Lobyerev V1

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## implementation of Lobyerev & Hoffman (2008) Selectivity model

This document describes the implementation of the selectivity algorithm described in Lobyrev, Feodor, and Matthew J. Hoffman. “A morphological and geometric method for estimating the selectivity of gill nets.” Reviews in Fish Biology and Fisheries 28.4 (2018): 909-924.

### Step 1: Import field data on fish catch and gill net properties

#### Step 1.1: Import catch data

Catch data structure: Column 1: ‘Mesh\_size’ - name of the net (later connected to net properties under the same name) Column 2: ‘Length\_group’ - Fish total length (cm) Column 3: ‘Wedged’ - Number of wedged individuals Column 4: ‘Tangled’ - Number of tangled individuals

Catch.data.Cod <- read.csv("~/kinneret modeling/selectivity/R code Feodor paper/Data/Catch data Cod.csv")  
#Show the first 6 lines:  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled  
## 1 20 14 2 2  
## 2 20 16 20 5  
## 3 20 18 15 12  
## 4 20 20 11 8  
## 5 20 22 20 18  
## 6 20 24 32 24

#### Step 1.2: Import table of net properties

Net properties data structure: (See Figure 2 in paper) Column 1: ‘Mesh\_size’ - mesh size (knot to knot) (mm) Column 2: ‘y’ - Smaller of the angels between mesh threads

net.properties <- read.csv("~/kinneret modeling/selectivity/R code Feodor paper/Data/net properties.csv")  
#Show table:  
print(net.properties)

## Mesh\_size y  
## 1 20 60  
## 2 25 60  
## 3 30 60

#### Step 1.3: Add angel in Radian

net.properties$Radian=0.018\*net.properties$y  
#Show table:  
print(net.properties)

## Mesh\_size y Radian  
## 1 20 60 1.08  
## 2 25 60 1.08  
## 3 30 60 1.08

#### Step 1.4: Define the angel between the end of upper and lower jaws (phi)

phi\_deg=7  
phi\_radian=0.018\*phi\_deg

#### Step 1.5: Calculate the jaw length approximated by the linear function

slope\_jaw=1.02  
intecept\_jaw=3.41  
Catch.data.Cod$Jaw\_length=intecept\_jaw + (slope\_jaw\*Catch.data.Cod$Length\_group)  
#Calculate h  
Catch.data.Cod$h=Catch.data.Cod$Jaw\_length \* sin(phi\_radian) \* 2  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h  
## 1 20 14 2 2 17.69 4.446094  
## 2 20 16 20 5 19.73 4.958815  
## 3 20 18 15 12 21.77 5.471535  
## 4 20 20 11 8 23.81 5.984256  
## 5 20 22 20 18 25.85 6.496977  
## 6 20 24 32 24 27.89 7.009698

#### Step 1.6: Merge the catch data with the net data

Catch.data.Cod=merge(Catch.data.Cod,net.properties,by="Mesh\_size")  
#print first 6 lines  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08

### Step 2: Calculate P(O|C) and P(Th|C)

For calculating P(O|C) use eq. 4 in the paper

#Calculate sin,cos,tan  
Catch.data.Cod$sin=sin(0.5\*Catch.data.Cod$Radian)  
Catch.data.Cod$cos=cos(0.5\*Catch.data.Cod$Radian)  
Catch.data.Cod$tan=tan(0.5\*Catch.data.Cod$Radian)  
#Calculate P(O|C) Eq. 4  
Catch.data.Cod$POC=(((Catch.data.Cod$cos \* Catch.data.Cod$Mesh\_size)-Catch.data.Cod$h)\*((Catch.data.Cod$sin\*Catch.data.Cod$Mesh\_size)-(Catch.data.Cod$tan\*Catch.data.Cod$h)))/(Catch.data.Cod$cos\*Catch.data.Cod$sin\*(Catch.data.Cod$Mesh\_size)^2)  
#Calculate P(Th|c)  
Catch.data.Cod$PThC=1-Catch.data.Cod$POC  
#Print first 6 rows  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807

### Step 3: Calculate P(W|E)

!!!!I just import the data from your Excel, but do not know how the calculation was made

PWE <- read.csv("~/kinneret modeling/selectivity/R code Feodor paper/Data/PWE.csv", stringsAsFactors=FALSE)  
#print the first 6 lines  
print(head(PWE))

