Swimming analysis of zoea 1 larvae of *Taliepus dentatus* reared at different temperatures

Reproducible report

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This document reproduces and supports all data work and statistical analysis of the larval swimming in the paper: swimming performance and morphometrics of the kelp-crab *Taliepus dentatus* zoea 1 exposed to different rearing temperatures.

```
# Packages used for the analysis
library(tidyverse)
library(lme4)
library(plyr)
library(lmerTest)
library(lme4)
library(car)
library(sjPlot)
library(effects)
library(cowplot)
library(emmeans)
library(sjPlot)
```

```
#setting working directory and uploading data (you must set your own working directory)
#data are available in the online version of the article
setwd("~/Desktop/ECOLAB!/paper tesis/swimming R/NEW TRIAL/")
data<-read.table("copia de full_mean.csv", sep=",", header=TRUE)
```

```
#Tidying data
data1<-data%>%group_by(Temp,Pote,Larva) %>%
  dplyr::summarise(Ist_Vel = mean(IV),
                   Tot_Time= sum(Time), Max_Time=max(Time))%>%rowid_to_column(var='ID')
data1$Temp<-as.factor(data1$Temp)
```

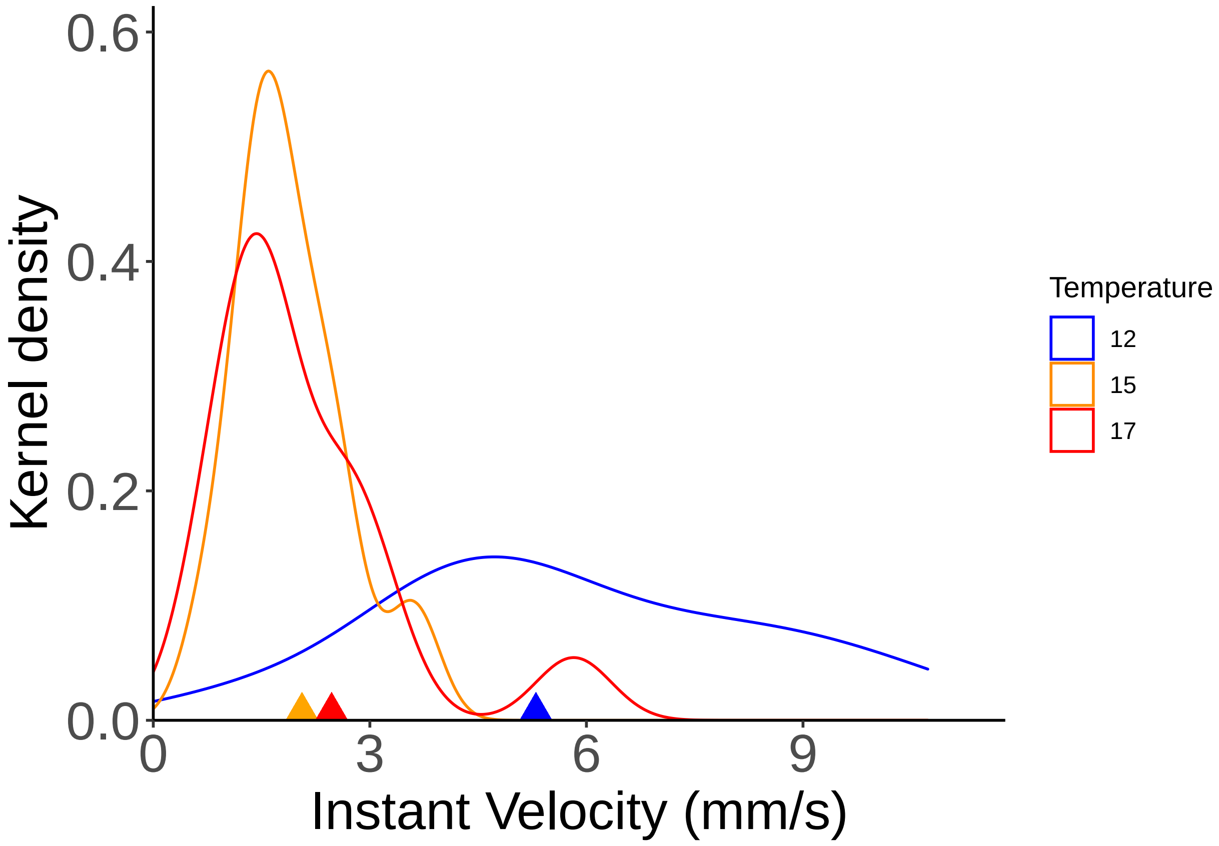
```
#Calculating median for each response variable
medIV <- ddply(data1, "Temp", summarise, grp.med=median(Ist_Vel))
head(medIV)
```

```
##   Temp  grp.med
## 1   12 5.138207
## 2   15 1.769275
## 3   17 1.568503
```

```
medTime <- ddply(data1, "Temp", summarise, grp.med=median(Tot_Time))
head(medTime)
```

