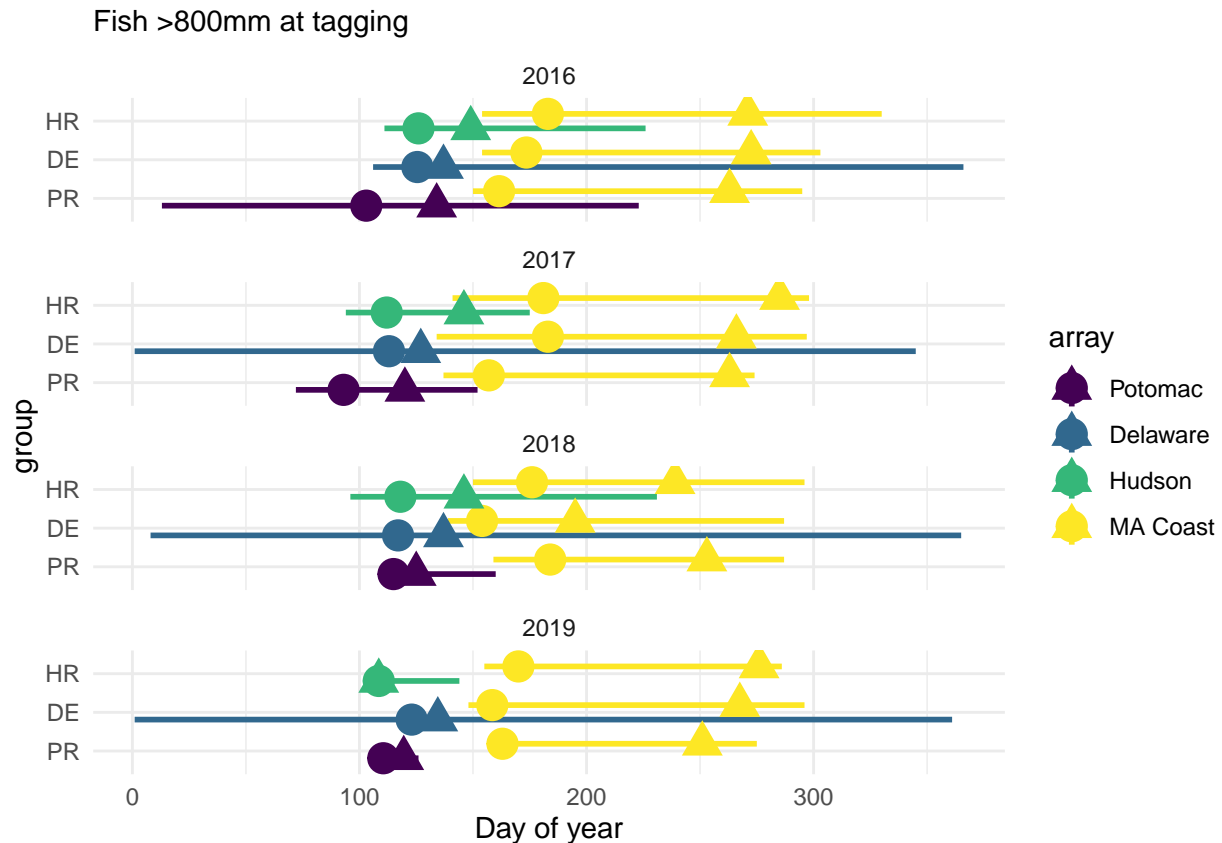


Early migration phenology models

As a reminder, the figure below displays a mile-high view of migration timing across different striped bass spawning groups: Hudson River (HR), Delaware River (DE), and Potomac River (PR). The length of the line displays the range of residence of each group in either the natal estuary (colors) or coastal Massachusetts (yellow). The circle shows the median day of arrival in the given array, and the triangle shows the median date of departure. Only fish that were larger than 800 mm at the time of tagging are shown.

```
## Warning: Invalid .internal.selfref detected and fixed by taking a (shallow)
## copy of the data.table so that := can add this new column by reference. At an
## earlier point, this data.table has been copied by R (or was created manually
## using structure() or similar). Avoid names<- and attr<- which in R currently
## (and oddly) may copy the whole data.table. Use set* syntax instead to avoid
## copying: ?set, ?setnames and ?setattr. If this message doesn't help, please
## report your use case to the data.table issue tracker so the root cause can be
## fixed or this message improved.
```



I'm going to make a quick-and-dirty model to compare the timing of entry into coastal Massachusetts by spawning group. The full model includes day of year ("yday", numeric), spawning group ("group", factor), the year ("year", ordered factor), and all interactions.

