

# Introduction to SppTrend

2025-12

## Introduction

The `SppTrend` package provides a statistical framework to analyze temporal shifts in species occurrences in relation to environmental drivers. By comparing individual species' trajectories against an aggregate overall trend, the package classifies biological responses into spatial and thermal strategies.

Detailed information is available in `README` .

## Workflow implementation

### 1. Installation and dependencies

```
# Install the development version from CRAN or GitHub
# install.packages("SppTrend")
# devtools::install_github("MarioMingarro/SppTrend")

library(SppTrend)
library(knitr)
library(DT)
library(ggplot2)
library(rnaturalearth)
library(sf)
library(readr)
```

### 2. Data acquisition and pre-processing

The package requires a `data frame` with species names, coordinates (WGS84), and temporal information (Year/Month).

*Note:*

Ensure that the column names in your input dataset match the default names expected by the `SppTrend` functions.

These default names are:

- Species Name: `species`
- Year: `year`
- Month: `month`
- Longitude: `lon`
- Latitude: `lat`

Environmental response variables (if applicable):

- Elevation: `elev`
- Temperature: `tme`

- Maximum temperature: `tmx`
- Minimum temperature: `tmn`

The data for this example is available in `/inst/extdata/example_ranidae.csv`

```
path_to_file <- system.file("extdata", "example_ranidae.csv", package = "SppTrend")
```

```
ranidae <- read_csv2(path_to_file,
                     col_types = cols(year = col_double(),
                                      month = col_double(),
                                      lon = col_double(),
                                      lat = col_double()))
```

Construct a continuous temporal predictor combining year and month

```
ranidae$year_month <- ranidae$year + (ranidae$month * 0.075)
```

Show  entries

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Table 1: Initial dataset structure.

	...1	species		year	month	lon	
1	1	Rana dalmatina	2012	5	2.06806	46.50429	2012.375
2	2	Lithobates clamitans	2021	12	-77.107738	36.950358	2021.9
3	3	Sylvirana guentheri	2014	4	121.16163	24.784924	2014.3
4	4	Lithobates johnei	1956	6	-98.790832	21.290833	1956.45
5	5	Rana pyrenaica	2011	5	-0.65564	43.0418	2011.375
6	6	Sanguirana sanguinea	1984	6	119.175	10.0743	1984.45
7	7	Rana temporaria	2016	8	6	52.75	2016.6
8	8	Pelophylax perezi	1970	4	-5.37	40.15	1970.3
9	9	Lithobates clamitans	2019	8	-72.062286	42.193805	2019.6
10	10	Rana temporaria	1991	4	4.6	52.1	1991.3

Showing 1 to 10 of 10,000 entries

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### 3. Environmental Data Extraction

If environmental response variables is not available, SppTrend facilitates the integration of geospatial environmental data (temperature and elevation).

#### 3.1 Temperature (ERA5-Land)

get\_era5\_tme() to extract mean monthly temperatures ( tme ) from a ERA5-Land ( .nc ) file.

```
ranidae <- get_era5_tme(data = ranidae,
                        nc_file = "personal/path/era5_land.nc")
```

#### 3.2 Elevation (DEM)

extract\_elevation() to obtain altitude ( ele ) from a Digital Elevation Model ( .tif ) file.

```
ranidae <- extract_elevation(data = ranidae,
                             dem_file = "personal/path/dem_wc21_30s.tif")
```

Show 10 ▾ entries

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Table 2: Data with environmental variables.