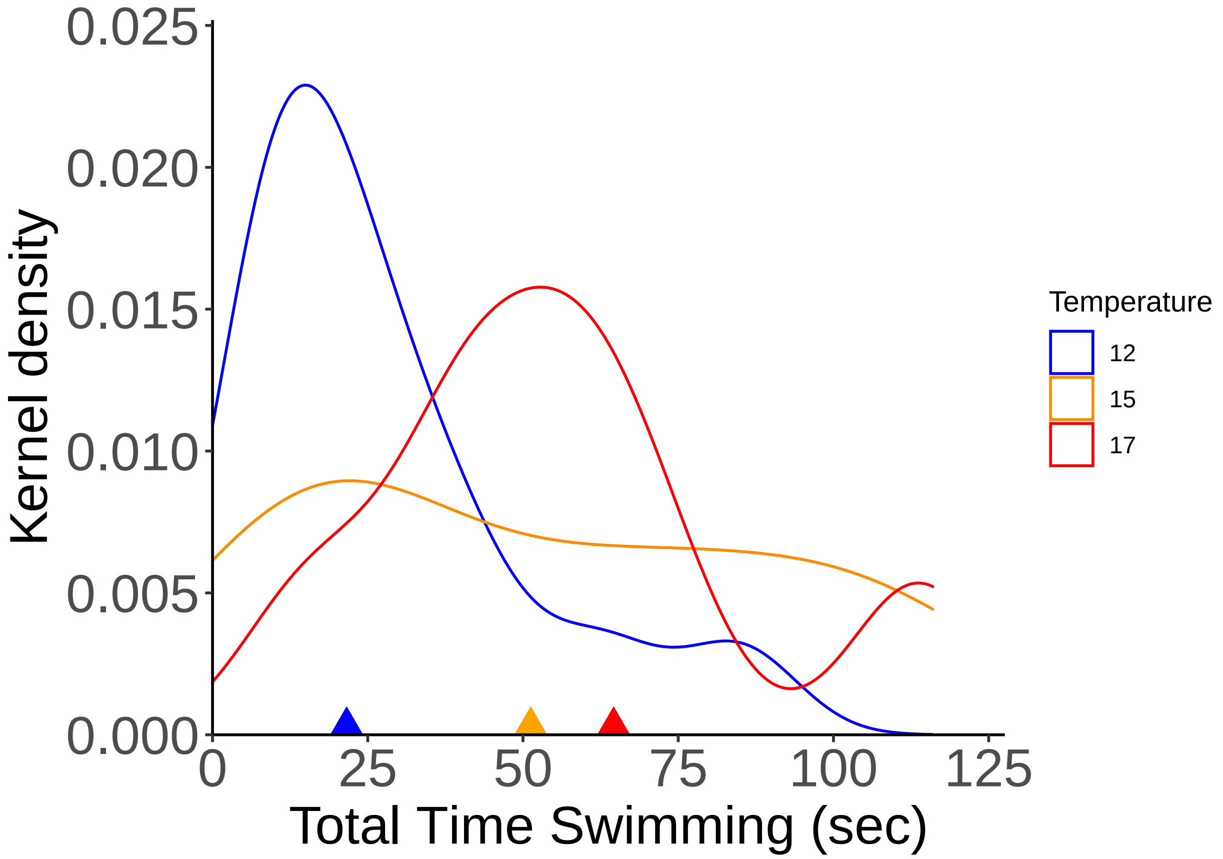
```
##   Temp grp.med
## 1   12   20.30
## 2   15   51.20
## 3   17   54.35
```

```
#plotting as Kernel Densities
dplot_IV<-ggplot(data1, aes(Ist_Vel, color=Temp))+
  geom_density(kernel = "gaussian")+
  geom_point(aes(x=5.30, y=0),colour="blue",shape=17, size=6)+
  geom_point(aes(x=2.06, y=0),colour="orange",shape=17, size=6)+
  geom_point(aes(x=2.47, y=0),colour="red",shape=17, size=6)+
  theme_classic()+
  labs(colour="Temperature", x="Instant Velocity (mm/s)", y="Kernel density")+
  scale_x_continuous(limits = c(0, NA), expand = expansion(mult = c(0, 0.1))) +
  scale_y_continuous(limits = c(0, NA),expand = expansion(mult = c(0, 0.1))) +
  theme(axis.title = element_text(size = 20),axis.text = element_text(size = 20)) +
  scale_colour_manual(values =c("blue","darkorange", "red"))
dplot_IV
```



```
dplot_Time<-ggplot(data1, aes(Tot_Time, color=Temp))+
  geom_density(kernel="gaussian")+
  geom_point(aes(x=21.60, y=0),color="blue",shape=17, size=6)+
  geom_point(aes(x=51.25, y=0),color="orange",shape=17, size=6)+
  geom_point(aes(x=64.6, y=0),color="red",shape=17, size=6)+
  theme_classic()+
  labs(colour="Temperature", x="Total Time Swimming (sec)", y="Kernel density")+
  scale_x_continuous(limits = c(0, NA), expand = expansion(mult = c(0, 0.1))) +
  scale_y_continuous(limits = c(0, NA),expand = expansion(mult = c(0, 0.1))) +
  theme(axis.title = element_text(size = 20),axis.text = element_text(size = 20)) +
  scale_color_manual(values =c("blue","darkorange", "red"))
```

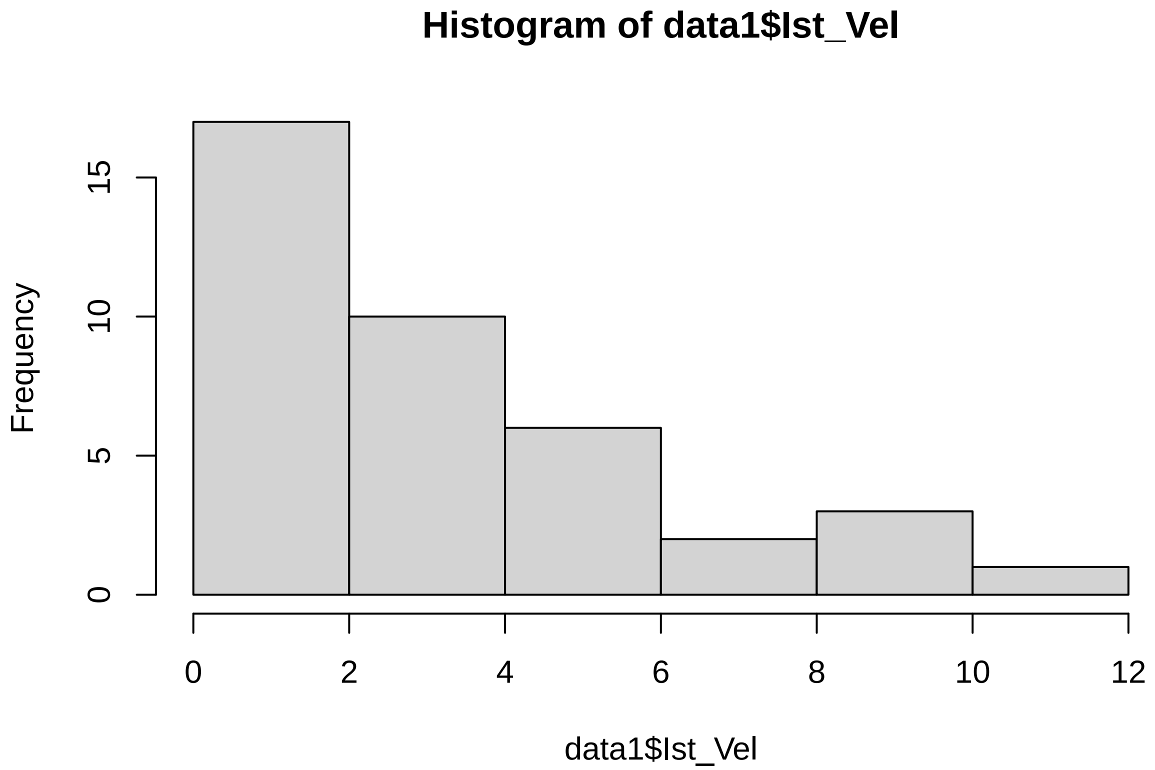
```
dplot_Time
```



```
#Checking for normality
shapiro.test(data1$Ist_Vel)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  data1$Ist_Vel
## W = 0.84219, p-value = 7.07e-05
```

