Movement patterns of peacock bass Cichla spp. (Perciformes, Cichlidae) and their implications for conservation and management in the middle Rio Negro, Central Amazon, Brazil

Mario J. F. Thomé-Souza; Michael J. Maceina; Bruce R. Forsberg; Álvaro C. Lima; Carla Sardelli; Bruce G. Marshall

Supplement S1

Data: mark and recapture (M&R) experiment

```
floytag<-read.csv("mark_and_recapture.csv", header = T, sep=";")
floytag$specie<-as.factor(floytag$specie)
floytag$mark<-as.factor(floytag$mark)
floytag$recapture<-as.factor(floytag$recapture)
floytag
```

```
##    specie size_cm     mark      recapture time_day distance_km water_level_cm
## 1       T    38.0 15/02/05 28/10/2005(co)      255       13.90            312
## 2       T    33.0  12/1/06 23/01/2006(sp)       11        1.45            546
## 3       T    36.5  7/12/05 13/10/2006(sp)      310        1.71            392
## 4       T    37.0 29/10/04 12/10/2006(sp)      713       10.96            402
## 5       T    27.5  8/12/05 22/11/2006(sp)      349       11.78            393
## 6       T    48.0 11/11/03 21/02/2004(sp)      102       11.82            126
## 7       T    44.5 25/11/05 26/12/2005(sp)       31       17.11            427
## 8       T    47.5  5/12/05 08/12/2005(sp)        3        2.36            419
## 9       T    40.0 14/12/05 26/01/2006(sp)       43        3.00            539
## 10      T    55.0 12/11/04 20/03/2005(sp)      128        4.55            557
## 11      T    40.5  8/12/05 15/12/2005(sp)        7        5.46            420
## 12      T    49.0 16/12/05 07/02/2007(sp)      418        6.72            376
## 13      T    42.0 17/10/05 20/01/2006(sp)       95        9.80            552
## 14      T    27.5  11/1/06 02/05/2006(su)      111        1.18            563
## 15      T    41.0   7/5/05 05/01/2006(su)      243        1.70            517
## 16      T    30.6 12/11/05 28/12/2005(co)       46       20.10            447
## 17      O    37.0 27/10/04 09/11/2004(sp)       13       16.69            345
## 18      O    32.5 10/12/03 05/11/2004(sp)      331       58.25            356
## 19      T    44.0  7/12/05 28/10/2006(sp)      325        1.86            350
## 20      T    54.0 24/01/05 27/10/2005(sp)      276       15.27            313
## 21      T    47.0 20/10/04 05/11/2004(sp)       16       15.35            355
## 22      T    39.5   8/3/04 26/05/2004(sp)       79       32.75            726
## 23      T    46.0 24/10/04 12/02/2005(sp)      111       49.25            328
## 24      T    35.0 13/10/04 25/11/2005(sp)      408       65.25            404
## 25      T    46.0 21/10/04 17/11/2004(sp)       27        9.00            330
## 26      T    42.0 25/10/05 10/11/2005(su)       16       20.95            323
## 27      T    26.0  11/1/06 25/02/2006(su)       45        3.90            706
## 28      T    46.0 28/01/05 17/10/2005(su)      262       49.90            325
## 29      T    57.0 12/12/05 18/01/2007(co)      402        2.66            369
## 30      T    43.0  5/11/04 16/12/2004(co)       41        3.21            315
## 31      T    23.0 16/11/05 28/10/2006(co)      346        3.45            351
## 32      T    55.0 22/11/04 17/01/2005(co)       56        4.11            256
## 33      O    48.0   8/3/04 22/11/2005(sp)      624        1.90            382
## 34      O    40.0 30/01/07 18/02/2007(sp)       19       17.20            245
## 35      T    45.0 22/01/05 08/12/2005(sp)      320        1.06            418
## 36      T    37.0   4/2/05 14/12/2005(sp)      313        1.15            422
## 37      T    62.0 10/11/04 04/12/2004(sp)       24        1.80            338
## 38      T    61.6   5/1/05 27/02/2005(sp)       53       37.70            450
## 39      O    33.5 20/01/05 01/11/2005(su)      285        6.15            306
## 40      T    32.5 11/11/05 23/08/2006(su)      285        5.30            773
## 41      O    32.0 18/01/07 10/02/2007(co)       23        0.76            344
## 42      T    35.1  11/1/06 15/06/2006(co)      155        0.11            920
## 43      T    40.0 12/12/05 13/12/2005(sp)        1        0.03            425
## 44      T    34.0   7/5/05 08/02/2006(sp)      277        0.04            609
## 45      T    68.0 19/01/05 15/02/2005(sp)       27        0.06            370
## 46      T    54.0  9/12/03 18/03/2004(sp)      100        0.31            329
## 47      T    48.0 17/10/04 15/12/2006(sp)      789        0.89            407
## 48      T    46.3   4/1/05 02/02/2007(sp)      759        0.95            398
## 49      T    35.0   7/5/05 21/07/2006(su)      440        0.05            907
```

