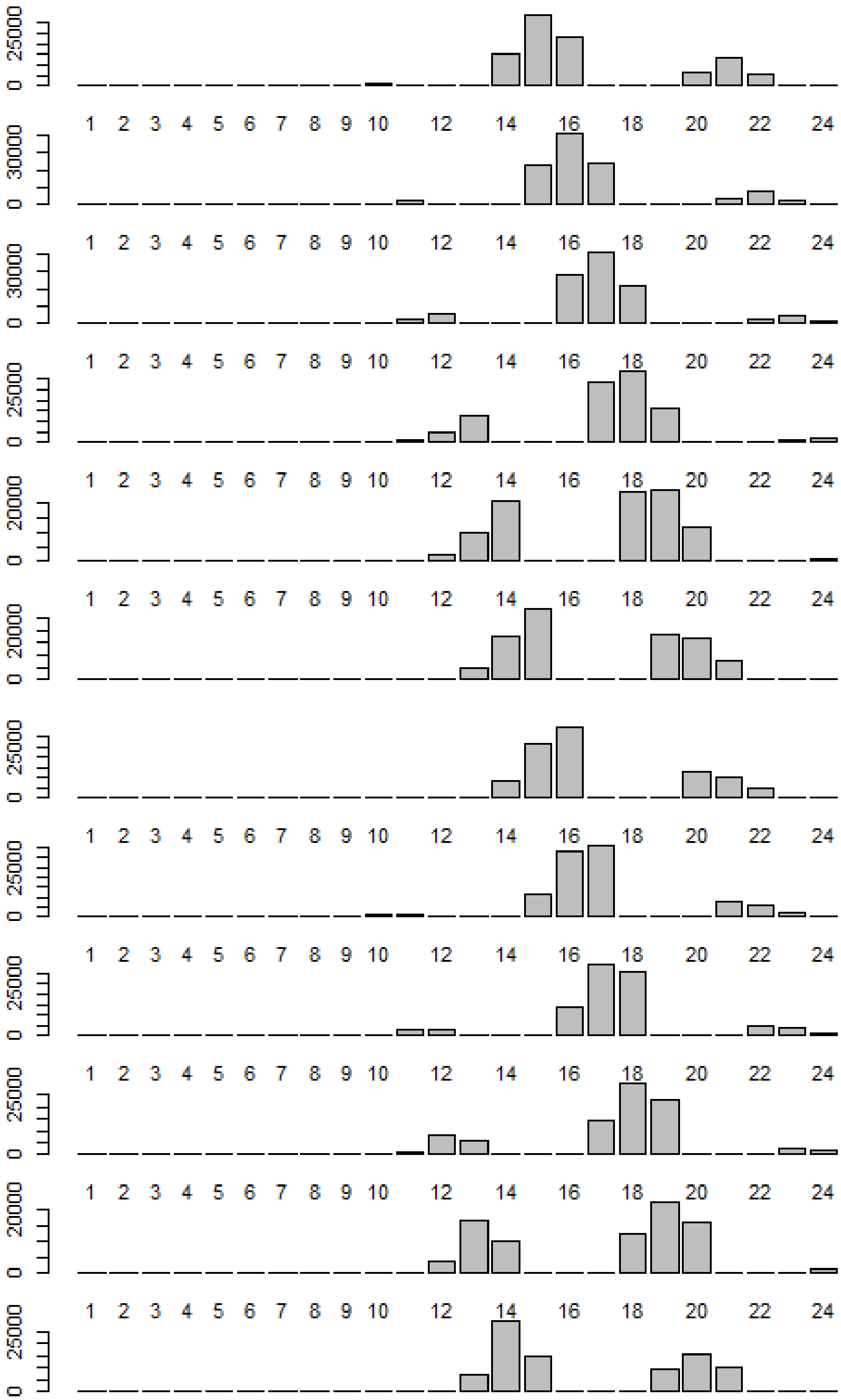
0
50000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
50000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
50000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
25000
0
30000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
40000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
30000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0
20000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0 30000
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0 30000
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0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 20000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 20000
0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 20000
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 22 24
0 25000

Figure 16. Length-age key.

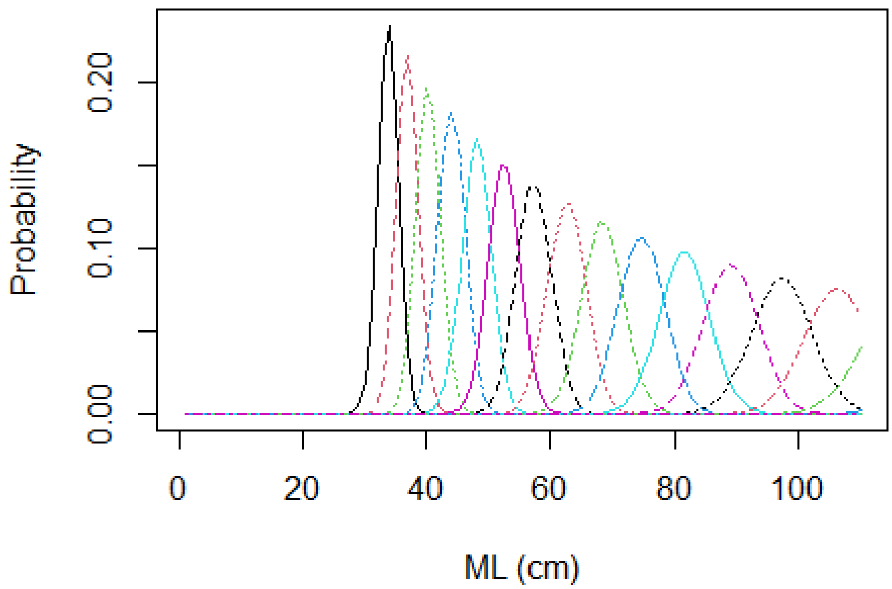
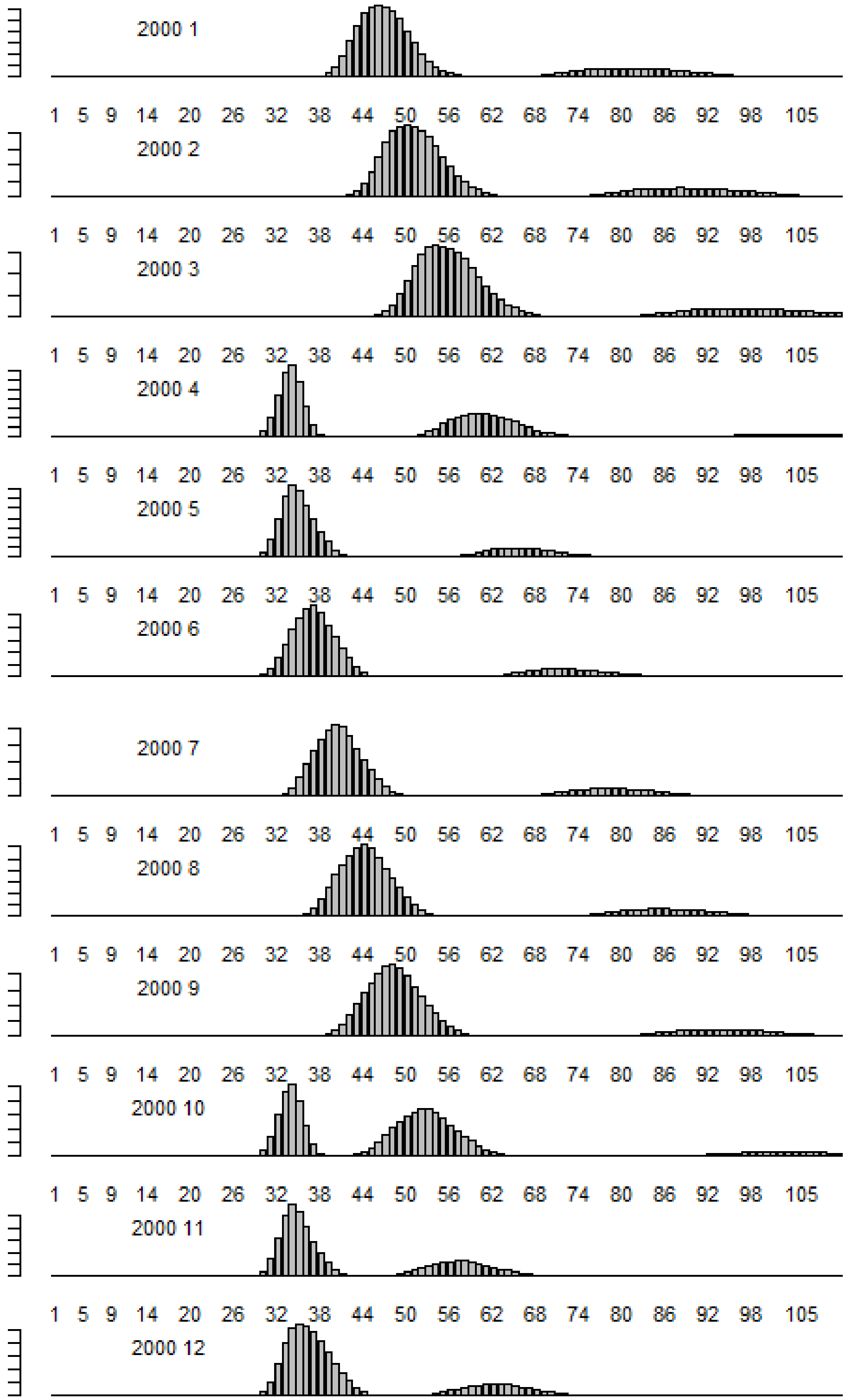
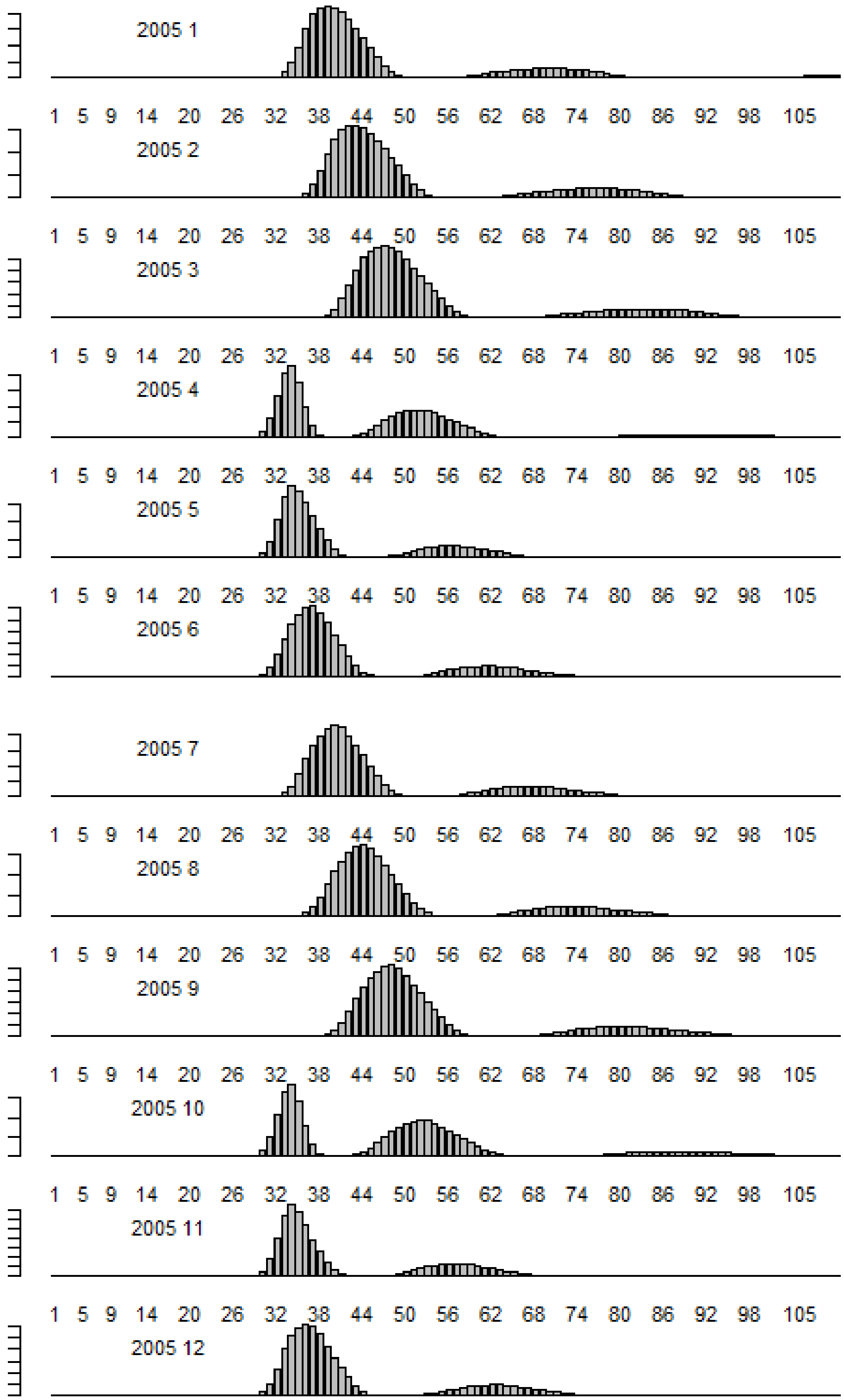


Figure 17. Length frequency by YEAR.MONTH.

