A primer on turning length frequencies into ages

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Goals

- compute a catch-at-age matrix that will be used as input to an age-strutured population model
- in our case, compute one row of that matrix for a specific year

Landings

Zonal Interchange File Format (ZIFF) are used to retrieve American Plaice landings data from NAFO Division 4T

Example for American Plaice from the southern Gulf of St. Lawrence

```
## [1] 1995
```

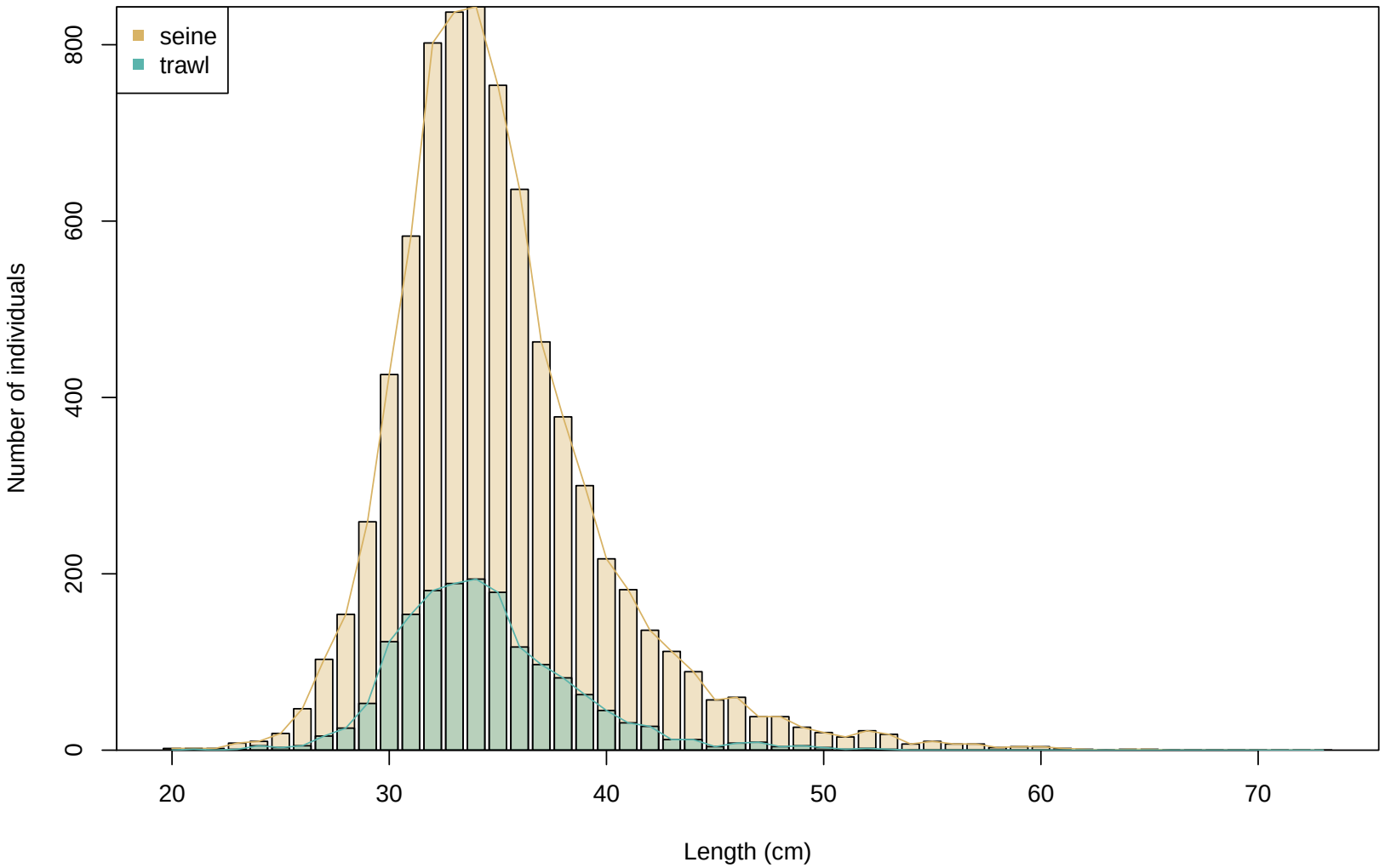
```
##    gear.class round.weight round.weight.mt
## 1         BXN          1775           1.775
## 2         FIX           591           0.591
## 3         GNS        134523         134.523
## 4         LHB           187           0.187
## 5         LLS          2583           2.583
## 6          NK         31131          31.131
## 7        OTB1          1414           1.414
## 8        OTB2        349001         349.001
## 9         PTB        123387         123.387
## 10        SDN       1449089        1449.089
## 11        SSC        298162         298.162
```

```
## [1] 2391.843
```

Length frequencies

Example of the available 235 length frequency samples available for American Plaice in NAFO Division 4T in 1995, a total of 9357 individuals were measured. From the annual landings of 2391.843 mt, the port samples come from landings of 1.070675×10^6 lbs (4.8667045×10^5 kg) and the weight of sampled individuals was 6.8708×10^4 lbs (3.1230909×10^4 kg).

