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: `tmx`
- Minimum temperature: `tmn`

```
path_to_file <- "PERSONAL/PATH/TO/DATA"


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	lat	year_mont
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.

species	year	month	lon	lat	year_month	tme
Amnirana albolabris	2019	3	25.26188	0.61064	2019.225	27.0793090820313
Amnirana albolabris	2015	4	11.16621	-0.05171	2015.3	25.5432067871094
Amnirana albolabris	2005	6	0.59449	8.33383	2005.45	23.8427978515625
Amnirana albolabris	1960	1	11.9667	2.9833	1960.075	23.7576538085938
Amnirana albolabris	1960	1	11.9667	2.9833	1960.075	23.7576538085938
Amnirana albolabris	2014	6	32.95413	0.4441	2014.45	20.9456115722656
Amnirana amnicola	2015	4	13.58746	-2.2419	2015.3	24.2541442871094
Amnirana galamensis	2010	5	2.936944	11.128611	2010.375	30.8308654785156
Amnirana galamensis	1955	1	-0.267	10.95	1955.075	26.5682006835938
Amnirana galamensis	2017	12	35.06064	-19.663631	2017.9	

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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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Table 3: Aggregate trends for all observations.

t	pvalue	ci_95_max	ci_95_min	n	hem
9530927	5.163070674293483e-10	0.06679479311359884	0.03478471643843097	9647	Glob
5089341	0.0003330989741228348	0.04289616318061844	0.01259292968344127	9578	Nort