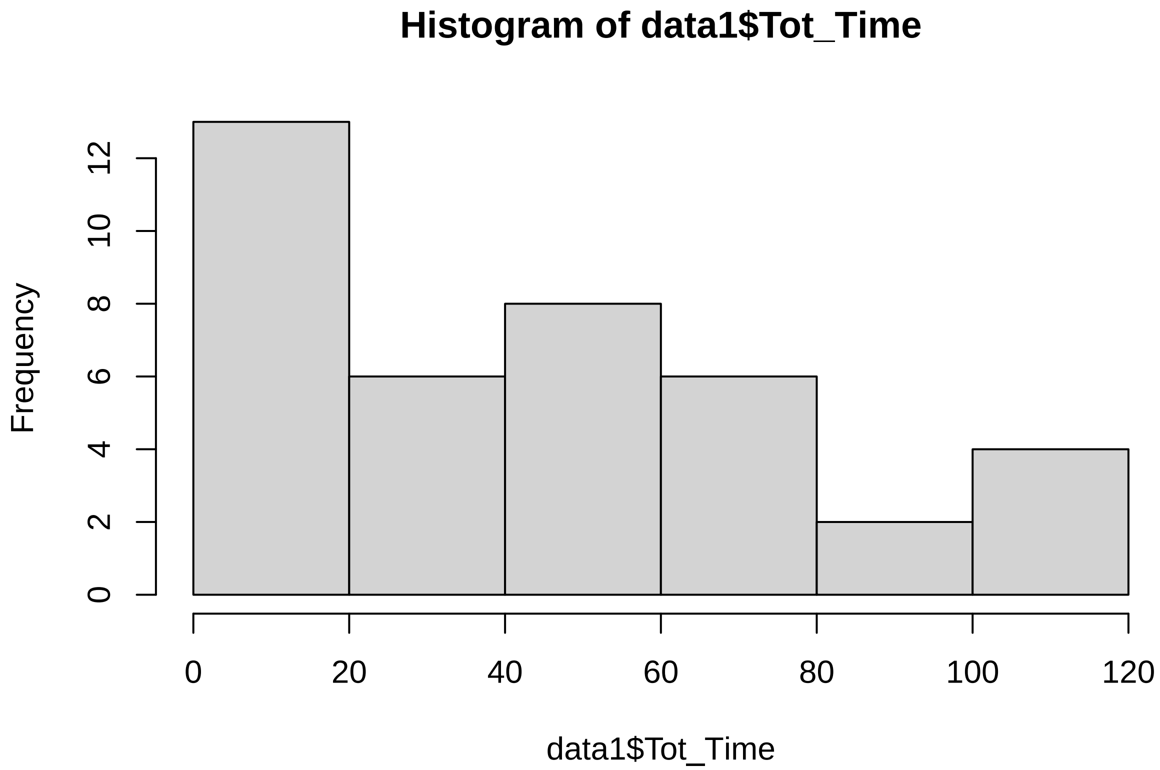
```
hist(data1$Ist_Vel)
```



```
shapiro.test(data1$Tot_Time)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  data1$Tot_Time
## W = 0.9082, p-value = 0.003824
```

```
hist(data1$Tot_Time)
```



```
#Checking for heteroscedasticity
leveneTest(data1$Ist_Vel, data1$Temp)
```

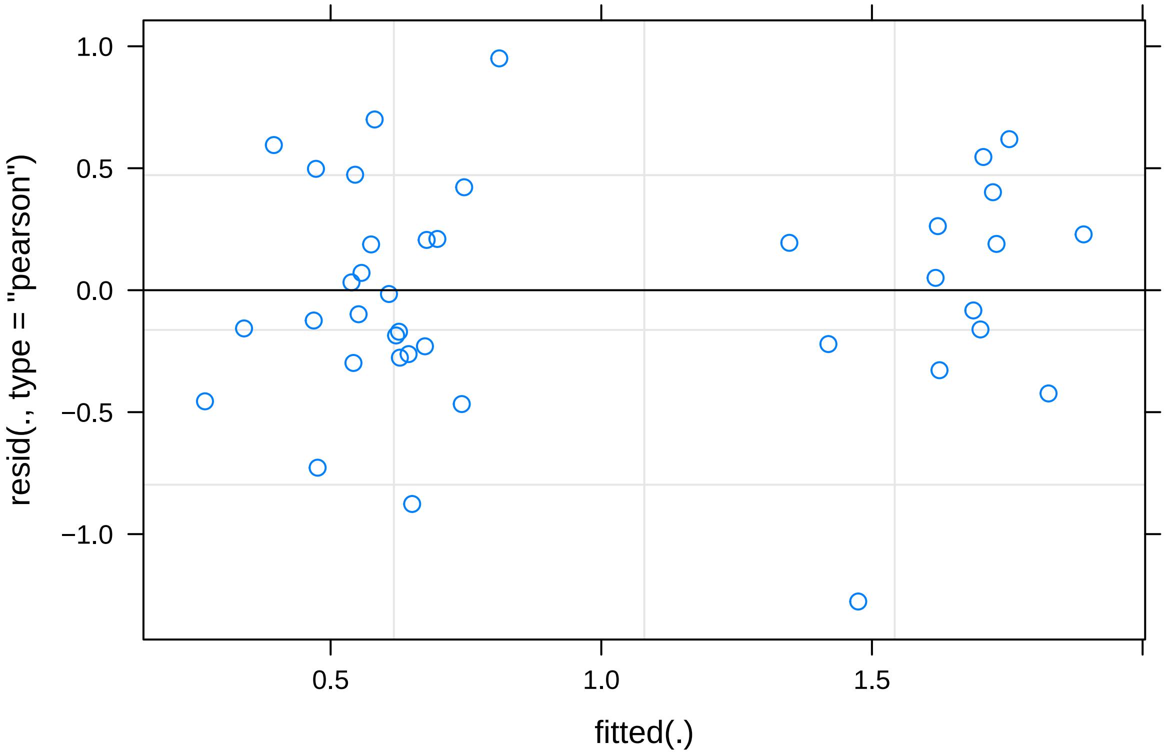
```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value   Pr(>F)
## group  2  5.4257 0.008718 **
##       36
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
leveneTest(data1$Tot_Time,data1$Temp)
```

