# Dredge

Integrated landings CPUEs for the Charleston Harbor Watershed seem to have a special predictive relationship when explained by the same year’s Harbor Trawl and Trammel Net Surveys’ total CPUEs, and by the Harbor Trawl and Creek Trawl Surveys’ subadult CPUEs with a lag (e.g. the abundances one year predict the landings of the next). The landings CPUE time series ranges from 2004-2018, which is the time limiting factor for all models except models incorporating the Trammel Net Survey, which range from 2006-2018. Any of the models, and dredges, sans Trammel Net Survey will have different summary statistics than models incorporating Trammel Net Survey variables due to the change in degrees of freedom after further filtering of the dataset.

A dredge function (MuMIn::dredge) was performed for the purposes of model exploration using several of the size and sex/maturity variables of the explanatory surveys (Harbor Trawl, Creek Trawl and Trammel Net Survey). Select results from all dredge function combinations can be found in the outline below. Only models with a  < 2.0 were considered. Traditional measures of model fit, including AICc and Akaike weight were not considered, as these are only exploratory analyses to uncover relationships between the variables.

#### Landings CPUE ~ lag(B90 subadult) + lag(T38 subadult) + B90 total CPUE

These were performed sans Trammel Net Survey just in case of effect of reduced degrees of freedom

Relevant additive models ranked in order by AICc:

1. Landings CPUE ~ lag(Harbor Trawl subadults)
2. Landings CPUE ~ lag(Creek Trawl subadults)
3. Landings CPUE ~ Harbor Trawl CPUE + lag(Harbor Trawl subadults)
4. Landings CPUE ~ Harbor Trawl CPUE
5. Landings CPUE ~ Harbor Trawl CPUE + lag(Creek Trawl subadults)
6. Model selection table
7. (Int) B90\_CPU B90\_SLA T38\_SLA df logLik AICc delta weight
8. 3 2.563 0.05643 3 1.525 5.1 0.00 0.207
9. 5 2.465 0.18890 3 1.518 5.1 0.02 0.205
10. 4 2.440 0.02074 0.04183 4 3.315 5.4 0.24 0.184
11. 2 2.507 0.02933 3 1.233 5.7 0.58 0.155
12. Figure 1: Example of Model Selection Output for all the following dredge outputs. Only models with < 2 were shown in these and the following results.

#### Landings CPUE ~ **.** (all B90 Vars)

Relevant models ranked in order of AICc:

1. Landings CPUE ~ Harbor Trawl mature females, lag(Harbor Trawl subadults)
2. Landings CPUE ~ Harbor Trawl adults, lag(Harbor Trawl subadults)
3. Landings CPUE ~ Harbor Trawl immature females

#### Landings CPUE ~ **.** (all T38 Vars)

Relevant models ranked in order of AICc:

1. Landings CPUE ~ lag(Creek Trawl subadults)

#### Landings CPUE ~ all relevant vars including Trammel Net Survey

1. Landings CPUE ~ (Trammel Net + Harbor Trawl), (Harbor Trawl subadults + Creek Trawl subadults)
2. Landings CPUE ~ (Trammel Net + Harbor Trawl), Creek Trawl CPUE
3. Landings CPUE ~ (Trammel Net + Harbor Trawl)
4. Landings CPUE ~ Harbor Trawl CPUE, (Trammel Net + Harbor Trawl), Creek Trawl CPUE #Disregard because includes a main effect?
5. Landings CPUE ~ Trammel Net CPUE, (Trammel Net + Harbor Trawl), Creek Trawl CPUE #Disregard because includes a main effect?
6. Landings CPUE ~ Harbor Trawl, Trammel Net CPUE, Creek Trawl CPUE
7. Landings CPUE ~ Trammel Net CPUE, Creek Trawl CPUE, (Harbor Trawl subadults + Creek Trawl subadults)
8. Landings CPUE ~ Harbor Trawl CPUE