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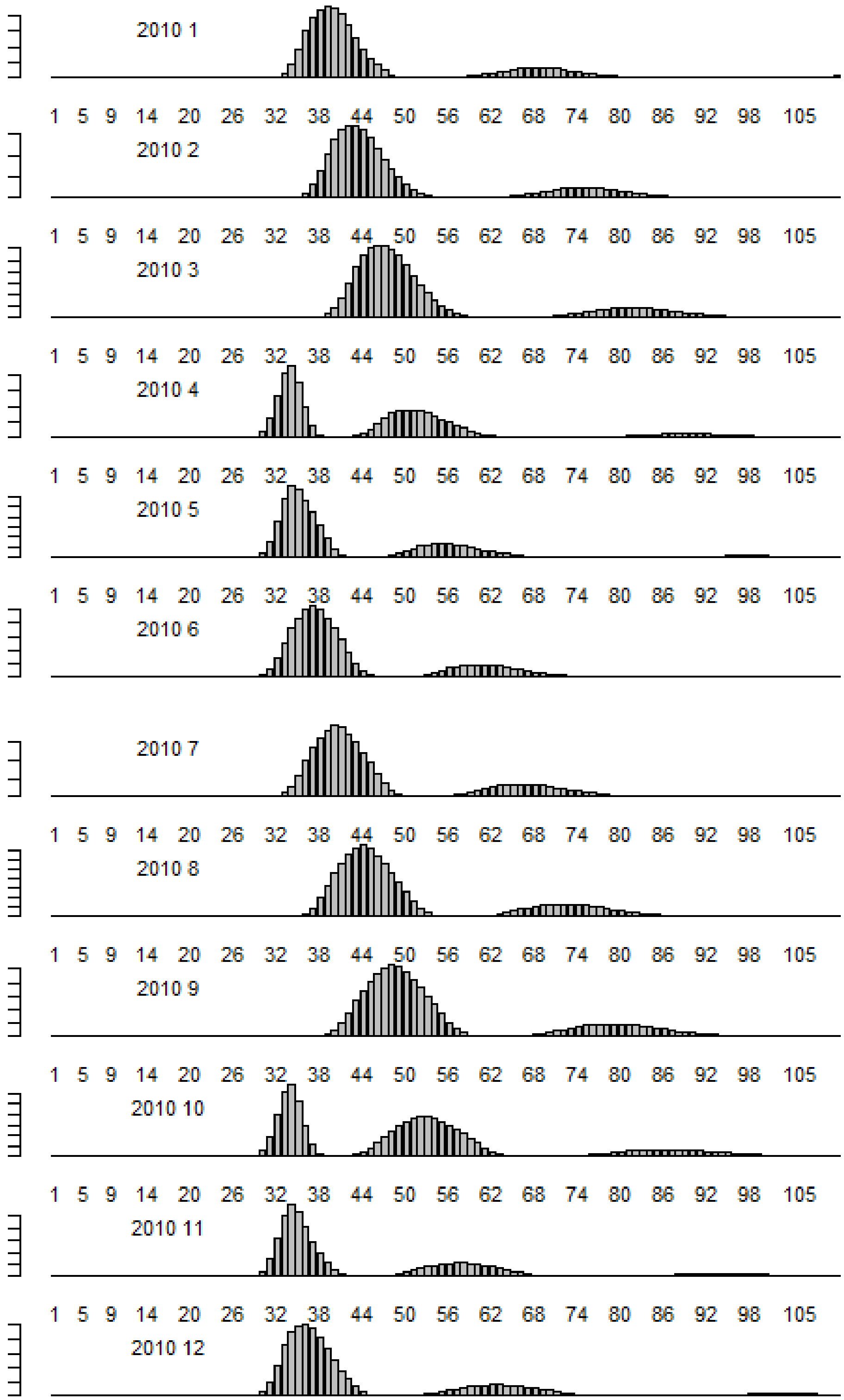
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
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
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

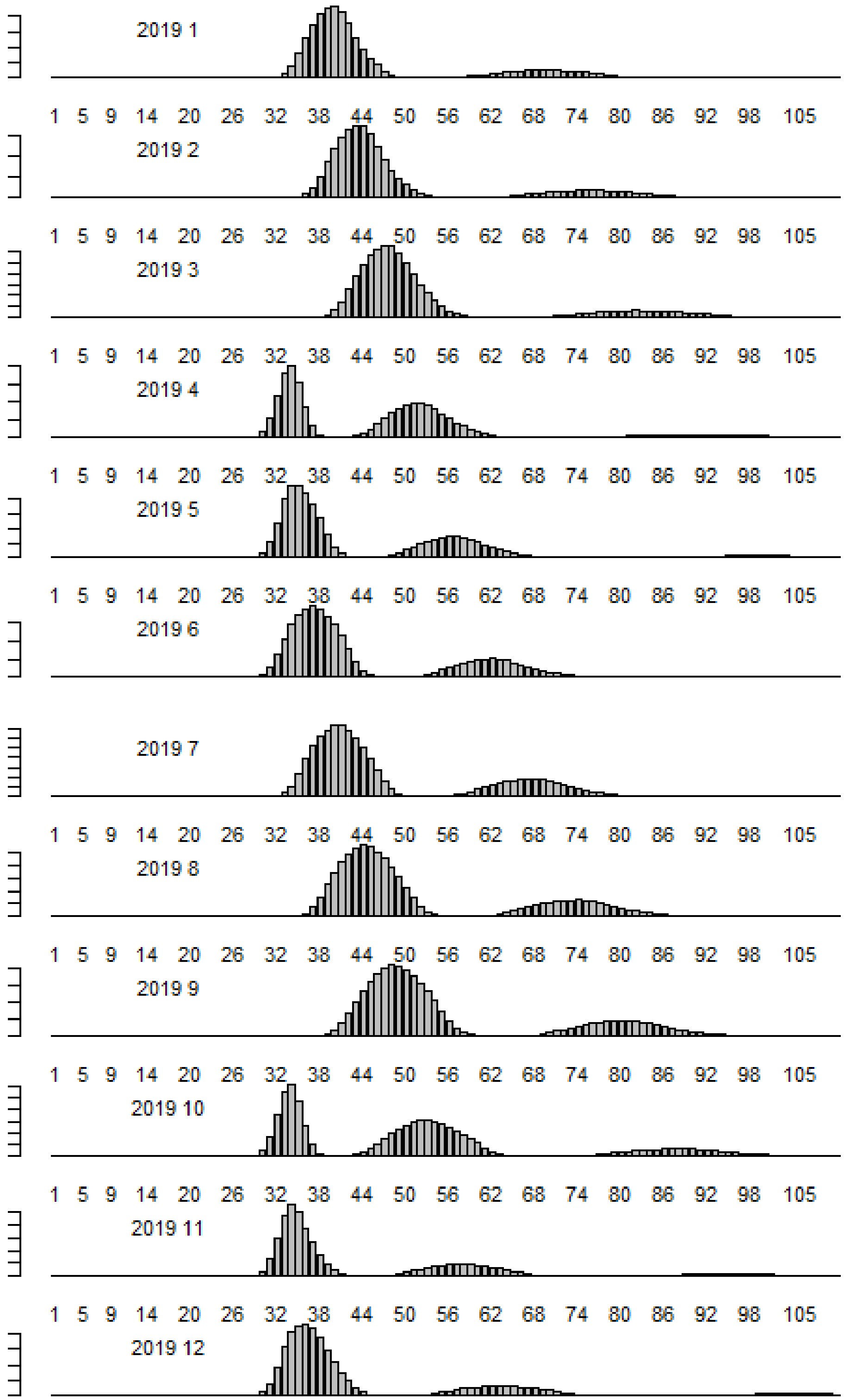
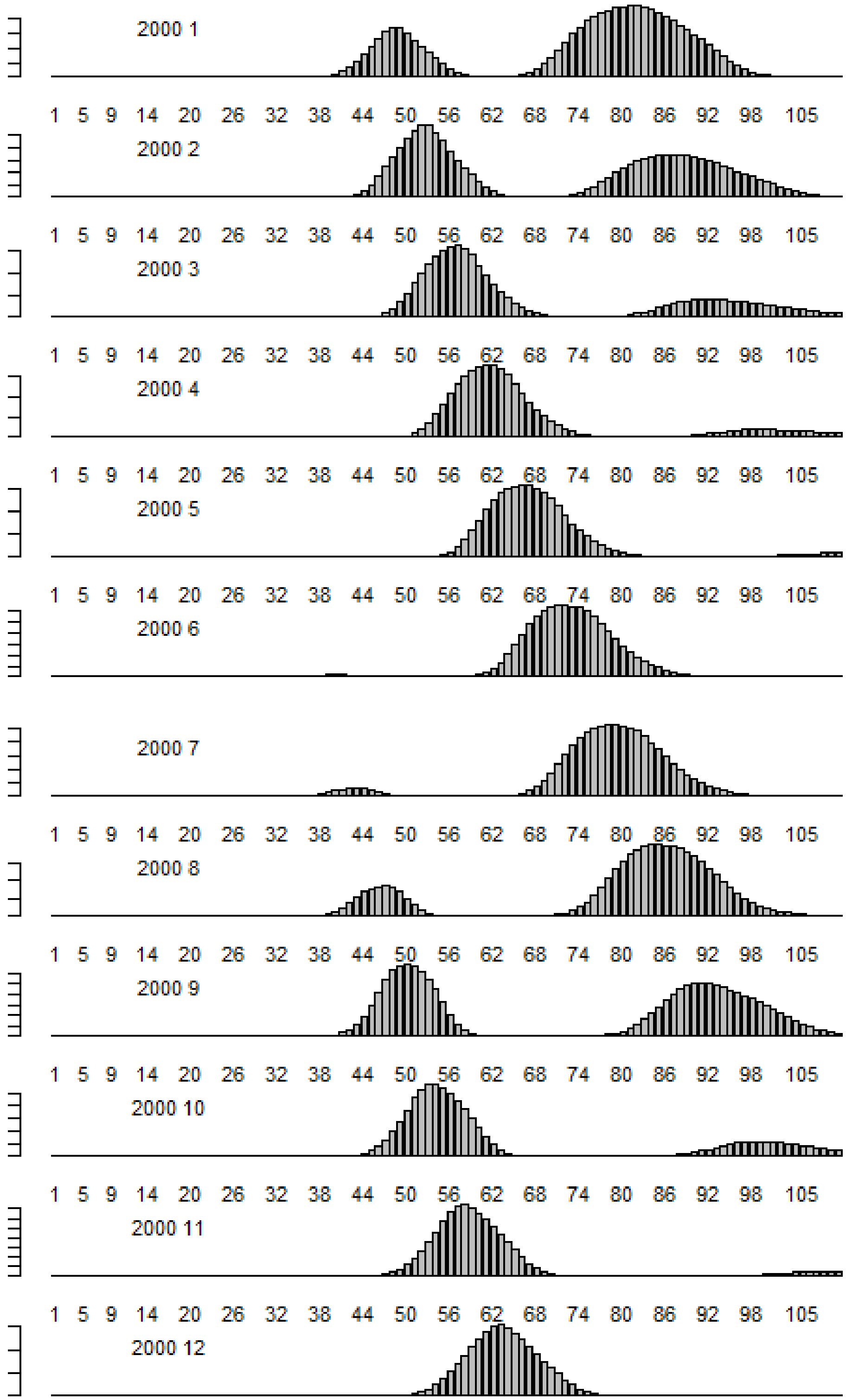
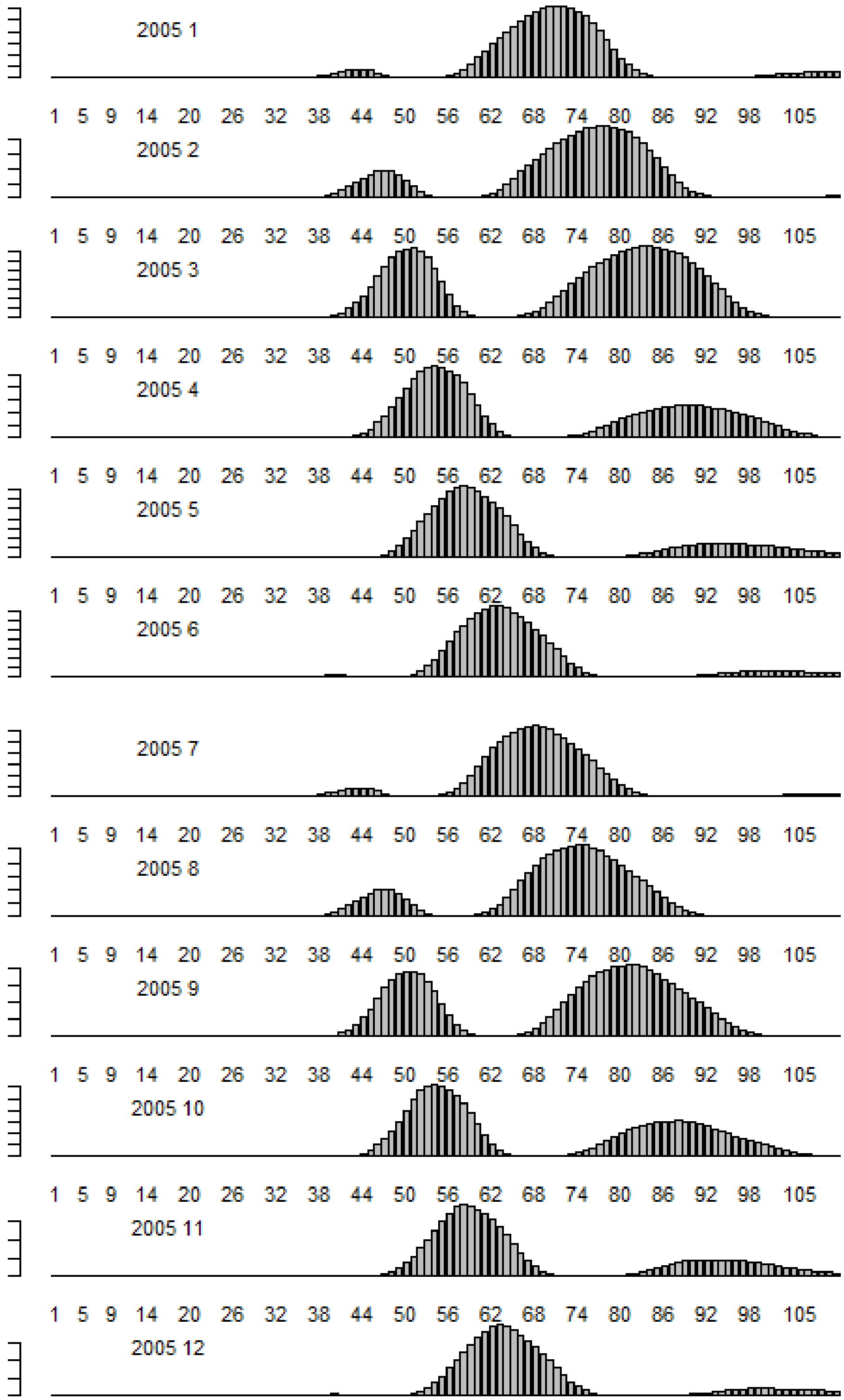

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105

Figure 18. Whole Catch in number at length by YEAR.MONTH.