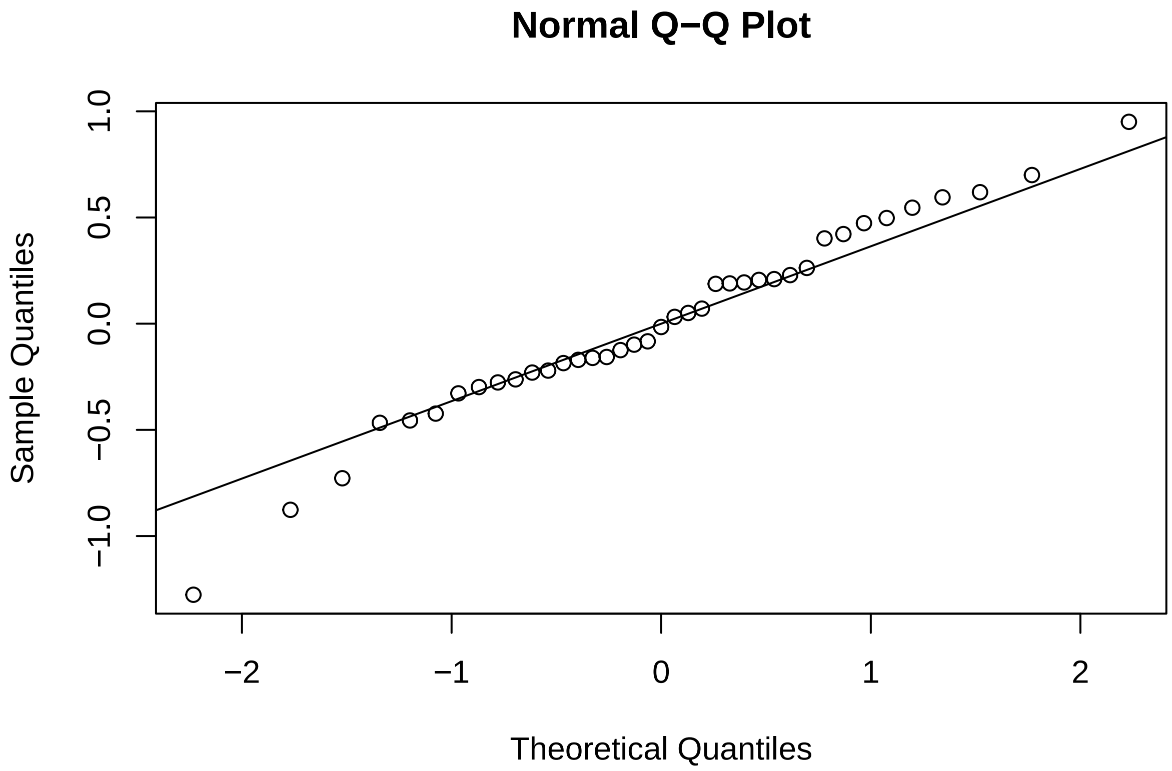
```
## Levene's Test for Homogeneity of Variance (center = median)
##       Df F value  Pr(>F)
## group  2  2.6217 0.08651 .
##       36
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#Linear mixed effects model with Log transformed data.
#Pote is a factor with random effects and larva is nested in Pote
modIV<-lmer(log(Ist_Vel)~Temp + (Pote|Larva), data=data1)

#model diagnostic
plot(modIV,which = 1)
```



```
qqnorm(resid(modIV))
qqline(resid(modIV))
```