	...1 ▾	...2 ▾	species		year ▾	month ▾	lon ▾	lat ▾	y
1	1	1	Rana dalmatina	2012	5	2.06806	46.50429	2012.375	1
2	2	2	Lithobates clamitans	2021	12	-77.107738	36.950358	2021.9	1
3	3	3	Sylvirana guentheri	2014	4	121.16163	24.784924	2014.3	2
4	4	4	Lithobates johni	1956	6	-98.790832	21.290833	1956.45	2
5	5	5	Rana pyrenaica	2011	5	-0.65564	43.0418	2011.375	1
6	6	6	Sanguirana sanguinea	1984	6	119.175	10.0743	1984.45	2
7	7	7	Rana temporaria	2016	8	6	52.75	2016.6	1
8	8	8	Pelophylax perezi	1970	4	-5.37	40.15	1970.3	
9	9	9	Lithobates clamitans	2019	8	-72.062286	42.193805	2019.6	2

# 4. Trend analysis

The analysis is performed in two stages: estimating the baseline trend and then calculating species-specific deviations.

```
predictor <- "year_month"

responses <- c("lat", "lon", "ele", "tme")

species_list <- unique(ranidae$species)

ranidae <- na.omit(ranidae)
```

## 4.1 Overall trend (OT)

The OT serves as a neutral reference, representing the average temporal change across all observations.

```
overall_res <- overall_trend(ranidae, predictor = predictor, responses = responses)
```

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3: Aggregate trends for all observations.

responses	trend	t	pvalue	ci_
lat	0.05078975477451399	6.220452695126689	5.163070680277896e-10	0.06679479
lat	0.02774454643049197	3.589398194891524	0.0003330989743752444	0.04289616
lat	0.0271486704443066	0.8782365504432227	0.382954018408926	0.0888506
lon	0.8992744629075236	19.33505955472533	9.4873532465649e-82	0.9904439
lon	0.980960492835405	21.12001277784664	8.217582128291112e-97	1.072006
lon	-0.8166756538545367	-2.221327227685297	0.02971218768108388	-0.0828389
ele	-6.252295643020735	-20.45193292326937	4.84237380227639e-91	-5.653046
ele	-6.196729103284971	-20.10191249974519	4.582615300553014e-88	-5.592463
ele	-5.399645093066535	-1.697895932728753	0.0941678030036246	0.948056
tme	0.05797072473846841	11.13535529376358	1.261110027479092e-28	0.06817558

## 4.2. Species-specific trends

Calculates individual slopes for each species, applying a minimum record threshold ( `n_min` ) to ensure model stability.

```
spp_res <- spp_trend(ranidae, species_list,
                    predictor = predictor,
                    responses = responses,
                    n_min = 5)
```

## 5. Ecological strategy classification

The `spp_strategy()` function categorizes species based on the significance and direction of their trends relative to the OT.

```
strategy_res <- spp_strategy(spp_res,
                             sig_level = 0.05,
                             responses = c("lat", "lon", "tme", "ele"))
```

Show **25** entries

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4: Classification of biological strategies.

species	n	Spatial_lon	Spatial_lat_Both	Spatial_lat_South	Spatial_lat_North
Lithobates septentrionalis	160	SC			SC
Lithobates spectabilis	48	SC			SC
Lithobates sphenoccephalus	676	SD			SC
Lithobates sylvaticus	1656	SA			SE
Lithobates vaillanti	60	SC			SC
Lithobates virgatipes	44	SC			SC
Lithobates warszewitschii	44	SC			SC
Lithobates yavapaiensis	60	SC			SC
Nidirana adenopleura	420	SC			SC

Odorrana chloronota	24	SC	SC
Odorrana swinhoana	688	SC	SC
Papurana daemeli	68	SC	SC
Papurana grisea	52	SC	SC
Pelophylax bedriagae	24	SC	SC
Pelophylax fukienensis	76	SC	SC
Pelophylax lessonae	1712	SC	SC
Pelophylax nigromaculatus	336	SC	SC
Pelophylax perezi	972	SC	SC
Pelophylax ridibundus	1132	SC	SP
Pulchrana grandocula	28	SC	SC
Pulchrana similis	44	SC	SC
Rana arvalis	1748	SD	SC
Rana aurora	136	SC	SC
Rana boylei	116	SD	SC
Rana cascadae	40	SC	SC