T=C. temensis, O=C. orinocensis

category fishery recapture: co=comercial; sp=sport; su=subsistence

```
summary(floytag)
```

```
##  specie    size_cm           mark              recapture     time_day
##  O: 6   Min.   :23.00   11/1/06 : 3   05/11/2004(sp): 2   Min.   :  1.0
##  T:43   1st Qu.:35.00   7/5/05  : 3   08/12/2005(sp): 2   1st Qu.: 31.0
##         Median :41.00   12/12/05: 2   01/11/2005(su): 1   Median :111.0
##         Mean   :42.09   7/12/05 : 2   02/02/2007(sp): 1   Mean   :206.4
##         3rd Qu.:47.50   8/12/05 : 2   02/05/2006(su): 1   3rd Qu.:320.0
##         Max.   :68.00   8/3/04  : 2   04/12/2004(sp): 1   Max.   :789.0
##                         (Other) :35   (Other)       :41
##   distance_km    water_level_cm
##  Min.   : 0.03   Min.   :126.0
##  1st Qu.: 1.45   1st Qu.:338.0
##  Median : 4.11   Median :393.0
##  Mean   :11.24   Mean   :432.3
##  3rd Qu.:15.27   3rd Qu.:450.0
##  Max.   :65.25   Max.   :920.0
##
```

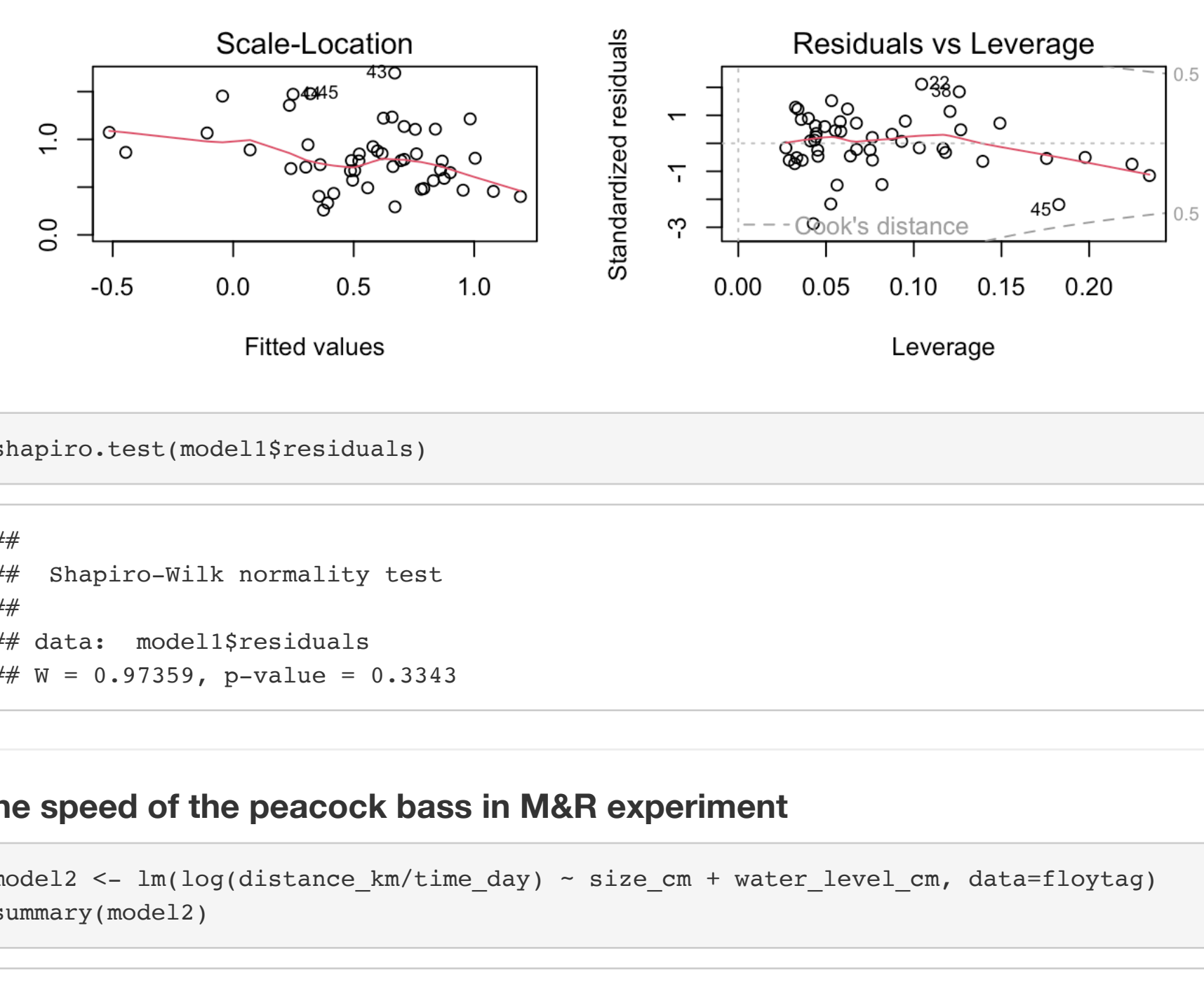
The distance of the peacock bass in M&R experiment

```
model1 <- lm(log10(distance_km) ~ time_day + size_cm + water_level_cm, data=floytag)
summary(model1)
```

```
##
## Call:
## lm(formula = log10(distance_km) ~ time_day + size_cm + water_level_cm,
##     data = floytag)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -2.19306 -0.39331  0.05013  0.51651  1.55947
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     2.3204911  0.7267704   3.193  0.00257 **
## time_day       -0.0003513  0.0005421  -0.648  0.52023
## size_cm        -0.0167023  0.0123377  -1.354  0.18257
## water_level_cm -0.0023103  0.0007603  -3.039  0.00395 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.7803 on 45 degrees of freedom
## Multiple R-squared:  0.178,  Adjusted R-squared:  0.1232
## F-statistic: 3.249 on 3 and 45 DF,  p-value: 0.03039
```

