LIVING PLANET REPORT CANADA 2020

Technical Supplement
2020

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CANADIAN LIVING PLANET INDEX

What is the Living Planet Index?

The Living Planet Index (LPI) is a biodiversity indicator used to measure the state of wildlife. Similar to the way a stock market index measures economic performance, the Living Planet Index measures ecological performance by tracking patterns in wildlife abundance over time (Collen *et al.* 2009). The LPI is calculated by aggregating temporal trends in wildlife abundance from multiple datasets across geographic areas of interest. In Canada, the LPI method has been applied to calculate an overall index at a national scale, focusing specifically on native vertebrate species.

Globally, the indicator was first published in 1998, and has been updated biennially to track average population abundance of monitored vertebrate species over time (WWF 2018). By contrast, the Canadian Living Planet Index (C-LPI) was first released by World Wildlife Fund (WWF) Canada in 2007 (WWF-Canada *et al.* 2007) with a singular, yet substantial update published in 2017 (WWF-Canada 2017). In 2017, WWF-Canada adopted a modified version of the global Living Planet Index in conjunction with the Zoological Society of London and Environment and Climate Change Canada (ECCC) (ECCC 2019a).

In the 2020 report, we have strengthened our analysis by requiring higher standards for data quality and by collecting additional data, including more recent data records. Due to these methodological and database changes, the C-LPI should be viewed as the best possible snapshot of trends in Canadian wildlife populations at a given time and should not be directly compared to previous iterations of the index.

Canadian Living Planet Index database

Where do the data come from?

Assessment and documentation of temporal population abundance is conducted across Canada for a variety of reasons. In some instances, monitoring is conducted before and after natural disturbances, anthropogenic pressures or conservation interventions to assess associated impacts on wildlife abundance. Other times, monitoring is carried out to determine sustainable harvest quotas. Irrespective of the circumstance, population monitoring over time can be used to determine whether populations are generally increasing, decreasing, or exhibiting stable trends of abundance. Notably, new technologies are helping to monitor population abundance in real time, and in remote locations, enhancing our knowledge base on the status of wildlife in Canada.

Numeric population data contributing to the C-LPI were compiled from a variety of sources, including peer-reviewed scientific literature, government monitoring (e.g., Parks Canada, Fisheries and Oceans Canada and provincial entities), and citizen science (e.g., data contributing to NABCI-Canada's State of Canada's Birds). While some of this data was previously compiled for the 2017 Living Planet Report Canada, WWF-Canada and the Zoological Society of London worked to obtain additional data on population trends for wildlife in Canada for the Living Planet Report Canada 2020. Approximately 800 new records were obtained and approximately 1580 records were updated with 2015 and/or 2016 data. Some population time series extended beyond 2016, but there was insufficient temporal coverage among taxonomic groups, and thus the C-LPI spans from 1970 to 2016. In total, over 300 sources of data, contributing to 3,781 monitored populations of 883 species are included within the C-LPI.

Taxonomic classifications were aligned with the International Union for the Conservation of Nature (IUCN), which provided synergy for populating contextual information such as Red List status and threats, and for greater ease of inclusion into the global LPI dataset. Importantly, species were categorized into four groups: fish, birds, mammals and herpetofauna. Herpetofauna — which include amphibians and reptiles — were combined to enhance sample size and draw more concrete conclusions.

The population time series data has broad spatial coverage (Figure 1). Birds are the best represented, with national bird trends for 351 species (which represent 44% of the species and 12% of the population time series in the dataset). There are, however, an impressive number of population time series for marine fish (40% of the species and 63% of the population time series in the dataset) owing to annual monitoring conducted by Fisheries and Oceans Canada.

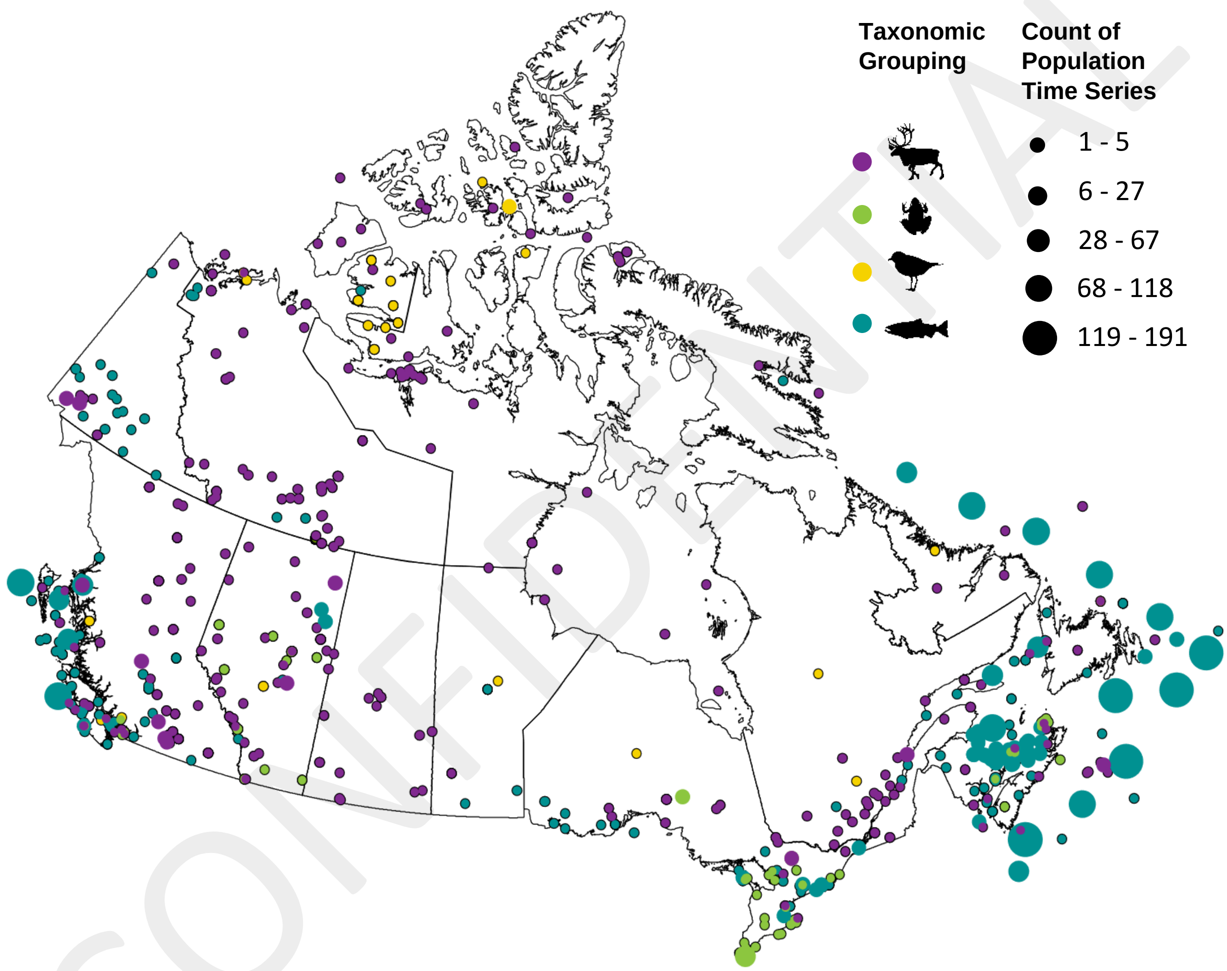


Figure 1. Distribution of the 3,415 population trends from the Canadian Living Planet Index. Point locations — which include some provincial-level data points — provide a rough indication of the distribution of the data. A point location may correspond to several monitored populations and/or species. Note that 366 population trends corresponding to nation-wide bird trends are not shown on this map as they lack spatial specificity.

