tpc_autocorrelation

Debora

2025-06-16

```r
set.seed(1234)
library(MuMIn)
library(nls.multstart)


# Quadratic function
quadratic <- function(temp, a, b, c) {
  a * temp^2 + b * temp + c
}

# Hinshelwood model
hinshelwood <- function(temp, a, b, E, Eh, R = 8.314) {
  T_kelvin <- temp + 273.15
  a * exp(-E / (R * T_kelvin)) - b * exp(-Eh / (R * T_kelvin))
}



# Logistic1 Model
logistic1 <- function(temp, a, b, c, d) {
  a * exp(b * temp) - exp(c * (d - temp))
}

# Logistic2 Model
logistic2 <- function(temp, a, b, c, d) {
  a / (1 + exp(-b * temp)) * (1 - exp(c * (d - temp)))
}

# Sharpe-Schoolfield Model
sharpe_schoolfield <- function(temp, k, c, a, b, R = 8.314) {
  k * (temp / 298.16) * exp(c / (R * 298.16) - c / (R * temp)) /
    (1 + exp(a / (R * (1 / temp - 1 / 298.16))) + exp(b / (R * (1 / temp - 1 / 298.16))))
}

# Ratkowsky Model
ratkowsky <- function(temp, a, b, tmin, tmax) {
  ((a * (temp - tmin) * (1 - exp(b * (temp - tmax))))^2)
}

# Briere 1 Model
briere1 <- function(temp, a, tmin, tmax) {
  a * temp * (temp - tmin) * sqrt(tmax - temp)
```

```r
}

# Weibull Model
weibull <- function(temp, a, b, c, d) {
  a * ((d - 1) / d)^(1 - d) * exp(-((temp - b) / c) + ((d - 1) / d)^(1 / d))
}

# Modified Gaussian Model
modified_gaussian <- function(temp, a, b, c) {
  a * exp(-0.5 * ((temp - b) / c)^2)
}

# Exponential Modified Gaussian Model
exp_modified_gaussian <- function(temp, a, b, c) {
  exp(0.5 * (b / a)^2 - (temp - c) / a) * (erf((1 / sqrt(2)) * ((c - temp) / b) - (b / a)) +
                                           erf((1 / sqrt(2)) * ((temp - c) / b) - (b / a)))
}

# Eppley curve
eppley <- function(temp, a, b, z, w) {
  a * exp(b * temp) * (1 - ((temp - z) / (w / 2))^2)
}

# Read dataset
tpc <- read.csv("https://raw.githubusercontent.com/Cuddington-Lab/thermal-experiments/main/autocorrelat
                header=TRUE, stringsAsFactors=TRUE, fileEncoding="UTF-8-BOM")

tpc$total_living_fronds <- tpc$Frond_count_1 + tpc$Frond_count_2 + tpc$Frond_count_3
tpc$total_living_fronds[tpc$total_living_fronds == 0] <- 0.00001
tpc$r <- (log(tpc$total_living_fronds) - log(12)) / 5

# Colors for treatments
colors <- c("#0072B2","#D55E00",  "grey37")
color_index <- 1
fit_results <- list()
fit_models <- list()
aicc <- list()

layout(matrix(c(1, 1, 2), nrow = 3, byrow = TRUE), heights = c(3, 1))
par(mar = c(4, 5, 1, 1) + 0.1,
    mgp = c(4, 0.5, 0))  # Adjusted margins for better spacing

# First plot
plot(
  "",  # Just plotting a point to initialize
  xlim = c(min(tpc$Mean_temperature)-2, max(tpc$Mean_temperature)+5), ylim = c(-0.5, 0.5),
  xaxt = "n", yaxt = "n", frame.plot = FALSE,
  xlab = "", ylab = ""
)

# Manually add the y-axis for the first plot
axis(2, at = seq(-0.5, 0.5, by = 0.2), col = "black", cex.axis = 2, cex.lab = 2)
