SUPPORTING INFORMATION

When can we trust population trends? A method for quantifying the effects of sampling interval and duration

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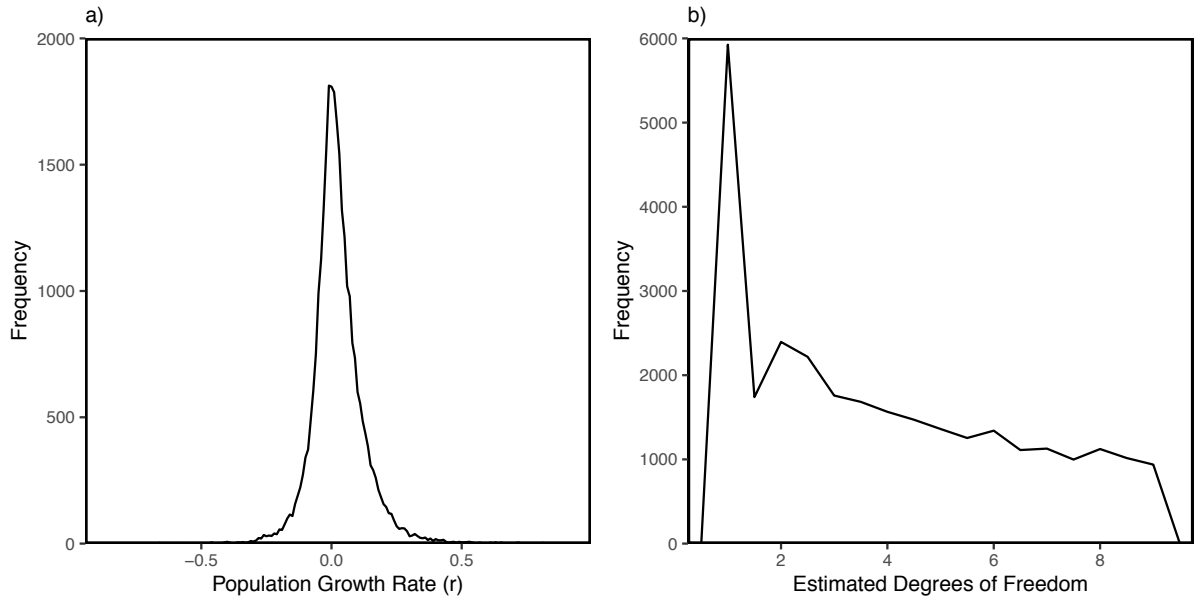
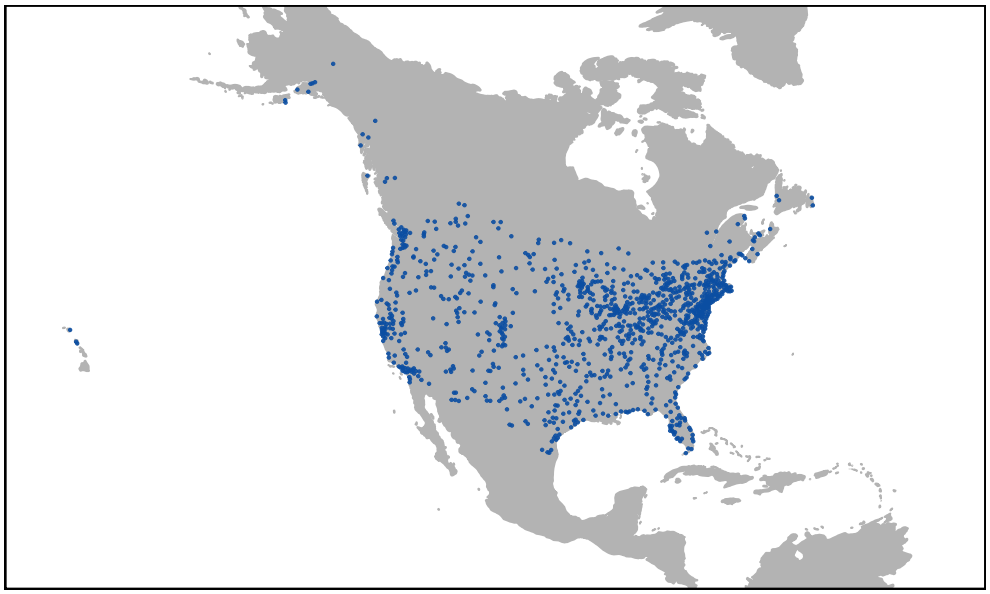
1. Dataset summary statistics

53% of the complete datasets (i.e. the full 30 years for each of the 29,226 populations) showed significant trends at $p<0.05$. Population growth rate (r) showed a roughly normal distribution centered on a mean of 0.026 (Supporting Figure 1a), max growth rate was 27.8 and min growth rate was -26.8, but 99.9% of populations had growth rates between -1 and 1. Curve shape was varied, with a skew towards lower Estimated Degrees of Freedom (i.e. less complex curve shapes; Supporting Figure 1); 17% of trends were linear, i.e. EDF=1. Also shown in this section is a map of all sites (Supporting Figure 2) and a table of all species (Supporting Table 1)



Supporting Figure 1. Summary statistics of population trends derived from 29,226 waterbird populations. Shows a) frequency distribution of population growth rate (r), from the 99.9% of trends that had a growth rate of greater than -1 and less than 1 and b) frequency distribution of estimated degrees of freedom.