Evaluate the residuals for the assumptions

```
par(mfrow=c(2,2))
plot(model1)
```




```
shapiro.test(model1$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  model1$residuals
## W = 0.97359, p-value = 0.3343
```

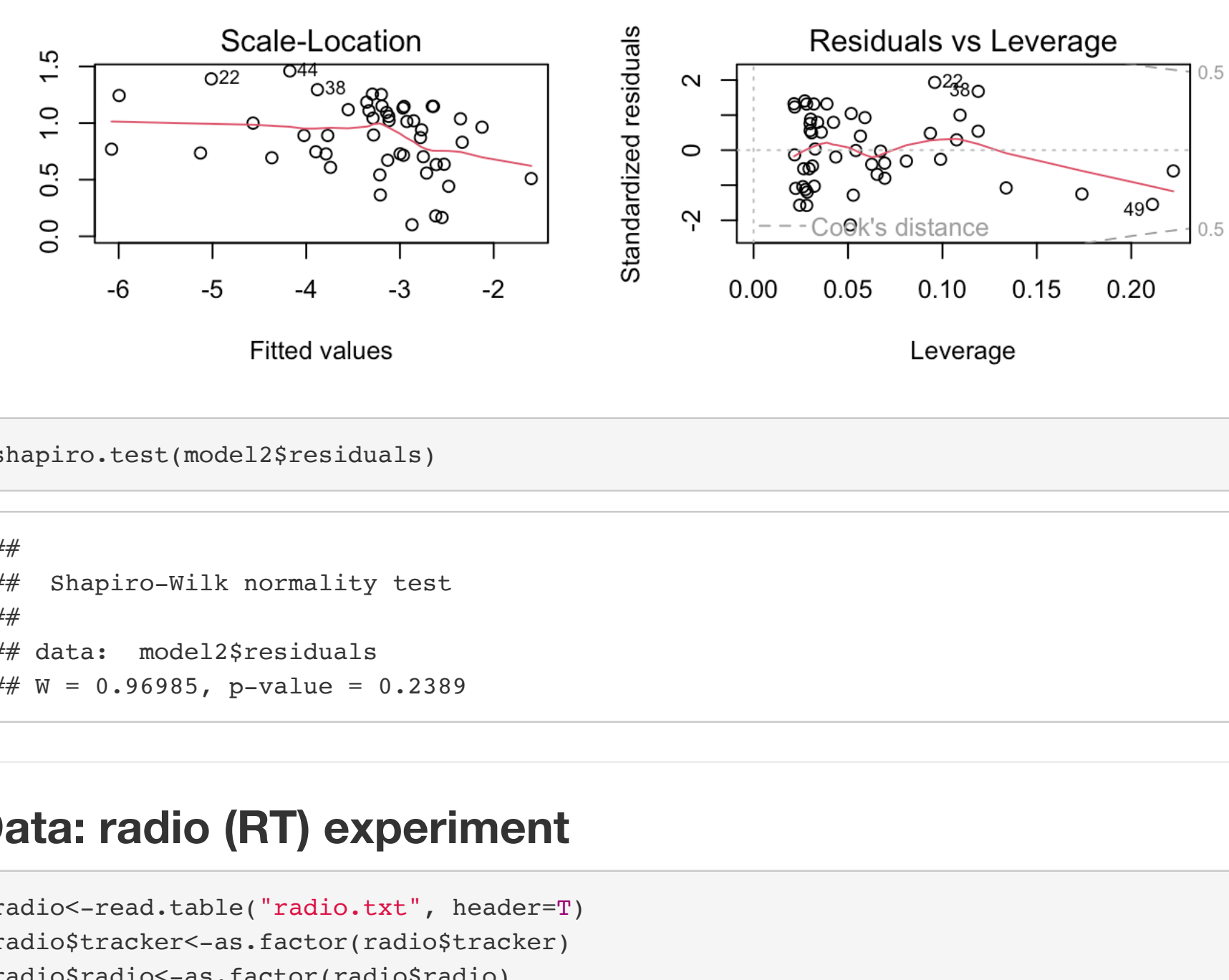
The speed of the peacock bass in M&R experiment

```
model2 <- lm(log(distance_km/time_day) ~ size_cm + water_level_cm, data=floytag)
summary(model2)
```

```
##
## Call:
## lm(formula = log(distance_km/time_day) ~ size_cm + water_level_cm,
##     data = floytag)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.6681 -1.7366 -0.0597  1.7522  4.1319
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)     0.314876   2.049854   0.154  0.87859
## size_cm        -0.024069   0.035458  -0.679  0.50066
## water_level_cm -0.006028   0.002191  -2.751  0.00846 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.249 on 46 degrees of freedom
## Multiple R-squared:  0.1426, Adjusted R-squared:  0.1053
## F-statistic: 3.826 on 2 and 46 DF,  p-value: 0.02905
```

Evaluate the residuals for the assumptions

```
par(mfrow=c(2,2))
plot(model2)
```




```
shapiro.test(model2$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  model2$residuals
## W = 0.96985, p-value = 0.2389
```