The response was modeled as binomial, with the cumulative number of fish that have entered Massachusetts waters per group-year combination considered “successes” and the total number of fish that arrived in coastal MA per group-year combination as the number of trials.

Using step-wise variable selection...

```
## Start: AIC=876.21
## cbind(success, trials - success) ~ 0 + group + yday + year +
##   group:yday + group:year + year:yday + group:year:yday
##
##               Df Deviance    AIC
## <none>                204.73 876.21
## - group:yday:year    6    220.74 880.23
```

...the variables selected are: group, yday, year, group:yday, group:year, yday:year, group:yday:year.

```
##
## Call:
## glm(formula = cbind(success, trials - success) ~ 0 + group +
##   yday + year + group:yday + group:year + year:yday + group:year:yday,
##   family = "binomial", data = binom_data[array == "MA Coast"])
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -3.9854  -0.6261   0.0378   0.4881   2.1411
##
## Coefficients:
##              Estimate Std. Error z value Pr(>|z|)
## groupDE          -15.875824    1.328794 -11.948 < 2e-16 ***
## groupHR           -11.264119    1.173194  -9.601 < 2e-16 ***
## groupPR           -18.541642    2.964276  -6.255 3.97e-10 ***
## yday              0.097072    0.008390  11.570 < 2e-16 ***
## year.L            -8.841642    2.298368  -3.847 0.00012 ***
## year.Q            -4.173475    2.657588  -1.570 0.11632
## year.C             4.614116    2.973727   1.552 0.12075
## groupHR:yday      -0.033435    0.010911  -3.064 0.00218 **
## groupPR:yday       0.014470    0.019871   0.728 0.46650
## groupHR:year.L     8.480084    3.853682   2.201 0.02777 *
## groupPR:year.L     9.320778    7.243423   1.287 0.19817
## groupHR:year.Q    -2.710364    3.545181  -0.765 0.44456
## groupPR:year.Q     0.729079    6.496961   0.112 0.91065
## groupHR:year.C    -4.344584    3.207141  -1.355 0.17553
## groupPR:year.C     4.656374    5.652772   0.824 0.41009
## yday:year.L        0.061693    0.014208   4.342 1.41e-05 ***
## yday:year.Q        0.023110    0.016779   1.377 0.16842
## yday:year.C       -0.033881    0.019006  -1.783 0.07464 .
## groupHR:yday:year.L -0.055324    0.023270  -2.377 0.01743 *
## groupPR:yday:year.L -0.072239    0.044520  -1.623 0.10467
## groupHR:yday:year.Q  0.018236    0.021822   0.836 0.40333
## groupPR:yday:year.Q  0.002267    0.039743   0.057 0.95451
## groupHR:yday:year.C  0.033170    0.020270   1.636 0.10177
## groupPR:yday:year.C -0.013135    0.034307  -0.383 0.70181
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## (Dispersion parameter for binomial family taken to be 1)
##
## Null deviance: 2656.34 on 202 degrees of freedom
## Residual deviance: 204.73 on 178 degrees of freedom
## AIC: 876.21
##
## Number of Fisher Scoring iterations: 5
```

When looking at pairwise contrasts by year, the only significant differences occur in 2018, where arrival in MA was more rapid in DE and PR fish when compared to HR fish (greater yday slope).

```
## year = 2016:
## contrast estimate      SE  df z.ratio p.value
## DE - HR -0.00538 0.00971 Inf -0.554 0.8443
## DE - PR -0.06700 0.05253 Inf -1.275 0.4091
## HR - PR -0.06162 0.05187 Inf -1.188 0.4604
##
## year = 2017:
## contrast estimate      SE  df z.ratio p.value
## DE - HR 0.00793 0.00513 Inf 1.547 0.2691
## DE - PR -0.02068 0.02399 Inf -0.862 0.6644
## HR - PR -0.02861 0.02372 Inf -1.206 0.4494
##
## year = 2018:
## contrast estimate      SE  df z.ratio p.value
## DE - HR 0.07717 0.02762 Inf 2.794 0.0144
## DE - PR -0.00599 0.03971 Inf -0.151 0.9875
## HR - PR -0.08317 0.02924 Inf -2.845 0.0124
##
## year = 2019:
## contrast estimate      SE  df z.ratio p.value
## DE - HR 0.05401 0.03196 Inf 1.690 0.2090
## DE - PR 0.03579 0.03750 Inf 0.955 0.6056
## HR - PR -0.01822 0.04316 Inf -0.422 0.9064
##
## P value adjustment: tukey method for comparing a family of 3 estimates
```