```

```r
# Add x-axis title
mtext("Relative growth rate per day", side = 2, line = 2.8, cex = 1.8)
mtext("//", side = 2, at = -0.5 - 0.1, cex = 2, las = 1)


# Add legend
legend(
  "bottomleft", legend = unique(tpc$Treatment),
  col = colors, lwd = 3, cex = 2, bty = "n"
)

# Loop through each treatment
for (treatment in unique(tpc$Treatment)) {
  tpc_treatm <- subset(tpc, Treatment == treatment)
  tpc_treatm <- data.frame(temp = as.numeric(tpc_treatm$Mean_temperature),
                           frond = as.numeric(tpc_treatm$r))

  # Fit modified Ratkowsky (cubic)
  cubic_ratkowsky_fit <- tryCatch({
    nls_multstart(
      frond ~ cubic_ratkowsky(temp, a, b, tmin, tmax),
      data = tpc_treatm,
      start_lower = list(a = 0.00001, b = 1, tmin = 0, tmax = 30),
      start_upper = list(a = 0.0001, b = 10, tmin = 10, tmax = 40),
      iter = 100, supp_errors = 'Y', convergence_count = FALSE
    )
  }, error = function(e) {
    return(NULL)
  })

  # Fit Hinshelwood model
  hinshelwood_fit <- tryCatch({
    nls_multstart(
      frond ~ hinshelwood(temp, a, b, E, Eh),
      data = tpc_treatm,
      start_lower = list(a = 0.01, b = 0.01, E = 50, Eh = 50),
      start_upper = list(a = 10, b = 10, E = 200, Eh = 200),
      iter = 100, supp_errors = 'Y', convergence_count = FALSE
    )
  }, error = function(e) {
    return(NULL)
  })

  # Fit Quadratic model
  quadratic_fit <- tryCatch({
    nls_multstart(
      frond ~ quadratic(temp, a, b, c),
      data = tpc_treatm,
      start_lower = list(a = -10, b = 0, c = 0),
      start_upper = list(a = 10, b = 5, c = 5),
      iter = 100, supp_errors = 'Y', convergence_count = FALSE
    )
  }, error = function(e) {
```

```
  return(NULL)
})

# Fit Briere 2 model
briere2_fit <- tryCatch({
  nls_multstart(
    frond ~ briere2(temp, a, tmin, tmax, b),
    data = tpc_treatm,
    start_lower = list(a = 0.0001, tmin = 0, tmax = 30, b = 1),
    start_upper = list(a = 1, tmin = 10, tmax = 40, b = 5),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Performance Model
performance_fit <- tryCatch({
  nls_multstart(
    frond ~ performance(temp, k, a, m, b, n),
    data = tpc_treatm,
    start_lower = list(k = 0.05, a = 0.0005, m = 10, b = -0.2, n = 30),
    start_upper = list(k = 0.5, a = 0.01, m = 20, b = 0.2, n = 35),
    iter = 200, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Logistic1 Model
logistic1_fit <- tryCatch({
  nls_multstart(
    frond ~ logistic1(temp, a, b, c, d),
    data = tpc_treatm,
    start_lower = list(a = 0.01, b = 0.01, c = 0.01, d = 30),
    start_upper = list(a = 10, b = 10, c = 10, d = 40),
    iter = 200, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Logistic2 Model
logistic2_fit <- tryCatch({
  nls_multstart(
    frond ~ logistic2(temp, a, b, c, d),
