

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: `ele`
- Temperature: `tme`

- Maximum temperature: `tmpx`
- 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)
```

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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 johni	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

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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")
```

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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
2	2	2	Lithobates clamitans	2021	12	-77.107738	36.950358	2021.9
3	3	3	Sylvirana guentheri	2014	4	121.16163	24.784924	2014.3
4	4	4	Lithobates johni	1956	6	-98.790832	21.290833	1956.45
5	5	5	Rana pyrenaica	2011	5	-0.65564	43.0418	2011.375
6	6	6	Sanguirana sanguinea	1984	6	119.175	10.0743	1984.45
7	7	7	Rana temporaria	2016	8	6	52.75	2016.6
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

10	10	10	Rana temporaria	1991	4	4.6	52.1	1991.3
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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	0.08885061
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	-5.6530461
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	0.068175581

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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"))
```

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4: Classification of biological strategies.

species	n	Spatial_Ion	Spatial_lat_Both	Spatial_lat_South	Spatial_lat_North
<i>Lithobates septentrionalis</i>	160	SC			SC
<i>Lithobates spectabilis</i>	48	SC			SC
<i>Lithobates sphenocephalus</i>	676	SD			SC
<i>Lithobates sylvaticus</i>	1656	SA			SE
<i>Lithobates vaillanti</i>	60	SC			SC
<i>Lithobates virgatipes</i>	44	SC			SC
<i>Lithobates warszewitschii</i>	44	SC			SC
<i>Lithobates yavapaiensis</i>	60	SC			SC
<i>Nidirana adenopleura</i>	420	SC			SC

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

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6. Visualization

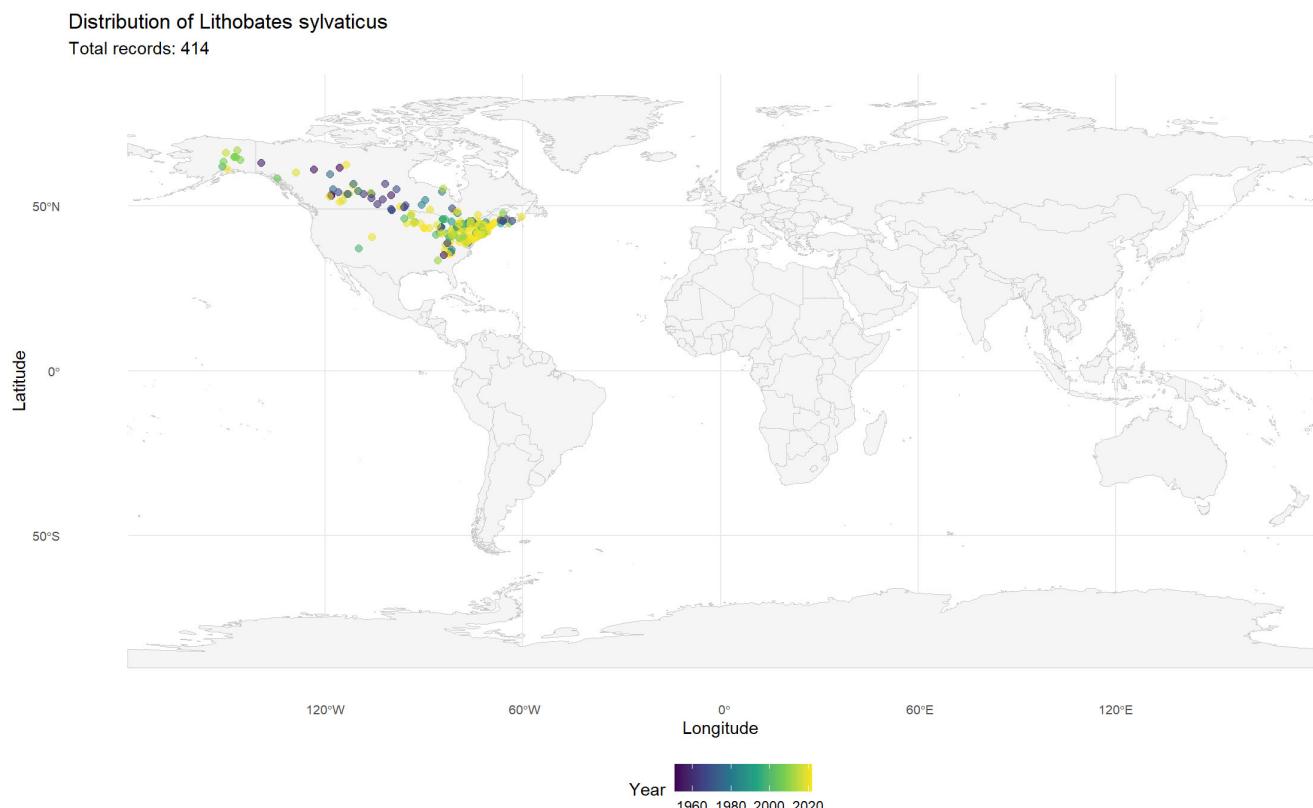
Visualizing the relationship between occurrence records and environmental shifts is useful for hypothesis generation.

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")
```