There is considerably more data contributing to the C-LPI since WWF-Canada's first publication in 2007 (Figure 2). Impressively, since 2007, the number of time series has tripled, and the number of species has more than doubled. Most of these data gains were realized in 2017. While substantial data collection was endeavored for the Living Planet Report Canada 2020, changes in methodology related to the criteria for inclusion within the C-LPI analysis resulted in only incremental shifts in the number of species and time series included.

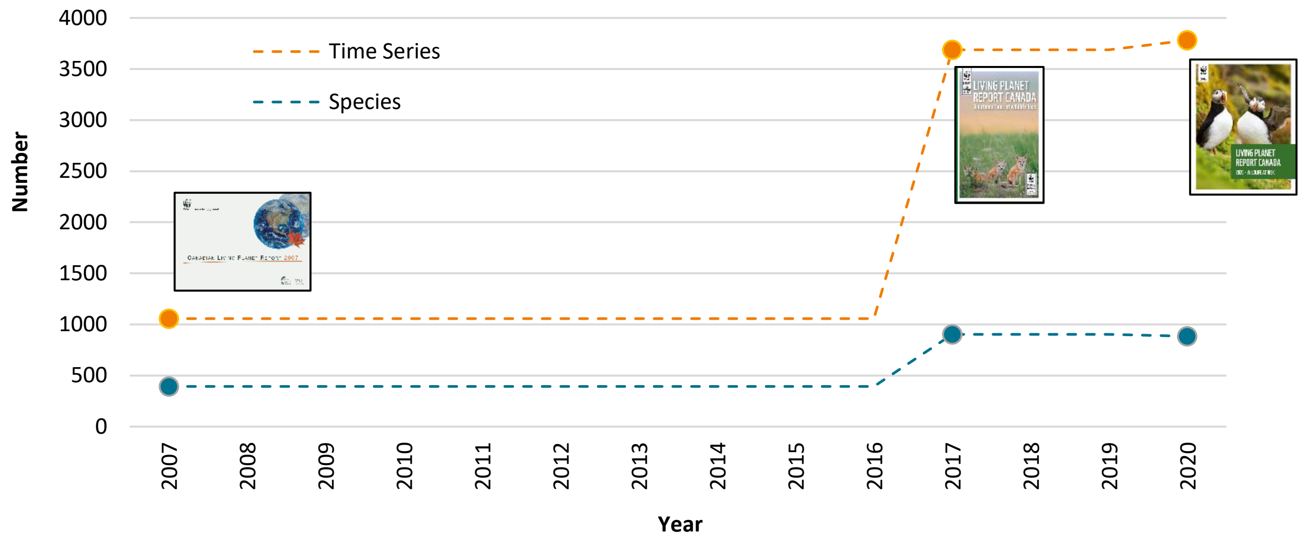


Figure 2. Number of population time series and species contributing to the national Canadian Living Planet Index within the Living Planet Reports published in 2007, 2017 and 2020.

What are the criteria for data inclusion in the C-LPI?

Criteria for the inclusion of species population data in the C-LPI were grounded in the methods of previous iterations of the global LPI, as developed by the ZSL (Collen *et al.* 2009), with slight modifications for the Canadian context.

- Populations must be consistently monitored in the same location, using the same method over time;
- Data must be numerical (i.e., a population count or a reliable population-size proxy, such as population estimates, spawning stock biomass, density, etc.);
- Data sources must be referenced and traceable;
- Specific to Canada, species should be native to Canada and have applicable conservation status rank according to the Wild Species Report (CESCC 2016) (i.e., exotic species, hybrids and accidental species under the NatureServe rank of “not applicable” were excluded); and
- Specific to Living Planet Report Canada 2020, population data must be available for at least three years in the period between 1970 and 2016. (Previously only two years of data were required.)

Change in the criteria for inclusion

In the Living Planet Report Canada 2020, WWF-Canada altered the criteria for inclusion in the C-LPI regarding time series fullness — the number of years (raw data points) of population data required within a singular time series. Recent analysis (Marconi *et al.* 2020 *in review*) suggests that lower quality population time series (measured via time series fullness, length and spatial coverage) in Canada diverge from trends in higher quality data and tend to exhibit negative population trajectories. In response, data inclusion criteria for the 2020 C-LPI were altered. Population data must have been available for at least three years in the period between 1970 and 2016 (previously, two years of data were required).

Importantly, changes in population abundance between two points in time are less representative than longer time series and may not necessarily reflect a trend. Rather, a difference in population abundance between two data points could be a result of sampling conditions each year, normal fluctuations in the population (that would otherwise be evened out with greater temporal coverage), etc. Other studies that use global LPI data to showcase associations between population trends and explanatory variables often require a minimum time series length or fullness (e.g., Barnes *et al.* 2016 set a minimum time series length of five years and fullness of three years).

The deviation in time series fullness (number of years with population data) from the original methodology was developed through consultation with academics in North America with expertise in long-term monitoring and was implemented as an incremental modification towards enhancing data quality. Any further deviations in time series fullness would have resulted in a significant loss of data for the C-LPI, which would have substantially limited the representativeness of the index.

Through the methodological change, 3,714 populations and 47 species (herpetofauna, mammals and less common fish species) were excluded. While some of these species are known to be in decline (e.g., the Endangered Oregon spotted frog) (COSEWIC 2011), others have "unknown" population trends (e.g., Dall's porpoise, narwhal) according to global IUCN assessments (Jefferson & Braulik 2018; Lowry *et al.* 2017) and have not been assessed by COSEWIC for >15 years. Moreover, monitored populations within the C-LPI do not necessarily reflect the known trend of the species in Canada regardless of time series fullness, as local environments, Designatable Units and sub-species may differ. Consequently, a systematic approach of eliminating all species with less than three years of data was employed to circumvent hand-selecting monitored populations with trends that match known species trends in the literature.

Given that lower quality data tends to exhibit negative population trajectories in Canada (Marconi *et al.* 2020 *in review*), the change in the criteria for inclusion resulted in an increase (a difference of 6%) in the final index value reported. Enhanced validation of the 2017 data by the Zoological Society of London also resulted in minor changes to the data included and incrementally shifted the final index value reported (a 2% difference).

Treatment of replicates and zeros

In cases where there was spatial and temporal overlap of population time series for a given species, only one of the overlapping populations was retained (to reduce geographic sampling bias). Priority for inclusion was given to higher quality data, which encompasses time series length, fullness, and credibility of the data source. For the *C-LPI for broad-scale conservation action in Canada*, some replicates were reinstated. For instance, because bird data from ECCC was national in scale, species from other sources with only local trends were considered replicates. However, for the purpose of the *C-LPI for broad-scale conservation action in Canada* (which showcases population trends of species targeted by broad-scale conservation actions such as protected area establishment), birds with trends in protected areas were included, replacing the national trends for these species. The spatial resolution of data was a key determinant in shaping the *C-LPI for broad-scale conservation action in Canada*, as location was essential for tagging monitored populations with abundance counts in protected areas, and/or captive breeding and reintroduction efforts.