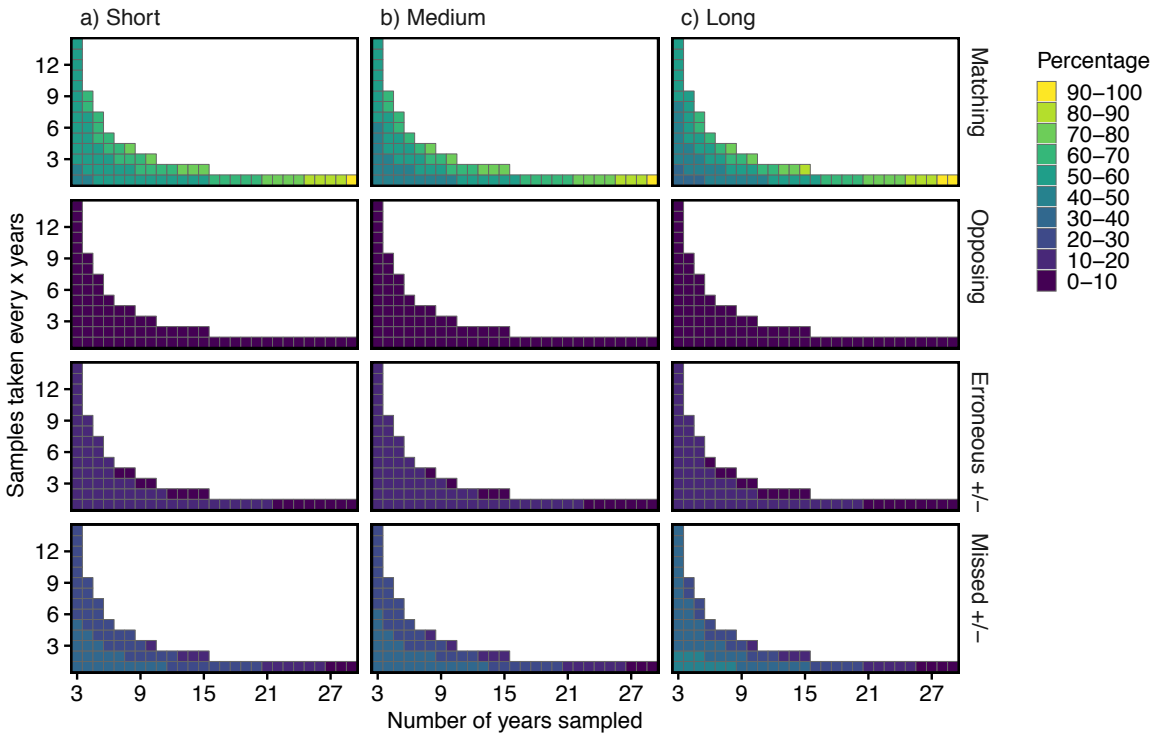
Supporting Figure 2. Map of where 1,110 sites are located across North America.