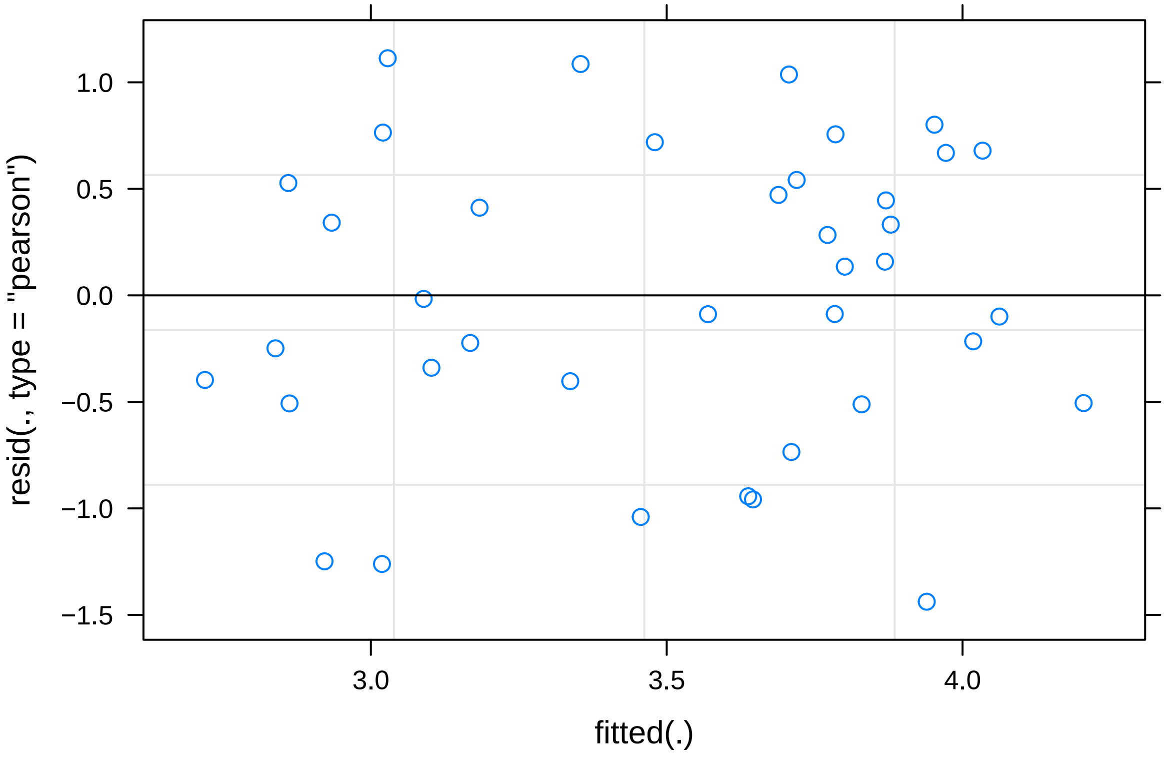
```
#model output
print(summary(modIV))
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: log(Ist_Vel) ~ Temp + (Pote | Larva)
##    Data: data1
##
## REML criterion at convergence: 60.4
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -2.6676 -0.5143 -0.0327  0.5135  1.9865
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  Larva    (Intercept) 0.039770 0.19942
##           PoteB       0.004512 0.06717   1.00
##           PoteC       0.002630 0.05128  -1.00 -1.00
##  Residual             0.228902 0.47844
## Number of obs: 39, groups:  Larva, 5
##
## Fixed effects:
##             Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   1.6338     0.1566 10.4830  10.435 7.26e-07 ***
## Temp15       -1.1488     0.1961 32.8937  -5.857 1.49e-06 ***
## Temp17       -1.0795     0.1814 31.4611  -5.952 1.33e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##        (Intr) Temp15
## Temp15 -0.550
## Temp17 -0.590  0.459
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help('isSingular')
```

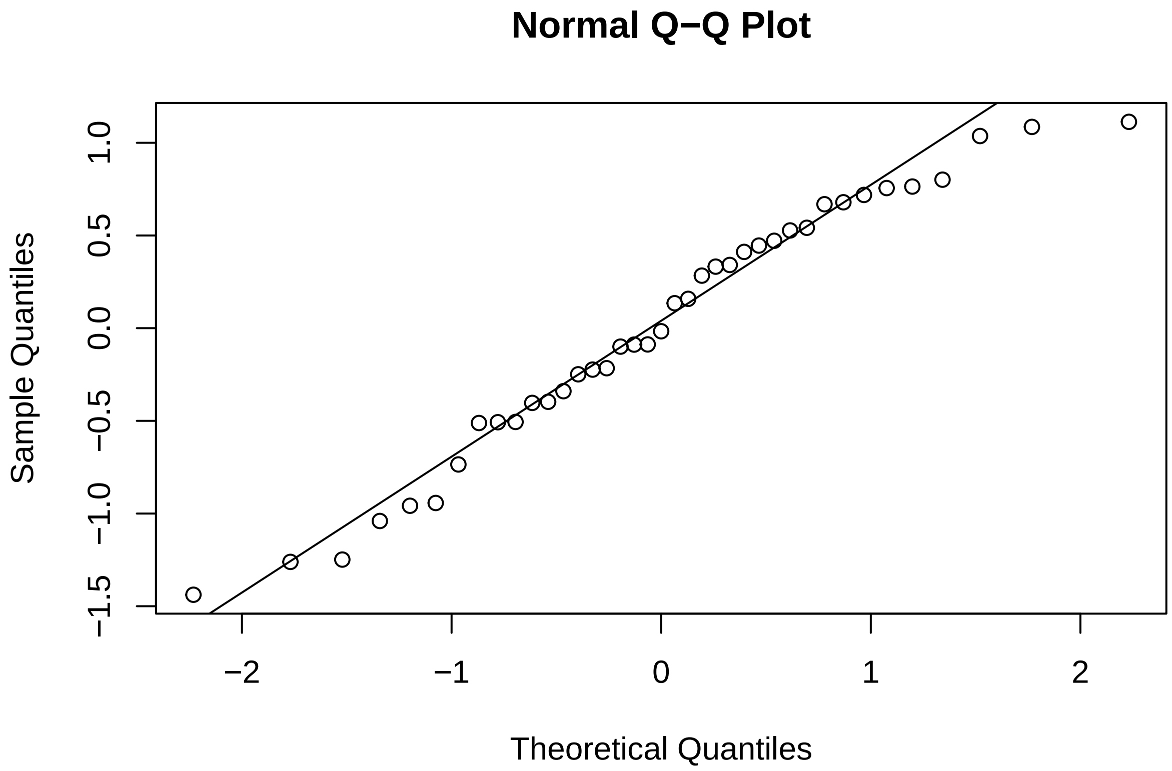
```
anova(modIV)
```

```
## Type III Analysis of Variance Table with Satterthwaite's method
##      Sum Sq Mean Sq NumDF  DenDF F value    Pr(>F)
## Temp 10.937  5.4685     2 32.411   23.89 4.209e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#model
modTime<-lmer(log(Tot_Time)~Temp + (Pote|Larva), data=data1)
#model diagnostic
plot(modTime,which = 1)
```



```
qqnorm(resid(modTime))
qqline(resid(modTime))
```



```
#model output
print(summary(modTime))
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite’s method [
## lmerModLmerTest]
## Formula: log(Tot_Time) ~ Temp + (Pote | Larva)
##    Data: data1
##
## REML criterion at convergence: 90.3
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.96091 -0.61973 -0.02265  0.72864  1.51772
##
## Random effects:
##  Groups   Name        Variance Std.Dev. Corr
##  Larva    (Intercept) 0.12318  0.3510
##           PoteB       0.03008  0.1734   -1.00
##           PoteC       0.02091  0.1446   -1.00  1.00
##  Residual             0.53782  0.7334
## Number of obs: 39, groups:  Larva, 5
##
## Fixed effects:
##             Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   3.0088     0.2232 15.2943  13.481 6.76e-10 ***
## Temp15        0.6174     0.2993 33.5858   2.062   0.0470 *
## Temp17        0.8502     0.2775 32.1512   3.063   0.0044 **
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Correlation of Fixed Effects:
##        (Intr) Temp15
## Temp15 -0.577
## Temp17 -0.620  0.464
## optimizer (nloptwrap) convergence code: 0 (OK)
## boundary (singular) fit: see help(’isSingular’)
```

```
anova(modTime)
```

```
## Type III Analysis of Variance Table with Satterthwaite’s method
##      Sum Sq Mean Sq NumDF  DenDF F value  Pr(>F)
## Temp 5.3292  2.6646     2 32.989  4.9544 0.01314 *
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
```