In calculating the C-LPI, population counts of zero — where a species was not observed in a given year — were treated as missing values, as they are more likely missing observations than representing population crashes (Marconi *et al.* 2020 *in review*). Mathematically, a number cannot be divided by zero. In order to include population counts of zero in the analysis, it is possible to add a small quantity to zeros for mathematical purposes. For instance, Collen *et al.* (2009) added one per cent of the mean population measure value for the time series for years in which there was a population count of zero. However, an analysis of the geometric mean of relative abundance indices argues that the index is sensitive to the quantity chosen to replace a zero (Buckland *et al.* 2011) — which was also reflected in a sensitivity analysis on the C-LPI data. In addition, the LPI analysis exhibits high variance and instability when rarely recorded species are included. Rarely recorded species are populations that have multiple zeros throughout the length of their time series yet are not truly extirpated or extinct. Critically, none of the population time series included in the C-LPI had a zero (or trailing zeros) recorded as the final numeric data point for the trend. For this reason, population counts of zero were treated as missing values for the purpose of calculating the C-LPI, following a sensitivity analysis on the Canadian dataset. The decision to eliminate population counts of zero was made in conjunction with the Zoological Society of London and Environment and Climate Change Canada (ECCC 2019a). Consequently, the index figures included in the Living Planet Report Canada 2020 can therefore be interpreted as conservative estimates of change, as population losses could be greater than the index suggests.

A closer look at the underlying data

In collecting temporal trends in population abundance for use in the LPI, all data that fits the criteria for inclusion is incorporated. However, a number of temporal, spatial, taxonomic and species biases underlie the data and can limit and influence population trends.

The underlying data included in the analysis of the C-LPI can impact the results that are obtained. For instance, population trends for approximately half of the native, regularly occurring species in Canada have been included within the C-LPI. Conversely, the C-LPI is missing population trends in abundance for half of Canadian wildlife. If the data were available, inclusion of these species may alter the final trajectory and magnitude of the C-LPI. However, a lack of publicly available population trend data hinders our ability to investigate the other half of the biodiversity picture in Canada. In addition, the collection of data is biased toward certain species, including those that are charismatic or of socioeconomic importance (Troudet *et al.* 2017), and non-random site selection that may exaggerate or dampen population trends (Fournier *et al.* 2019). Furthermore, the data for these species may not be evenly distributed on a spatial or temporal scale, and consequently some regions and time periods may be contributing more prominently, thereby influencing overall average trends in abundance. The variation and inherent biases in the underlying data can subsequently impact calculation of the geometric mean of relative abundance indices.

The quality of the data affecting the national C-LPI is primarily driven by time series fullness (the number of years for which there is a population count) and length (the difference between the first and last year of data collection). For the national C-LPI, the average time series fullness and length was 15.73 (±13.36) and 17.59 (±12.85) years, respectively. Data quality was predominantly enhanced by fish and birds, which were the most robust taxonomic groups in terms of time series fullness and length, given the comprehensive datasets provided by Fisheries and Oceans Canada and the North American Bird Conservation Initiative in Canada. Importantly, while the criteria for inclusion of data in the C-LPI enhanced time series fullness, the requirement of three years of data further constrains the monitoring data that can be included in the analysis.

Data availability also improves over time. For instance, there is more data contributing to the national C-LPI in the latter half of the time period examined (Figure 3). When examining either population time series or species, 1970 holds the lowest number of records and 2010 holds the highest. Consequently, the baseline year can affect the final calculation of the geometric mean. Importantly, the C-LPI is a relative measure, comparing trends to the baseline year of 1970. Therefore, any shift in the baseline year may result in differing overall average trends. Within the C-LPI dataset, the number of population time series triples from 1970 to 2010 and falls off thereafter. On average, 4.28 population time series contributed to a species, with variation among taxonomic groups (Figure 4). For instance, national-level time series were available for most birds through aggregated trends provided through NABCI-Canada, yet fish trends were available for each management unit and/or stock in Canada.

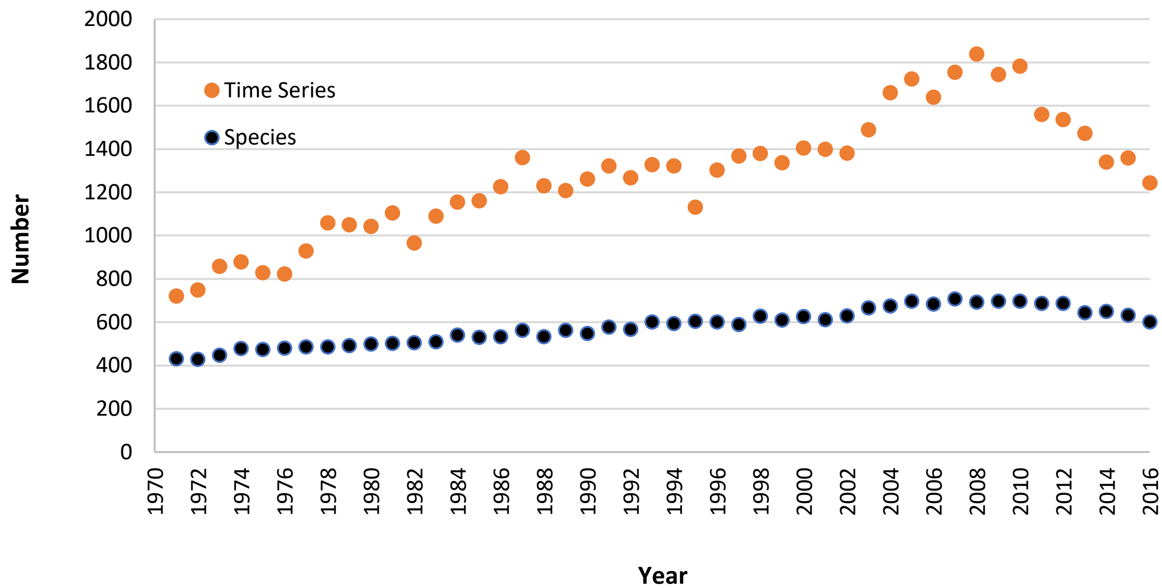


Figure 3. Number of population time series and species contributing to the Canadian Living Planet Index by year. On average, there were 1,513 population times series and 609 species.