Supporting Table 1. List of species used in analysis

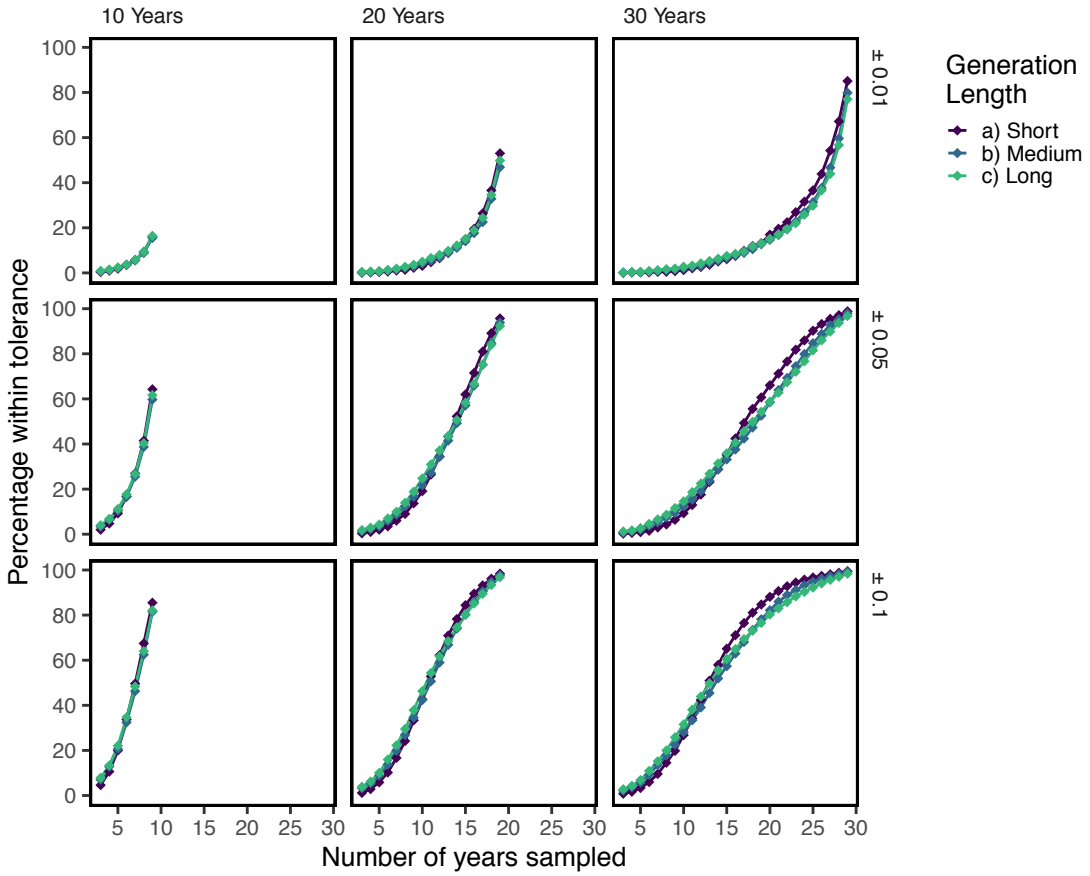
Order	**Family**	**Species**	
Anseriformes	Anatidae	Aix sponsa	Cairina moschata
		Anas acuta	Cygnus buccinator
		Anas crecca	Cygnus columbianus
		Anas fulvigula	Cygnus olor
		Anas platyrhynchos	Dendrocygna autumnalis
		Anas rubripes	Lophodytes cucullatus
		Anser albifrons	Mareca americana
		Anser caerulescens	Mareca penelope
		Aythya affinis	Mareca strepera
		Aythya americana	Melanitta americana
		Aythya collaris	Melanitta fusca
		Aythya marila	Mergus merganser
		Aythya valisineria	Mergus serrator
		Branta bernicla	Oxyura jamaicensis
		Branta hutchinsii	Spatula clypeata
		Bucephala albeola	Spatula cyanoptera
		Bucephala clangula	Spatula discors
		Bucephala islandica	
Charadriiformes	Alcidae	Cepphus columba	Cerorhinca monocerata
	Charadriidae	Charadrius alexandrinus	Charadrius vociferus
		Charadrius melodus	Pluvialis squatarola
		Charadrius semipalmatus	
	Laridae	Gelochelidon nilotica	Larus livens
		Hydrocoloeus minutus	Larus marinus
		Hydroprogne caspia	Larus occidentalis
		Larus argentatus	Larus philadelphia
		Larus atricilla	Larus thayeri
		Larus californicus	Rynchops niger
		Larus canus	Sterna forsteri
		Larus delawarensis	Sterna hirundo
		Larus fuscus	Thalasseus maximus
		Larus glaucescens	Thalasseus sandvicensis
		Larus heermanni	
	Recurvirostridae	Himantopus himantopus	Recurvirostra americana
	Scolopacidae	Actitis macularius	Limnodromus griseus
		Arenaria melanocephala	Limnodromus scolopaceus
		Calidris alba	Limosa fedoa
		Calidris alpina	Numenius americanus
		Calidris canutus	Numenius phaeopus
		Calidris himantopus	Scolopax minor
		Calidris mauri	Tringa flavipes
		Calidris minutilla	Tringa melanoleuca
		Calidris pusilla	Tringa semipalmata
		Gallinago gallinago	Tringa solitaria
	Stercorariidae	Stercorarius parasiticus	Stercorarius pomarinus
Ciconiiformes	Ciconiidae	Mycteria americana	
Gaviformes	Gaviidae	Gavia immer	Gavia stellata
Gruiformes	Aramidae	Aramus guarauna	

	Rallidae	Coturnicops noveboracensis	Rallus elegans
		Fulica americana	Rallus limicola
		Gallinula chloropus	Rallus longirostris
		Laterallus jamaicensis	Zapornia akool
		Porzana carolina	
Pelicaniformes	Ardeidae	Ardea alba	Egretta thula
		Ardea herodias	Egretta tricolor
		Botaurus lentiginosus	Ixobrychus exilis
		Bubulcus ibis	Nyctanassa violacea
		Egretta caerulea	Nycticorax nycticorax
	Pelecanidae	Pelecanus erythrorhynchos	Pelecanus occidentalis
	Threskiornithidae	Platalea ajaja	Plegadis falcinellus
		Plegadis chihi	
Podicipediformes	Podicipedidae	Aechmophorus clarkii	Podiceps nigricollis
		Aechmophorus occidentalis	Podilymbus podiceps
		Podiceps auritus	Tachybaptus dominicus
		Podiceps grisegena	
Suliformes	Anhingidae	Anhinga anhinga	
	Phalacrocoracidae	Phalacrocorax auritus	Phalacrocorax pelagicus
		Phalacrocorax brasilianus	Phalacrocorax penicillatus
	Sulidae	Morus bassanus	