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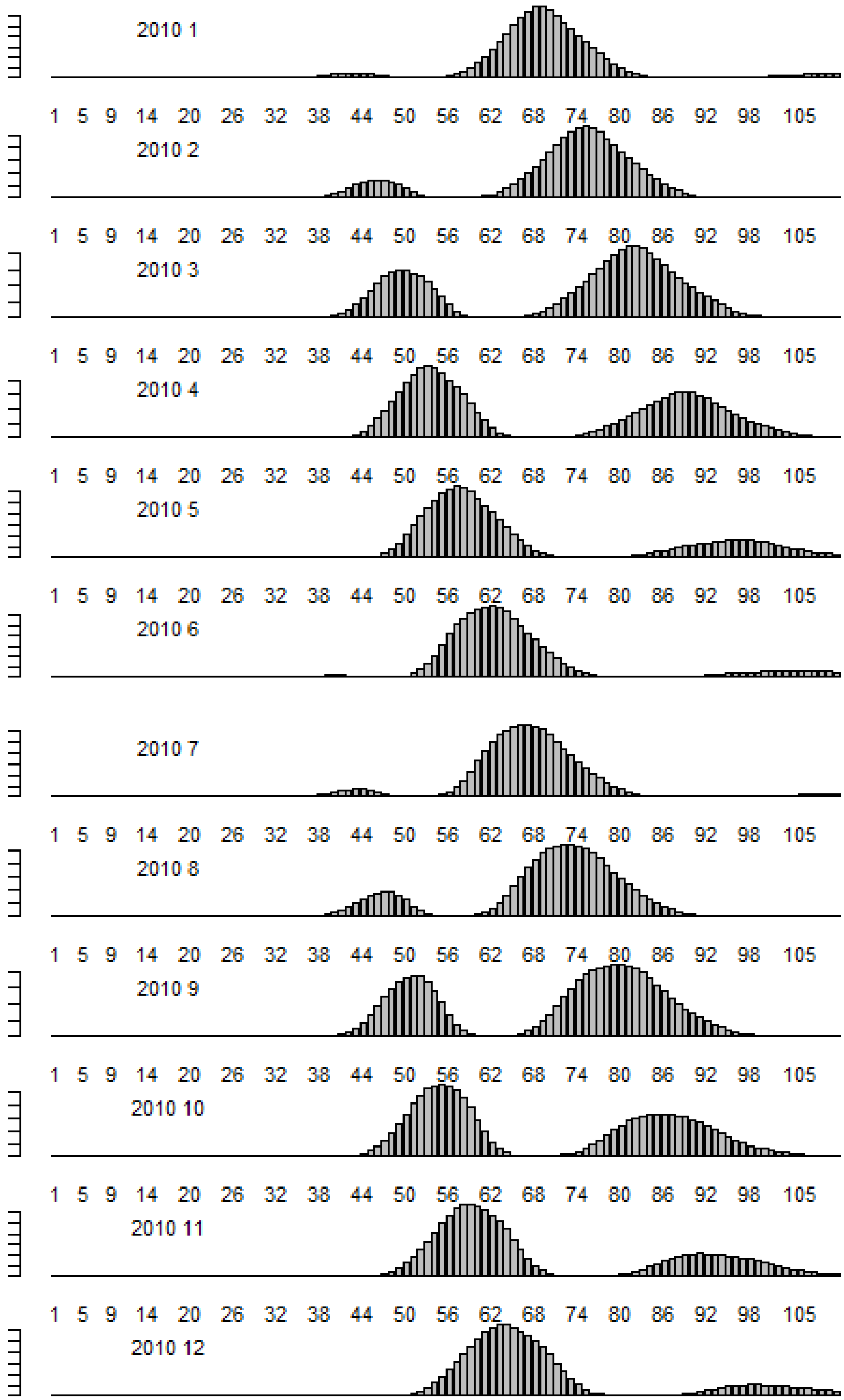
2005 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 6
2005 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 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
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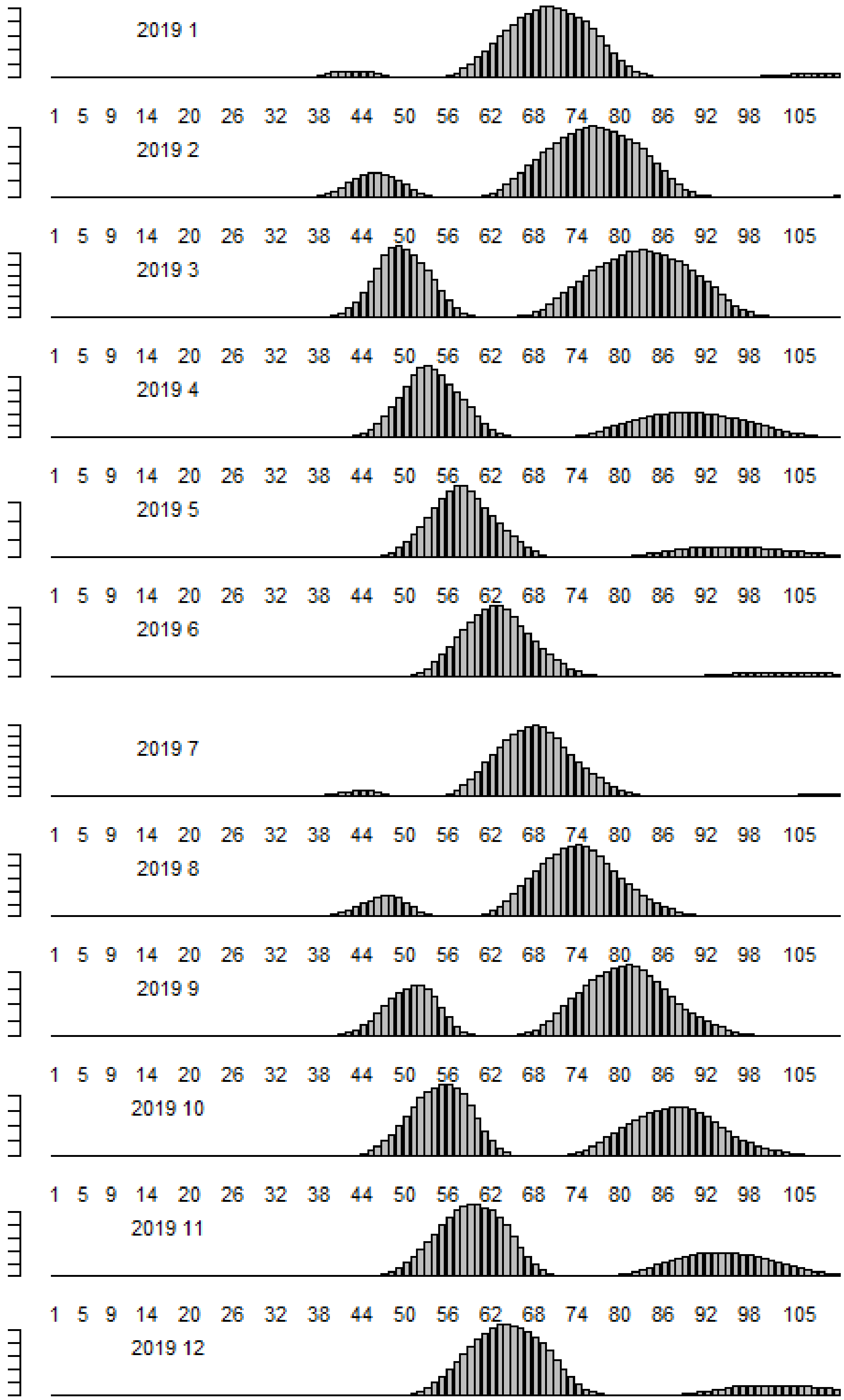
2010 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 6
2010 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 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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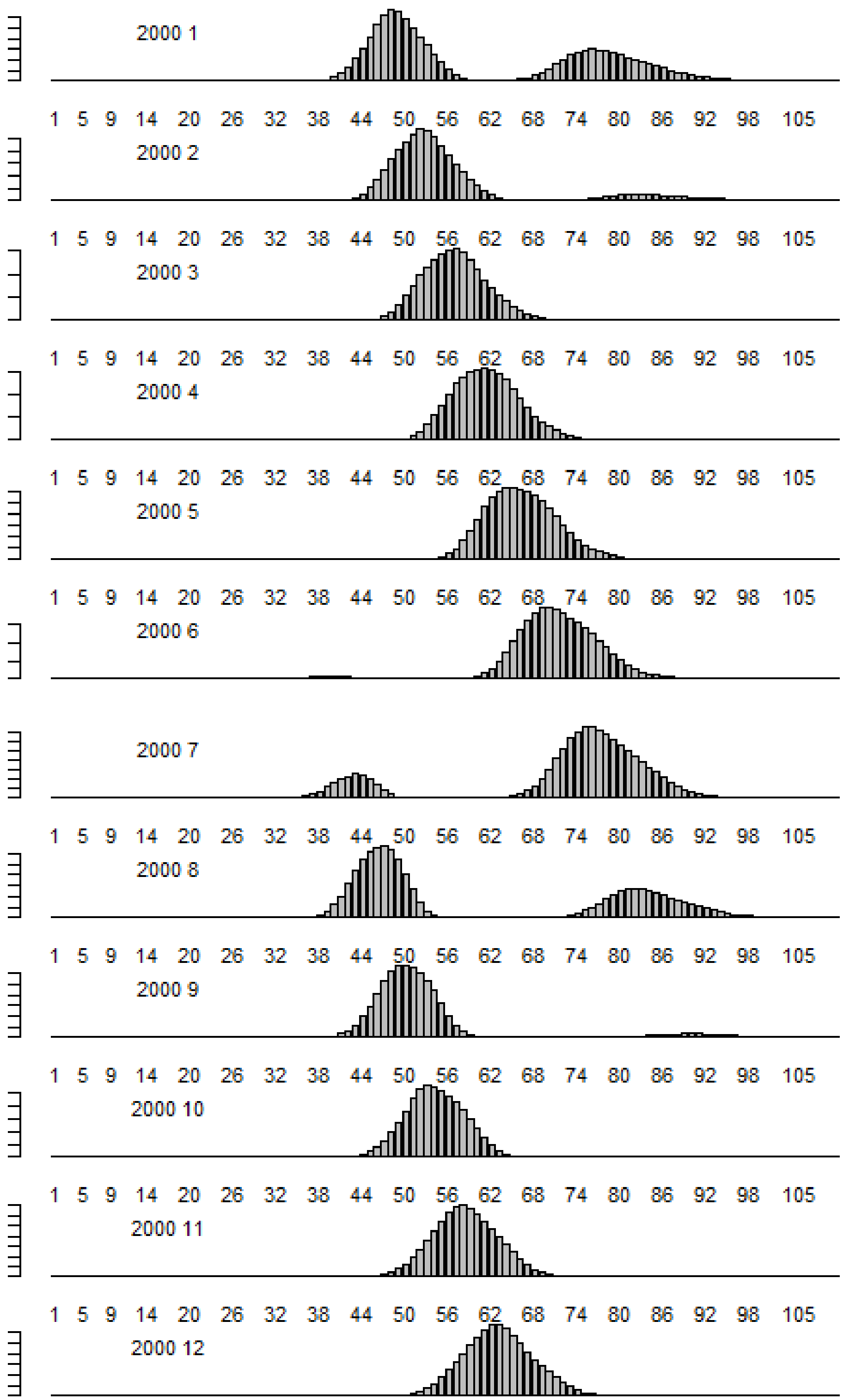
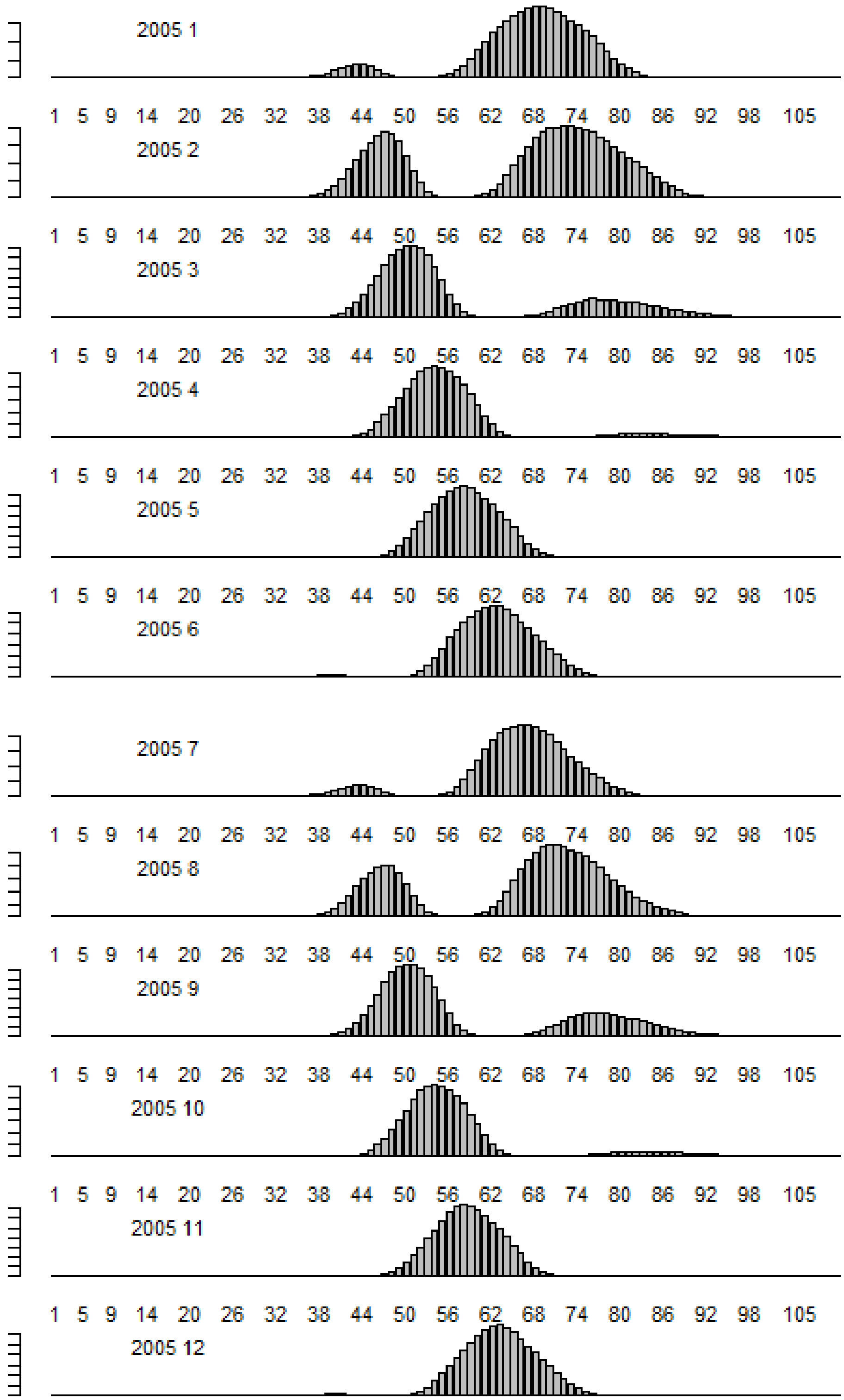
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12

Figure 19. Fleet 1 Catch in number at length by YEAR.MONTH.