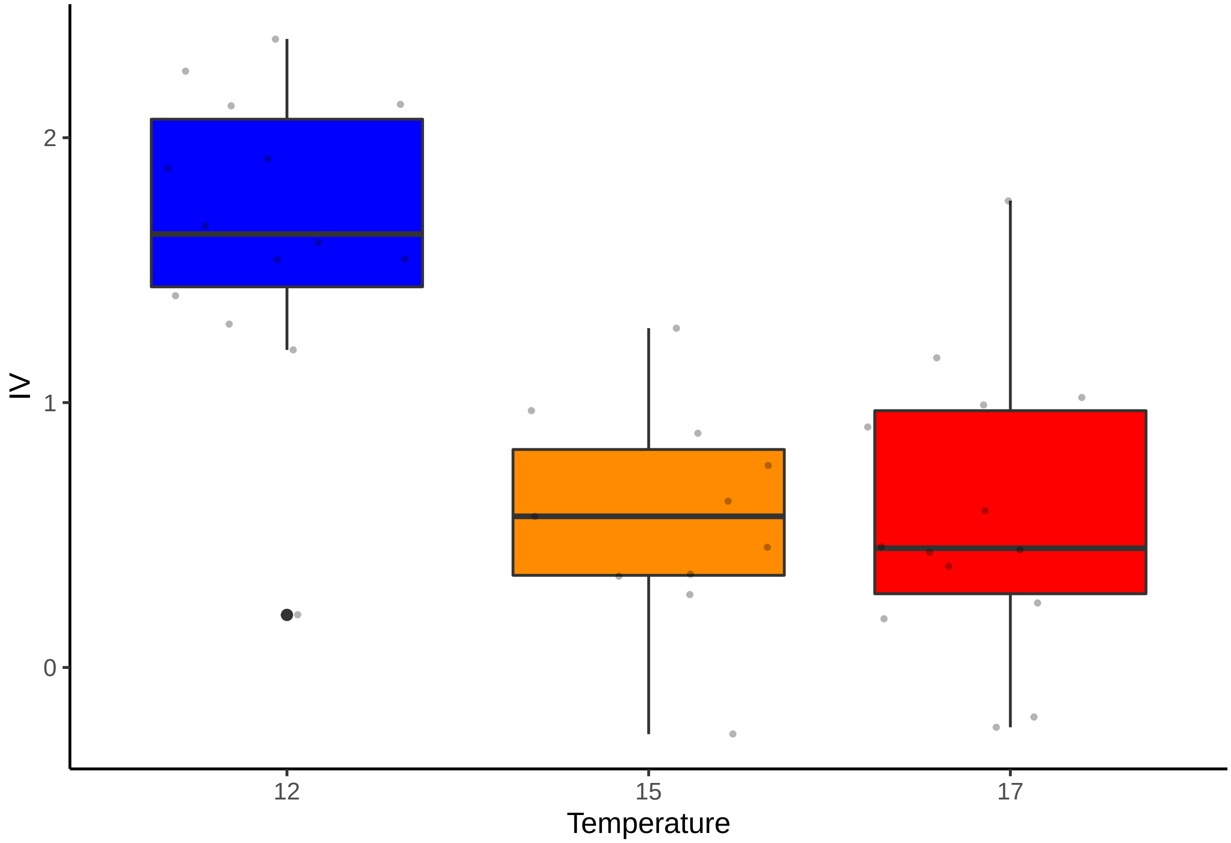
```
#pairwise comparison using estimated means
emmeans(modIV, pairwise ~ Temp, adjust="bonferroni")
```

```
## $emmeans
##  Temp emmean    SE   df lower.CL upper.CL
##  12    1.634 0.200 7.66   1.1691    2.099
##  15    0.485 0.221 9.01  -0.0138    0.984
##  17    0.554 0.200 6.95   0.0797    1.029
##
## Degrees-of-freedom method: kenward-roger
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
##
## $contrasts
##  contrast        estimate    SE   df t.ratio p.value
##  Temp12 - Temp15   1.1488 0.207 24.8   5.554  <.0001
##  Temp12 - Temp17   1.0795 0.186 23.4   5.799  <.0001
##  Temp15 - Temp17  -0.0693 0.207 24.7  -0.335  1.0000
##
## Degrees-of-freedom method: kenward-roger
## Results are given on the log (not the response) scale.
## P value adjustment: bonferroni method for 3 tests
```