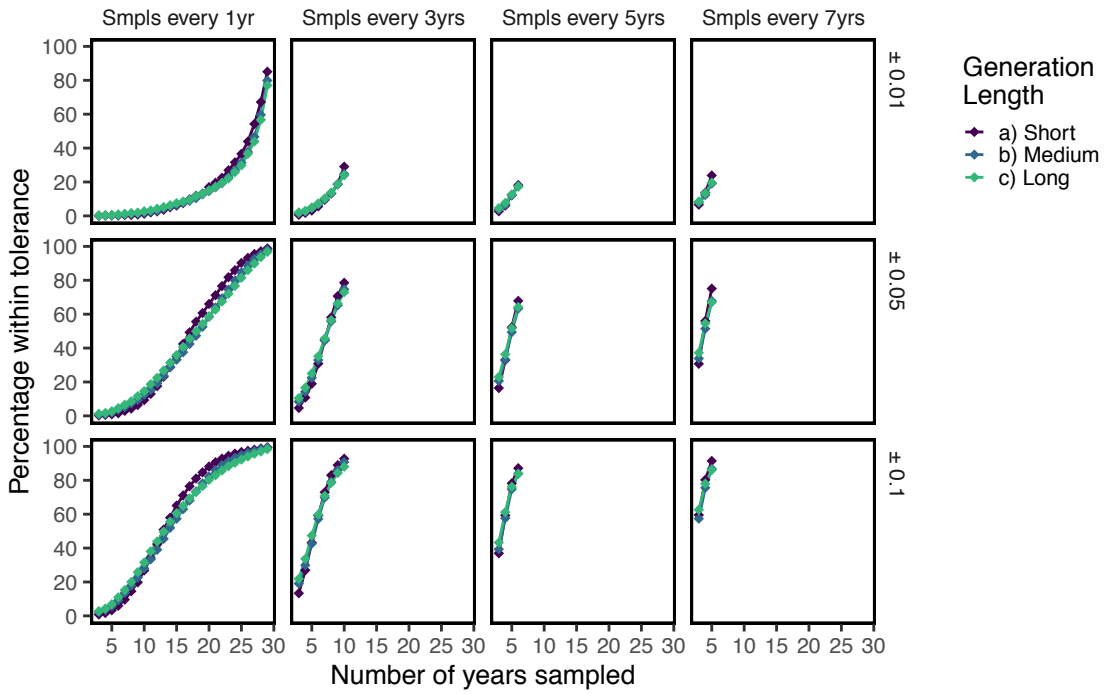
2. Generation length



Supporting Figure 3. Direction comparison of sample trends using interval sampling. Heat shows percentage of sample trends that, relative to the complete trend, were correct, opposing, a false positive/negative or a missed positive/negative (see Table 1). Shown for all combinations of interval sampling, with number of years sampled (x-axis) and interval length (y-axis). Thus 8 on the x-axis and 4 on the y-axis would mean 8 samples were taken, one every 4 years. The bottom row of each plot is equal to the right most column of the equivalent Figure 7 plot, but is included here to ease comparison. Complete trend length is always 30 years. Divided by populations with either a) short (1-5 years), b) medium (6-10 years) or c) long (11-15 years) generation lengths.

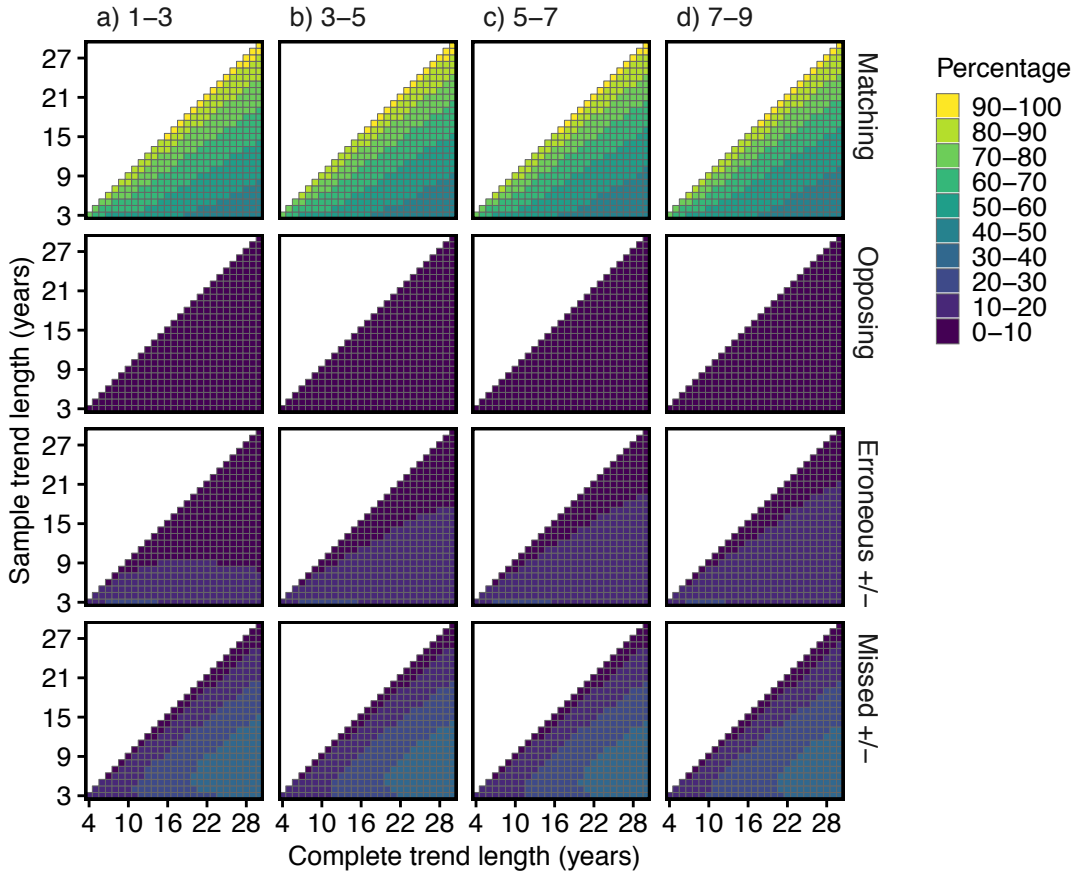


Supporting Figure 4. Percentage of sampled trends that correctly match the complete trend (x axis), measured by whether the sample *r* matches the complete *r* within the threshold (rows); samples taken using Consecutive sampling. Shown for three complete trend lengths, 10, 20, and 30 years (columns), and for all sample lengths (y-axis). Divided by populations with either a) short (1-5 years), b) medium (6-10 years) or c) long (11-15 years) generation lengths (colours).