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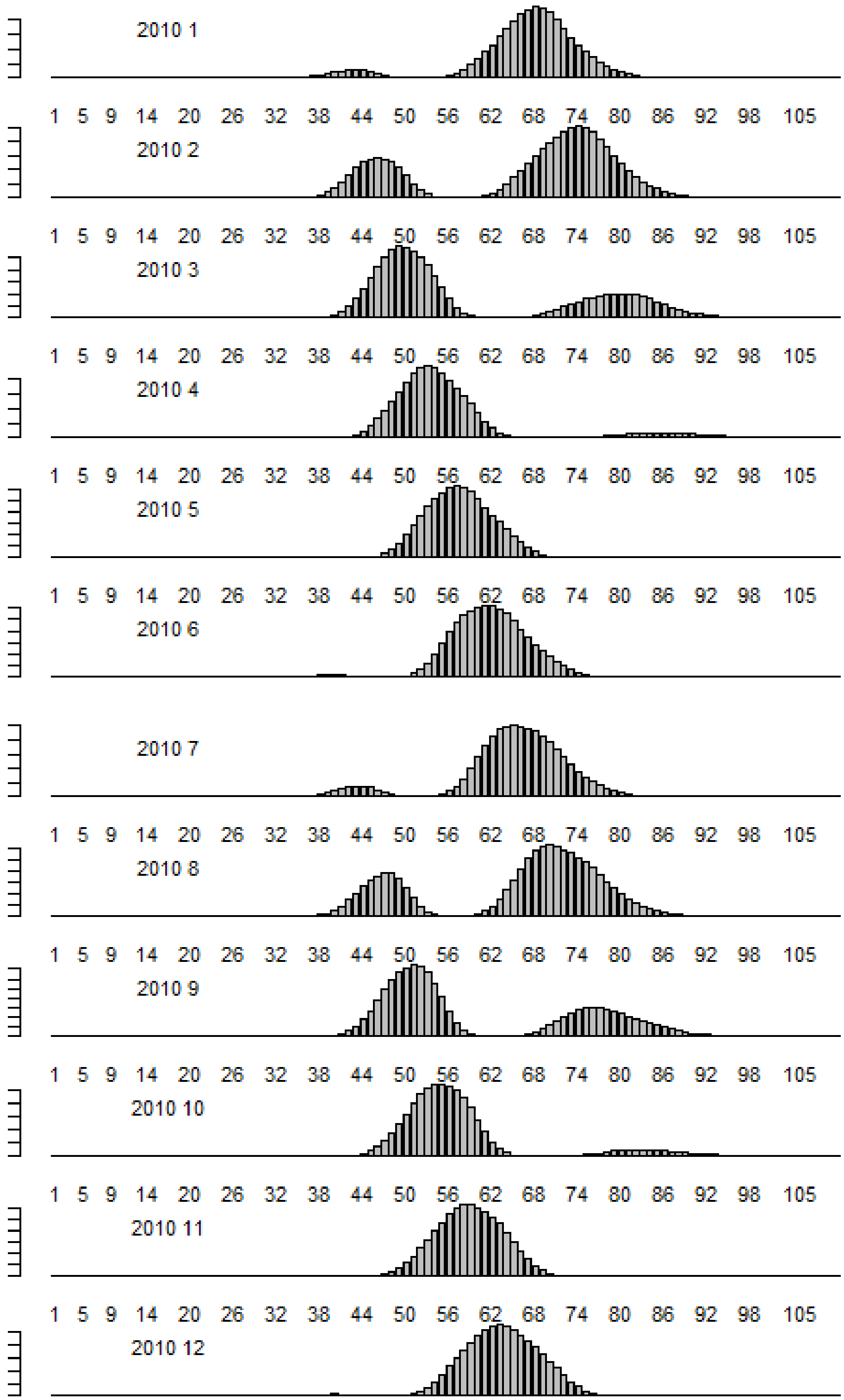
2005 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 6
2005 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74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

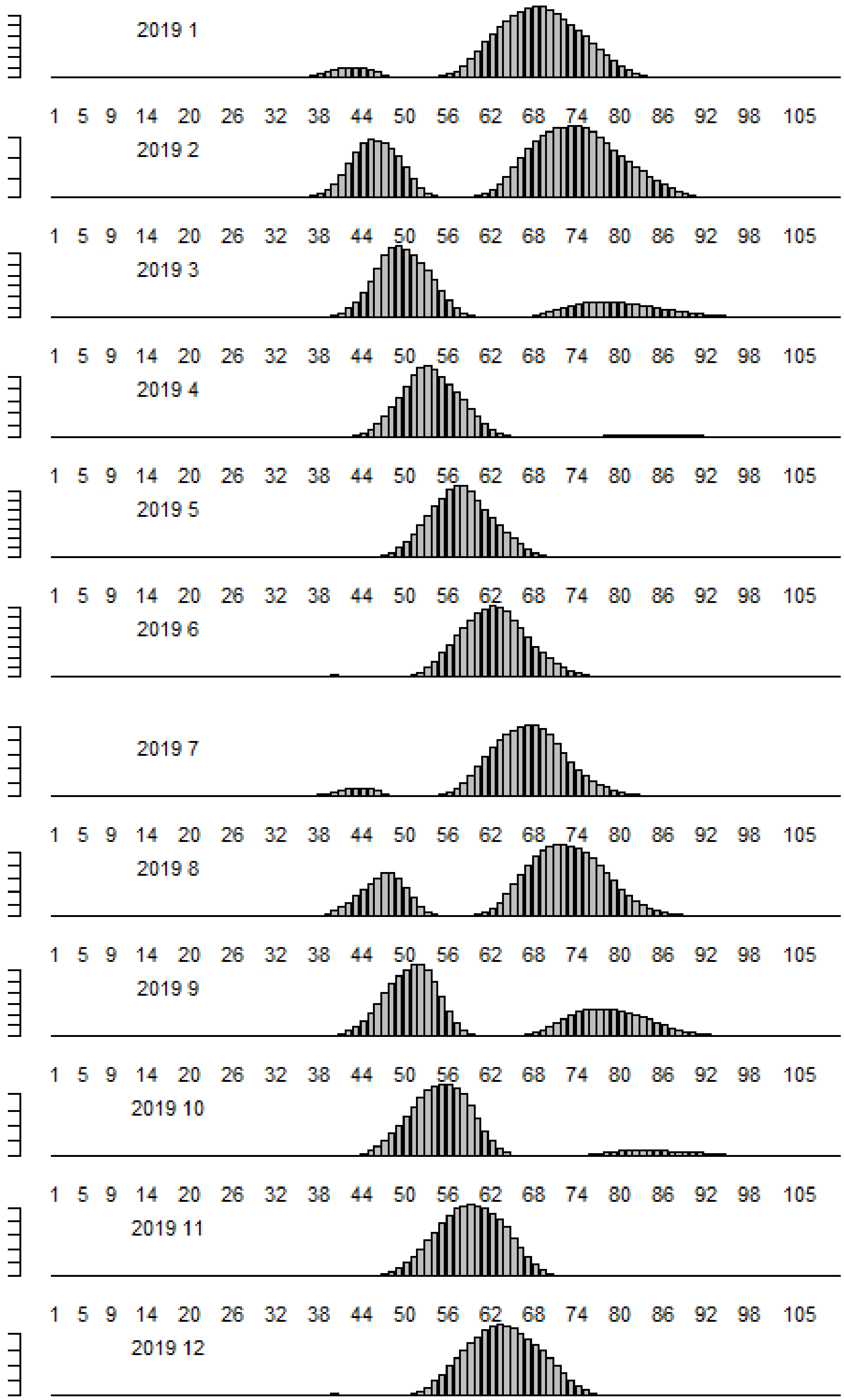
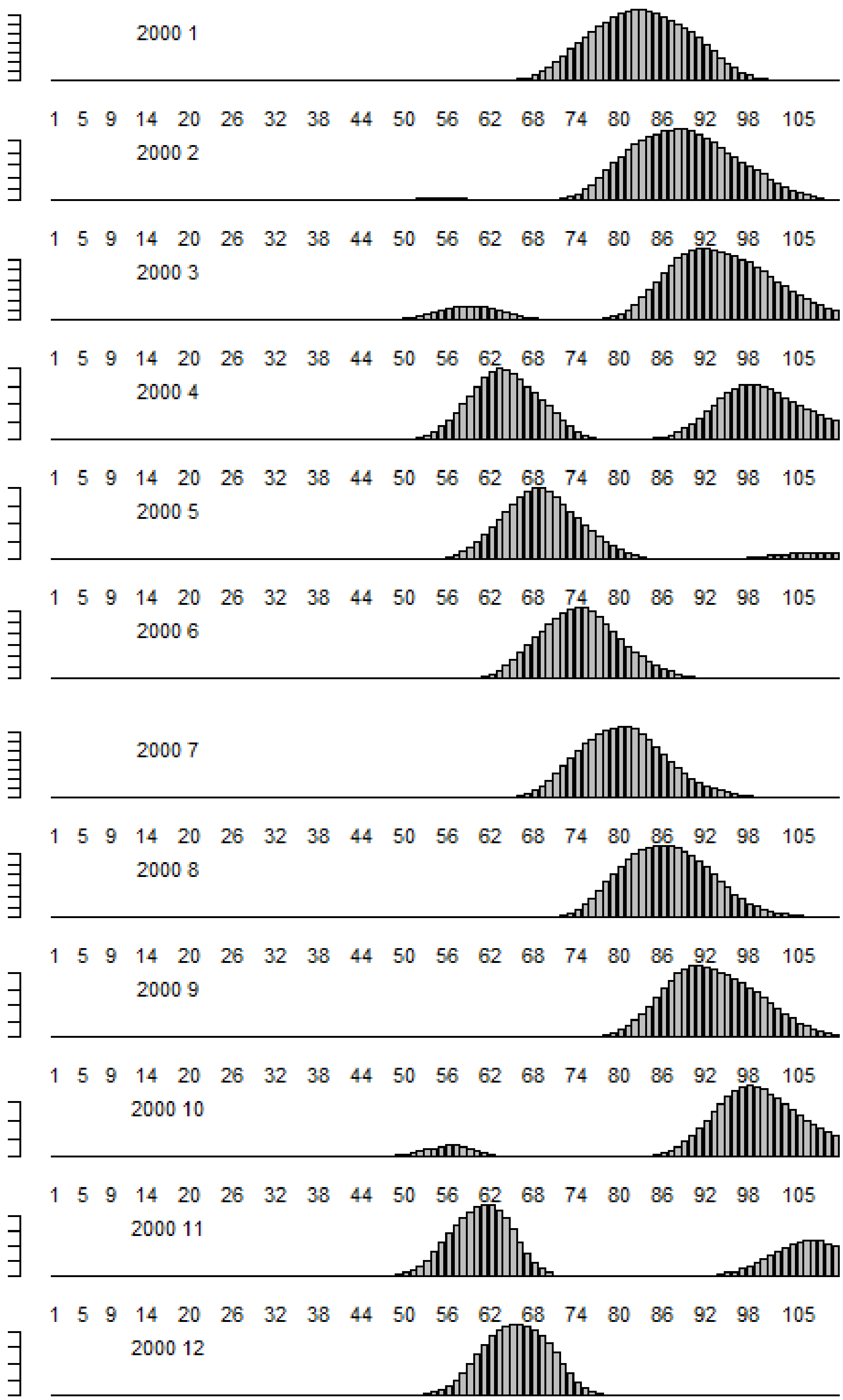
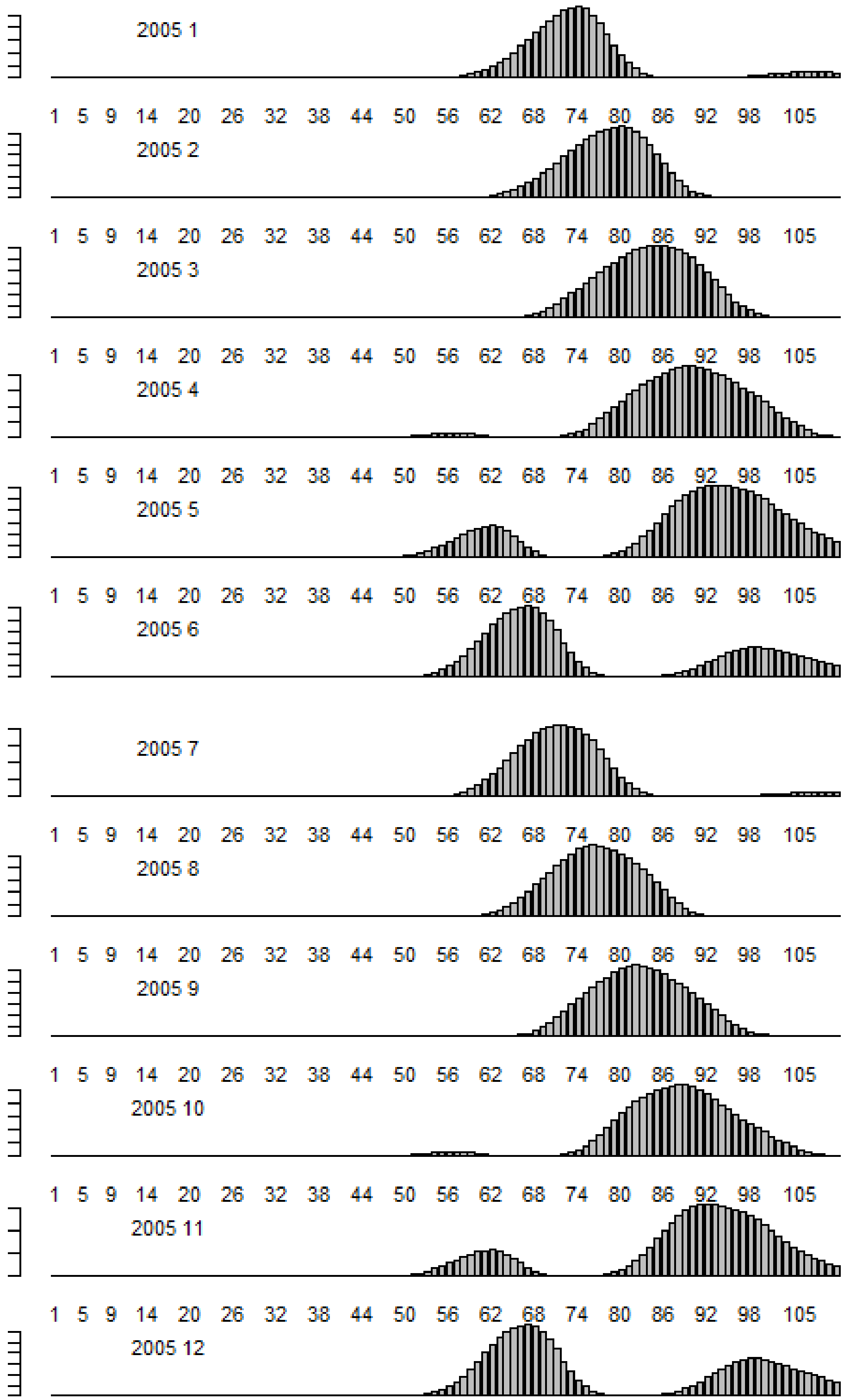

2019 1
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105

Figure 20. Fleet 2 Catch in number at length by YEAR.MONTH.