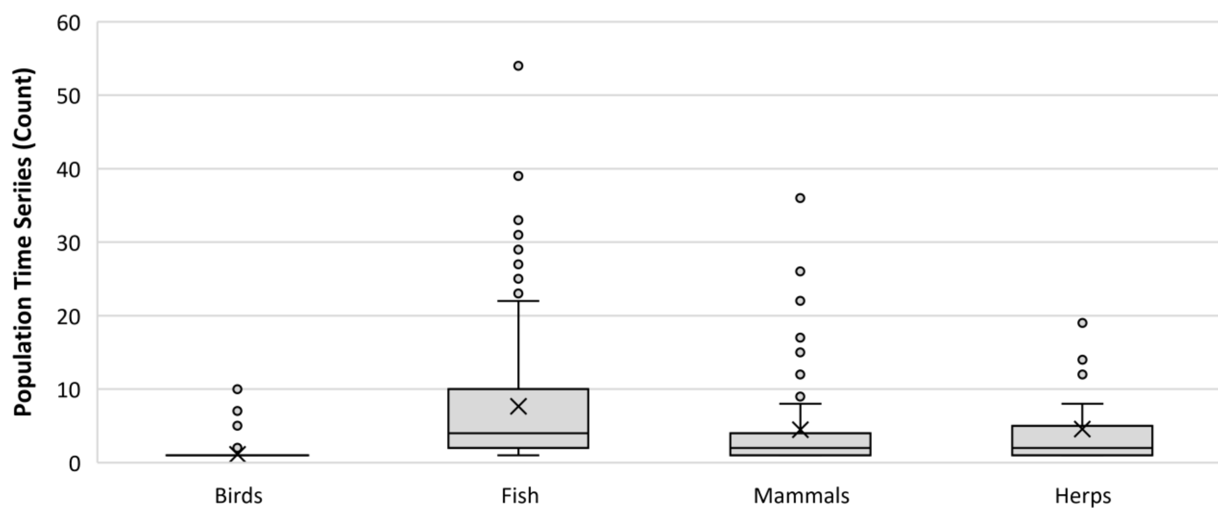


Figure 4. Boxplot representing the number of population time series contributing to a species in the Canadian Living Planet Index, by taxonomic group. Xs represent the average number of population time series contribution to a specific species.

Birds were the best represented taxonomic group included in the national C-LPI (representing 86% of bird species in Canada; Table 3), largely attributable to the North American Bird Conservation Initiative's State of Canada's Birds analysis, which included nation-wide trends for 351 birds. While the relative proportion of birds and fish included in the analysis was similar (Figure 5), fish were comparatively poorly represented (34%). Time series data for fish were plentiful on both the Atlantic and Pacific coasts, but the dataset was predominantly composed of species of commercial interest. Moreover, there was a considerable lack of spatially representative freshwater fish data across the country. Notably, the C-LPI aggregates existing data, and therefore any biases associated with biodiversity data collection are inherited into the index, such as biases towards species of commercial interest, species with aesthetic or iconic value, and species that are easier to monitor by virtue of geography or biology.

Mammals (51%) and herpetofauna (43%) are considered well-represented in terms of the number of native Canadian species included in the C-LPI, but these taxonomic groups were often less well represented spatially. While the compiled bird data and marine fish data covered broad geographic regions, data for mammals and herpetofauna tended to be limited to local study areas, covering only a fraction of the species' ranges. Therefore, trends for species with limited spatial representation are not necessarily reflective of the total population.

Table 3. Representation of native vertebrate species considered of conservation interest according to Canada's *Wild Species Report* (i.e., exotic species, hybrids and accidental species under the NatureServe rank of "not applicable" were excluded) included in the Canadian Living Planet Index.

Class	Number in C-LPI	Number in Canada	Percentage Included *(Number in C-LPI / Number in Canada)*100*
Birds	389	452	86%
Fish	357	1043	34%
Mammals	100	196	51%
Herps	37	87	43%
Total	**883**	**1778**	**50%**

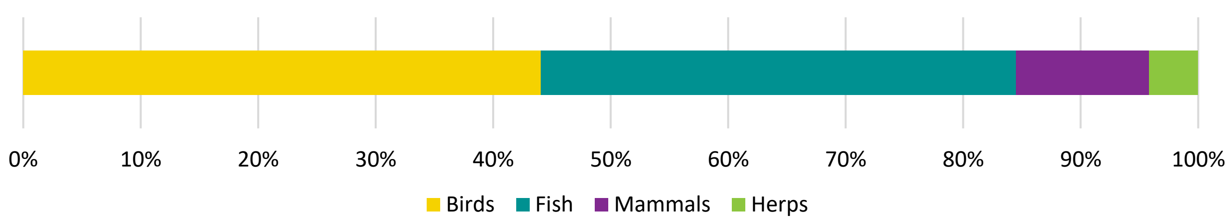


Figure 5. Relative proportion of taxonomic groups included in the Canadian Living Planet Index (883 species).

Calculating the Canadian Living Planet Index

How is the C-LPI calculated?

The Zoological Society of London's publicly available R-Statistical package on ***GitHub*** (Freeman *et al.* 2017) was used to run the C-LPI, which was created following the methods outlined in Collen *et al.* (2009) with selectable options for calculating the modified version used in Canada. For consistency with the international Living Planet Report, index values were calculated with a baseline year of 1970. Consequently, any changes in wildlife populations that occurred prior to 1970 are not reflected in the results reported in the Living Planet Report Canada 2020, which showcases only recent changes in population abundance. This is important to note, given that population abundance in 1970 may be low compared to historic abundance, and average trends likely underestimate the overall anthropogenic impact on biodiversity.

Changes in population abundance are calculated using a geometric mean of relative abundance from 1970 to 2016. Two methods are used to interpolate time series values. Time series (population trends) with at least six data points were modelled using a Generalized Additive Model (GAM) (N = 1581; 42%) and fitted GAM values were used to interpolate values for all years between the start and end year of the time series. Alternatively, we applied a linear regression model for shorter time series (N = 851; 22%) or those that resulted in a poor GAM fit (N = 1349; 36%) (Collen *et al.* 2009; Loh *et al.* 2005). Importantly, not all time series began in 1970 and ended in 2016. The C-LPI was calculated by averaging trends in monitored populations to create a trend in abundance for each unique species. These trends were then averaged across all species to generate the C-LPI. All indices are presented with 95% uncertainty intervals calculated from bootstrapping species (keeping the series of lambda values over time together for each species) and creating an index for each of the 10,000 bootstrapped resamples.[1] These uncertainty intervals include the range of indices that can be fit into the existing dataset, capturing the variability within the data. They do not incorporate the uncertainty associated with population counts of individual studies. The uncertainty intervals are multiplicative and increase in width over time as the uncertainty of previous years are inherited by the rest of the trend. The uncertainty intervals around the final index value represent uncertainty around that value in relation to the baseline. Similarly, the final index value reported is relative to the baseline value in 1970.

The C-LPI, calculated as a geometric mean of relative abundance indices, is a useful tool to track large-scale changes in population abundance. However, the use of averages can mask detailed nuances of the compiled data. For example, let's assume there are two monitored population trends (data records) for one species. One data record accounts for 90% of the population, and shows a drastic decline, whereas the other data record accounts for 10% of the population and exhibits a slight increase. The C-LPI weights these two data records equally to give an average trend in abundance for the species, thereby masking the fact that most of the population is in decline

Recent studies utilizing the LPI — including the global Living Planet Report — have employed proportional weighting to address taxonomic and geographic bias in biodiversity data by accounting for the estimated number of species within systems and relative diversity of taxonomic groups (McRae *et al.* 2017). The results of the proportionally weighted index did not differ significantly from an unweighted index (also a stable trend with overlapping uncertainty bounds) for Canada.

[1] This approach differs from Collen et al. (2009) where bootstrapping was conducted by randomly sampling species for each year, independently, which did not account for autocorrelations in lambdas over time for a given species.

Repeatability of analysis and transparency of process

Methodological approaches, decisions, population trend data and associated R-scripts for calculating a Living Planet Index are all publicly available online, contributing to an era of open-access data and transparent science.