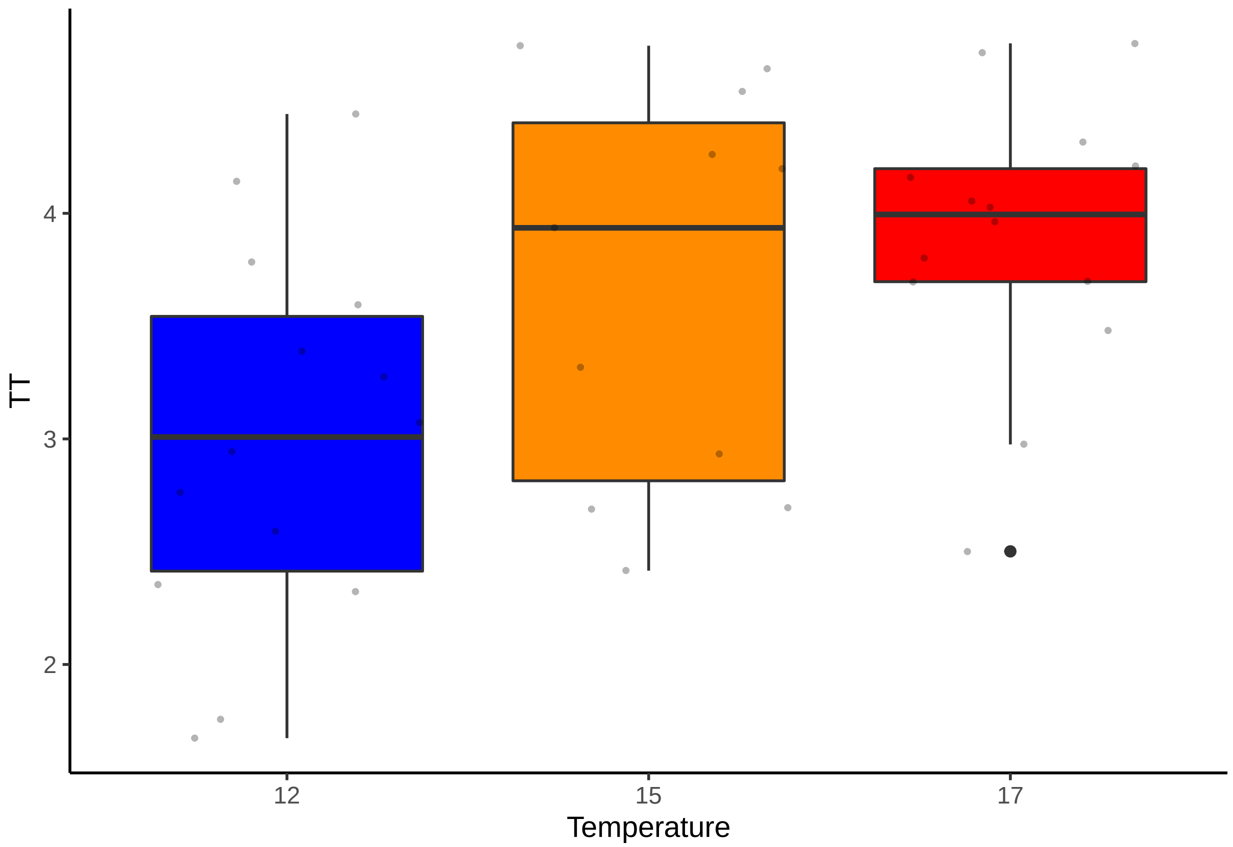
```
emmeans(modTime, pairwise ~ Temp, adjust="bonferroni")
```

```
## $emmeans
##  Temp emmean    SE   df lower.CL upper.CL
##  12     3.01 0.282 7.35     2.35     3.67
##  15     3.63 0.315 9.87     2.92     4.33
##  17     3.86 0.281 7.46     3.20     4.52
##
## Degrees-of-freedom method: kenward-roger
## Results are given on the log (not the response) scale.
## Confidence level used: 0.95
##
## $contrasts
##  contrast        estimate    SE   df t.ratio p.value
##  Temp12 - Temp15   -0.617 0.318 25.1  -1.944  0.1897
##  Temp12 - Temp17   -0.850 0.286 23.6  -2.976  0.0199
##  Temp15 - Temp17   -0.233 0.317 25.1  -0.735  1.0000
##
## Degrees-of-freedom method: kenward-roger
## Results are given on the log (not the response) scale.
## P value adjustment: bonferroni method for 3 tests
```

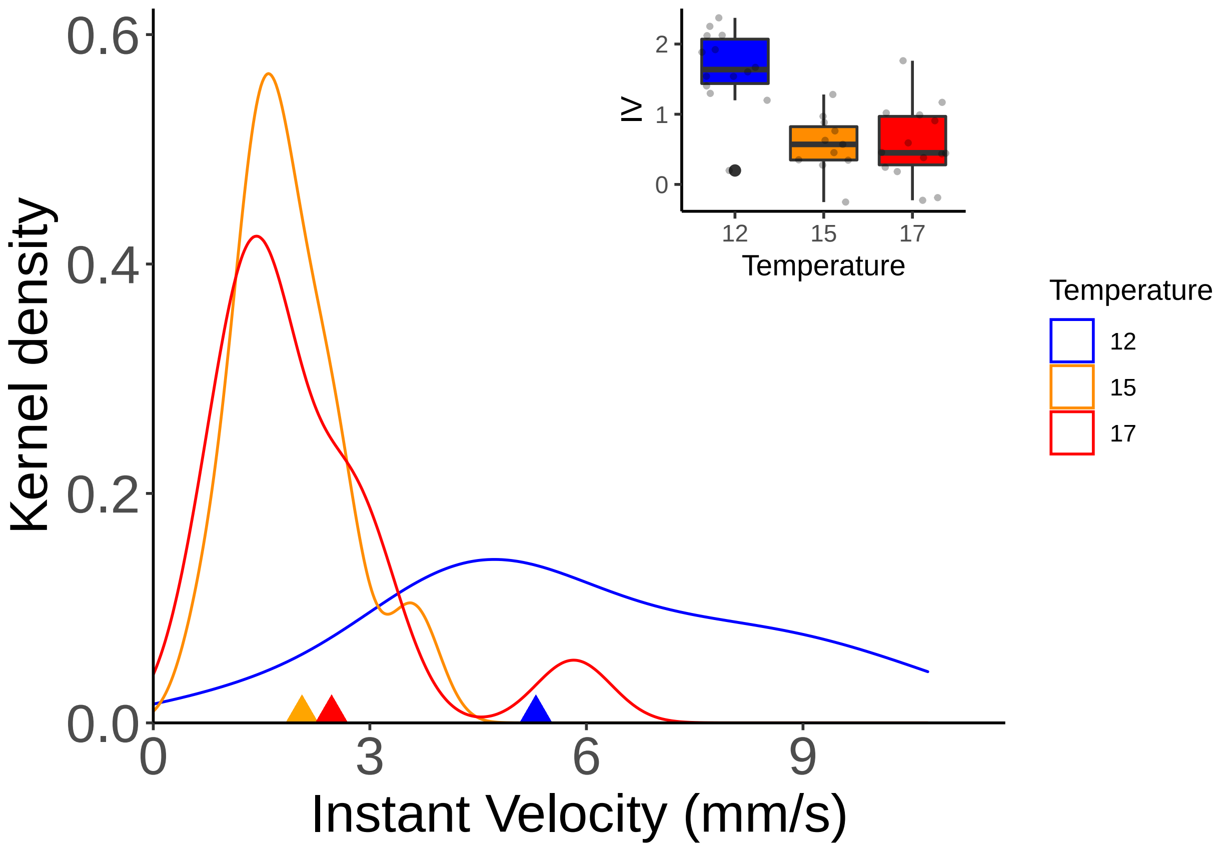
```
#Plotting as boxplots with log transformed data
p1<-ggplot(data1, aes(x=Temp, y=log(Ist_Vel), fill=Temp))+geom_boxplot()+
  geom_jitter(color="black", size=0.6, alpha=0.3)+
  theme_classic()+labs(x="Temperature", y="IV")+theme(legend.position="none")+
   scale_fill_manual(values =c("blue","darkorange", "red"))+ scale_y_continuous(breaks = c(1,2,0))
p1
```