4432227	0.382954018408926	0.0888506947795132	-0.0345533538909	69	Sou
5470017	9.487353251020447e-82	0.9904439142416323	0.8081050115709673	9647	Glob
7783315	8.217582130532059e-97	1.072006379069404	0.889914606599784	9578	Nort
7717964	0.02971218767876569	-0.08283896051241801	-1.550512347226483	69	Sou
2326937	4.84237380227639e-91	-5.653046059964432	-6.851545226077037	9647	Glob
9974519	4.582615300553014e-88	-5.592463157113986	-6.800995049455956	9578	Nort
2728753	0.0941678030036246	0.948056498521118	-11.74734668465419	69	Sou
6730406	1.260633948389954e-28	0.06817573666040583	0.04776601649764749	9647	Glob

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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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Table 4: Classification of biological s

species	n	Spatial_lon	Spatial_lat_Both	Spatial_lat_South	Spatial_lat_
Lithobates septentrionalis	160	SC			SC
Lithobates spectabilis	48	SC			SC
Lithobates sphenocephalus	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 boylii	116	SD			SC
Rana cascadae	40	SC			SC

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6. Visualization

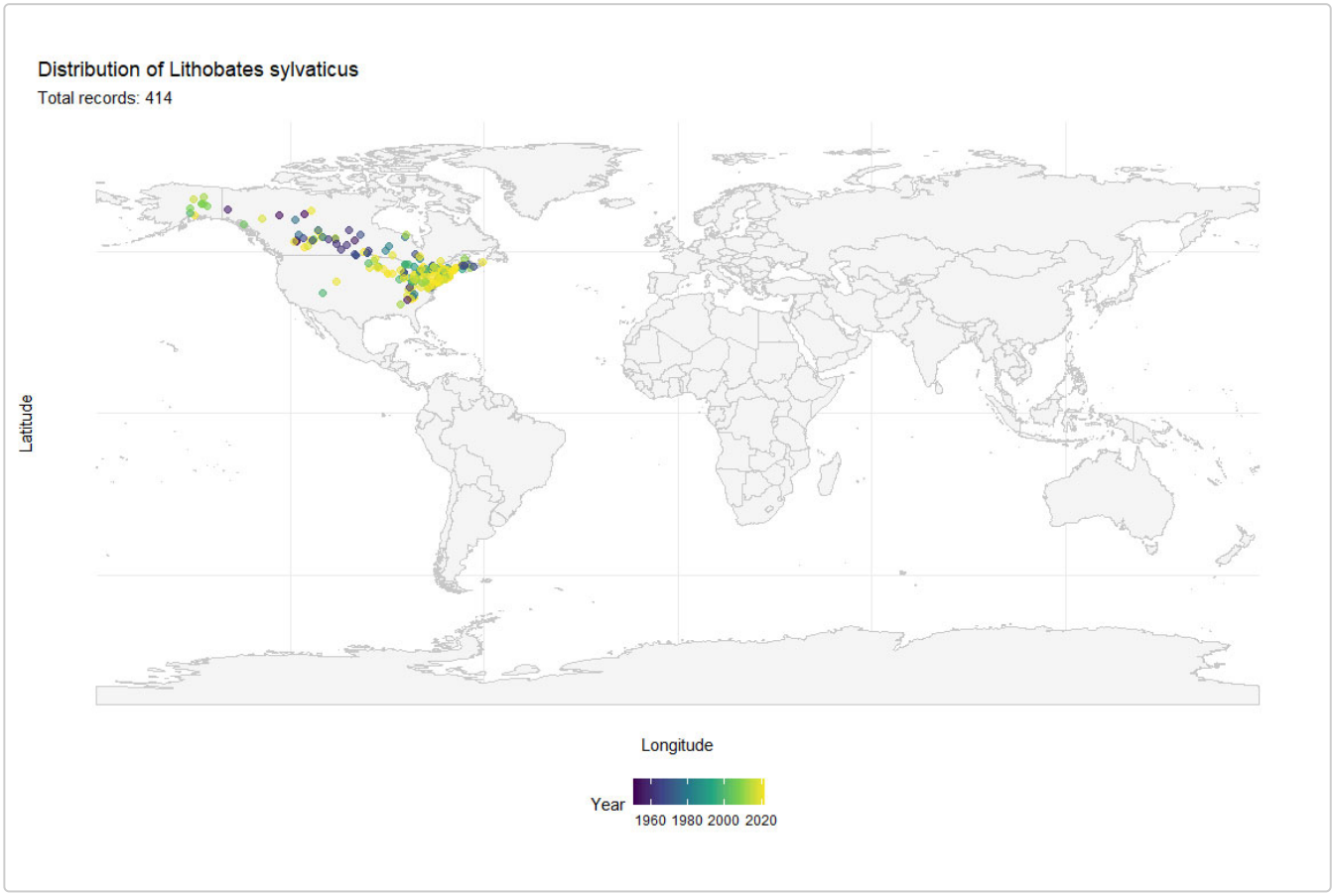
Visualizing the relationship between occurrence records and environmental shifts is useful for hypothesis generation.