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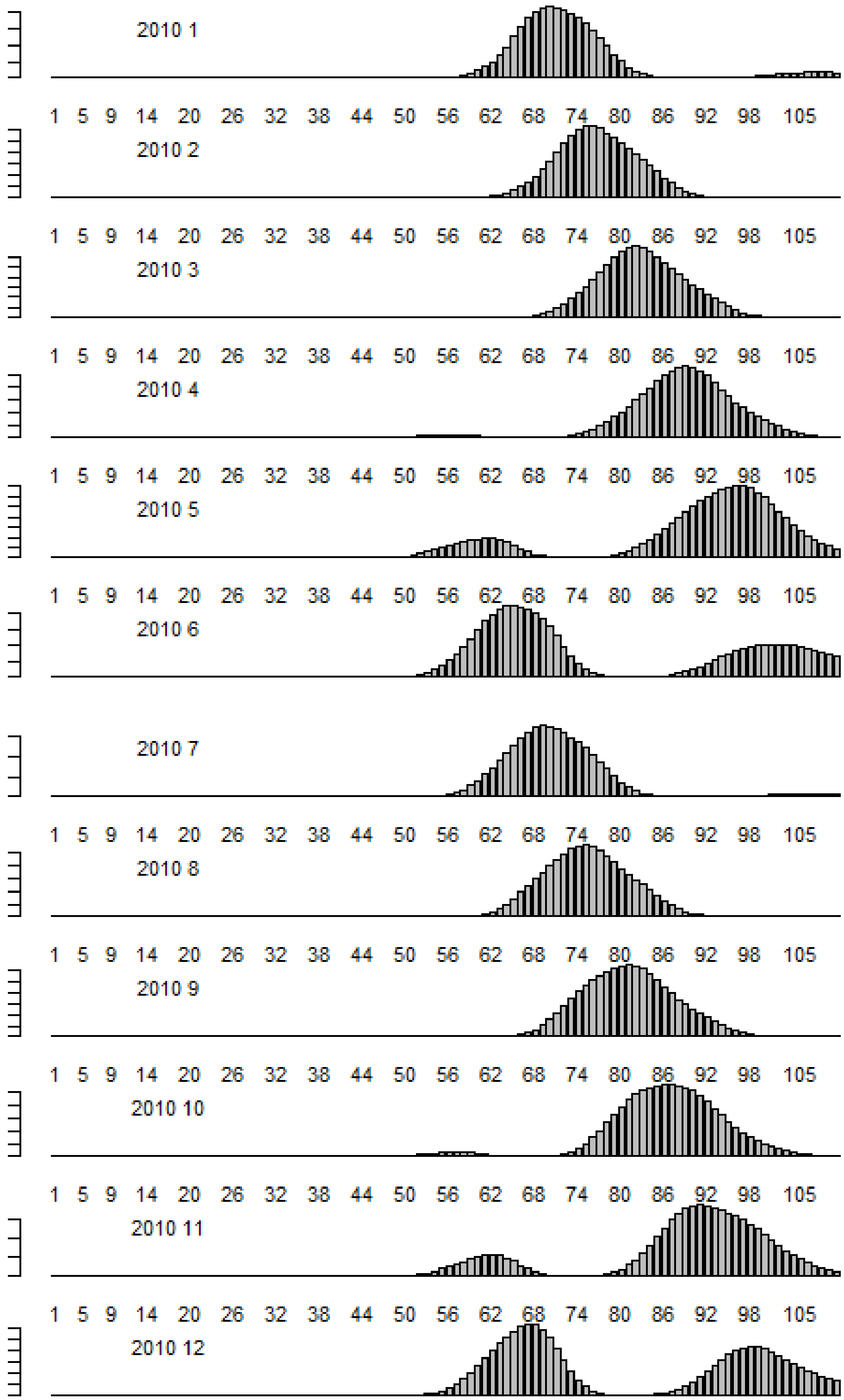
2005 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2005 6
2005 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 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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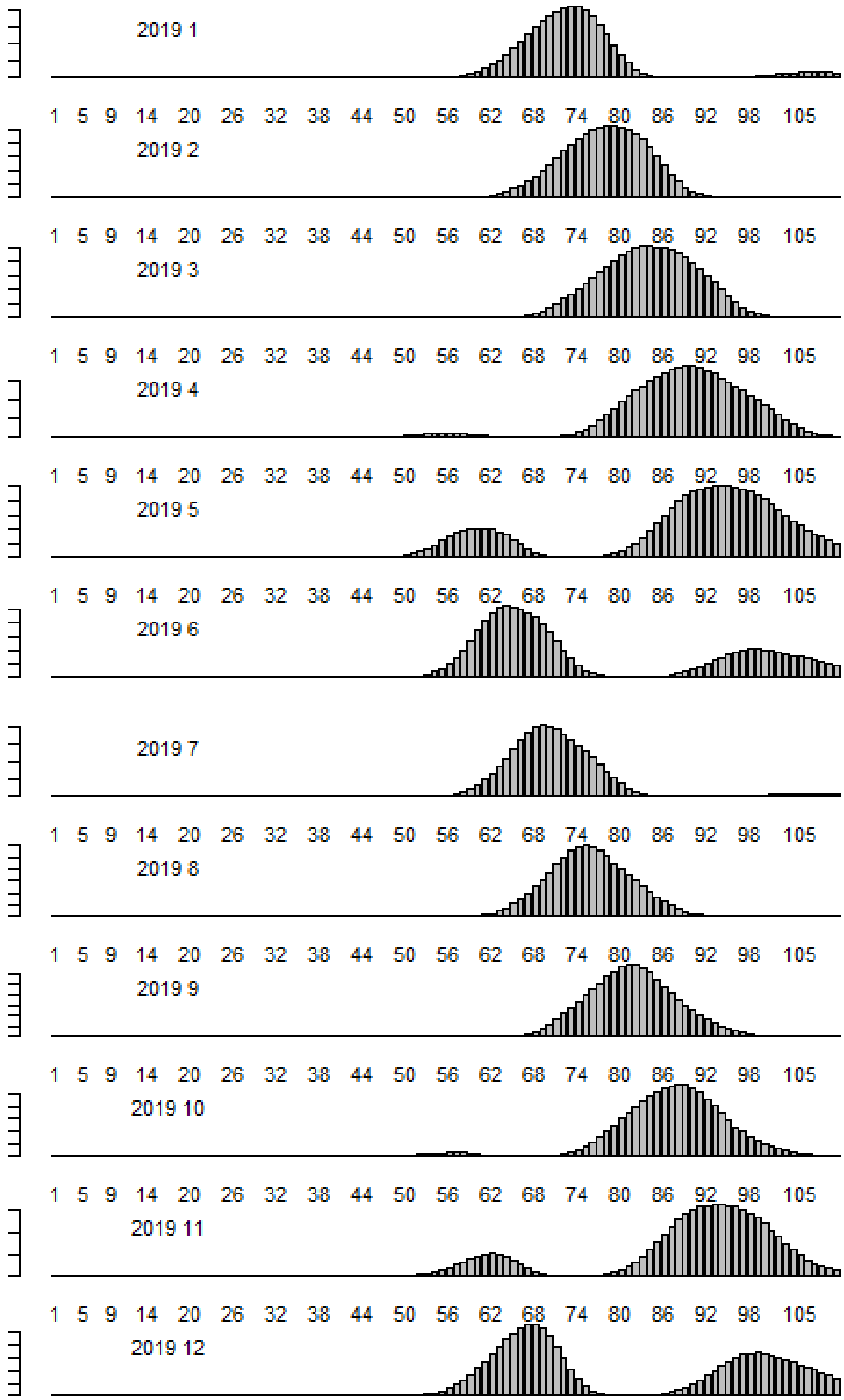
2010 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2010 6
2010 7
1 5 9 14 20 26 32 38 44 50 56 62 68 74 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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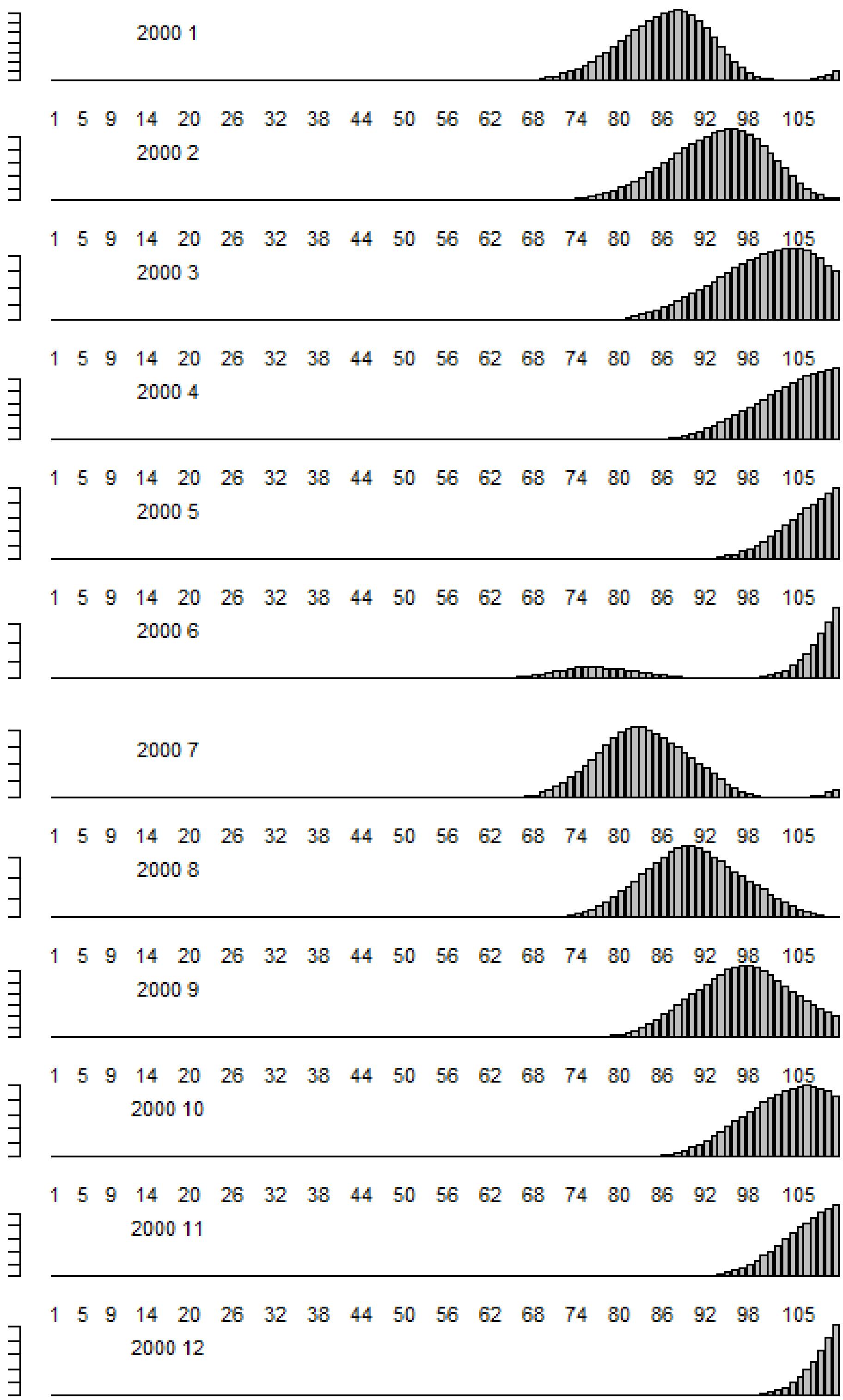
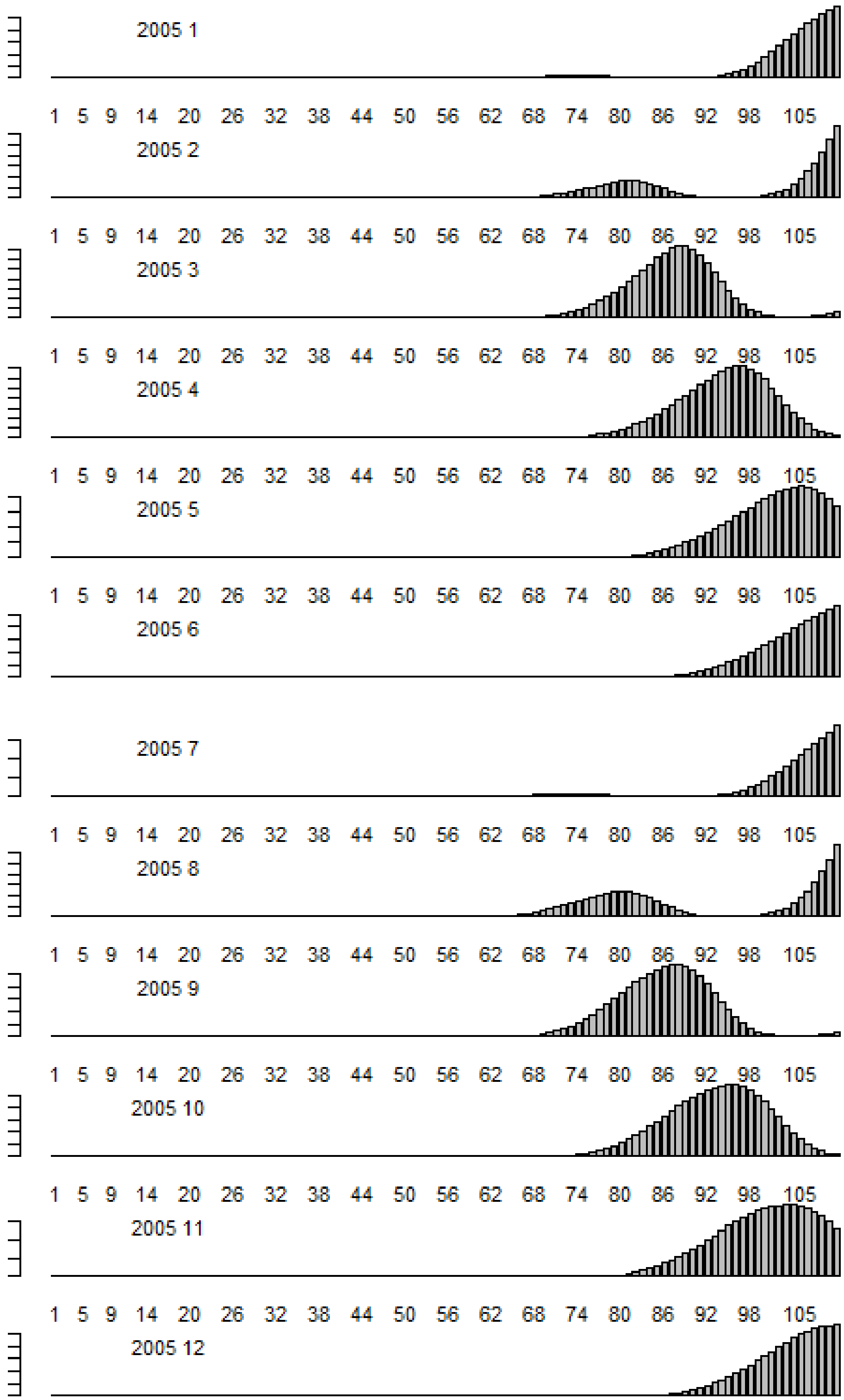
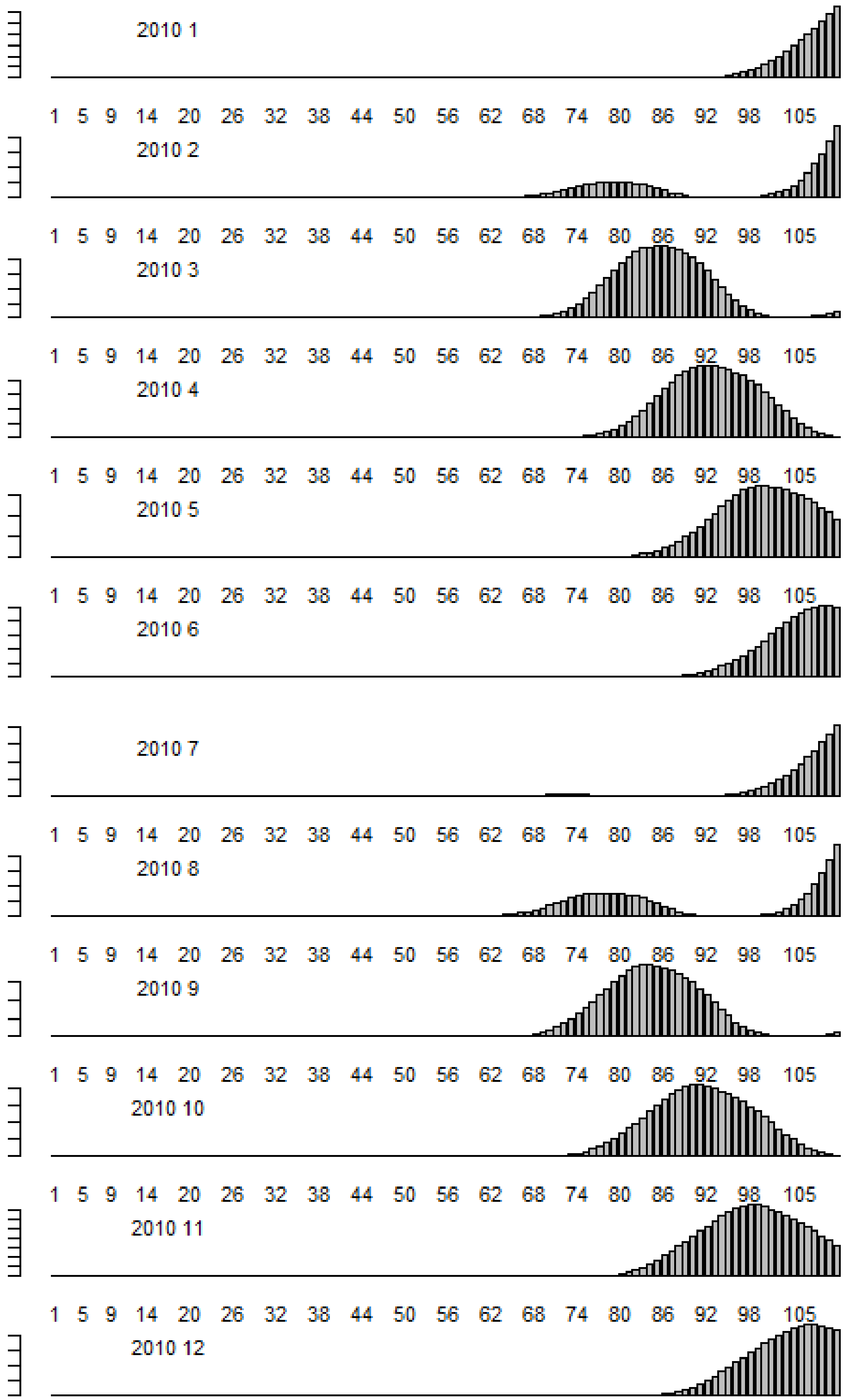
2019 2
2019 3
2019 4
2019 5
2019 6
2019 7
2019 8
2019 9
2019 10
2019 11
2019 12
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105