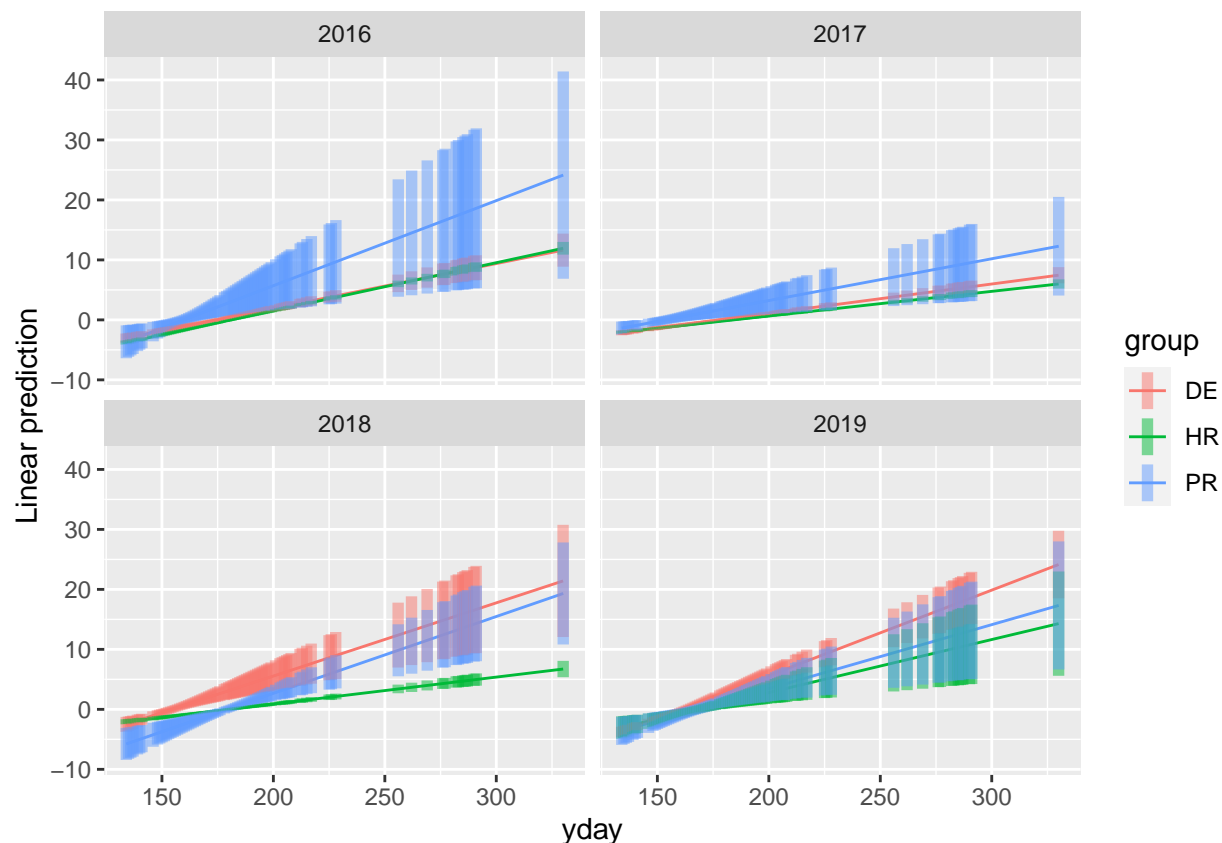
```
## NOTE: Results may be misleading due to involvement in interactions
```

```
## $emmeans
## year = 2016:
## group emmean      SE  df asymp.LCL asymp.UCL
## DE 1.376 0.2072 Inf 0.970 1.782
## HR 0.953 0.0709 Inf 0.814 1.092
## PR 4.711 1.7653 Inf 1.251 8.171
##
## year = 2017:
## group emmean      SE  df asymp.LCL asymp.UCL
## DE 0.738 0.1255 Inf 0.492 0.984
## HR 0.364 0.0666 Inf 0.233 0.495
## PR 2.738 1.0116 Inf 0.755 4.721
##
```

```

## year = 2018:
##   group emmean      SE df asymp.LCL asymp.UCL
##   DE      4.691 1.0661 Inf      2.602      6.780
##   HR      0.575 0.1176 Inf      0.344      0.805
##   PR      1.778 0.4627 Inf      0.871      2.685
##
## year = 2019:
##   group emmean      SE df asymp.LCL asymp.UCL
##   DE      4.627 0.5827 Inf      3.485      5.769
##   HR      2.177 0.7645 Inf      0.678      3.675
##   PR      2.711 0.9279 Inf      0.893      4.530
##
## Results are averaged over the levels of: yday
## Results are given on the logit (not the response) scale.