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, ]
```

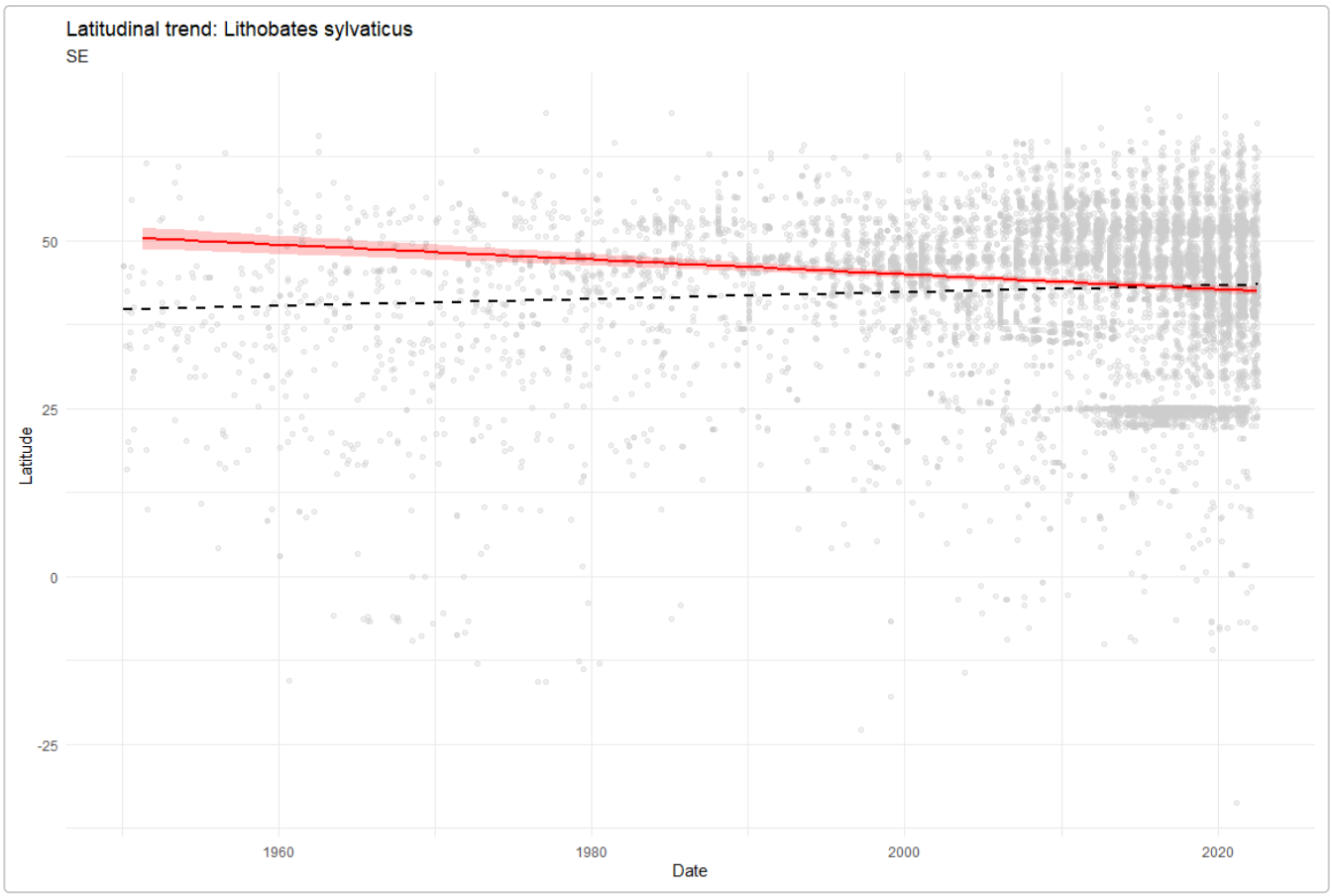
```
world_map <- ne_countries(scale = "medium", returnclass = "sf")
ggplot() +
  geom_sf(data = world_map, fill = "#f9f9f9", color = "grey80") +
  geom_point(data = viz_data, aes(x = lon, y = lat, col = year), alpha = 0.6, size = 2) +
  scale_colour_viridis_c(option = "viridis", name = "Year") +
  labs(title = 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).