    data = tpc_treatm,
    start_lower = list(a = 0.01, b = 0.01, c = 0.01, d = 30),
    start_upper = list(a = 10, b = 10, c = 10, d = 40),
    iter = 200, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
```

```
})

# Fit Sharpe-Schoolfield Model
sharpe_schoolfield_fit <- tryCatch({
  nls_multstart(
    frond ~ sharpe_schoolfield(temp, k, c, a, b),
    data = tpc_treatm,
    start_lower = list(k = 0.01, c = 0.01, a = 0.01, b = 0.01),
    start_upper = list(k = 10, c = 10, a = 10, b = 10),
    iter = 200, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Ratkowsky Model
ratkowsky_fit <- tryCatch({
  nls_multstart(
    frond ~ ratkowsky(temp, a, b, tmin, tmax),
    data = tpc_treatm,
    start_lower = list(a = 0.01, tmin = 10, b = 0.01, tmax = 30),
    start_upper = list(a = 10, tmin = 30, b = 10, tmax = 50),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Briere 1 Model
briere1_fit <- tryCatch({
  nls_multstart(
    frond ~ briere1(temp, a, tmin, tmax),
    data = tpc_treatm,
    start_lower = list(a = 0.0001, tmin = 0, tmax = 30),
    start_upper = list(a = 1, tmin = 10, tmax = 40),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Weibull Model
weibull_fit <- tryCatch({
  nls_multstart(
    frond ~ weibull(temp, a, b, c, d),
    data = tpc_treatm,
    start_lower = list(a = 0.01, b = 1, c = 10, d = 30),
    start_upper = list(a = 10, b = 5, c = 50, d = 50),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})
```

```r
# Fit Modified Gaussian Model
modified_gaussian_fit <- tryCatch({
  nls_multstart(
    frond ~ modified_gaussian(temp, a, b, c),
    data = tpc_treatm,
    start_lower = list(a = 0.01, b = 10, c = 30),
    start_upper = list(a = 10, b = 50, c = 50),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Exponential Modified Gaussian Model
exp_modified_gaussian_fit <- tryCatch({
  nls_multstart(
    frond ~ exp_modified_gaussian(temp, a, b, c),
    data = tpc_treatm,
    start_lower = list(a = 0.01, b = 1, c = 30),
    start_upper = list(a = 10, b = 5, c = 50),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})

# Fit Eppley Curve Model with z fixed at 27BOC
eppley_fit <- tryCatch({
  nls_multstart(
    frond ~ eppley(temp, a, b, z, w),
    data = tpc_treatm,
    start_lower = list(a = 0.01, b = 0.05, z = 20, w = 5),
    start_upper = list(a = 10, b = 0.12, z = 27, w = 30),
    iter = 100, supp_errors = 'Y', convergence_count = FALSE
  )
}, error = function(e) {
  return(NULL)
})


color_index <- color_index %% length(colors) + 1

# Compare models based on AICc
fit_list <- list(
  Newfunction = cubic_ratkowsky_fit,
  Hinshelwood = hinshelwood_fit,
  Quadratic = quadratic_fit,
  Briere2 = briere2_fit,
  Performance = performance_fit,
  Logistic1 = logistic1_fit,
  Logistic2 = logistic2_fit,