The data underlying the C-LPI is accessible on WWF-Canada's Living Planet Report Canada website. Some authors recognize that the contribution of their data enhances the accuracy of the C-LPI but have requested that their data remain confidential — frequently due to sensitivities and concerns associated with sharing species locations and trends. In the C-LPI, nearly 20% of population time series are classified as confidential records and have therefore been withheld. Global LPI data is also accessible via the ***LPI Data Portal*****,** which houses 27,127 populations of 4,773 species across the globe (ZSL & WWF 2019). At the present time [2020], a portion (nearly 70%) of the database included in the C-LPI is publicly downloadable from the Living Planet Index Data Portal. There is a lag period between compilation for the C-LPI and validation by the Zoological Society of London for incorporation into the larger, global dataset.

Moreover, data on temporal trends in population abundance can be run through the *rlpi* package housed on ***GitHub.*** The *rlpi* package includes selectable options for calculating the LPI, such as using the chain method as opposed to linear regression models for shorter time series. Time frames can also be altered to adjust for a different baseline year, or end point of interest.

If using the data for publication purposes, we encourage you to reach out to WWF-Canada (science@WWFCanada.org) and the Zoological Society of London (Valentina.Marconi@ioz.ac.uk) to ensure that all caveats and limitations have been discussed.

Canadian Living Planet Index

What indices are included in the Living Planet Report Canada 2020?

The Living Planet Report Canada 2020 includes a national C-LPI which is used to track the state of wildlife across the country. The data contributing to the national C-LPI have also been subset to reflect trends in (i) nationally assessed (COSEWIC) at-risk species, (ii) globally assessed (IUCN Red List) at-risk species, and (iii) species that were targeted by broad-scale conservation initiatives.

(A) COSEWIC-assessed at-risk species
The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an independent advisory panel to the Minister of Environment and Climate Change Canada that scientifically assesses the status of species in Canada. COSEWIC uses the best available scientific and Indigenous knowledge to categorize species as Extinct, Extirpated, Endangered, Threatened, Special Concern, Not at Risk or Data Deficient. COSEWIC meets biannually to discuss and evaluate the status of a pre-determined list of Canadian flora and fauna. Evaluations take into account a number of biodiversity elements, including trends in population size, distribution, threats, etc. (ECCC 2016). Species or Designatable Units (DU) assessed as Special Concern, Threatened or Endangered as of March 2019 were included within the *Canadian Living Planet Index for nationally assessed at-risk species* as determined via binomial Latin name and geographic location of the monitored population data (to account for differences in statuses among DUs). Importantly, it is anticipated that these species will exhibit an overall decline in abundance, given that declining population trends are considered when designating species in the first place. Of interest is the magnitude of the anticipated decline. Importantly, the index is reflective of species currently

assessed as at risk and does not include species that have improved in population size to the point where they are no longer considered at risk (<15 species in the dataset). Further, the C-LPI includes a subset of native Canadian vertebrate species; other species that have not yet been assessed by COSEWIC, or others that lack population trend data for inclusion here, may also be vulnerable to extinction in Canada.

To accompany the C-LPI specific to nationally assessed at-risk species, an index was produced for species that had been assessed by COSEWIC as Not at Risk of extinction — *Canadian Living Planet Index for species assessed as nationally not at risk*. As COSEWIC assessments take into account trends in population size, it was anticipated that this trend would be increasing relative to the index, which included only species scientifically assessed as at risk of extinction.

(B) IUCN Red-listed species

The International Union for Conservation of Nature's (IUCN) Red List of Threatened Species is the world's most comprehensive information source on the global conservation status of biodiversity. To date, the IUCN has assessed over 120,000 species, of which nearly 27% are threatened with extinction (IUCN 2020). Species assessments are conducted by members of the IUCN Species Survival Commission, appointed Red List Authorities, Red List Partners, assessment specialists and individuals with sufficient knowledge of a given species. While regional assessments have been included, the IUCN Red List focuses primarily on global-level assessments, acting as a "Barometer of Life" on an international scale. All assessors must use the best available scientific knowledge on a variety of topics including population trends, threats, stresses and conservation actions needed (IUCN 2019). Species classified as Vulnerable, Endangered, or Critically Endangered as of March 2019 were included within the *Canadian Living Planet Index for globally assessed at-risk species living in Canada*, as determined via binomial Latin name and sub-population (associated with geographic range) where applicable. IUCN Red-Listed populations were also included and compared to monitored populations in the C-LPI dataset to determine applicability. While COSEWIC-assessed species were anticipated to be in decline, the same hypothesis does not hold true for IUCN Red-Listed species within Canada. Species in Canada that are Threatened on the IUCN Red List may be faring well in Canada, but poorly around the globe. The alternative may also be true. Finally, some species that are IUCN Red-Listed may be endemic to Canada (such as the Vancouver Island marmot), and thus Canada has the sole responsibility of ensuring their survival (for these species, a decline is anticipated).

In addition to creating a C-LPI specific to globally assessed at-risk species, a C-LPI was created for species that had been assessed by the IUCN but were not considered at risk. Species classified as Near Threatened and Least Concern were included within the *Canadian Living Planet Index for species assessed as globally not at risk.*

(C) Species that were targeted by large-scale conservation initiatives

Despite declines in wildlife, many positive conservation success stories exist. For the most part, these successes stem from large-scale policy changes or global commitments, benefiting wildlife directly through initiatives such as harvest bans, and indirectly via protected areas. Within the *Canadian Living Planet Index for broad-scale conservation action in Canada*, five large-scale conservation actions were included. Some species and populations benefited from multiple conservation actions, while others were the target of just one. These initiatives were selected on the basis that species could be tagged within the C-LPI dataset according to their taxonomic classification and geographic location to ensure accuracy. Conservation initiatives included:

- Protected areas
    - A protected area is a clearly defined geographical space managed through legal or other effective means for the purpose of conserving biodiversity. As of 2019, 12.1% of

    Canada’s terrestrial and inland waters were conserved, including 11.4% in protected areas. In addition, 13.8% of marine waters were conserved, including 8.9% in protected areas (ECCC, 2020).
  - Population occurrence within a protected area was treated as a dichotomous variable based on a comparison of protected areas designated prior to 2014 (ECCC 2019b) and geospatial coordinates of population trends. Population trend data with insufficient geospatial information or coverage that more than doubled the size of the protected area in question were not included.
- Captive breeding and reintroduction
  - Captive breeding involves breeding rare or endangered species in captivity before reintroducing them back to their natural habitats. Successful reintroductions of species are possible, but typically only if the threats that triggered the original decline have been removed.
  - Species that have likely benefited from captive breeding and reintroduction were tagged within the C-LPI as identified via literature review, expert knowledge and a scan of organizations known for captive breeding initiatives in Canada. Binomial Latin name and geographic location of the monitored population were used to tag species accordingly, as the entirety of a species’ range and multiple Designatable Units are not necessarily covered through captive breeding and reintroduction efforts.
- North American Waterfowl Management Plan
  - The NAWMP is an international partnership between Canada, the United States and Mexico, in which the countries work on a variety of waterfowl and habitat management issues, including conserving and restoring key waterfowl habitats across North America.
  - Waterfowl and wetland birds were tagged within the C-LPI database using contextual information from the NABCI-Canada’s State of Canadas Birds supplementary material.
- Harvest bans
  - Different policies and regulations have been introduced throughout Canada to prohibit the harvest of wildlife, largely due to population declines that result from unsustainable harvesting practices. (For example, the Minister of Fisheries declared a moratorium on commercial whaling in Canada in 1972.)
  - Harvest bans were determined via literature review and expert knowledge.
- Ban of persistent organic pollutants
  - The Stockholm Convention on Persistent Organic Pollutants (POPs) is an international environmental treaty aimed at reducing levels of POPs in the environment by eliminating or restricting the release of specific chemicals and pesticides that accumulate in the environment and can be harmful to wildlife and humans. Canada was the first country to sign and ratify the Convention in 2004.
  - Species benefiting from the elimination of persistent organic pollutants were determined via literature review and expert knowledge.