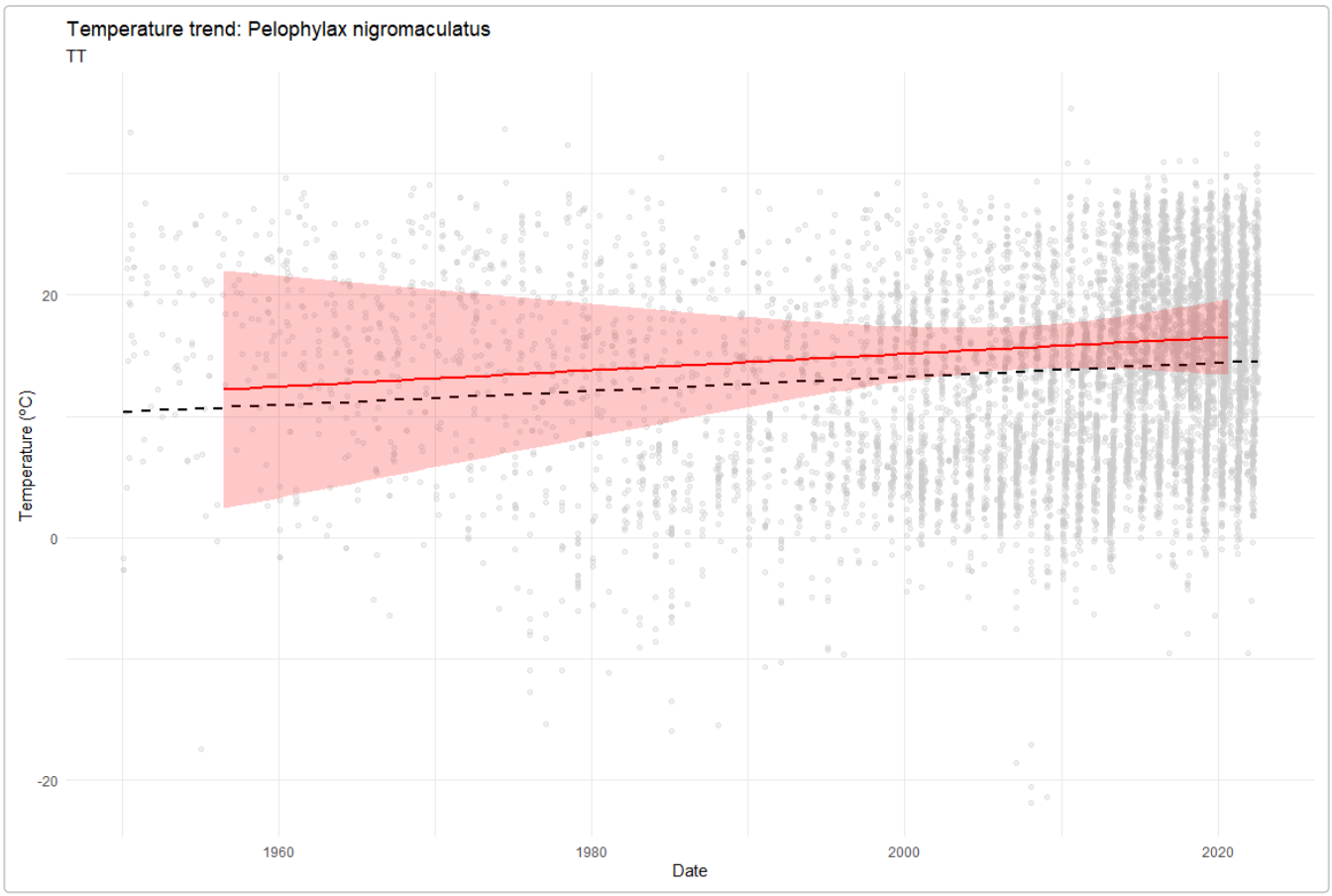
```
ggplot() +
  geom_point(data = ranidae, aes(x = year_month, y = lat), color = "grey80", alpha = 0.3) +
  geom_smooth(data = ranidae, aes(x = year_month, y = lat),
              method = "lm", color = "black", linetype = "dashed", se = FALSE) +
  geom_smooth(data = viz_data, aes(x = year_month, y = 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).