## Confidence level used: 0.95
##
## $contrasts
## year = 2016:
##   contrast estimate      SE df z.ratio p.value
##   DE - HR      0.423 0.219 Inf      1.929 0.1304
##   DE - PR     -3.335 1.777 Inf     -1.876 0.1455
##   HR - PR     -3.758 1.767 Inf     -2.127 0.0844
##
## year = 2017:
##   contrast estimate      SE df z.ratio p.value
##   DE - HR      0.374 0.142 Inf      2.635 0.0229
##   DE - PR     -2.000 1.019 Inf     -1.962 0.1218
##   HR - PR     -2.374 1.014 Inf     -2.342 0.0502
##
## year = 2018:
##   contrast estimate      SE df z.ratio p.value
##   DE - HR      4.116 1.073 Inf      3.838 0.0004
##   DE - PR      2.913 1.162 Inf      2.506 0.0327
##   HR - PR     -1.203 0.477 Inf     -2.521 0.0314
##
## year = 2019:
##   contrast estimate      SE df z.ratio p.value
##   DE - HR      2.450 0.961 Inf      2.549 0.0291
##   DE - PR      1.915 1.096 Inf      1.748 0.1875
##   HR - PR     -0.535 1.202 Inf     -0.445 0.8967
##
## Results are averaged over the levels of: yday
## Results are given on the log odds ratio (not the response) scale.
## P value adjustment: tukey method for comparing a family of 3 estimates