Data: radio (RT) experiment

```
radio<-read.table("radio.txt", header=T)
radio$tracker<-as.factor(radio$tracker)
radio$radio<-as.factor(radio$radio)
radio$date<-as.factor(radio$date)
radio$hydrology_stage<-as.factor(radio$hydrology_stage)
radio
```

```
##    radio size_cm     date tracker       lat      long time_day distance_km
## 1    R02      57  3/11/04       0 -0.382930 -63.78330        0       0.000
## 2    R02      57  6/12/04       1 -0.384317 -63.80875       33       3.244
## 3    R06      59   4/1/05       0 -0.415367 -63.73265        0       0.000
## 4    R06      59   6/1/05       1 -0.418717 -63.73293        2       0.373
## 5    R06      59   7/1/05       2 -0.418667 -63.73290        1       0.007
## 6    R06      59  10/1/05       3 -0.416850 -63.73235        3       0.212
## 7    R06      59 17/01/05       4 -0.407583 -63.73302        7       1.047
## 8    R06      59 23/01/05       5 -0.414090 -63.74186        6       1.702
## 9    R06      59 27/01/05       6 -0.414200 -63.74125        4       0.072
## 10   R06      59 13/02/05       7 -0.413888 -63.74080       17       0.063
## 11   R06      59 20/02/05       8 -0.414300 -63.74183        7       0.124
## 12   R06      59 21/02/05       9 -0.414313 -63.74180        1       0.004
## 13   R07      60 31/01/05       0 -0.382440 -63.77715        0       0.000
## 14   R07      60 13/02/05       1 -0.382250 -63.77699       13       0.028
## 15   R07      60 21/02/05       2 -0.382300 -63.77700        8       0.006
## 16   R07      60 25/02/05       3 -0.382260 -63.77714        4       0.016
## 17   R10      71   4/1/05       0 -0.409567 -63.73122        0       0.000
## 18   R10      71   6/1/05       1 -0.408250 -63.73328        2       0.275
## 19   R10      71   7/1/05       2 -0.414850 -63.73652        1       1.028
## 20   R10      71  10/1/05       3 -0.421433 -63.73637        3       1.048
## 21   R10      71 17/01/05       4 -0.407583 -63.73302        7       1.807
## 22   R10      71 23/01/05       5 -0.408130 -63.73325        6       0.067
## 23   R10      71 27/01/05       6 -0.406170 -63.73060        4       0.368
## 24   R10      71 21/02/05       7 -0.418455 -63.73071       25       1.467
## 25   R10      71 25/02/05       8 -0.423250 -63.73062        4       0.532
## 26   R13      68  2/11/04       0 -0.381830 -63.77782        0       0.000
## 27   R13      68  3/11/04       1 -0.382920 -63.75913        1       2.377
## 28   R13      68  6/12/04       2 -0.398033 -63.75927       34       2.333
## 29   R14      69  4/11/04       0 -0.446380 -63.66111        0       0.000
## 30   R14      69  7/11/04       1 -0.451600 -63.65791        3       0.674
## 31   R20      77 31/10/04       0 -0.386540 -63.82835        0       0.000
## 32   R20      77  1/11/04       1 -0.386400 -63.82130        1       0.780
## 33   R20      77  2/11/04       2 -0.385770 -63.81920        1       0.249
## 34   R20      77  6/12/04       3 -0.387600 -63.75930       