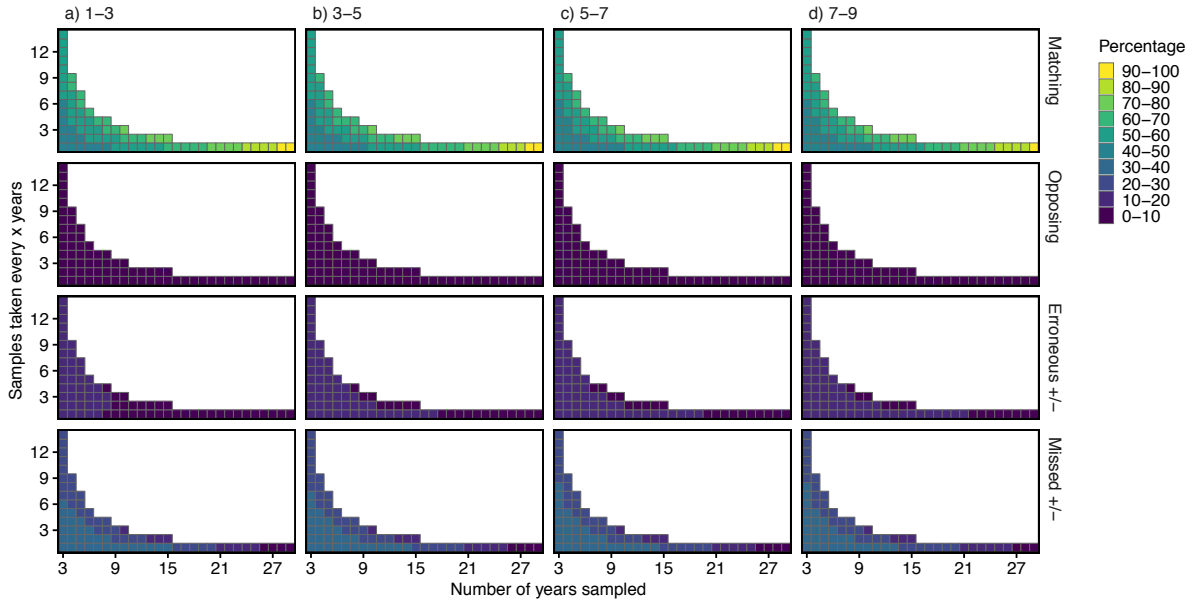


Supporting Figure 5. Percentage of samples (y-axis) that correctly match the complete trend, measured by whether the sample *r* matches the complete *r* within the threshold (rows); samples taken using Interval sampling. Shown for four stages of interval sampling: samples taken either every 1, 3, 5 or 7 years (columns), for all possible number of years sampled (x-axis). Complete trend length is always 30 years. Divided by populations with either a) short (1-5 years), b) medium (6-10 years) or c) long (11-15 years) generation lengths (colours).