Showing 26 to 50 of 68 entries

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## 6. Visualization

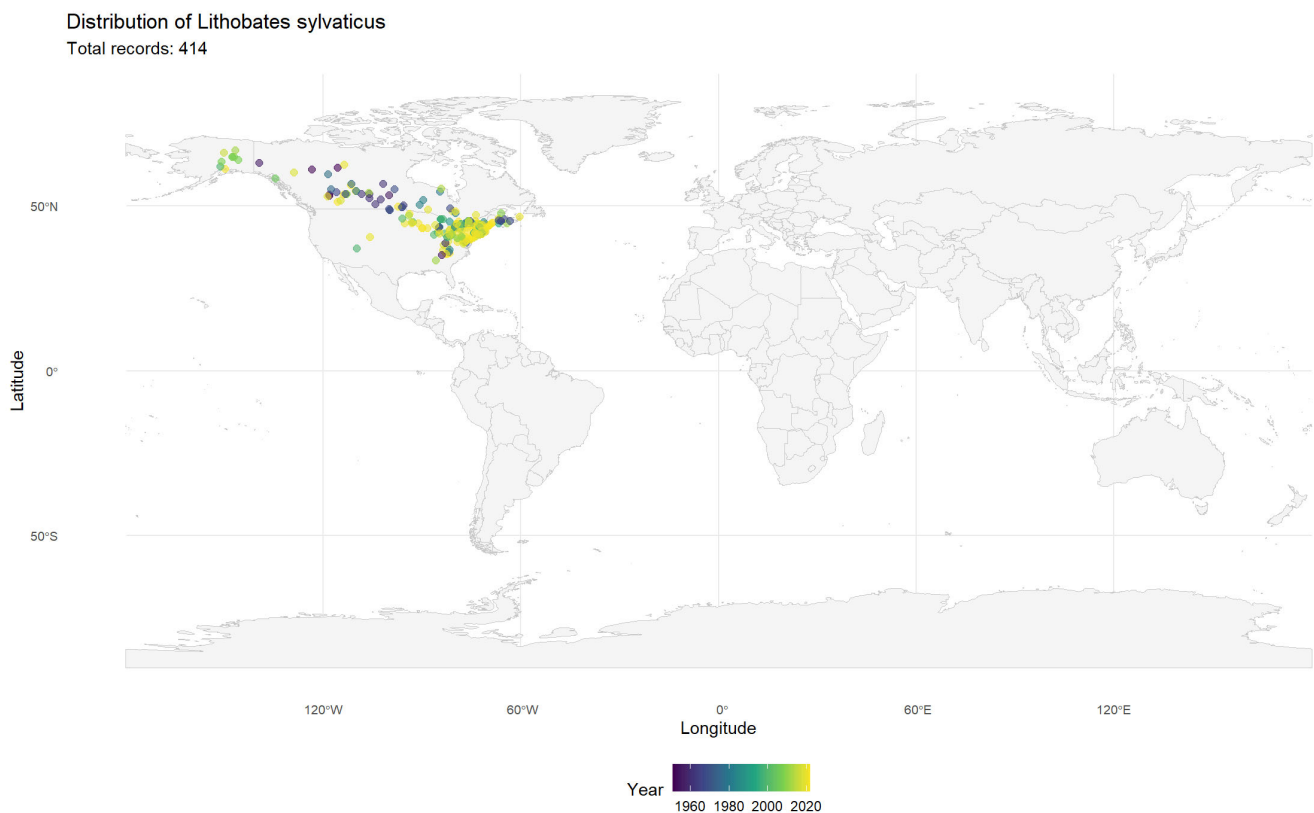
Visualizing the relationship between occurrence records and environmental shifts is useful for hypothesis generation.