# Models (based-on dredge results)

Outline of regression work found in tables below

* **No Lag**
  + Individual models
    - Mean Landings CPUE ~ Harbor Trawl CPUE (R2 = 0.3231)
    - Mean Landings CPUE ~ Trammel Net CPUE (R2 = 0.3762)
    - Mean Landings CPUE ~ (Harbor Trawl CPUE + Trammel Net CPUE (R2 = 0.5165) #Sum of variable values before adding to the model
  + Additive model
    - Mean Landings CPUE ~ Harbor Trawl + Trammel Net (R2 = 0.5566)
  + Multiple model
    - Mean Landings CPUE ~ Harbor Trawl \* Trammel Net (R2 = 0.7189)

***Discussion*** – Strong relationship with the Harbor Trawl Survey, Trammel Net survey and their interaction with the whole system landings of Charleston Harbor. Decent relationships with all variables in bivariate modeling, but stronger when each variable is a main effect separately as opposed to a summed variable of both. These data have a range of 2004-2018. This interaction could reflect a different survey range (the Trammel Net Survey occurs in the Wando and Cooper Rivers, in addition to the Ashley and Chas Harbor covered by the Harbor Trawl survey), or could reflect a different make-up of catch, i.e., Trammel Net catching more adult males.

* **1-Yr Lag (only**)
  + Individual models
    - Mean Landings CPUE ~ Harbor Trawl subadult CPUE (R2 = 0.349)
    - Mean Landings CPUE ~ Creek Trawl subadult CPUE (R2 = 0.3483)
    - Mean Landings CPUE ~ lag(Harbor Trawl CPUE + Creek Trawl CPUE (R2 = 0.312) #Sum of variable values before adding to the model
  + Additive model
    - Mean Landings CPUE ~ lag(Harbor Trawl subadult) + lag(Creek Trawl subadult) (R2 = 0.4149)
  + Multiple model
    - Mean Landings CPUE ~ lag(Harbor Trawl subadult) \* lag(Creek Trawl subadult) (R2 = 0.4493, **p-value = 0.07736**)
      * This model only has 11 degrees of freedom. Another couple of years of sampling, and I think this is a significant relationship.

***Discussion*** – Decent relationship with the Harbor Trawl and Creek Trawl survey subadults through all models (bivariate, additive and multiple). The Harbor Trawl and Creek Trawl surveys have a nearly identical R2 despite a weak, but still significant, positive correlation (r = 0.26) between their populations. Does each of these surveys cover a subset of the subadult blue crab population in Charleston Harbor? There is a significant interaction between harbor and creek trawl surveys, but the whole multiple regression model shows no significance

* **Mixed Lag (including all independent variables w/ and w/out lag)**
  + Additive model
    - Mean Annual Landings CPUE ~ lag(Harbor Trawl subadult) + lag(Creek Trawl subadult) (R2 = 0.4149)
  + Multiple model
    - Mean Annual Landings CPUE ~ lag(Harbor Trawl subadult) + lag(Creek Trawl subadult) (R2 = 0.4493, **p-value = 0.07736**)
      * This model only has 11 degrees of freedom. Another couple of years of sampling, and I think this is a significant relationship.

# Regressions

### NO LAG

#### Individual Models

Mean Annual Landings CPUE ~ Harbor Trawl CPUE

lm(formula = MeanLandingsCPUE ~ B90\_CPUE, data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.39959 -0.10796 -0.02369 0.09489 0.53296

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.50696 0.11507 21.786 1.29e-11 \*\*\*

B90\_CPUE 0.02933 0.01177 2.491 0.027 \*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2394 on 13 degrees of freedom

(32 observations deleted due to missingness)

Multiple R-squared: 0.3231, Adjusted R-squared: 0.2711

F-statistic: 6.206 on 1 and 13 DF, p-value: 0.02703

Mean Annual Landings CPUE ~ Trammel Net CPUE

lm(formula = MeanLandingsCPUE ~ T06\_CPUE, data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.31024 -0.17533 -0.00542 0.04975 0.34281

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.31169 0.16882 13.693 2.96e-08 \*\*\*

T06\_CPUE 0.23735 0.09216 2.575 0.0258 \*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2205 on 11 degrees of freedom

(34 observations deleted due to missingness)

Multiple R-squared: 0.3762, Adjusted R-squared: 0.3194

F-statistic: 6.633 on 1 and 11 DF, p-value: 0.0258

#### Additive Model

Mean Annual Landings CPUE ~ Harbor Trawl CPUE + Trammel Net CPUE)

lm(formula = MeanLandingsCPUE ~ T06\_CPUE + B90\_CPUE, data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.24977 -0.10151 -0.02481 0.07537 0.43159

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.27652 0.15029 15.147 3.18e-08 \*\*\*

T06\_CPUE 0.13187 0.09683 1.362 0.2031

B90\_CPUE 0.03111 0.01542 2.017 0.0713 .