While conservation actions have targeted many species, there exists variability within population sizes as many additional factors also influence the trends in abundance of these species. In addition, in some cases, dominant threats to recovery and success are still prevalent and these cumulative pressures impact the magnitude of the recovery for the species included within the *C-LPI for broad-scale conservation action in Canada*. Other caveats include the differing time periods of management intervention (i.e., management interventions were not all implemented in 1970), and the strength of some conservation actions (i.e., protected areas are often designated in politically viable areas as opposed to those with high concentrations of biodiversity).

What are the final results reported?

The national C-LPI examined the status of 883 vertebrate species, representing roughly half of the country's native vertebrate animals. The index included 3,781 time series of varying lengths, spanning from 1970 to 2016. Nationally, monitored populations of native vertebrate species exhibited a near-stable trend of 6% on average relative to 1970. By contrast, species that are designated as at risk by both COSEWIC and the IUCN Red List have declined by 59% and 42% over the 47-year time period, respectively. Importantly, conservation effort may have contributed to increasing trends for species where targeted conservation intervention was employed. On average, monitored populations that have benefited from harvest bans, protected areas, captive breeding and reintroduction, the North American Waterfowl Management Plan, and/or the elimination of Persistent Organic Pollutants have increased by more than 40% on average relative to 1970, though there are, of course, other factors that have likely contributed to the directionality and magnitude of the underlying trends in population abundance.

Various iterations of C-LPIs were endeavored and evaluated for data robustness in terms of the strength of the underlying data, the number of species included, and the total number of time series contributing to the trend. Yet, trends with small sample size and exceptionally large uncertainty bounds were not included. In addition, a diversity-weighted index was employed to evaluate the inherent bias of the index, which relies upon non-random and available data. However, there were no significant differences in final index values compared to the basic approach of weighting all species equally.

Results for all C-LPIs included in the Living Planet Report Canada 2020 are summarized in Table 1. Results of complementary indices are summarized in Table 2.

Table 1. Summary of the four Canadian Living Planet Indices included within the Living Planet Report Canada 2020. Each categorical trend has a corresponding number of species, population time series and percent change relative to 1970. Uncertainty bounds around the final index value represent uncertainty around that value in relation to the baseline.

Trend	**Species (Count)**	**Time Series (Count)**	**Change Relative to 1970 (%)**	**95% Uncertainty Bounds**		**Direction**
				[Lower]	**[Upper]**	
Canadian Living Planet Index	883	3781	+6.37	-4.97	+19.17	Near-stable
Canadian Living Planet Index for nationally assessed at-risk species (COSEWIC)	139	629	-59.42	-70.38	-43.97	Decline
Canadian Living Planet Index for globally assessed at-risk species living in Canada (IUCN)	51	316	-41.76	-64.31	-4.86	Decline
Canadian Living Planet Index for broad-scale conservation action in Canada	191	410	+40.38	+2.85	+91.91	Increase

Table 2. Summary of two additional Canadian Living Planet Indices that accompany the negative trajectories associated with globally and nationally assessed at-risk species in the 2020 Living Planet

Report Canada, focusing instead on species assessed as not at risk of extinction. Each categorical trend has a corresponding number of species, population time series and a percent change relative to 1970. Uncertainty bounds around the final index value represent uncertainty around that value in relation to the baseline.

Trend	**Species (Count)**	**Time Series (Count)**	**Change Relative to 1970 (%)**	**95% Uncertainty Bounds**		**Direction**
				[Lower]	**[Upper]**	
Canadian Living Planet Index for species assessed as nationally not at risk (COSEWIC)	62	192	+82.03	+18.22	+172.97	Increase
Canadian Living Planet Index for species assessed as globally not at risk (IUCN)	630	1941	+12.14	-0.55	+26.70	Increase

Interpreting the results

What does the C-LPI indicate?

The LPI is an indicator of monitored population trends for vertebrate species. The C-LPI is an indicator of wildlife abundance over time and does not reflect species extinctions, especially given that population counts of zero have been removed. In addition, an average of population trends is not synonymous with an average of total numbers of animals lost. For instance, a loss of 20 to 10 individuals in a population would have the same proportional loss as a decline of 10,000 to 5,000 but the total number of animals lost differs substantially. These discrepancies and clarifications are noteworthy given that the LPI is often misinterpreted.

From 1970 to 2016, the national C-LPI shows a near-stable trend of 6% (Figure 6). Upon examination of the trends for individual species, we can gain an understanding of the aggregate C-LPI measure. The overall trend is likely attributable to the fact that 53% of species are either stable or increasing in population abundance, which is marginally larger than those in decline (Figure 7). The distribution of the per cent change in monitored population abundance from 1970 to 2016 is anticipated to be skewed, hence the use of a geometric mean of relative abundance. Abundance can decline by nearly 100% but can increase infinitely. According to the data underlying the C-LPI, there are a greater number of populations (N = 1137) experiencing more substantial rates of decline (≤1/2x) than those with more moderate and incremental declines (N = 773; between 0 and 1/2). While the opposite is also true (there are a greater number of populations experiencing more significant increases in comparison to those with moderate changes), conservation should focus on reversing trends for species currently in decline, particularly given that a greater number of species are experiencing more substantial rates of decline (Figure 8). Finally, within the dataset, the percentage of negative years was marginally higher (near equal) than positive years for the population time series (Figure 9).

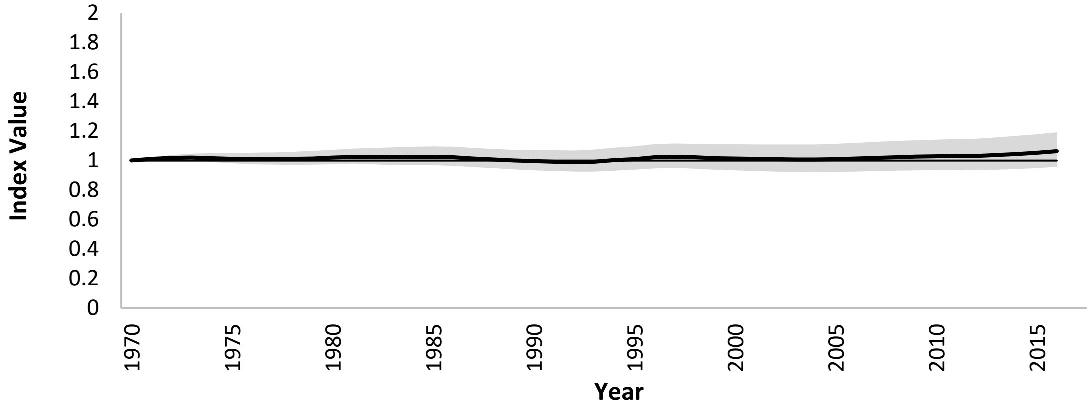


Figure 6. From 1970 to 2016, the Canadian Living Planet Index shows a near-stable trend of 6.37% (3,781 population time series; 883 species).