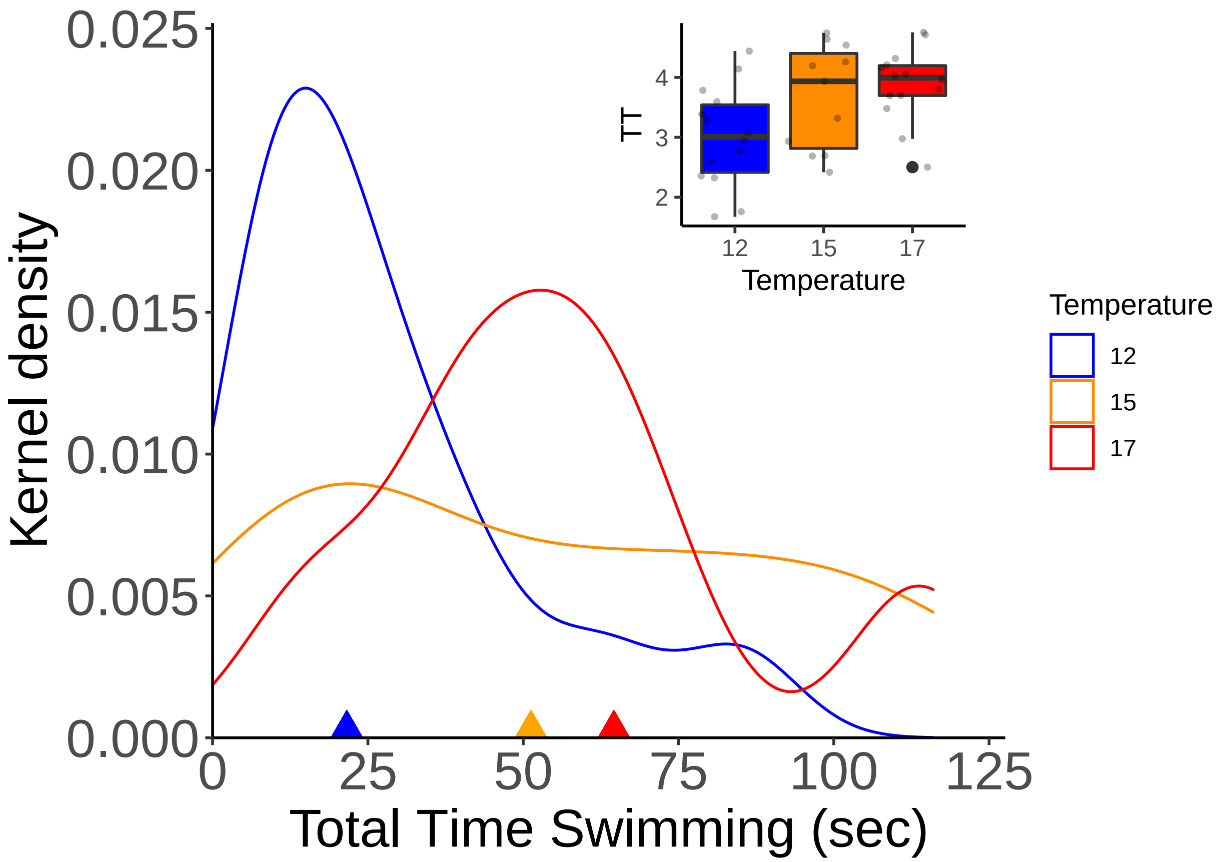
```
p2<-ggplot(data1, aes(x=Temp, y=log(Tot_Time), fill=Temp))+geom_boxplot()+
  geom_jitter(color="black", size=0.6, alpha=0.3)+
  theme_classic() + theme(legend.position="none") +
  labs(x="Temperature", y="TT")+
   scale_fill_manual(values =c("blue","darkorange", "red"))
p2
```



```
#plotting final kernel graphs with insets
plot.with.inset.IV <-
  ggdraw() +
  draw_plot(dplot_IV) +
  draw_plot(p1, x = .49, y = 0.65, width = .3, height = .35)
plot.with.inset.IV
```



```
plot.with.inset.Tot_Time <-
  ggdraw() +
  draw_plot(dplot_Time) +
  draw_plot(p2, x = .49, y = 0.65, width = .3, height = .35)
plot.with.inset.Tot_Time
```


Kernel density
0.025
0.020
0.015
0.010
0.005
0.000
0
25
50
75
100
125
Total Time Swimming (sec)
TT
4
3
2
12
15
17
Temperature
Temperature
12
15
17