```



```
## PhantomJS not found. You can install it with webshot::install_phantomjs(). If it is installed, please
```

Entry into MA waters significantly different between DE and HR fish, but not between PR and HR or PR and DE fish.

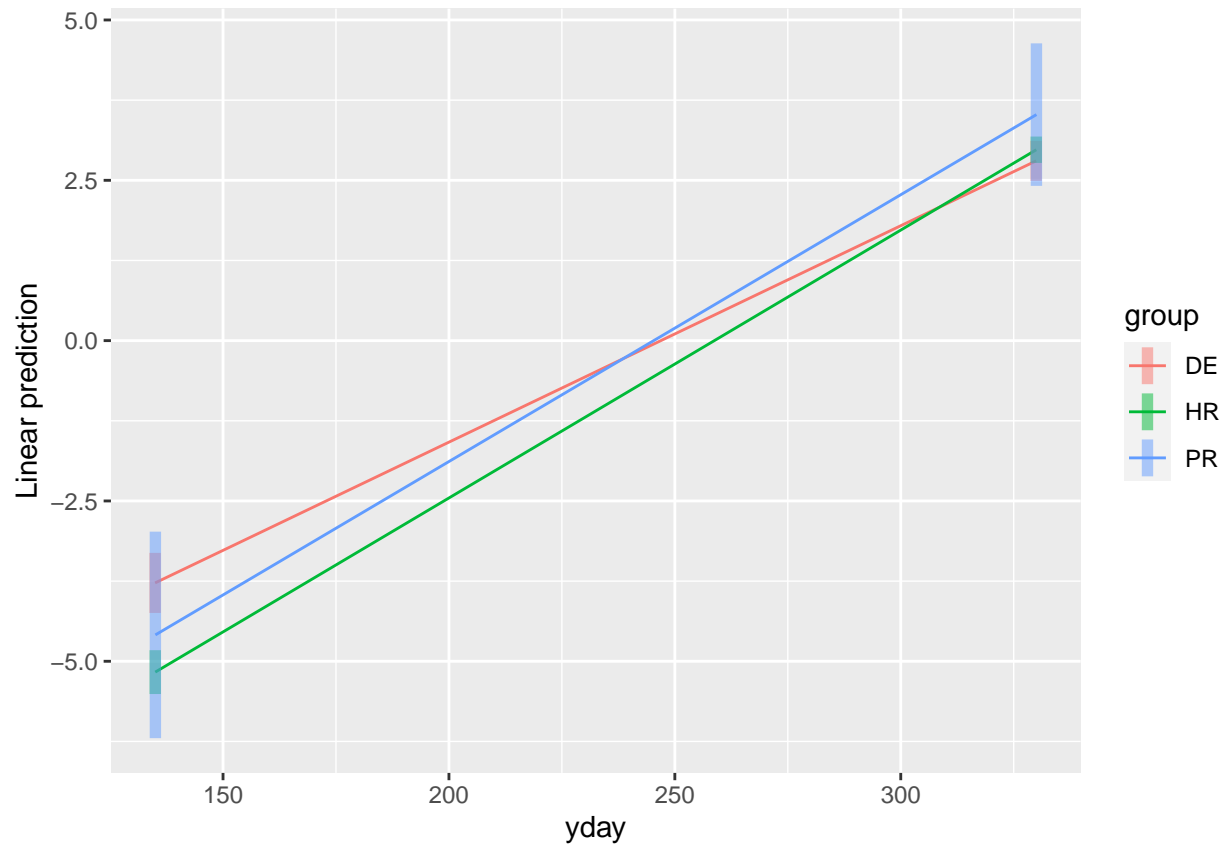
```
## Start: AIC=991.5
## cbind(success, trials - success) ~ 0 + group + yday + group:yday +
##   year
##
##           Df Deviance    AIC
## <none>          382.39  991.50
## - group:yday   2    394.16  999.26
## - year         3    528.96 1132.06
##
## Call:
## glm(formula = cbind(success, trials - success) ~ 0 + group +
##   yday + group:yday + year, family = "binomial", data = binom_data[array ==
##   "MA Coast"])
##
## Deviance Residuals:
##      Min       1Q   Median       3Q      Max
## -3.0910  -0.9008   0.0119   0.9630   5.2940
##
## Coefficients:
```

```

##               Estimate Std. Error z value Pr(>|z|)
## groupDE      -8.542018   0.499708 -17.094 < 2e-16 ***
## groupHR     -11.015699   0.352014 -31.293 < 2e-16 ***
## groupPR     -10.413725   1.745313  -5.967 2.42e-09 ***
## yday         0.033748   0.001915  17.623 < 2e-16 ***
## year2017     -0.374309   0.070063  -5.342 9.17e-08 ***
## year2018      0.906559   0.108262   8.374 < 2e-16 ***
## year2019      0.300201   0.130164   2.306 0.021092 *
## groupHR:yday  0.008022   0.002301   3.486 0.000491 ***
## groupPR:yday  0.007858   0.007130   1.102 0.270393
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##    Null deviance: 2536.41  on 192  degrees of freedom
## Residual deviance:  382.39  on 183  degrees of freedom
## AIC: 991.5
##
## Number of Fisher Scoring iterations: 5

## $emtrends
##   group yday.trend      SE df asymp.LCL asymp.UCL
## DE      0.0337 0.00191 Inf    0.0300    0.0375
## HR      0.0418 0.00133 Inf    0.0392    0.0444
## PR      0.0416 0.00689 Inf    0.0281    0.0551
##
## Results are averaged over the levels of: year
## Confidence level used: 0.95
##
## $contrasts
##   contrast estimate      SE df z.ratio p.value
## DE - HR  -0.008022 0.00230 Inf   -3.486  0.0014
## DE - PR  -0.007858 0.00713 Inf   -1.102  0.5127
## HR - PR   0.000164 0.00700 Inf    0.023  0.9997
##
## Results are averaged over the levels of: year
## P value adjustment: tukey method for comparing a family of 3 estimates

```



exit times not significantly different