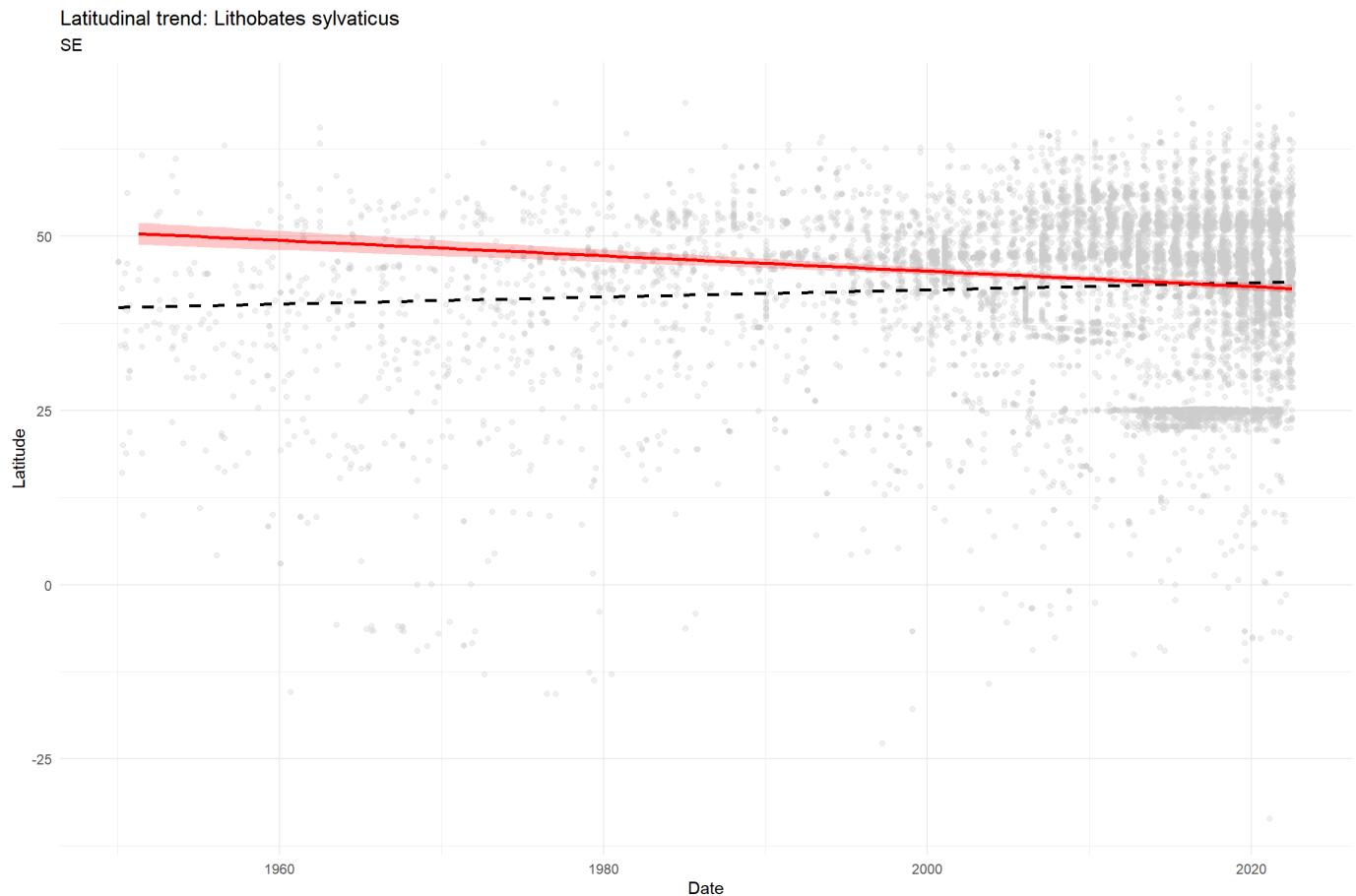
Latitudinal trend plots

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

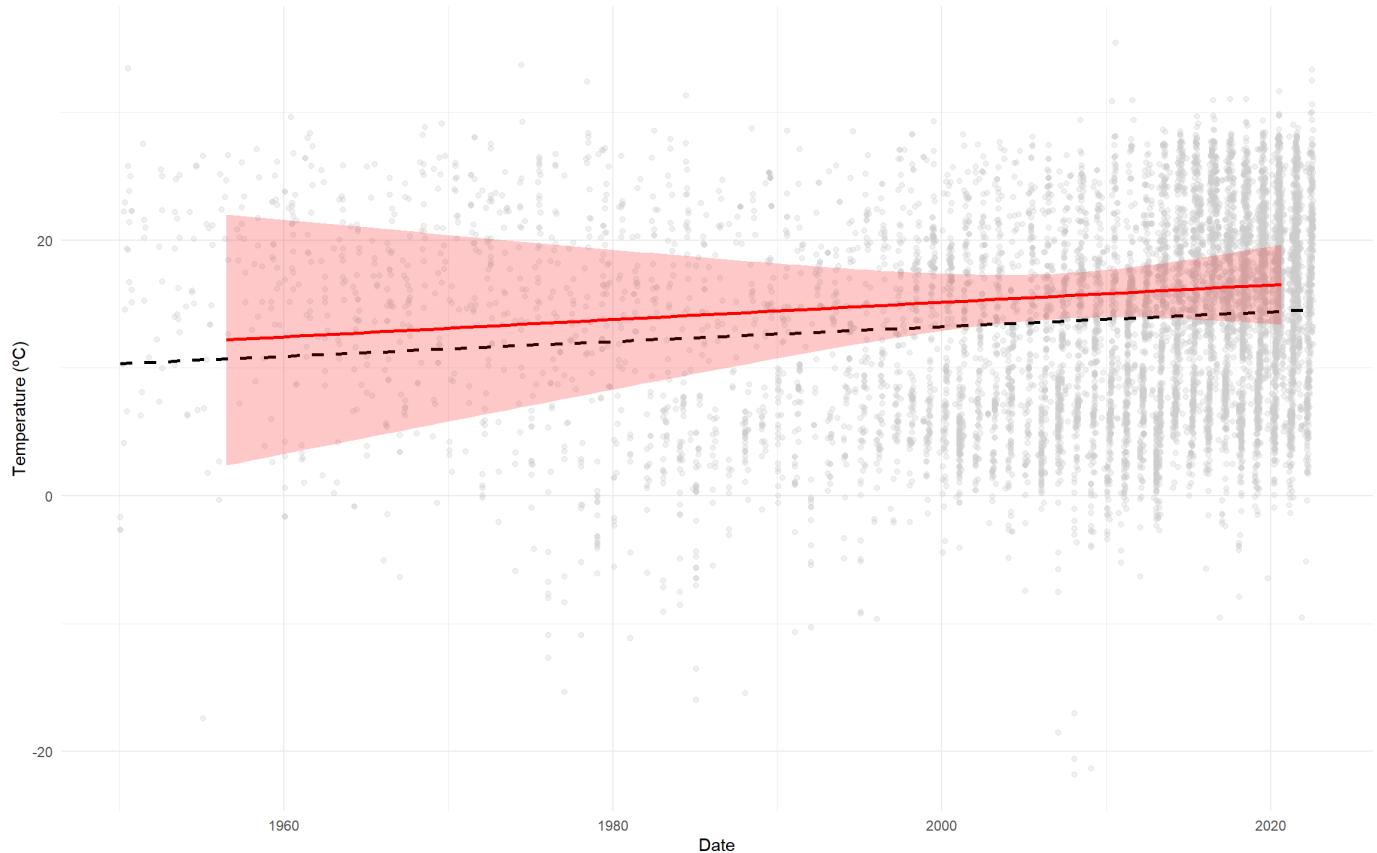
Pelophylax nigromaculatus has been selected as an example of a species with Thermal Tolerance (TT) for visualization (see table 4).

```

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()