Figure 21. Fleet 3 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
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

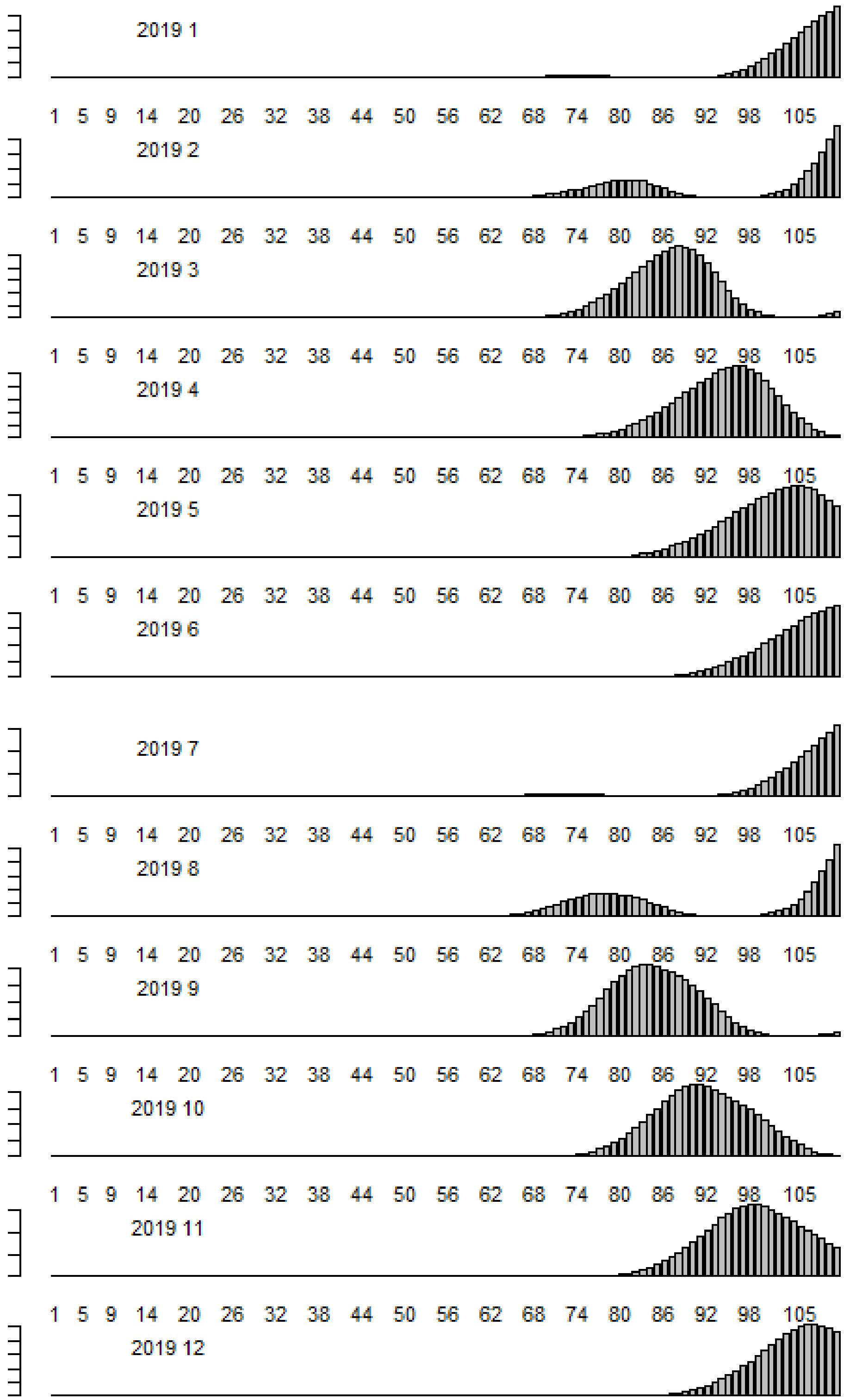

2019 1
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 2
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 3
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 4
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 98 105
2019 5
1 5 9 14 20 26 32 38 44 50 56 62 68 74 80 86 92 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 22. Number at age in the first Year and Recruitment by YEAR.MONTH.

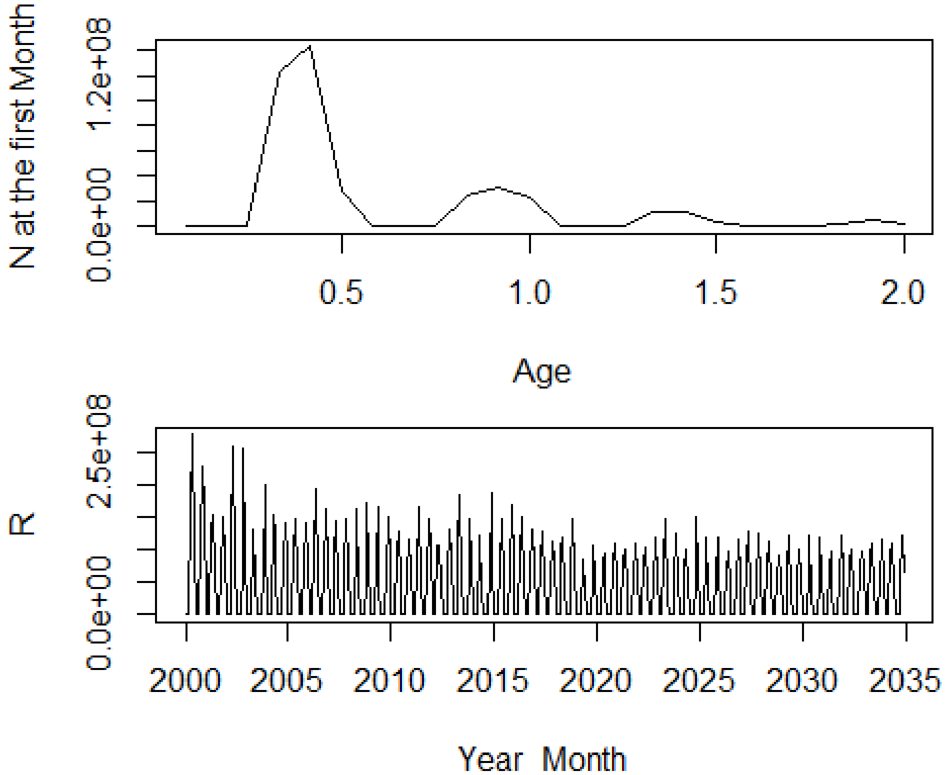


Figure 23. Whole number by YEAR.MONTH.

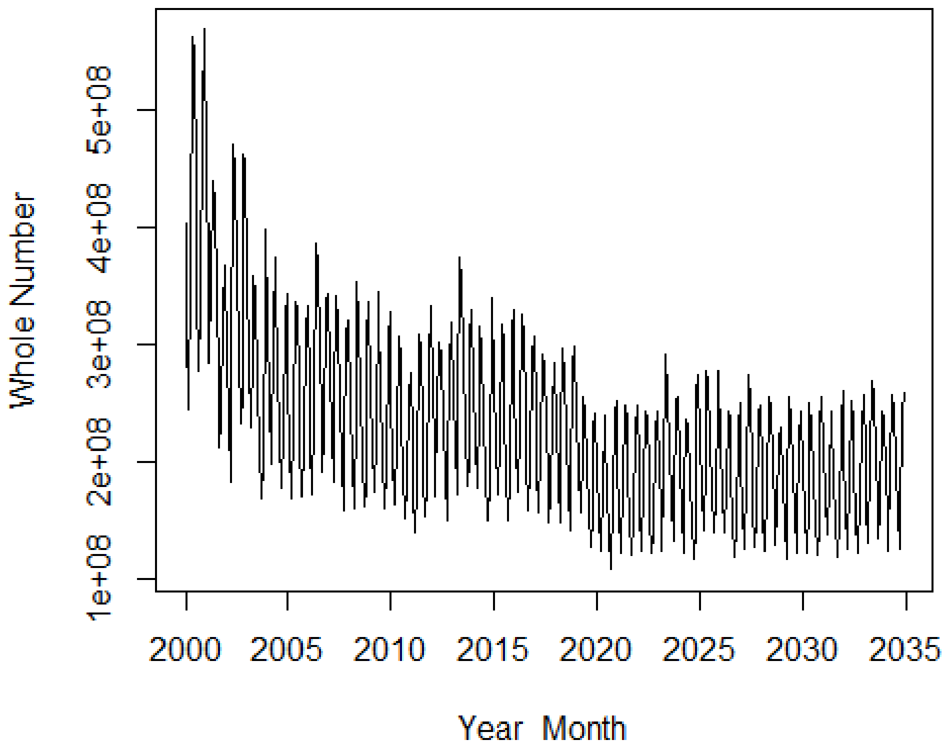


Figure 24_a. Catch (tons) by YEAR.MONTH.