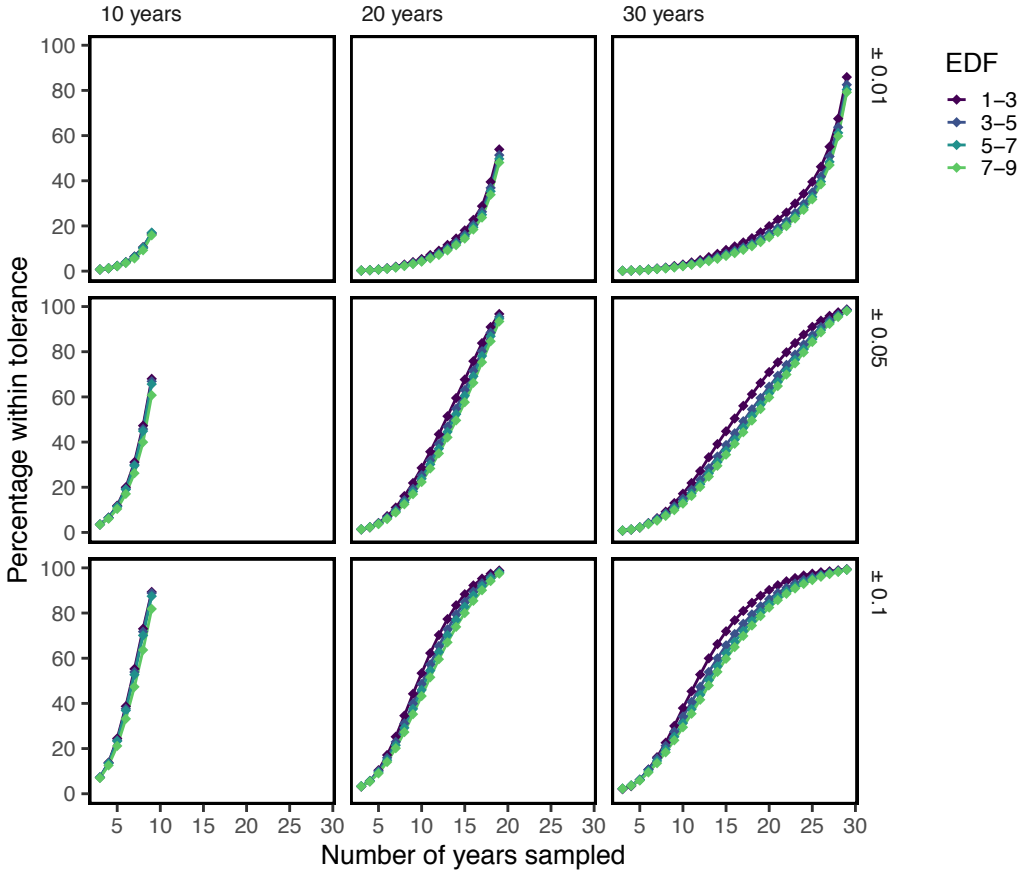
3. Trend shape



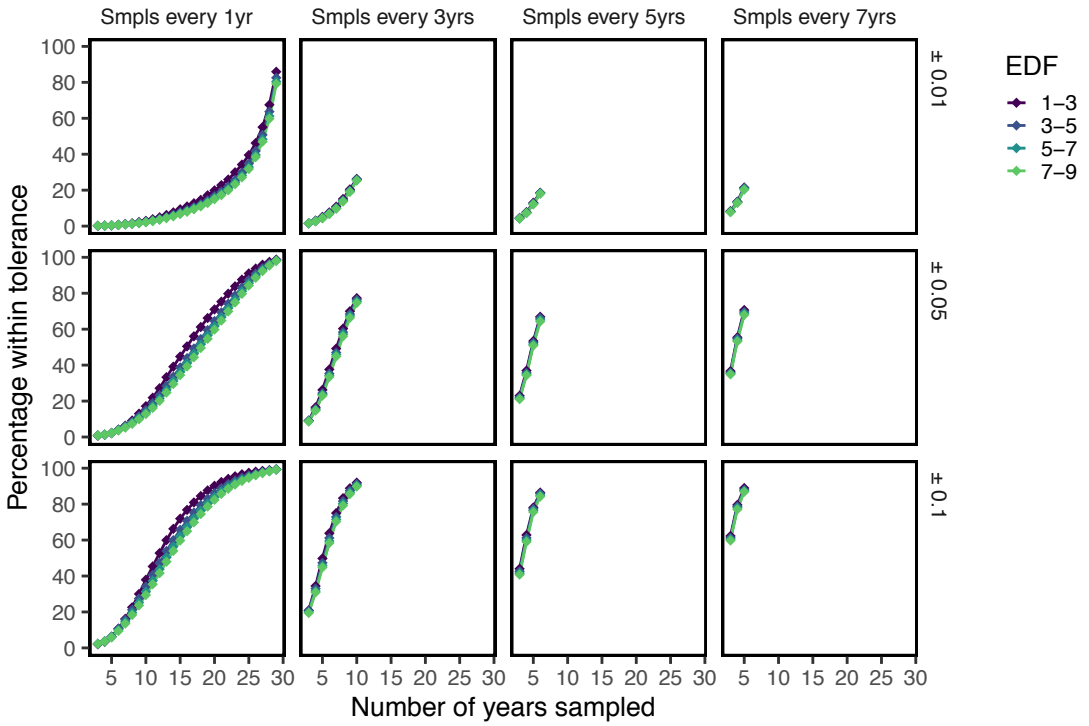
Supporting Figure 6. Direction comparison of sample population trends using consecutive sampling. Heat shows percentage of sample trends that, relative to the complete trend, were correct, opposing, a false positive/negative or a missed positive/negative (see Table 1). Shown for all combinations of sample lengths (y-axis), and complete lengths (x-axis). Divided by complete trends with estimated degrees of freedom (EDF) of 1-3, 3-5, 5-7 and 7-9.



Supporting Figure 7. Direction comparison of sample trends using interval sampling. Heat shows percentage of sample trends that, relative to the complete trend, were correct, opposing, a false positive/negative or a missed positive/negative (see Table 1). Shown for all combinations of interval sampling, with number of years sampled (x-axis) and interval length (y-axis). Thus 8 on the x-axis and 4 on the y-axis would mean 8 samples were taken, one every 4 years. The bottom row of each plot is equal to the right most column of the equivalent Supporting Figure 5 plot, but is included here to ease comparison. Complete trend length is always 30 years. Divided by complete trends with estimated degrees of freedom (EDF) of 1-3, 3-5, 5-7 and 7-9.



Supporting Figure 8. Percentage of sampled trends that correctly match the complete trend (x axis), measured by whether the sample *r* matches the complete *r* within the threshold (rows); samples taken using Consecutive sampling. Shown for three complete trend lengths, 10, 20, and 30 years (columns), and for all sample lengths (y-axis). Divided by complete trends with estimated degrees of freedom (EDF) of 1-3, 3-5, 5-7 and 7-9 (colours).



Supporting Figure 9. Percentage of samples (y-axis) that correctly match the complete trend, measured by whether the sample *r* matches the complete *r* within the threshold (rows); samples taken using Interval sampling. Shown for four stages of interval sampling: samples taken either every 1, 3, 5 or 7 years (columns), for all possible number of years sampled (x-axis). Complete trend length is always 30 years. Divided by complete trends with estimated degrees of freedom (EDF) of 1-3, 3-5, 5-7 and 7-9 (colours).

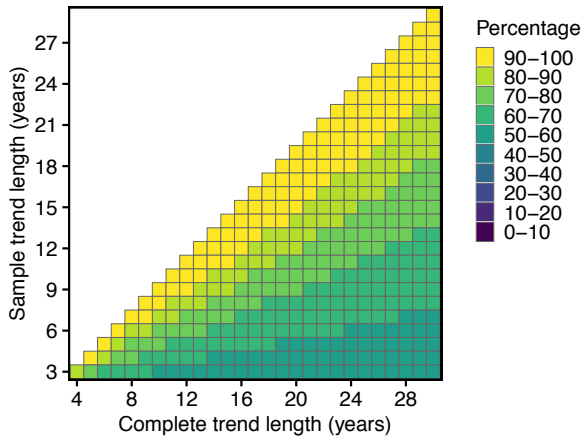
4. Supplementary investigation: Rate of matching slopes for insignificant sample trends compared to significant complete trends.