  Sharpe_Schoolfield = sharpe_schoolfield_fit,
  Ratkowsky = ratkowsky_fit,
```

```
    Briere1 = briere1_fit,
    Weibull = weibull_fit,
    Modified_Gaussian = modified_gaussian_fit,
    Exp_Modified_Gaussian = exp_modified_gaussian_fit,
    Eppley = eppley_fit
  )

  fit_models[[treatment]] <- fit_list

  aicc_values <- sapply(fit_list, function(fit) {
    if (!is.null(fit)) AICc(fit) else Inf
  })

  aicc[[treatment]] <- aicc_values

  best_model_name <- if (treatment == "hot-cold") {
    "Eppley"
  } else {
    "Briere1"
  }

  best_model <- fit_list[[best_model_name]]

  if (!is.null(best_model)) {
    fit_results[[treatment]] <- list(model_name = best_model_name, model = best_model)

    # Plot the best model
    new_data <- data.frame(temp = seq(min(tpc_treatm$temp), max(tpc_treatm$temp), by = 0.1))
    new_data$frond <- predict(best_model, newdata = new_data)

    lines(new_data$temp, new_data$frond, col = colors[color_index], lwd = 3)
    points(tpc_treatm$temp + rnorm(nrow(tpc_treatm), mean = 0, sd = 0.4),
           tpc_treatm$frond, pch = 1, cex = 3, col = colors[color_index], lwd = 2)
  }

  color_index <- color_index + 1
  abline(h = 0, lty = 2, col = "black")

}

par(mar = c(5, 5, 1, 1) + 0.1)

# Second plot (hot-cold group: 2 very low points)
plot(
  "",
  xlim = c(min(tpc$Mean_temperature)-2, max(tpc$Mean_temperature)+5), ylim = c(-2.9, -2.7),
  yaxt = "n", xaxt = "n", frame.plot = FALSE,
  xlab = "", ylab = ""
)

# Manually add the x-axis and y-axis for the second plot
axis(1, col = "black", cex.axis = 2, cex.lab = 2)  # x-axis with black lines
axis(2, at = -2.8, labels = -2.8, col = "black", cex.axis = 2, cex.lab = 2)  # y-axis showing only -2.8
```

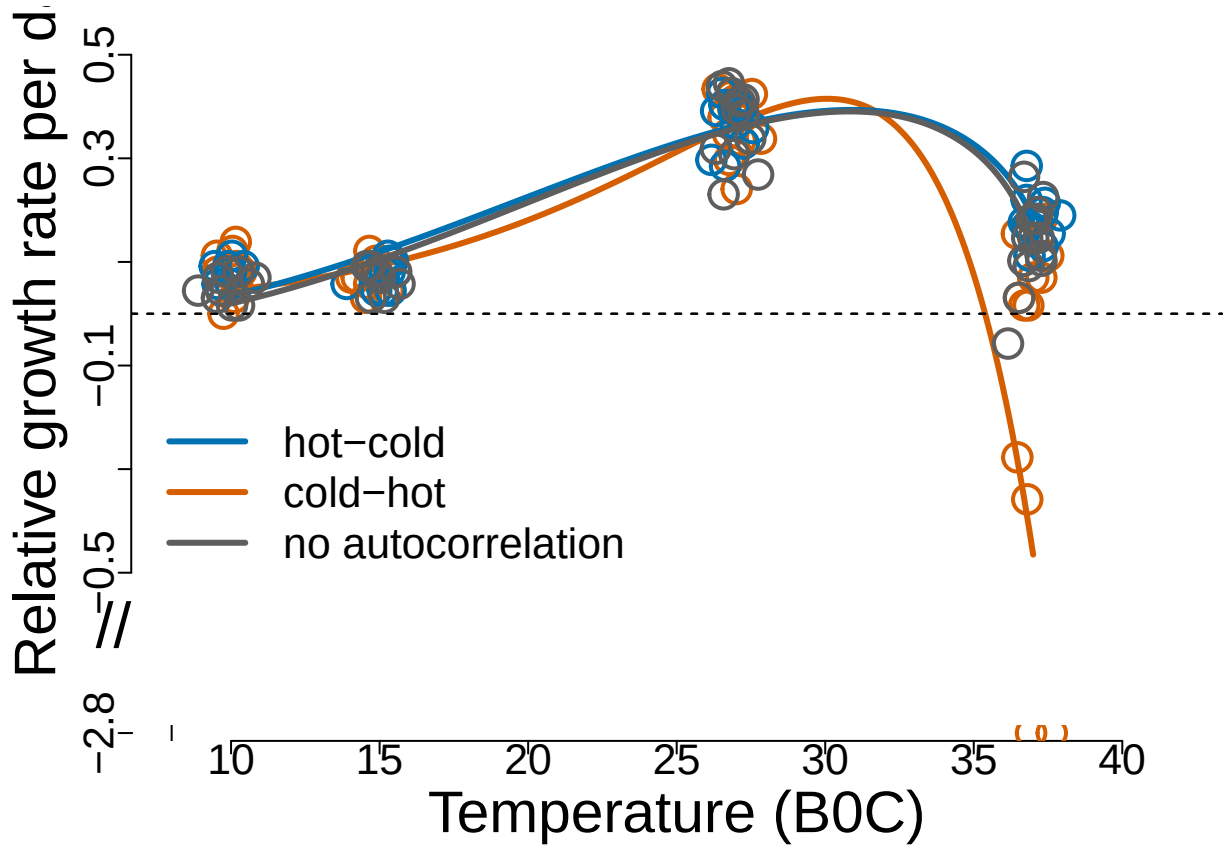
```
# Add x-axis title for the second plot
mtext("Temperature (B0C)", side = 1, line = 2.8, cex = 1.8)

# Add a vertical line to act as the y-axis
abline(v = min(tpc$Mean_temperature) - 2, col = "black", lwd = 1)

# Filter for hot-cold group
tpc_hot_cold <- subset(tpc, Treatment %in% c("hot-cold"))

# Plot scatter for hot-cold group
jittered_temp <- tpc_hot_cold$Mean_temperature + rnorm(length(tpc_hot_cold$Mean_temperature), mean = 0,
points(jittered_temp, tpc_hot_cold$r, col = colors[2],
       pch = 1, cex = 3, lwd = 2)

# Add a horizontal dashed black line at y = 0
abline(h = 0, lty = 2, col = "black")
```




```
aicc[[1]]
```

```
##           Newfunction          Hinshelwood            Quadratic
##                   Inf             85.19723             82.01599
##              Briere2           Performance            Logistic1
##                   Inf                   Inf             93.88953
##            Logistic2     Sharpe_Schoolfield            Ratkowsky
##                   Inf              90.80891             90.39049
##              Briere1               Weibull     Modified_Gaussian
```