## Mesh\_size Length\_group PWE  
## 1 20 14 0.35  
## 2 20 16 0.69  
## 3 20 18 0.81  
## 4 20 20 0.88  
## 5 20 22 0.88  
## 6 20 24 1.00

#merge with table 'Catch.data.Cod'  
Catch.data.Cod=merge(Catch.data.Cod,PWE ,by=c("Mesh\_size", "Length\_group"))

### Step 4: Calculate Eq. 2

#### Step 4.1: Calculate P(E|O) by the linear equation

##Get the min and max size groups for each net  
#Create table  
net\_PEO=data.frame(Mesh\_size=unique(Catch.data.Cod$Mesh\_size))  
#Length group interval  
Length\_group\_interval=2  
#The minimal size for each net  
min\_wedged=data.frame(Catch.data.Cod %>%  
 filter(!is.na(Wedged)) %>%  
 group\_by(Mesh\_size) %>%  
 summarize(min\_size = min(Length\_group, na.rm = TRUE)))  
#The maximal size for each net  
max\_wedged=data.frame(Catch.data.Cod %>%  
 filter(!is.na(Wedged)) %>%  
 group\_by(Mesh\_size) %>%  
 summarize(max\_size = max(Length\_group, na.rm = TRUE)))  
#merge  
net\_PEO=merge(net\_PEO,min\_wedged,by="Mesh\_size")  
net\_PEO=merge(net\_PEO,max\_wedged,by="Mesh\_size")  
#Substract and add the Length group interval  
net\_PEO$min\_size=net\_PEO$min\_size-(Length\_group\_interval/2)  
net\_PEO$max\_size=net\_PEO$max\_size+(Length\_group\_interval/2)  
#Calculate the linear function  
net\_PEO$slope=-1/(net\_PEO$max\_size-net\_PEO$min\_size)  
net\_PEO$intercept=1-(net\_PEO$slope\*net\_PEO$min\_size)  
#print  
print(net\_PEO)

## Mesh\_size min\_size max\_size slope intercept  
## 1 20 13 31 -0.05555556 1.722222  
## 2 25 17 35 -0.05555556 1.944444  
## 3 30 21 37 -0.06250000 2.312500

#Calculate PEO  
#Merge slope and intercept to data  
Catch.data.Cod=merge(Catch.data.Cod,net\_PEO,by="Mesh\_size")  
Catch.data.Cod$PEO=Catch.data.Cod$intercept+(Catch.data.Cod$Length\_group)\*Catch.data.Cod$slope  
#Remove PEO values if no fish were wedged  
Catch.data.Cod[is.na(Catch.data.Cod$Wedged),"PEO"]=NA  
#Print first 6 lines  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC PWE min\_size max\_size  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922 0.35 13 31  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833 0.69 13 31  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877 0.81 13 31  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054 0.88 13 31  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364 0.88 13 31  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807 1.00 13 31  
## slope intercept PEO  
## 1 -0.05555556 1.722222 0.9444444  
## 2 -0.05555556 1.722222 0.8333333  
## 3 -0.05555556 1.722222 0.7222222  
## 4 -0.05555556 1.722222 0.6111111  
## 5 -0.05555556 1.722222 0.5000000  
## 6 -0.05555556 1.722222 0.3888889

#### Step 4.2: Claculate Eq.2

Catch.data.Cod$Ntotal=Catch.data.Cod$Wedged/(Catch.data.Cod$POC\*Catch.data.Cod$PWE\*Catch.data.Cod$PEO)  
#Print first 6 lines  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC PWE min\_size max\_size  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922 0.35 13 31  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833 0.69 13 31  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877 0.81 13 31  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054 0.88 13 31  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364 0.88 13 31  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807 1.00 13 31  
## slope intercept PEO Ntotal  
## 1 -0.05555556 1.722222 0.9444444 11.02466  
## 2 -0.05555556 1.722222 0.8333333 68.81967  
## 3 -0.05555556 1.722222 0.7222222 55.28320  
## 4 -0.05555556 1.722222 0.6111111 48.24247  
## 5 -0.05555556 1.722222 0.5000000 117.76900  
## 6 -0.05555556 1.722222 0.3888889 235.29074

### Step 5: Calculate CPUE

(table 21)