A final investigation we felt would be important to conduct was the frequency with which the slope of *insignificant* sample trends matched the complete slope of *significant* trends. In the paper, we recorded these cases as missed positives/negatives, and did not consider the slope of the insignificant samples. However, in some applications it may be useful to know how likely it is that the direction of the insignificant slope matches the direction of the complete trend.

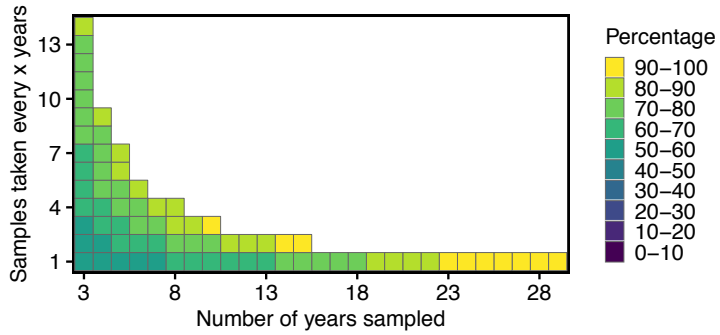
For this reason we conducted a final investigation, looking only at cases where the complete time-series trend was significant, and the sample trend was insignificant (i.e. the missed positives/negatives of the Direction Comparison method). We calculated how often the direction of the slope of the insignificant sample trend matched the direction of the slope of the complete trend. For Consecutive Sampling, we found that rates of agreement were high, with sample trends being 90-100% likely to match the complete trends when the sample data was approximately 3/4s of the length of the complete data (Supporting Figure 10). When the sample data was a small proportion of the complete data, chances of it matching were at lowest 50-60%. Similar rates of agreement occurred when sampling in intervals, not consecutive years (Supporting Figure 11).

We also investigated how the magnitude of slope compared between insignificant sample trends and significant complete trends. Results were similar to comparing significant sample and complete trends (as in the main paper), except that in this case larger samples were needed for trend magnitudes to be within tolerance thresholds (Supporting Figures 12 & 13).

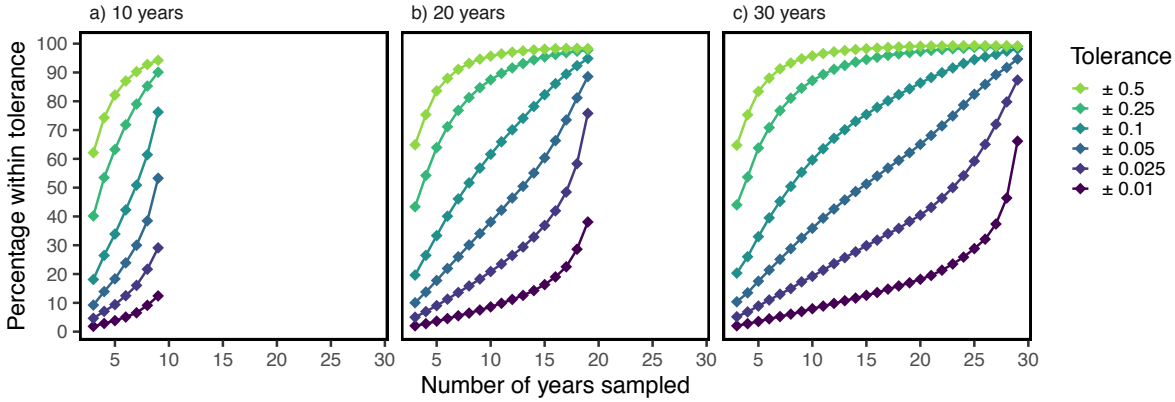
Code and data for these analysis are provided in the supporting code and results zip file, see below.



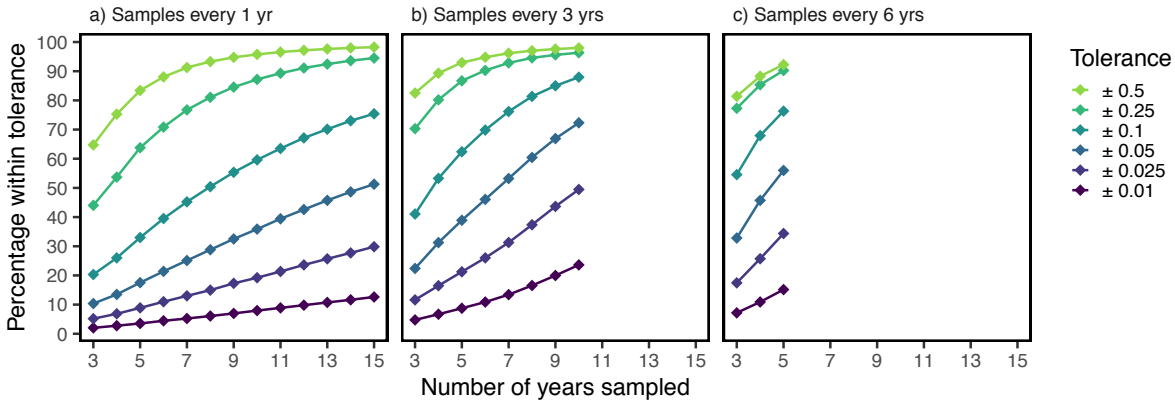
Supporting Figure 10. Direction comparison of insignificant sample population trends to significant complete population trends using Consecutive Sampling. Colour shows percentage of sample trends that, relative to the complete trend, were matching. Shown for all combinations of sample lengths (y-axis), and complete lengths (x-axis).