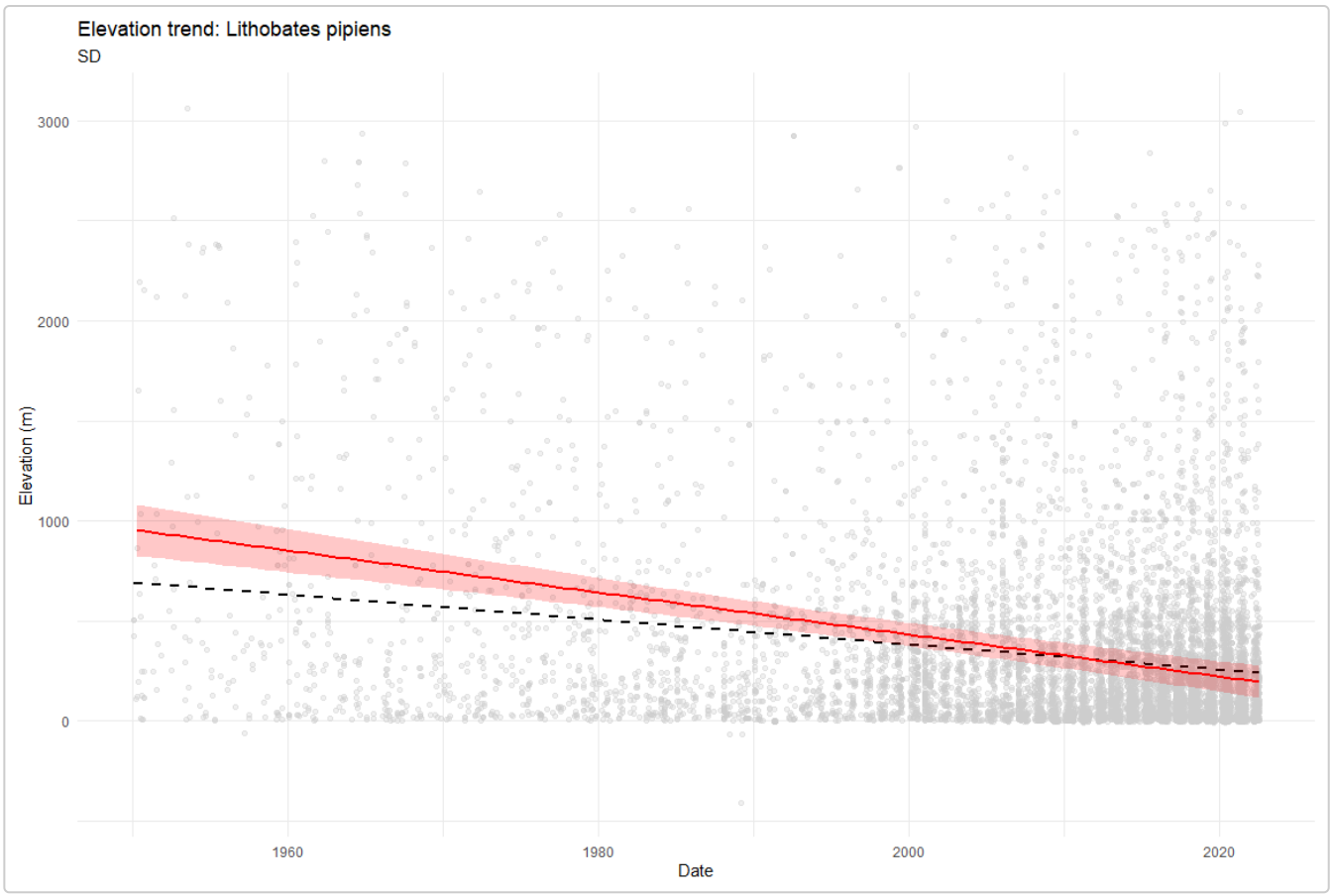
```
example_spp <- "Pelophylax nigromaculatus"
viz_data <- ranidae[ranidae$species == example_spp, ]
ggplot() +
  geom_point(data = ranidae, aes(x = year_month, y = tme), color = "grey80", alpha = 0.3) +
  geom_smooth(data = ranidae, aes(x = year_month, y = tme),
              method = "lm", color = "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 (ºC)") +
  theme_minimal()
```



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.