```
##              85.49611              94.24204              87.94117
## Exp_Modified_Gaussian                Eppley
##                   Inf              82.99815
```

```
aicc[[2]]
```

```
##           Newfunction           Hinshelwood             Quadratic
##                   Inf             -65.64973             -87.83372
##               Briere2           Performance             Logistic1
##                   Inf                   Inf             -68.24971
##             Logistic2    Sharpe_Schoolfield             Ratkowsky
##                   Inf            -108.88733                   Inf
##               Briere1               Weibull     Modified_Gaussian
##            -121.02830             -39.23266            -125.10297
## Exp_Modified_Gaussian                Eppley
##                   Inf            -140.13536
```

```
aicc[[3]]
```

```
##           Newfunction           Hinshelwood             Quadratic
##                   Inf             -57.659477            -88.195640
##               Briere2           Performance             Logistic1
##                   Inf                   Inf            -64.863520
##             Logistic2    Sharpe_Schoolfield             Ratkowsky
##             -1.867309            -99.323673           -114.696481
##               Briere1               Weibull     Modified_Gaussian
##           -113.493951            -39.037103           -116.197395
## Exp_Modified_Gaussian                Eppley
##                   Inf            -117.170274
```

```
library(knitr)


aicc_table <- lapply(aicc, function(treatment_aicc) {
  # Replace Inf with "No fit"
  treatment_aicc[treatment_aicc == Inf] <- "No fit"

  # Convert character strings back to numeric and round to 2 decimal places
  treatment_aicc <- sapply(treatment_aicc, function(x) {
    if(is.character(x)) {
      if(x == "No fit") {
        return(x)
      } else {
        return(round(as.numeric(x), 2))
      }
    } else {
      return(round(x, 2))
    }
  })

  return(treatment_aicc)
})

# Convert to a data frame for better readability
aicc_table_df <- as.data.frame(aicc_table)
```

```r
# Print the table using kable
kable(aicc_table_df, digits = 2)
```

	hot.cold	cold.hot	no.autocorrelation
Newfunction	No fit	No fit	No fit
Hinshelwood	85.2	-65.65	-57.66
Quadratic	82.02	-87.83	-88.2
Briere2	No fit	No fit	No fit
Performance	No fit	No fit	No fit
Logistic1	93.89	-68.25	-64.86
Logistic2	No fit	No fit	-1.87
Sharpe_Schoolfield	90.81	-108.89	-99.32
Ratkowsky	90.39	No fit	-114.7
Briere1	85.5	-121.03	-113.49
Weibull	94.24	-39.23	-39.04
Modified_Gaussian	87.94	-125.1	-116.2
Exp_Modified_Gaussian	No fit	No fit	No fit
Eppley	83	-140.14	-117.17