

# Predicting age at maturity in black carp

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## Introduction

We used different temperature metrics to predict black carp age at maturity. Simple linear regression model was used for all metrics.

1. Annual average temperature. (obtained from the WORLDCLIM dataset BIO1) (1970 - 2000)
2. Cold quarter temperature. (obtained from the WORLDCLIM dataset BIO11) (1970 - 2000)
3. Warm quarter temperature. (obtained from the WORLDCLIM dataset BIO10) (1970 - 2000)
4. Growing degree day Base 0. (calculated from CPC Global Daily Temperature) (1979 - 2022)
5. Winter duration (calculated from CPC Global Daily Temperature) (1979 - 2022)
6. Annual water temperature. (averaged weekly water temperature calculated from futureStream database) (1979 - 2005)
7. Cold quarter water temperature. (averaged weekly water temperature calculated from future-Stream database) (1979 - 2005)

Both water temperature metrics using the calculation method in the WorldClim database in terms of “annual” and “cold quarter”. (package dismo)

## Predict black carp age at maturity

```
library(car)
library(dplyr)

## Import data
Black <- read.csv("eddie_carp_new.csv")
Black$condition <- as.factor(Black$condition)

# Clean data
Black <- Black %>% filter(!row_number() == 5) %>% filter(sex != "male")

# Remove the South Ukraine data point
black.clean <- Black %>% filter(!row_number() == 20)

black.annual <- lm(log(AAM)~AnnualTemp, data = black.clean)
black.cold <- lm(log(AAM)~ColdTemp, data = black.clean)
black.warm <- lm(log(AAM)~WarmTemp, data = black.clean)
black.gdd <- lm(log(AAM)~average_gdd_0, data = black.clean)
black.below5 <- lm(log(AAM)~below5, data = black.clean)
black.water <- lm(log(AAM)~WaterTemp, data = black.clean)
black.coldwater <- lm(log(AAM)~WaterCold, data = black.clean)
```

```
summary(black.annual)
```

```
##
## Call:
## lm(formula = log(AAM) ~ AnnualTemp, data = black.clean)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.42489 -0.12464  0.00059  0.09959  0.30683
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.984762   0.074361  26.691 < 2e-16 ***
## AnnualTemp  -0.017186   0.005344  -3.216  0.00433 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1754 on 20 degrees of freedom
## Multiple R-squared:  0.3409, Adjusted R-squared:  0.3079
## F-statistic: 10.34 on 1 and 20 DF,  p-value: 0.004333
```

```
summary(black.cold)
```

```
##
## Call:
## lm(formula = log(AAM) ~ ColdTemp, data = black.clean)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.39468 -0.12079 -0.00699  0.08961  0.29562
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.767262   0.035603  49.638 <2e-16 ***
## ColdTemp    -0.011423   0.003084  -3.704  0.0014 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1664 on 20 degrees of freedom
## Multiple R-squared:  0.4069, Adjusted R-squared:  0.3772
## F-statistic: 13.72 on 1 and 20 DF,  p-value: 0.001405
```

```
summary(black.warm)
```

```
##
## Call:
## lm(formula = log(AAM) ~ WarmTemp, data = black.clean)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.44602 -0.15359  0.03875  0.13845  0.30624
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.13752   0.26482   8.072 1.02e-07 ***
```

```
## WarmTemp    -0.01511    0.01098   -1.377    0.184
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2065 on 20 degrees of freedom
## Multiple R-squared:  0.08655,    Adjusted R-squared:  0.04087
## F-statistic: 1.895 on 1 and 20 DF,  p-value: 0.1839
```

```
summary(black.gdd)
```

```
##
## Call:
## lm(formula = log(AAM) ~ average_gdd_0, data = black.clean)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.46712 -0.09978  0.00423  0.08019  0.32039
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   2.142e+00  1.276e-01  16.787 2.97e-13 ***
## average_gdd_0 -6.895e-05  2.307e-05  -2.988  0.00727 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1797 on 20 degrees of freedom
## Multiple R-squared:  0.3086, Adjusted R-squared:  0.2741
## F-statistic: 8.929 on 1 and 20 DF,  p-value: 0.007268
```

```
summary(black.below5)
```

```
##
## Call:
## lm(formula = log(AAM) ~ below5, data = black.clean)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.34614 -0.13083  0.01528  0.08633  0.32716
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.6449045  0.0474995  34.630 < 2e-16 ***
## below5       0.0018623  0.0004611   4.039 0.000643 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1604 on 20 degrees of freedom
## Multiple R-squared:  0.4492, Adjusted R-squared:  0.4217
## F-statistic: 16.31 on 1 and 20 DF,  p-value: 0.0006427
```

```
summary(black.water)
```

```
##
## Call:
## lm(formula = log(AAM) ~ WaterTemp, data = black.clean)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.43891 -0.14624  0.01017  0.12283  0.35815
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.077127   0.137615  15.094 2.15e-12 ***
## WaterTemp   -0.020957   0.009204  -2.277  0.0339 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1926 on 20 degrees of freedom
## Multiple R-squared:  0.2059, Adjusted R-squared:  0.1661
## F-statistic: 5.184 on 1 and 20 DF,  p-value: 0.03393
```

```
summary(black.coldwater)
```

```
##
## Call:
## lm(formula = log(AAM) ~ WaterCold, data = black.clean)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.49139 -0.09544 -0.02325  0.11838  0.29075
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.923428   0.059900  32.111 < 2e-16 ***
## WaterCold   -0.023142   0.007403  -3.126  0.00532 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1771 on 20 degrees of freedom
## Multiple R-squared:  0.3283, Adjusted R-squared:  0.2947
## F-statistic: 9.773 on 1 and 20 DF,  p-value: 0.005318
```

```
plot(black.annual, which=5)
```