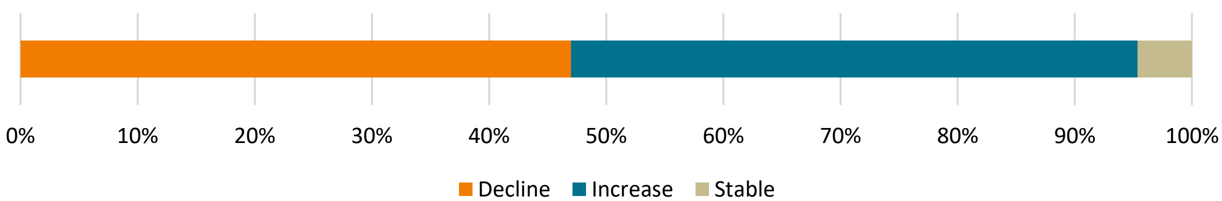


Figure 7. Relative proportion of declining, increasing and stable trends included in the Canadian Living Planet Index.

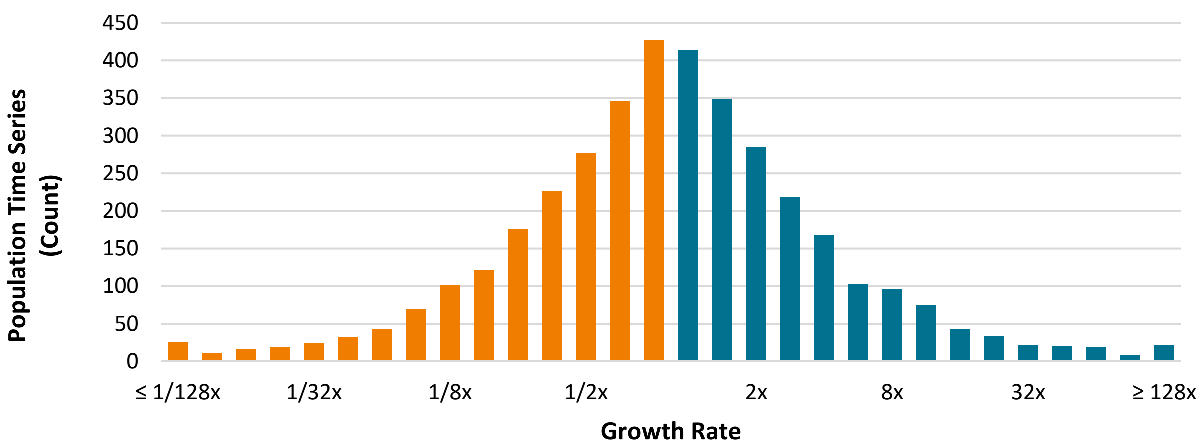


Figure 8. Distribution of the growth rate in monitored population abundance from 1970 to 2016 for the 3,781 population times series included in the Canadian Living Planet Index. Orange bars are indicative of a decline, and blue showcase a positive growth rate.

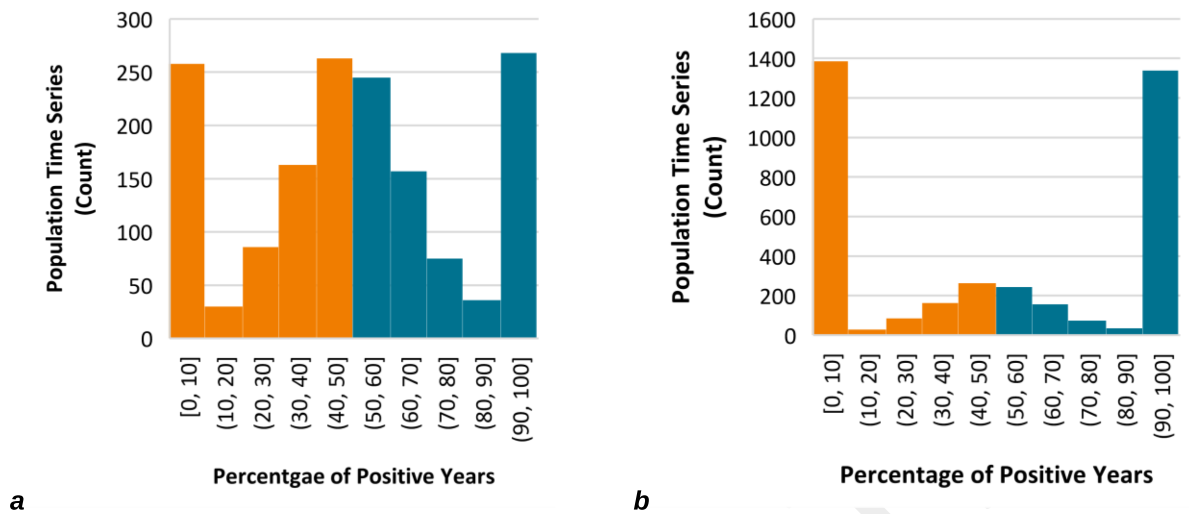


Figure 9. **(a)** Percentage of positive years (years with a positive interannual change in abundance) for the 1,581 population time series modelled using the Generalized Additive Model (GAM). **(b)** Percentage of positive years (years with a positive interannual change in abundance) for all 3,781 population time series included in the C-LPI. Orange bars are indicative of a decline, and blue showcase a positive trend.

THREATS ANALYSIS

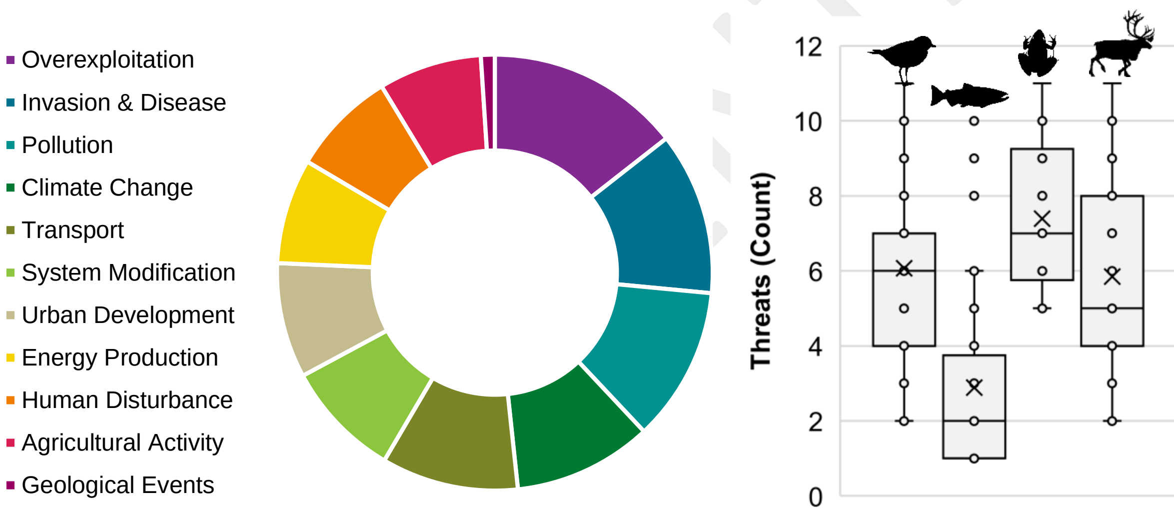
Threats methodology

The quantification of threats for at-risk species provided insight into (i) the primary drivers of population declines and (ii) the average number of threats impacting a given species. Both elements are useful for directing future research to inform conservation action.