Supporting Figure 11. Direction comparison of insignificant sample trends to significant complete trends using Interval Sampling. Colour shows percentage of sample trends that, relative to the complete trend, were matching. Shown for all combinations of Interval Sampling, with number of years sampled (x-axis) and interval length (y-axis). Thus 8 on the x-axis and 4 on the y-axis would mean 8 samples were taken, one every 4 years. Complete trend length is always 30 years.



Supporting Figure 12. Percentage of insignificant sampled trends that correctly estimate the significant complete trend, measured by whether the sample *r* matches the complete *r* within the tolerance (colours). Samples taken using Consecutive Sampling. Shown for three complete trend lengths, 10, 20, and 30 years, and for all sample lengths (x-axis).



Supporting Figure 13. Percentage of insignificant samples (y-axis) that correctly estimate the significant complete trend, measured by whether the sample *r* matches the complete *r* within the tolerance (colours); samples taken using Interval sampling. Shown for three stages of Interval Sampling: samples taken either every 1, 3 or 6 years (facets), for all possible number of years sampled (x-axis). Complete trend length is always 30 years.

5. Description of Supporting code and results zip file

The Supporting code is fully annotated code detailing all analysis, with instructions on transferring to other data. The results file contains the full data, detailing propotions of confidence for samples of various lengths (and intervals) when compared to complete trends also of varying lengths. The columns in each file are as follows:

- DirectionDataConsecutive.csv:
  - SampleLength: The length of the sample
  - Prop: The proportion of samples that were the category (e.g. if Category is Correct and Prop is 0.71, then 71% of samples were correct for that sample and complete length)
  - Category: See main paper Table 1 for direction categories, either Correct, Erroneous Positive, Erroneous Negative, Missed Positive, Missed Negative or Opposing.
  - CompleteLength: The length of the complete time-series that the sample was compared to
  - EDF: The estimated degrees of freedom of complete trends in that group of data (if NA, full dataset used, otherwise if 3: EDF was 1-3, 5 = 3-5, 7 = 5-7 and 9 = 7-9)
  - GenLength: The generation length of species in that group of data (if NA, full dataset used, otherwise if 5: generation length was 1-5, 10 = 6-10 and 15 = 11-15)
- DirectionDataInterval.csv
  - IntervalLength: Samples taken every x years (e.g. if 1, samples taken every year, if 2 every two years etc)
  - Category: See main paper Table 1 for direction categories, either Correct, Erroneous Positive, Erroneous Negative, Missed Positive, Missed Negative or Opposing.
  - NumYearsInSample: The actual number of samples (e.g. if IntervalLength is 3 and NumYearsInSample is 4, then 4 samples were taken, one every 3 years)
  - Prop: The proportion of samples that were the category (e.g. if Category is Correct and Prop is 0.71, the 71% of samples were correct for that sample and complete length)
  - CompleteLength: The length of the complete trend that the sample was compared to (nb. always 30 for interval data)
  - EDF: The estimated degrees of freedom of complete trends in that group of data (if NA, full dataset used, otherwise if 3: EDF was 1-3, 5 = 3-5, 7 = 5-7 and 9 = 7-9)
  - GenLength: The generation length of species in that group of data (if NA, full dataset used, otherwise if 5: generation length was 1-5, 10 = 6-10 and 15 = 11-15)
- MagnitudeDataConsecutive.csv:
  - SampleLength: The length of the sample
  - PropWithinTolerance: The proportion of samples for which absolute difference between the sample growth rate (r) and compelte growth rate was not more than the tolerance.
  - Tolerance: Amount by which sample and complete growth rate can differ
  - CompleteLength: The length of the complete time-series that the sample was compared to (nb. always 30 for interval data).

    - EDF: The estimated degrees of freedom of complete trends in that group of data (if NA, full dataset used, otherwise if 3: EDF was 1-3, 5 = 3-5, 7 = 5-7 and 9 = 7-9)
    - GenLength: The generation length of species in that group of data (if NA, full dataset used, otherwise if 5: generation length was 1-5, 10 = 6-10 and 15 = 11-15)
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    - IntervalLength: Samples taken every x years (e.g. if 1, samples taken every year, if 2 every two years etc)
    - NumYearsInSample: The actual number of samples (e.g. if IntervalLength is 3 and NumYearsInSample is 4, then 4 samples were taken, one every 3 years)
    - PropWithinTolerance: The proportion of samples for which absolute difference between the sample growth rate (r) and compelte growth rate was not more than the tolerance.
    - Tolerance: Amount by which sample and complete growth rate can differ
    - CompleteLength: The length of the complete trend that the sample was compared to
    - EDF: The estimated degrees of freedom of complete trends in that group of data (if NA, full dataset used, otherwise if 3: EDF was 1-3, 5 = 3-5, 7 = 5-7 and 9 = 7-9)
    - GenLength: The generation length of species in that group of data (if NA, full dataset used, otherwise if 5: generation length was 1-5, 10 = 6-10 and 15 = 11-15)
    -

The same column names apply to the files ending in “SupportingDataSection4.csv”, just without the category section (see Section 4 above for an explanation of how this data was created).