```

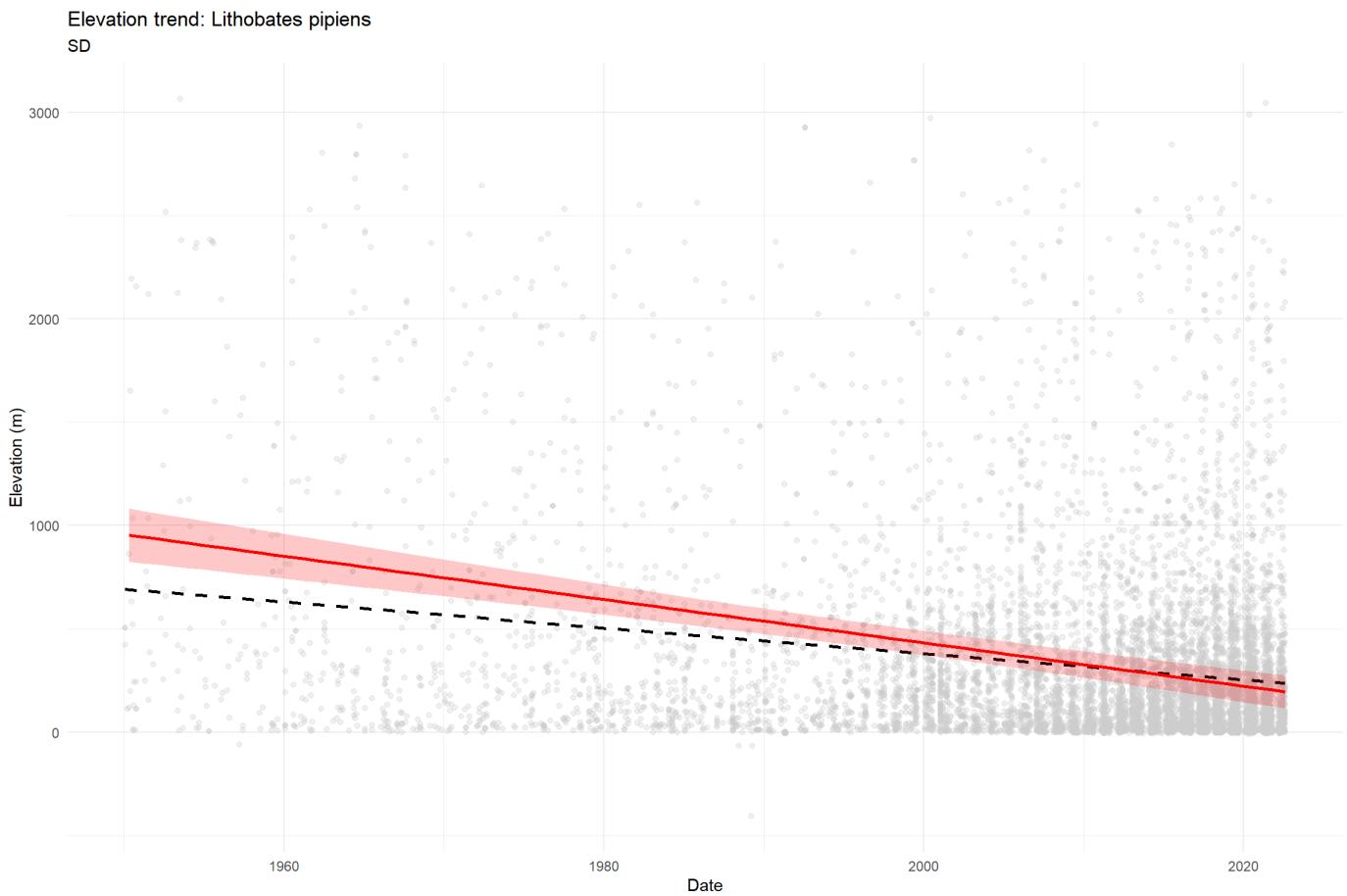
Temperature trend: *Pelophylax nigromaculatus*
TT



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.