#Define the number of trials  
n\_trials=11  
#Aggregate catch for each mesh size  
Catch.data.Cod$CPUE=rowSums(Catch.data.Cod[,c("Wedged","Tangled")],na.rm=T)/n\_trials  
#Print first 6 lines  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC PWE min\_size max\_size  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922 0.35 13 31  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833 0.69 13 31  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877 0.81 13 31  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054 0.88 13 31  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364 0.88 13 31  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807 1.00 13 31  
## slope intercept PEO Ntotal CPUE  
## 1 -0.05555556 1.722222 0.9444444 11.02466 0.3636364  
## 2 -0.05555556 1.722222 0.8333333 68.81967 2.2727273  
## 3 -0.05555556 1.722222 0.7222222 55.28320 2.4545455  
## 4 -0.05555556 1.722222 0.6111111 48.24247 1.7272727  
## 5 -0.05555556 1.722222 0.5000000 117.76900 3.4545455  
## 6 -0.05555556 1.722222 0.3888889 235.29074 5.0909091

### Step 6: Calculate Nw per hour

(table 23)

#Define number of hours of single (??) field trial  
n\_hours=12  
Catch.data.Cod$Ntotal\_per\_hour=Catch.data.Cod$Ntotal/n\_hours  
#Print first 6 lines  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC PWE min\_size max\_size  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922 0.35 13 31  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833 0.69 13 31  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877 0.81 13 31  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054 0.88 13 31  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364 0.88 13 31  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807 1.00 13 31  
## slope intercept PEO Ntotal CPUE Ntotal\_per\_hour  
## 1 -0.05555556 1.722222 0.9444444 11.02466 0.3636364 0.9187218  
## 2 -0.05555556 1.722222 0.8333333 68.81967 2.2727273 5.7349724  
## 3 -0.05555556 1.722222 0.7222222 55.28320 2.4545455 4.6069330  
## 4 -0.05555556 1.722222 0.6111111 48.24247 1.7272727 4.0202057  
## 5 -0.05555556 1.722222 0.5000000 117.76900 3.4545455 9.8140830  
## 6 -0.05555556 1.722222 0.3888889 235.29074 5.0909091 19.6075616

### Step 7:

#### Step 7.1: SLl,t for each length class as Ntotal-Qt

(table 24)

Catch.data.Cod$SL\_l\_t=Catch.data.Cod$Ntotal\_per\_hour-Catch.data.Cod$CPUE  
#Print first 6 lines  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC PWE min\_size max\_size  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922 0.35 13 31  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833 0.69 13 31  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877 0.81 13 31  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054 0.88 13 31  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364 0.88 13 31  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807 1.00 13 31  
## slope intercept PEO Ntotal CPUE Ntotal\_per\_hour  
## 1 -0.05555556 1.722222 0.9444444 11.02466 0.3636364 0.9187218  
## 2 -0.05555556 1.722222 0.8333333 68.81967 2.2727273 5.7349724  
## 3 -0.05555556 1.722222 0.7222222 55.28320 2.4545455 4.6069330  
## 4 -0.05555556 1.722222 0.6111111 48.24247 1.7272727 4.0202057  
## 5 -0.05555556 1.722222 0.5000000 117.76900 3.4545455 9.8140830  
## 6 -0.05555556 1.722222 0.3888889 235.29074 5.0909091 19.6075616  
## SL\_l\_t  
## 1 0.5550854  
## 2 3.4622451  
## 3 2.1523876  
## 4 2.2929329  
## 5 6.3595376  
## 6 14.5166525

#### Step 7.2: N\_AP calculation

First the table of Nlim (table 22c) is defined, in reality it is in input

!!!Notice- value of tau is very sensitive to the sum of the CPUE

###The next data frame will be an experimental input  
n\_lim=data.frame(Mesh\_size=c(20,25,30),Nlim=c(36,32,12))  
#Sum CPUE per net  
CPUE=data.frame(Catch.data.Cod %>%  
 group\_by(Mesh\_size) %>%  
 summarize(CPUE\_sum = sum(CPUE, na.rm = TRUE)))  
#merge to n\_lim table  
n\_lim=merge(n\_lim,CPUE,by="Mesh\_size")  
#Calculate tau (table 25)  
n\_lim$tau=n\_hours/(-log(1-(n\_lim$CPUE/n\_lim$Nlim)))  
n\_lim$N\_AP=((n\_lim$Nlim\*(1.71))/n\_lim$tau)\*n\_hours  
print(n\_lim)

## Mesh\_size Nlim CPUE\_sum tau N\_AP  
## 1 20 36 25.09091 10.050904 73.49787  
## 2 25 32 26.27273 6.974731 94.14557  
## 3 30 12 11.72727 3.171088 77.65157

#### Step 7.3: Size specific N\_AP

!!!In table 26 you use data from table 24 (SL)- is SL=0 if there is no value for this length group in table 24?