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.195 on 10 degrees of freedom

(34 observations deleted due to missingness)

Multiple R-squared: 0.5566, Adjusted R-squared: 0.4679

F-statistic: 6.276 on 2 and 10 DF, p-value: 0.01714

#### Multiple Regression Model

Mean Annual Landings CPUE ~ Harbor Trawl CPUE \* Trammel Net CPUE)

lm(formula = MeanLandingsCPUE ~ T06\_CPUE \* B90\_CPUE, data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.29022 -0.05661 -0.01850 0.07032 0.26046

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 1.89333 0.21012 9.011 8.46e-06 \*\*\*

T06\_CPUE 0.42851 0.15339 2.794 0.0209 \*

B90\_CPUE 0.10688 0.03566 2.997 0.0150 \*

T06\_CPUE:B90\_CPUE -0.04866 0.02134 -2.280 0.0486 \*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1636 on 9 degrees of freedom

(34 observations deleted due to missingness)

Multiple R-squared: 0.7189, Adjusted R-squared: 0.6252

F-statistic: 7.674 on 3 and 9 DF, p-value: 0.007508

### 1-yr LAG

#### Individual Models

Mean Annual Landings CPUE ~ Harbor Trawl Subadults

lm(formula = MeanLandingsCPUE ~ lag(B90\_SubadultCPUE), data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.5004 -0.1245 0.0194 0.1008 0.3399

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.56290 0.09291 27.59 6.37e-13 \*\*\*

lag(B90\_SubadultCPUE) 0.05643 0.02138 2.64 0.0204 \*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2348 on 13 degrees of freedom

(32 observations deleted due to missingness)

Multiple R-squared: 0.349, Adjusted R-squared: 0.2989

F-statistic: 6.969 on 1 and 13 DF, p-value: 0.0204

Mean Annual Landings CPUE ~ Creek Trawl Subadults

lm(formula = MeanLandingsCPUE ~ lag(T38\_SubadultCPUE), data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.50391 -0.12880 -0.01098 0.12127 0.48439

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.46536 0.12344 19.972 3.87e-11 \*\*\*

lag(T38\_SubadultCPUE) 0.18887 0.07165 2.636 0.0206 \*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2349 on 13 degrees of freedom

(32 observations deleted due to missingness)

Multiple R-squared: 0.3483, Adjusted R-squared: 0.2982

F-statistic: 6.948 on 1 and 13 DF, p-value: 0.02055

#### Additive Model

Mean Annual Landings CPUE ~ lag(Harbor Trawl Subadult CPUE) + lag(\*Creek Trawl Subadult CPUE)

lm(formula = MeanLandingsCPUE ~ lag(B90\_SubadultCPUE) +

lag(T38\_SubadultCPUE), data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.50928 -0.10005 0.01038 0.10311 0.40099

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.46968 0.12180 20.277 1.19e-10 \*\*\*

lag(B90\_SubadultCPUE) 0.03365 0.02880 1.168 0.265

lag(T38\_SubadultCPUE) 0.11214 0.09647 1.163 0.268

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2317 on 12 degrees of freedom

(32 observations deleted due to missingness)

Multiple R-squared: 0.4149, Adjusted R-squared: 0.3174

F-statistic: 4.254 on 2 and 12 DF, p-value: 0.04013

#### Multiple Regression Model

Mean Annual Landings CPUE ~ lag(Harbor Trawl Subadult CPUE) \* lag(\*Creek Trawl Subadult CPUE)

lm(formula = MeanLandingsCPUE ~ lag(B90\_SubadultCPUE) \*

lag(T38\_SubadultCPUE), data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.54710 -0.09392 0.02667 0.05481 0.35341