## 6.1. Spatial distribution

*Lithobates sylvaticus* has been selected as an example of a species with Spatial Equatorward (SE) shift for visualization (see table 4).

```
example_spp <- "Lithobates sylvaticus"
viz_data <- ranidae[ranidae$species == example_spp, ]
```

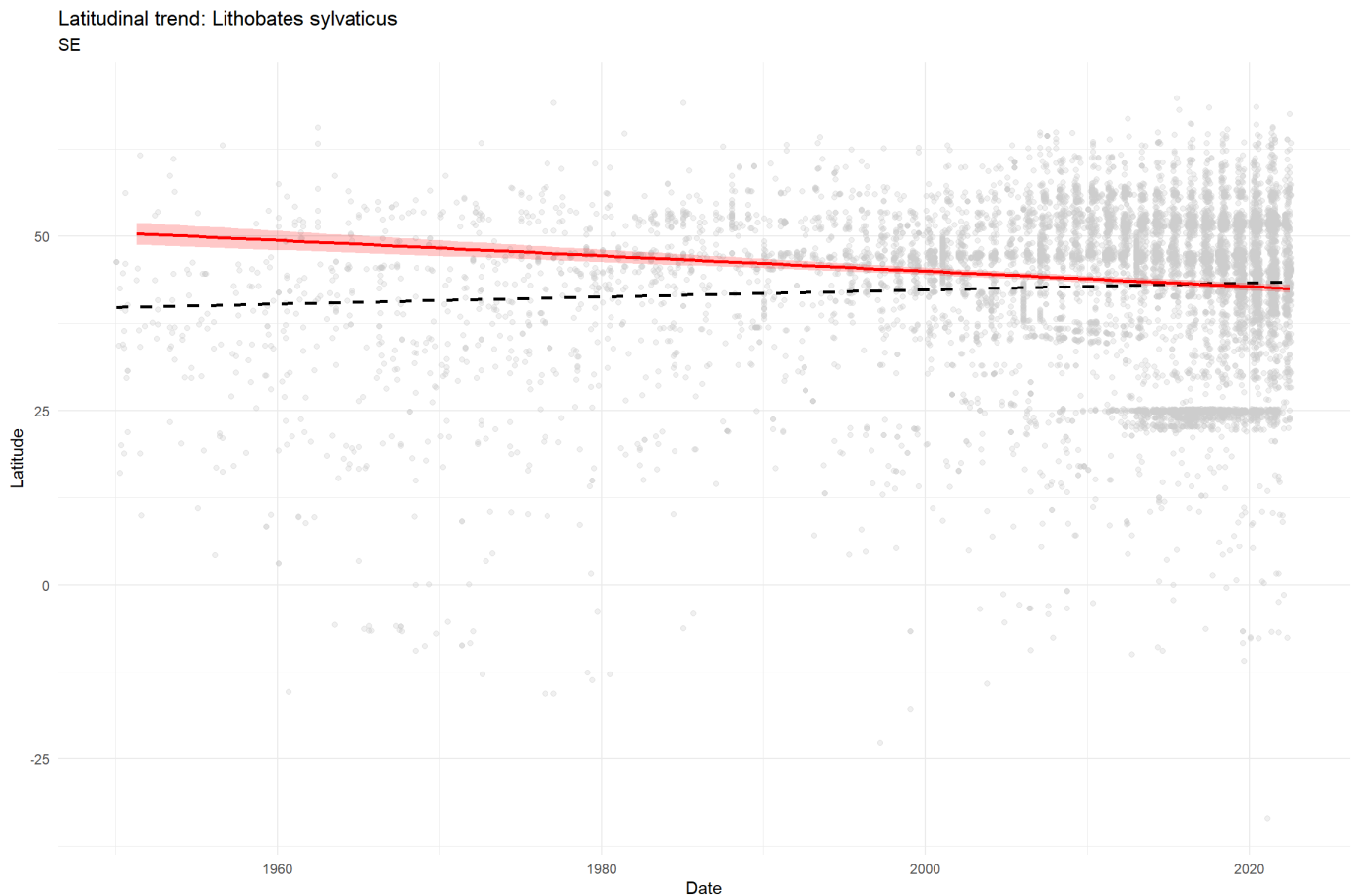
```
world_map <- ne_countries(scale = "medium", returnclass = "sf")
ggplot() +
  geom_sf(data = world_map, fill = "#f9f9f9", color = "grey80") +
  geom_point(data = viz_data, aes(x = lon, y = lat, col = year), alpha = 0.6, size = 2) +
  scale_colour_viridis_c(option = "viridis", name = "Year") +
  labs(title = paste("Distribution of", example_spp),
       subtitle = paste("Total records:", nrow(viz_data)),
       x = "Longitude", y = "Latitude") +
  theme_minimal() +
  theme(axis.text = element_text(size = 8),
        legend.position = "bottom")
```