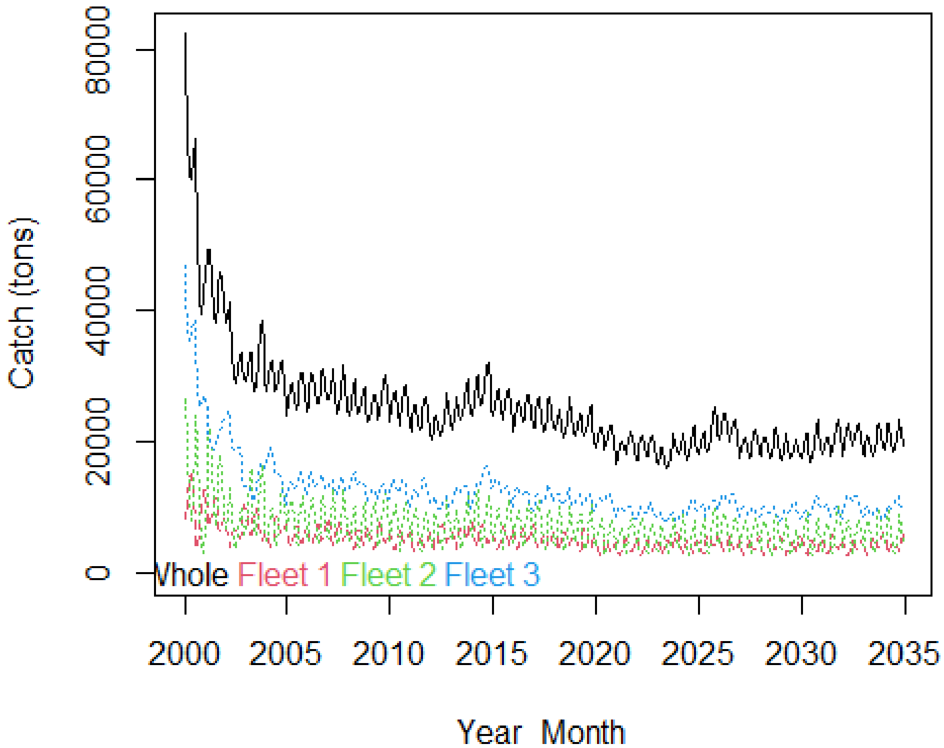


Figure 24_b. Catch (tons) by YEAR.

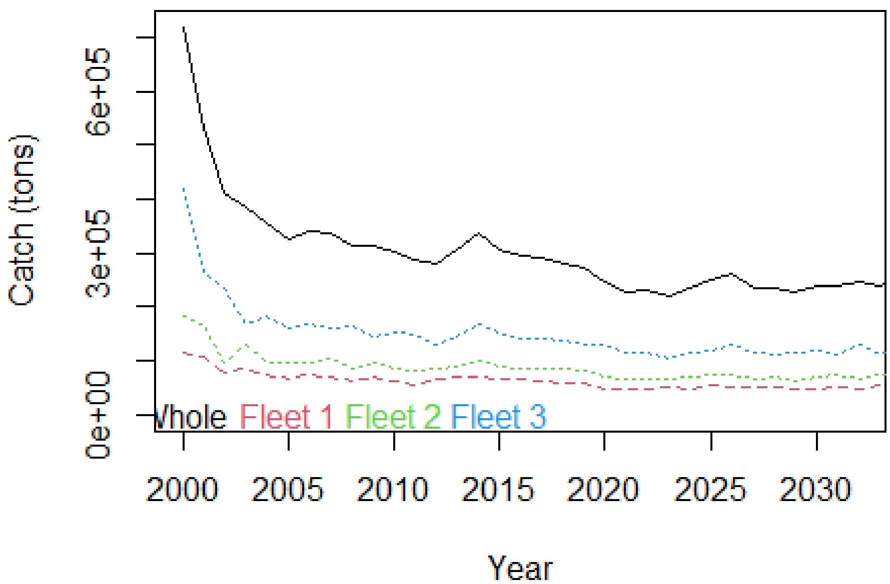


Figure 25. Whole number by YEAR.MONTH.

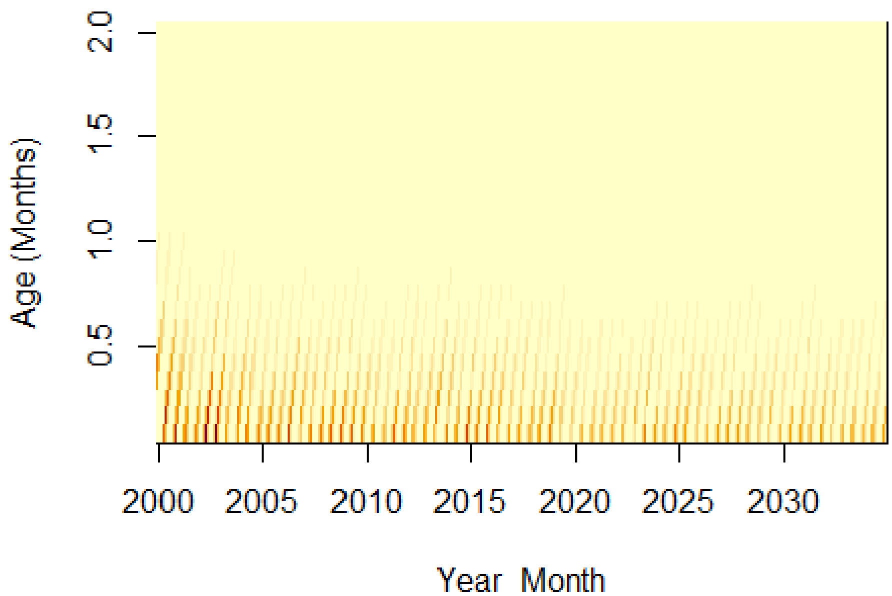


Figure 26. Biomass by YEAR.MONTH.

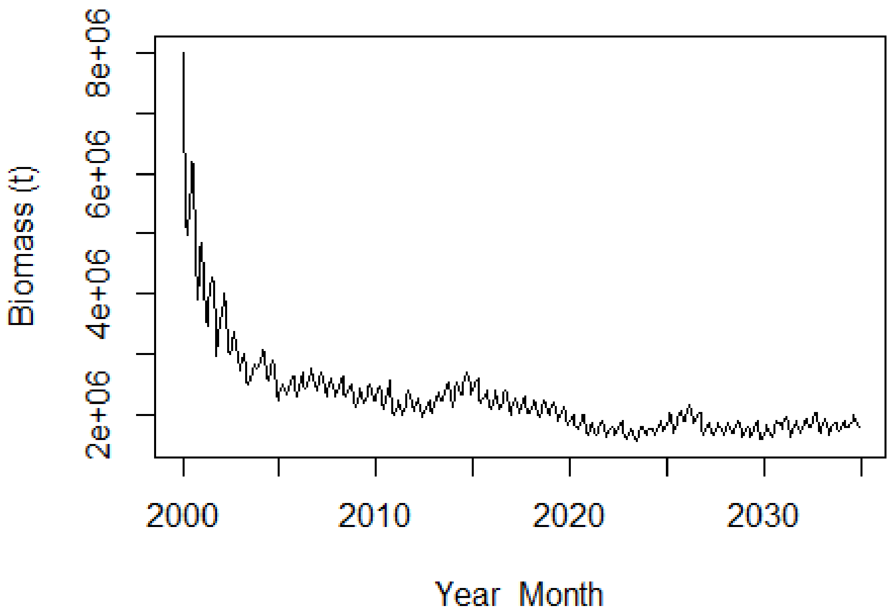
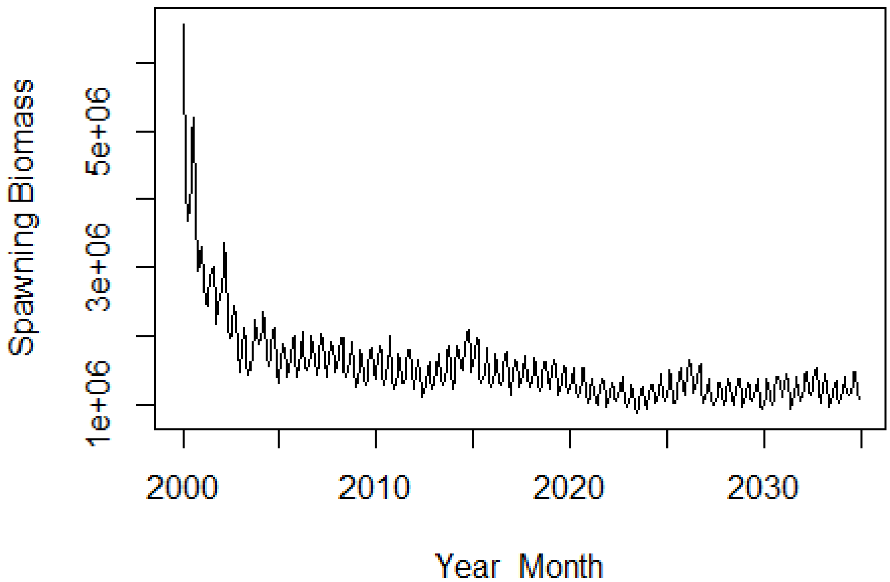


Figure 27. Spawning Biomass by YEAR.MONTH.



ABUNDANCE INDICES

Figure 28. Hyperstability.

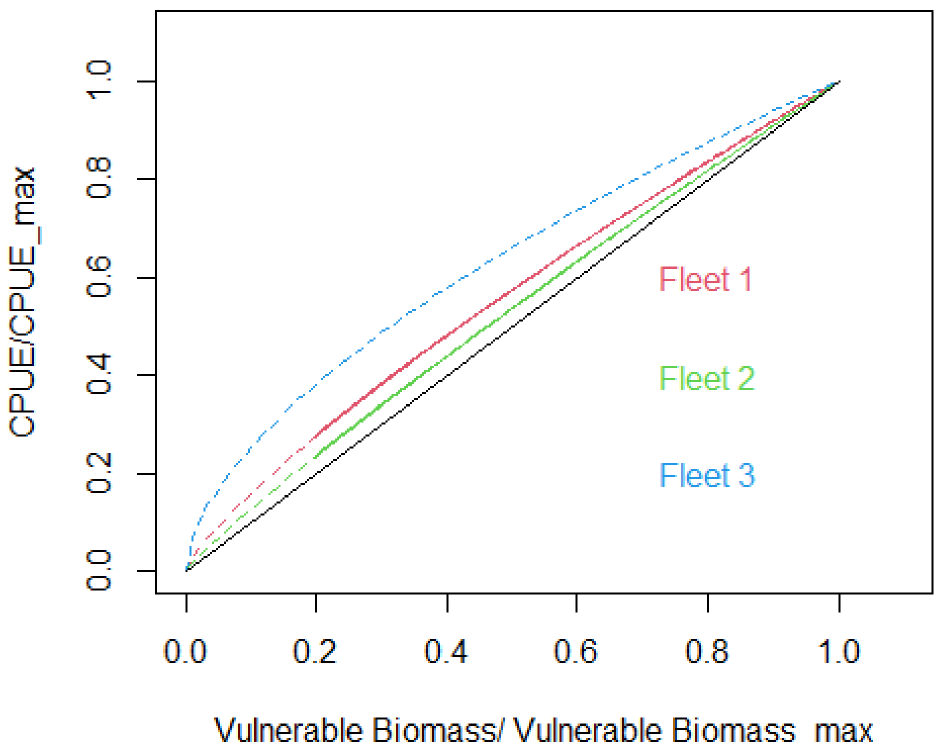


Figure 29. CPUE by YEAR.MONTH.

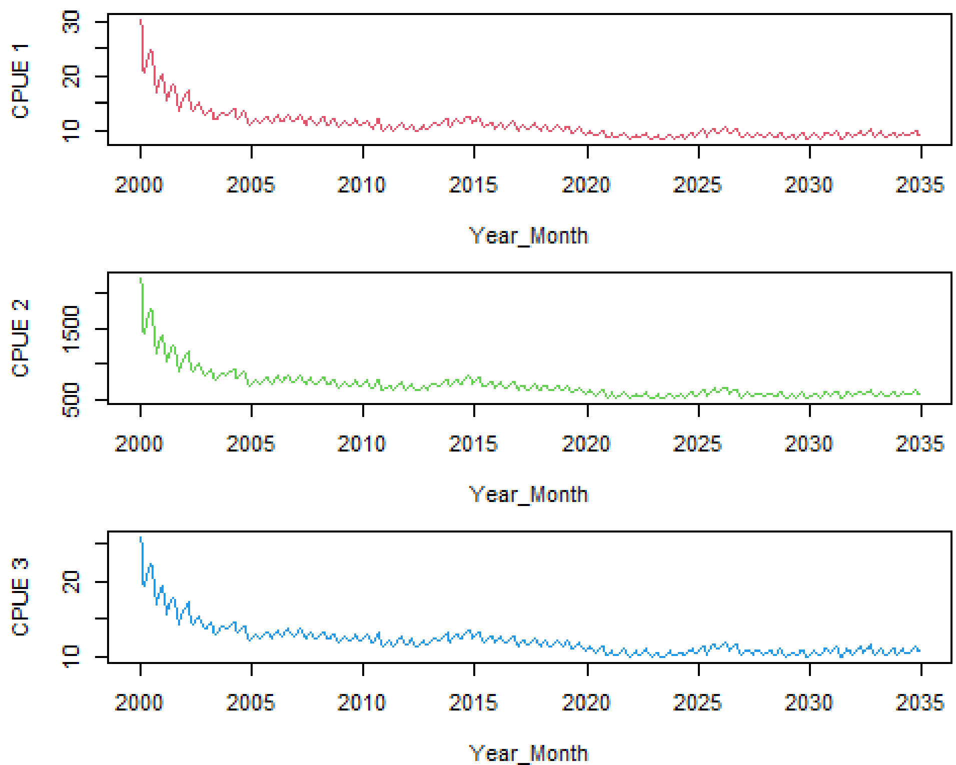


Figure 30. Examples of CPUE by month and fleet in two different years.