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.33161 0.20730 11.248 2.26e-07 \*\*\*

lag(B90\_SubadultCPUE) 0.07152 0.05422 1.319 0.214

lag(T38\_SubadultCPUE) 0.18850 0.13431 1.403 0.188

lag(B90\_SubCPUE):lag(T38\_SubCPUE) -0.01540 0.01858 -0.829 0.425

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2348 on 11 degrees of freedom

(32 observations deleted due to missingness)

Multiple R-squared: 0.4493, Adjusted R-squared: 0.2991

F-statistic: 2.991 on 3 and 11 DF, p-value: 0.07736

**NO SIGNIFICANCE**

### Multiple (all iv) Regression

#### Additive Model

lm(formula = MeanLandingsCPUE ~

lag(B90\_SubadultCPUE) + lag(T38\_SubadultCPUE) +

T06\_CPUE + B90\_CPUE, data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.24036 -0.10436 0.00844 0.08402 0.36789

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.21170 0.21129 10.468 6.03e-06 \*\*\*

lag(B90\_SubadultCPUE) 0.02014 0.03401 0.592 0.570

lag(T38\_SubadultCPUE) 0.03513 0.12726 0.276 0.789

T06\_CPUE 0.14150 0.10738 1.318 0.224

B90\_CPUE 0.02321 0.02222 1.045 0.327

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2127 on 8 degrees of freedom

(34 observations deleted due to missingness)

Multiple R-squared: 0.578, Adjusted R-squared: 0.367

F-statistic: 2.739 on 4 and 8 DF, p-value: 0.105

**NO SIGNIFICANCE**

#### Multiple Regression Model

lm(formula = MeanLandingsCPUE ~

lag(B90\_SubadultCPUE) \* lag(T38\_SubadultCPUE \*

T06\_CPUE \* B90\_CPUE), data = crab)

Residuals:

Min 1Q Median 3Q Max

-0.3457 -0.1338 0.0120 0.1473 0.2881

Coefficients:

Estimate Std. Error t value Pr(>|t|)

(Intercept) 2.351691 0.179011 13.137 1.07e-06 \*\*\*

lag(B90\_SubadultCPUE) 0.237899 0.099570 2.389 0.0439 \*

lag(T38\_SubadultCPUE \* T06\_CPUE \*

B90\_CPUE 0.014616 0.014236 1.027 0.3346

Lag(B90\_SubadultCPUE):

lag(T38\_SubadultCPUE \*

T06\_CPUE \* B90\_CPUE) -0.008960 0.004541 -1.973 0.0839 .

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.2766 on 9 degrees of freedom

(35 observations deleted due to missingness)

Multiple R-squared: 0.08064, Adjusted R-squared: -0.1237

F-statistic: 0.3947 on 2 and 9 DF, p-value: 0.685

F-statistic: 2.991 on 3 and 11 DF, p-value: 0.07736

**NO SIGNIFICANCE**

# Creek Trawl, Harbor Trawl & Trammel Net Surveys Catch Analyses

* B90’s catch is dominated by immature females
  + - Correlation between B90 subadult and B90 Immature females = 0.74 R2. That is the highest correlation off all sex and maturity categories.
    - Correlation between B90 CPUE and B90 subadult = 0.83 R2. That is the highest correlation of any size and six/maturity variable

A close up of a piece of paper

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Figure 1: Kendall Rank Correlation Coeffiecients for all harbor trawl CPUEs

* T38’s catch is dominated by immature females, albeit these immature females are less influential on the creek trawl than immature females are on the harbor trawl.
  + - Correlation between T38 subadult and immature females = 0.77 R2. This is slightly higher than the juveniles and immature female correlation (0.72 R2)
    - Correlation between T38 CPUE and both subadults and immature females = 0.82 R2.

A close up of a piece of paper

Description automatically generatedFigure 2: Kendall Rank Correlation Coeffiecients for all harbor trawl CPUEs

* T06

# Metadata for Landings and Dependent CPUEs

* Mean Landings
  + 1972-1977 – Harbor only
  + 1978-2003 – Wando and Harbor
  + 2004-2018 – Ashley, Cooper, Wando and Harbor
* Mean Landings CPUE
  + 2004-2018 – Ashley, Cooper, Wando and Harbor