## Latitudinal trend plots

*Lithobates sylvaticus* latitudinal trend (red) compared against the community-wide OT (dashed black).

```
ggplot() +
  geom_point(data = ranidae, aes(x = year_month, y = lat), color = "grey80", alpha = 0.3) +
  geom_smooth(data = ranidae, aes(x = year_month, y = lat),
             method = "lm", color = "black", linetype = "dashed", se = FALSE) +
  geom_smooth(data = viz_data, aes(x = year_month, y = lat),
             method = "lm", color = "red", fill = "red", alpha = 0.2) +
  labs(title = paste("Latitudinal trend:", example_spp),
       subtitle = "SE",
       x = "Date", y = "Latitude") +
  theme_minimal()
```



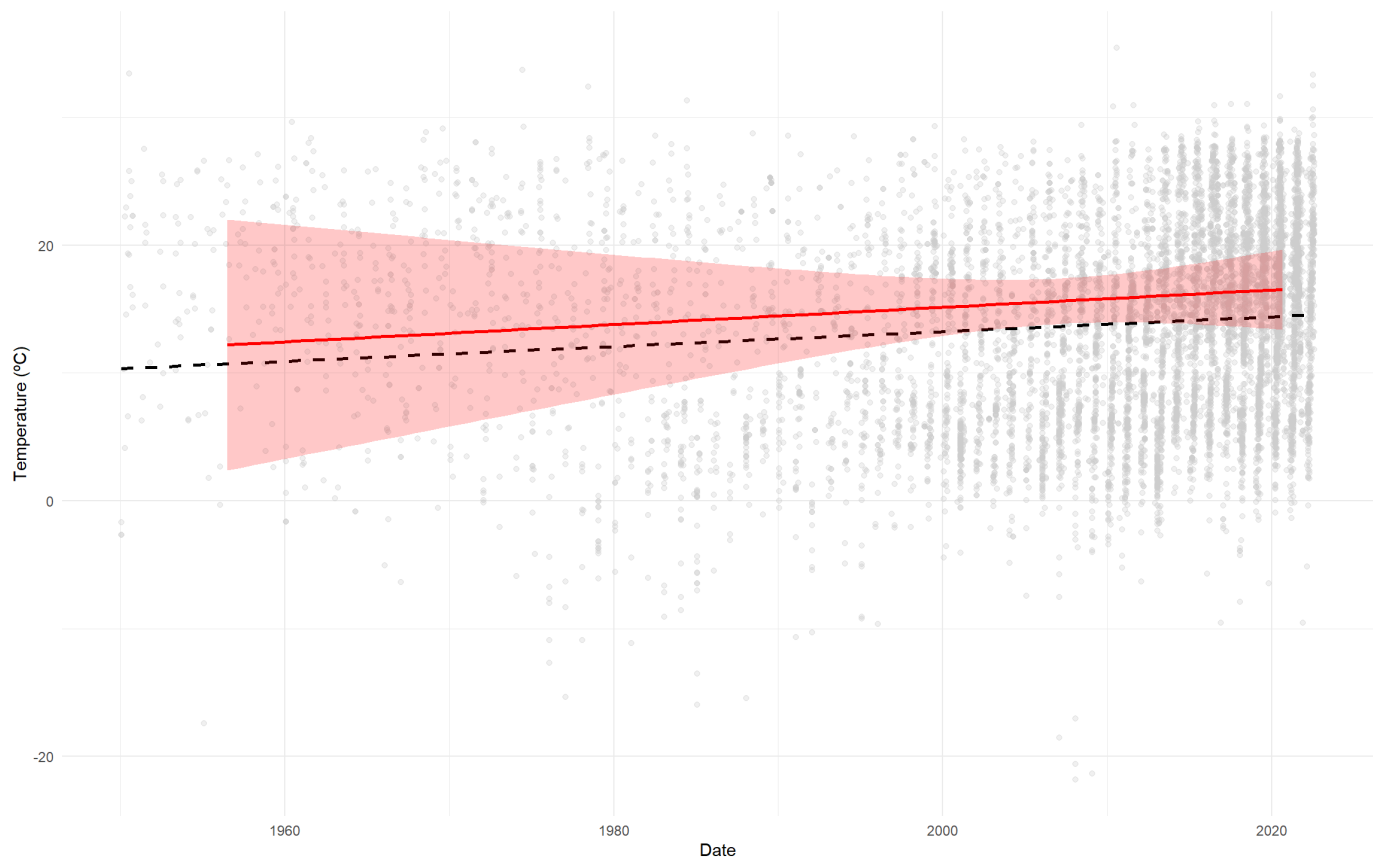
## Temperature trend plot

*Pelophylax nigromaculatus* has been selected as an example of a species with Thermal Tolerance (TT) for visualization (see table 4).

```
example_spp <- "Pelophylax nigromaculatus"
viz_data <- ranidae[ranidae$species == example_spp, ]
ggplot() +
  geom_point(data = ranidae, aes(x = year_month, y = tme), color = "grey80", alpha = 0.3) +
  geom_smooth(data = ranidae, aes(x = year_month, y = tme),
             method = "lm", color = "black", linetype = "dashed", se = FALSE) +
  geom_smooth(data = viz_data, aes(x = year_month, y = tme),
             method = "lm", color = "red", fill = "red", alpha = 0.2) +
  labs(title = paste("Temperature trend:", example_spp),
       subtitle = "TT",
       x = "Date", y = "Temperature (°C)") +
  theme_minimal()
```