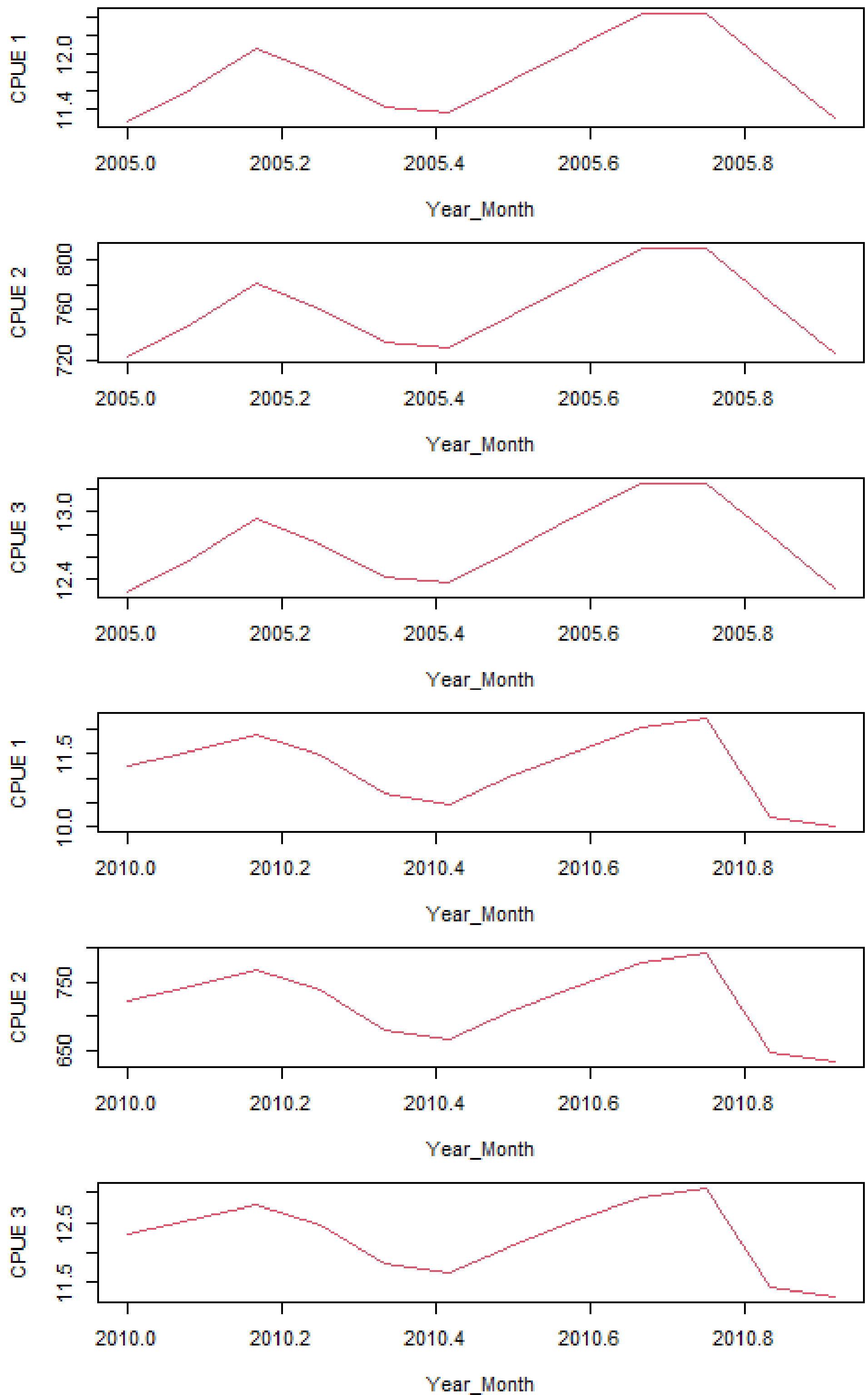


Figure 31. Acoustic Biomass by YEAR.MONTH.

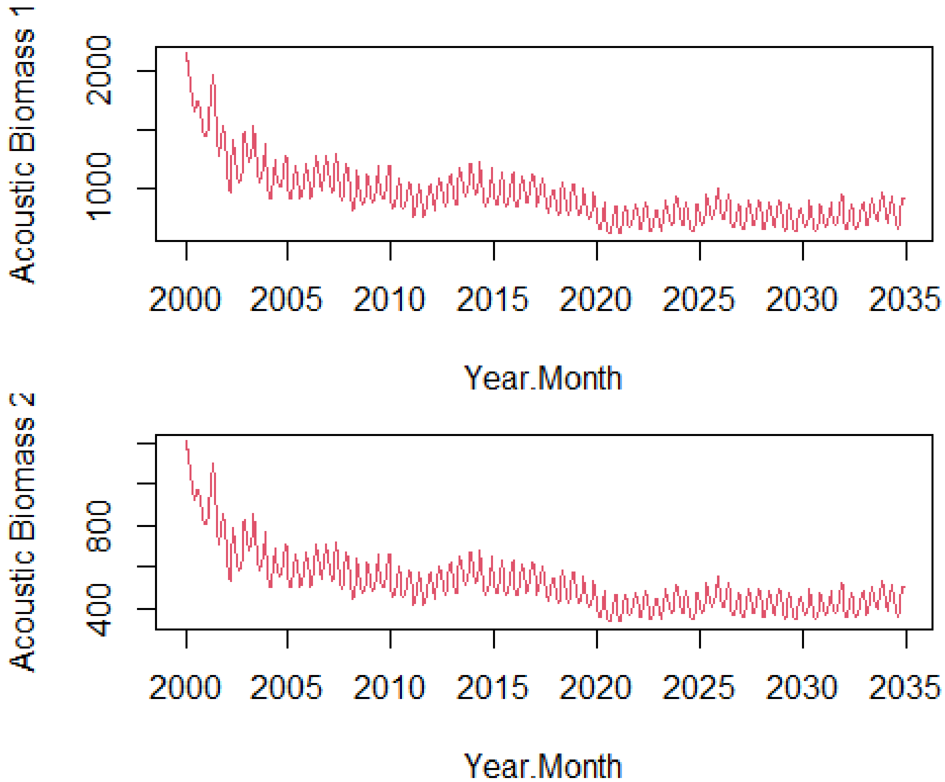


Figure 32. Acoustic Selectivity.

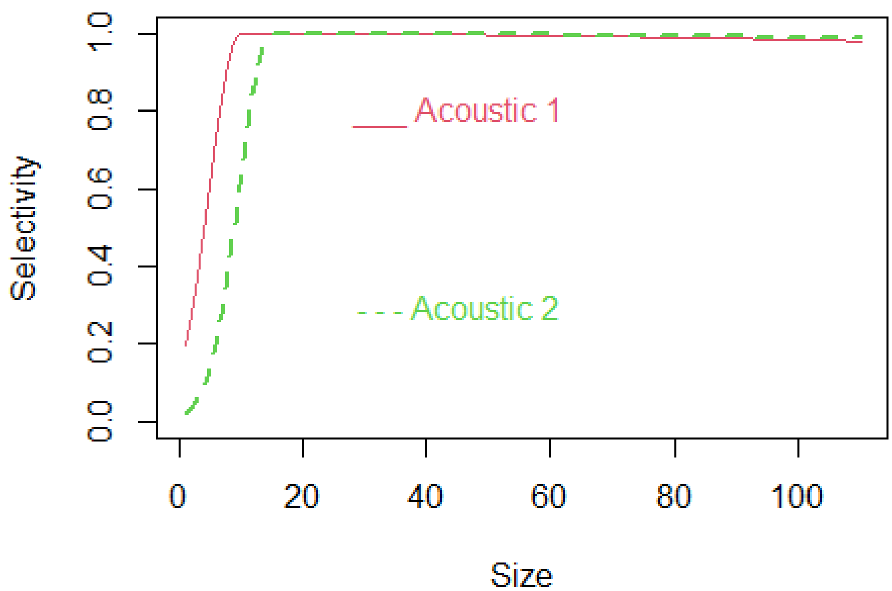


Figure 33. Mean weight by Fleet and YEAR.MONTH.

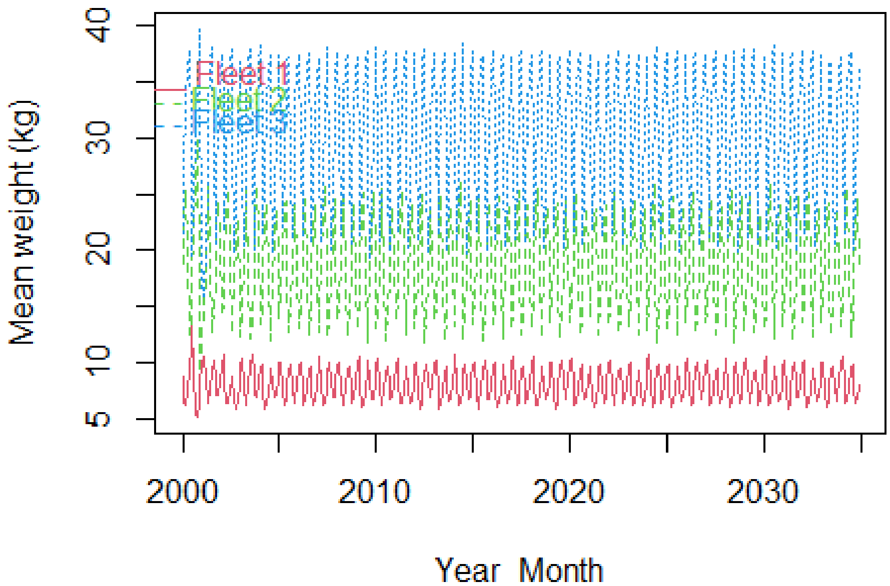


Figure 34. Mean weight by Acoustic Survey and YEAR.MONTH.

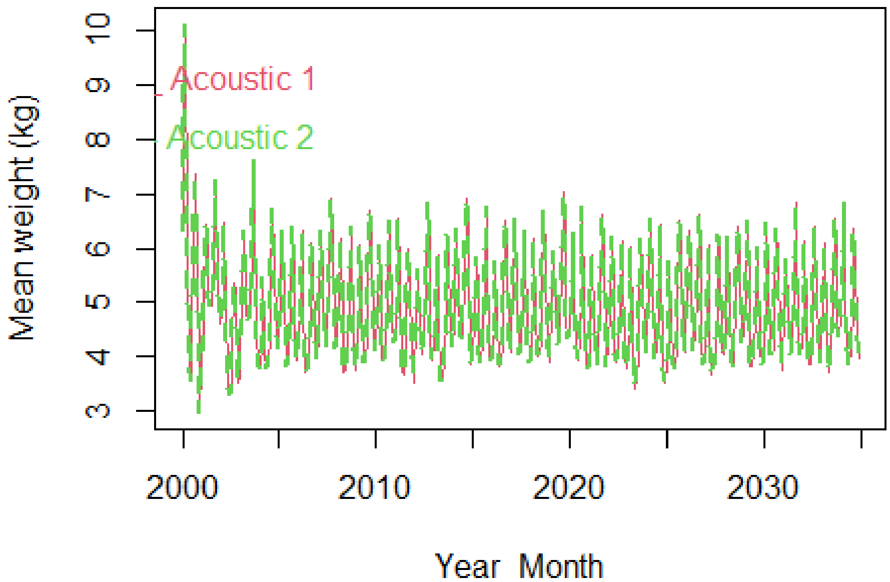


Figure 35. Egg production method biomass by YEAR.MONTH.

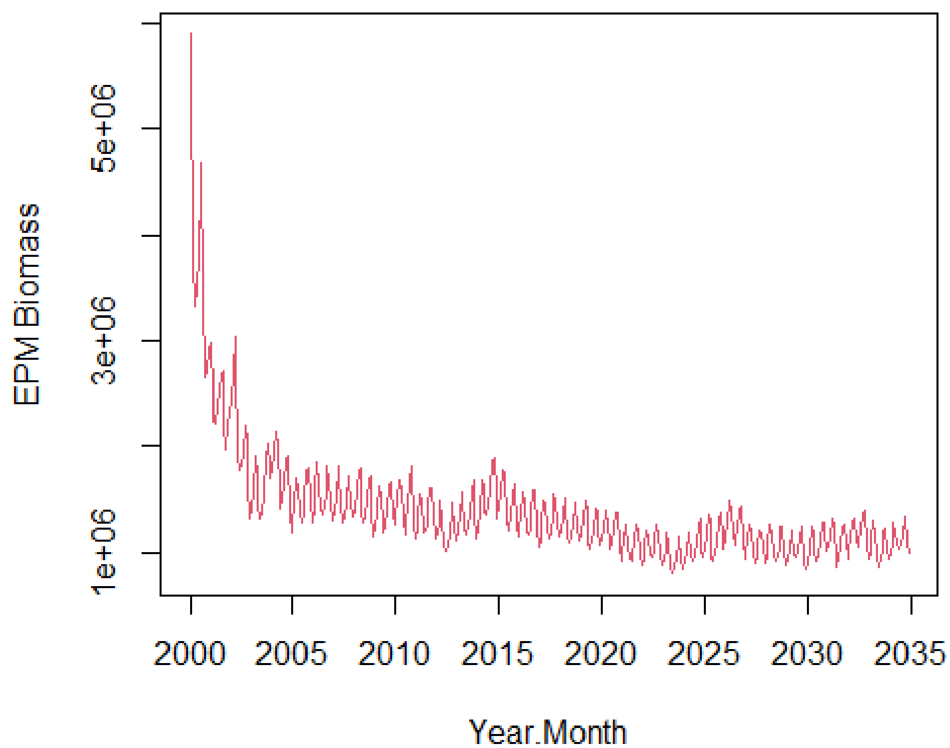


Table 2. Population, Fishery and Indices Parameters.

Longevity and Fecundity Parameters

Longv	2
Fec	192410148

Gnomic M Parameters

	Egg	Paralarvae	Juvenile	Subadult	Adult
Gnomonic_interval	1.00	2.00	3.00	4.00	5.00
interval_duration_day	6.00	13.93	46.25	153.62	510.20
total_duration	6.00	20.00	66.00	220.00	730.00
M_day	0.61	0.26	0.08	0.02	0.01
M_year	223.65	96.35	29.01	8.73	2.63
No_Surv	4870666.00	123296.00	3121.00	79.00	2.00

M and Stock Recruitment Parameters

M_Annual	2.630
M_bin	0.219
M_cv	0.150
SB0	15000000.000
SRModel	1.000
h	0.700
prev.rsigma	0.000
rsigma	0.150

Recruitment Seasonal Parameters

RSeason	3
SdSeason	0

Fishery Parameters

Fref1	0.20
as1	0.15
bs1	0.70
cs1	0.15
Fref2	0.30
as2	0.15
bs2	1.00
cs2	0.10
Fref3	0.20
as3	0.20
bs3	1.50
cs3	0.30

Indices Parameters

q1	0.0001
hyp1	0.8000
q2	0.0015
hyp2	0.9000
q3	0.0020
hyp3	0.6000
as1	0.1500
bs1	0.7000
cs1	0.1500
as2	0.1500
bs2	1.0000
cs2	0.1000
as3	0.2000
bs3	1.5000
cs3	0.3000
as4	5.0000
bs4	10.0000
cs4	500.0000
as5	5.0000

bs5	15.0000
cs5	600.0000
qacous1	0.9000
qacous2	0.5000
qMPH	0.9000

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