#Replace NA's in column 'SL\_l\_t' with 0  
Catch.data.Cod[is.na(Catch.data.Cod$SL\_l\_t),"SL\_l\_t"]=0  
#merge   
Catch.data.Cod=merge(Catch.data.Cod,n\_lim,by="Mesh\_size")  
#Calculate N\_AP per size class  
Catch.data.Cod$N\_AP\_size=(Catch.data.Cod$N\_AP\*(Catch.data.Cod$CPUE/Catch.data.Cod$CPUE\_sum))+Catch.data.Cod$SL\_l\_t  
print(head(Catch.data.Cod))

## Mesh\_size Length\_group Wedged Tangled Jaw\_length h y Radian  
## 1 20 14 2 2 17.69 4.446094 60 1.08  
## 2 20 16 20 5 19.73 4.958815 60 1.08  
## 3 20 18 15 12 21.77 5.471535 60 1.08  
## 4 20 20 11 8 23.81 5.984256 60 1.08  
## 5 20 22 20 18 25.85 6.496977 60 1.08  
## 6 20 24 32 24 27.89 7.009698 60 1.08  
## sin cos tan POC PThC PWE min\_size max\_size  
## 1 0.514136 0.8577087 0.5994296 0.5488078 0.4511922 0.35 13 31  
## 2 0.514136 0.8577087 0.5994296 0.5054167 0.4945833 0.69 13 31  
## 3 0.514136 0.8577087 0.5994296 0.4638123 0.5361877 0.81 13 31  
## 4 0.514136 0.8577087 0.5994296 0.4239946 0.5760054 0.88 13 31  
## 5 0.514136 0.8577087 0.5994296 0.3859636 0.6140364 0.88 13 31  
## 6 0.514136 0.8577087 0.5994296 0.3497193 0.6502807 1.00 13 31  
## slope intercept PEO Ntotal CPUE Ntotal\_per\_hour  
## 1 -0.05555556 1.722222 0.9444444 11.02466 0.3636364 0.9187218  
## 2 -0.05555556 1.722222 0.8333333 68.81967 2.2727273 5.7349724  
## 3 -0.05555556 1.722222 0.7222222 55.28320 2.4545455 4.6069330  
## 4 -0.05555556 1.722222 0.6111111 48.24247 1.7272727 4.0202057  
## 5 -0.05555556 1.722222 0.5000000 117.76900 3.4545455 9.8140830  
## 6 -0.05555556 1.722222 0.3888889 235.29074 5.0909091 19.6075616  
## SL\_l\_t Nlim CPUE\_sum tau N\_AP N\_AP\_size  
## 1 0.5550854 36 25.09091 10.0509 73.49787 1.620272  
## 2 3.4622451 36 25.09091 10.0509 73.49787 10.119661  
## 3 2.1523876 36 25.09091 10.0509 73.49787 9.342396  
## 4 2.2929329 36 25.09091 10.0509 73.49787 7.352569  
## 5 6.3595376 36 25.09091 10.0509 73.49787 16.478809  
## 6 14.5166525 36 25.09091 10.0509 73.49787 29.429263

### Step 8: Calculate selectivity

(table 28)

##Calculate selectivity  
Catch.data.Cod$selectivity=Catch.data.Cod$CPUE/Catch.data.Cod$Ntotal\_per\_hour  
##plot  
Catch.data.Cod$Mesh\_size\_fac=as.character(Catch.data.Cod$Mesh\_size)  
ggplot(Catch.data.Cod, aes(x=Length\_group, y=selectivity, group=Mesh\_size\_fac)) +  
 geom\_line(aes(color=Mesh\_size\_fac))+  
 geom\_point(aes(color=Mesh\_size\_fac))+  
 labs(x = "length Group",y="Selectivity",color="Mesh Size")

## Warning: Removed 25 rows containing missing values (geom\_path).

## Warning: Removed 25 rows containing missing values (geom\_point).