Length frequencies



Age-length pairs

Length versus age for the 4864 aged individuals from the 1995 September survey (the figure is a random sample of 500 individuals with jitter added to ages)

Age-length pairs

Notation from Ailloud and Hoenig (2019)

Ailloud and Hoenig (2019)

Age class	i	$1, 2, ..., I$
Length bin	j	$1, 2, ..., J$
Year	k	$1, 2, ..., K$
Number of fish of age i and length bin j in the age-length sample	n_{ij}	
Number of fish of length j in the length frequency sample	y_j	
Number of fish of age i in the age only sample	x_i	
Total size of the age-length sample	n	
Total size of the length frequency sample	N	
Total size of the age only sample	M	
Total number of fish belonging to the i^{th} age class of the age-length sample	$n_{i.}$	
Total number of fish belonging to the j^{th} length bin of the age-length sample	$n_{.j}$	

Empirical age-length key

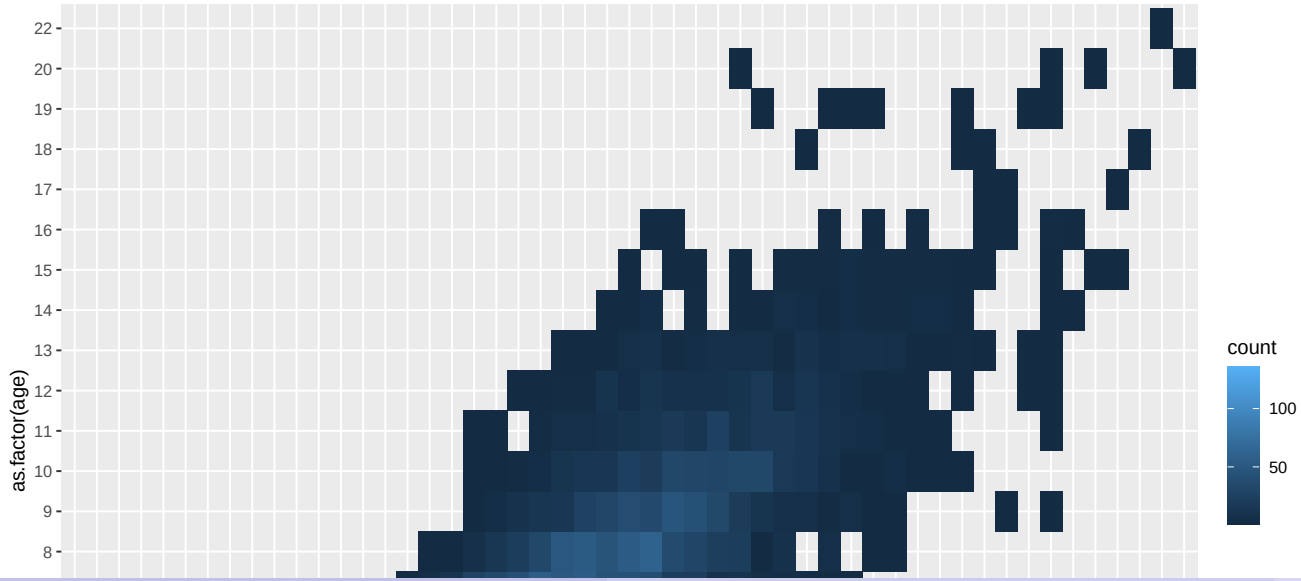
From the sample of fish that were aged, we can examine the number of individuals at each age and length:

$$\begin{bmatrix} n_{age=1,length=1} & n_{age=1,length=2} & \cdots & n_{age=1,length=J} \\ n_{age=2,1} & n_{age=2,length=2} & \cdots & n_{age=2,length=J} \\ \cdots & \cdots & \cdots & \cdots \\ n_{age=I,1} & n_{age=I,length=2} & \cdots & n_{age=I,length=J} \end{bmatrix}$$

Example for American Plaice from the southern Gulf of St. Lawrence

Empirical age-length key from the 4864 aged individuals from the 1995 September survey

```
##
##   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15
## 121 260 341 831 496 648 493 471 360 307 196 128  93  46  36
##  22
##   1
```



Forward age-length key

$$\hat{P}(i|j) = \hat{q}_{ij} = n_{ij}/n_j$$

$$\hat{A} = \boldsymbol{Q}Y/N$$

Catch-at-age matrices

For our example to compute the catch-at-age matrix for American Plaice in 1995, we have the following information:

- total landings of American Plaice by gear type
- length frequency samples from port sampling activities
- length frequency samples from at-sea observers
- length frequency samples from the September survey
- age-length pairs obtained from ageing the otoliths collected from port sampling activities
- age-length pairs obtained from ageing the otoliths collected from at-sea observers
- age-length pairs obtained from ageing the otoliths collected in the September survey

Showing the 3 pieces together

Complications and solutions

- some years have no data
- some ages are not present in the aged samples
- some lengths are not present in the aged samples
-

Catch-at-age matrices

Extend the analyses to all years where data is available

References

Ailloud, L.E., and Hoenig, J.M. 2019. A general theory of age-length keys: Combining the forward and inverse keys to estimate age composition from incomplete data. ICES Journal of Marine Science 76: 1515–1523.