Threat data for COSEWIC-assessed at-risk species was provided by the University of Ottawa (Findlay & McKee 2018) using threat information detailed in the most recent COSEWIC assessment reports. In 2015, COSEWIC approved a threats classification and assessment calculator for inclusion in every COSEWIC status report (COSEWIC 2016). The calculator is based on the IUCN-CMP threats classification system which includes 11 broad categories of threats (Salafsky *et al.* 2008). Prior to 2015, threats were not incorporated into COSEWIC status reports in a systematic, quantitative manner. Consequently, researchers from the University of Ottawa constructed species-specific threat profiles according to the IUCN-CMP threat classification for status reports prior to 2015. For each species or Designatable Unit (DU), the description of threats was extracted from individual COSEWIC status reports. Extractions were independently evaluated by two to three researchers using the explicit IUCN threat classifications (e.g., "agriculture") and a set of related terms (e.g., "farming," "ranching," "crops," "plantations") to obtain a binary classification of presence/absence for each of the 11 broad-level threats. As data was sometimes collected at the DU-level, and the *Canadian Living Planet Index for nationally assessed at-risk species* is calculated at the species-level (binomial Latin name), threats for multiple DUs included within the index were combined for a single species. This approach differs from that of Currie & Marconi (2020). More specifically, if for any DU a threat was present, it was included in the final threat profile for the species. Threat data was available for 132 of the 139 COSEWIC-assessed at risk species included in the *Canadian Living Planet Index for nationally assessed at-risk species*.

Threats to at-risk species in Canada

While overexploitation was the primary threat listed, the distribution of threats among COSEWIC-assessed at-risk species included in the *Canadian Living Planet Index for nationally assessed at-risk species* was similar (Figure 10a). With the exception of geological events, there was a 6% range in the type of threat as a percent of all threats faced by COSEWIC-assessed at-risk species in Canada. The distribution of threats reinforces the fact that species are often threatened by multiple pressures. COSEWIC-assessed at-risk species included in the analysis had five threats listed on average, with differences among taxonomic groups (Figure 10b). Overexploitation was the most frequently cited threat among fish species (88 per cent) and was also frequently listed for mammals (66 per cent) and herpetofauna (61 per cent). Herpetofauna had comparatively more threats cited within their COSEWIC status reports in comparison to other taxonomic groups, contrasting sharply with fish which were sometimes threatened solely by overexploitation (Figure 11). Nevertheless, threats were rarely listed in isolation, with only 13% of species experiencing a single threat — all of which were marine fish.



a ***b***

Figure 10. **(a)** *Type of threats as a percent of all threats faced by COSEWIC-assessed at-risk species in Canada. While the Canadian Living Planet Index for nationally assessed at-risk species includes 139 species, threat data were only available for 132 species.* **(b)** *Number of threats impacting COSEWIC-assessed at-risk species in Canada. Lines represent median values, and Xs represent average values.*

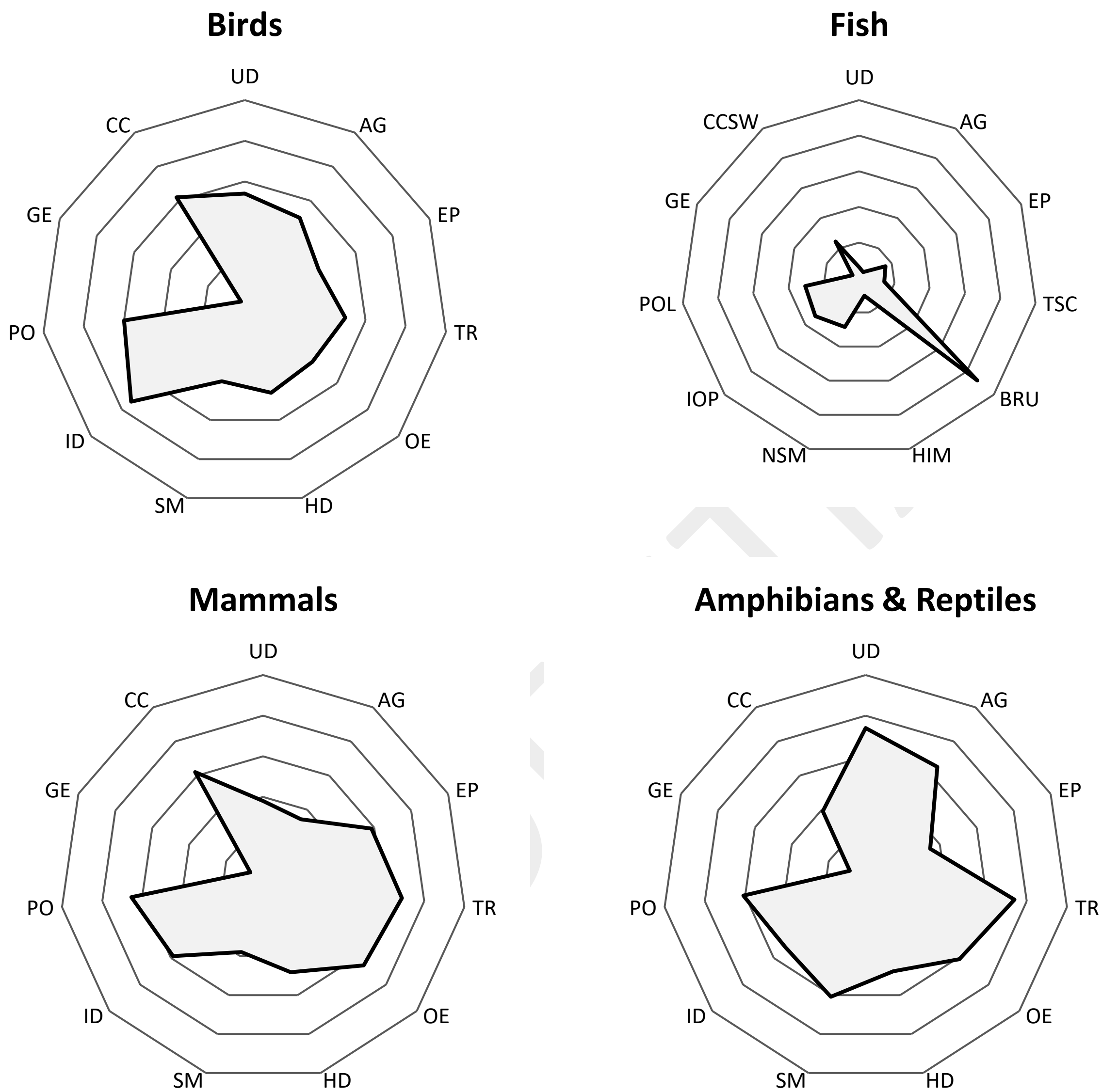


Figure 10. Proportion of COSEWIC-assessed at-risk species included in the Canadian Living Planet Index exposed to each of the 11 threat categories, by taxonomic group. A large surface area indicates that a taxonomic group is exposed to many threats. In addition, a high proportion of species is exposed to a single threat if the polygon is closer to the threat label. Threats include urban development (UD), agricultural activity (AG), energy production (EP), transport (TR), overexploitation (OE), human disturbance (HD), system modification (SM), invasion and disease (ID), pollution (PO), geological events (GE) and climate change (CC).

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