36       7.936
##    water_level_cm hydrology_stage
## 1             365             ebb
## 2             338             ebb
## 3             255            rise
## 4             244            rise
## 5             239            rise
## 6             226            rise
## 7             256            rise
## 8             288            rise
## 9             276            rise
## 10            346            rise
## 11            421            rise
## 12            425            rise
## 13            264            rise
## 14            346            rise
## 15            425            rise
## 16            447            rise
## 17            255            rise
## 18            244            rise
## 19            239            rise
## 20            226            rise
## 21            256            rise
## 22            288            rise
## 23            276            rise
## 24            425            rise
## 25            447            rise
## 26            372             ebb
## 27            365             ebb
## 28            338             ebb
## 29            359             ebb
## 30            348             ebb
## 31            398             ebb
## 32            383             ebb
## 33            372             ebb
## 34            338             ebb
```

```
radio<-radio[-which(radio$tracker=="0"),]
summary(radio)
```

```
##  radio      size_cm           date       tracker       lat
##  R02:1   Min.   :57.00   21/02/05: 3   1      :7   Min.   :-0.4516
##  R06:9   1st Qu.:59.00   6/12/04 : 3   2      :5   1st Qu.:-0.4158
##  R07:3   Median :68.00   10/1/05 : 2   3      :4   Median :-0.4083
##  R10:8   Mean   :65.63   13/02/05: 2   4      :2   Mean   :-0.4061
##  R13:2   3rd Qu.:71.00   17/01/05: 2   5      :2   3rd Qu.:-0.3870
##  R14:1   Max.   :77.00   23/01/05: 2   6      :2   Max.   :-0.3822
##  R20:3                   (Other) :13   (Other):5
##       long           time_day       distance_km     water_level_cm
##  Min.   :-63.82   Min.   : 1.000   Min.   :0.0040   Min.   :226.0
##  1st Qu.:-63.76   1st Qu.: 2.000   1st Qu.:0.0695   1st Qu.:256.0
##  Median :-63.74   Median : 4.000   Median :0.3730   Median :338.0
##  Mean   :-63.75   Mean   : 8.667   Mean   :1.0311   Mean   :326.7
##  3rd Qu.:-63.73   3rd Qu.: 7.500   3rd Qu.:1.2575   3rd Qu.:377.5
##  Max.   :-63.66   Max.   :36.000   Max.   :7.9360   Max.   :447.0
##
##  hydrology_stage
##  ebb : 7
##  rise:20
##
##
##
##
##
```

The speed of the peacock bass in RT experiment

```
wilcox.test(radio$distance_km/radio$time_day ~ radio$hydrology_stage, alternative="two.sided")
```

```
## Warning in wilcox.test.default(x = DATA[[1L]], y = DATA[[2L]], ...): cannot
## compute exact p-value with ties
```

```
##
##  Wilcoxon rank sum test with continuity correction
##
## data:  radio$distance_km/radio$time_day by radio$hydrology_stage
## W = 109, p-value = 0.03313
## alternative hypothesis: true location shift is not equal to 0
```