Temperature trend: *Pelophylax nigromaculatus*

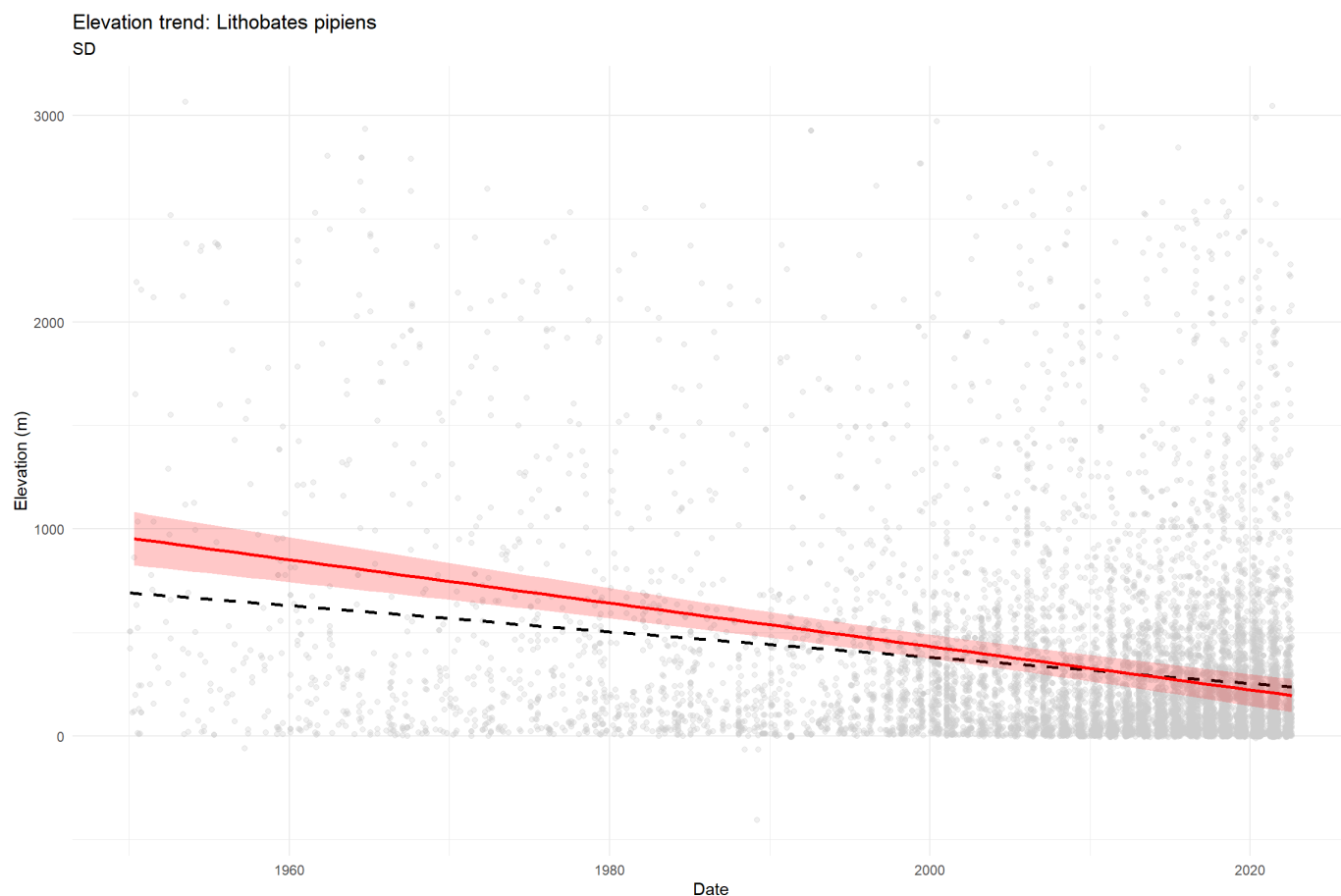
TT



## Elevation trend plot

*Lithobates pipiens* has been selected as an example of a species with elevational Spatial Discordance (SD) for visualization (see table 4).

```
example_spp <- "Lithobates pipiens"
viz_data <- ranidae[ranidae$species == example_spp, ]
ggplot() +
  geom_point(data = ranidae, aes(x = year_month, y = ele), color = "grey80", alpha = 0.3) +
  geom_smooth(data = ranidae, aes(x = year_month, y = ele),
    method = "lm", color = "black", linetype = "dashed", se = FALSE) +
  geom_smooth(data = viz_data, aes(x = year_month, y = ele),
    method = "lm", color = "red", fill = "red", alpha = 0.2) +
  labs(title = paste("Elevation trend:", example_spp),
    subtitle = "SD",
    x = "Date", y = "Elevation (m)") +
  theme_minimal()
```



# Conclusions

## Disclaimer

The results presented in this vignette are based on a reduced sample of 10,000 records. These outputs are intended for demonstration purposes and should not be interpreted as definitive biological findings.

SppTrend provides a methodology for transforming raw occurrence data into interpretable ecological strategies. However, users are encouraged to account for potential sampling biases and heterogeneities in historical datasets to ensure the reliability of the estimated trends.