BIRD STRIKE EVENTS UNDERREPORTING

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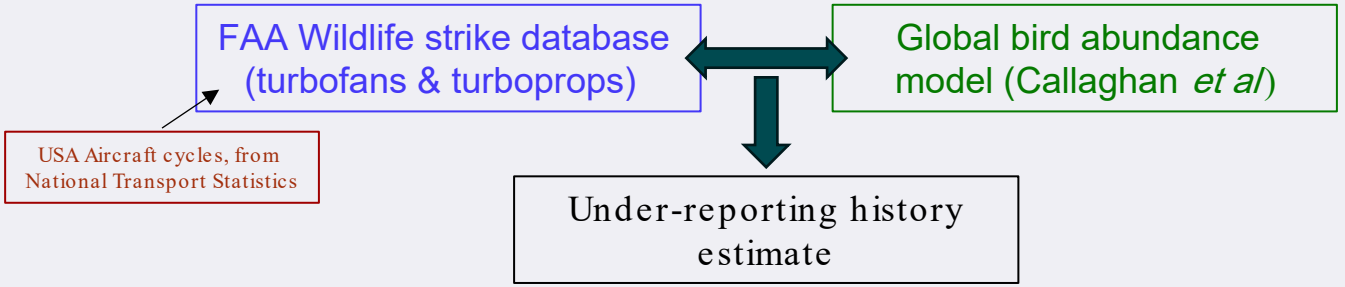
Introduction

- US airlines are encouraged to report all bird strikes for inclusion in the FAA Wildlife Strike database.
- This contains some 340,000 events since 1990; 184,551 of those were on aircraft with turbofan or turboprop engines.
- Whilst this is an excellent resource, in 2000, Barras & Dolbeer estimated that under-reporting may be as high as 75%.
- Since then, the large increase in reported strikes suggests this has improved markedly.
- This work aims to estimate trends in under-reporting rates, from 1990 -> 2024, as follows:



Regulations

Key Bird strike Regulations

Aircraft regulations , requiring “continued safe flight and landing”:

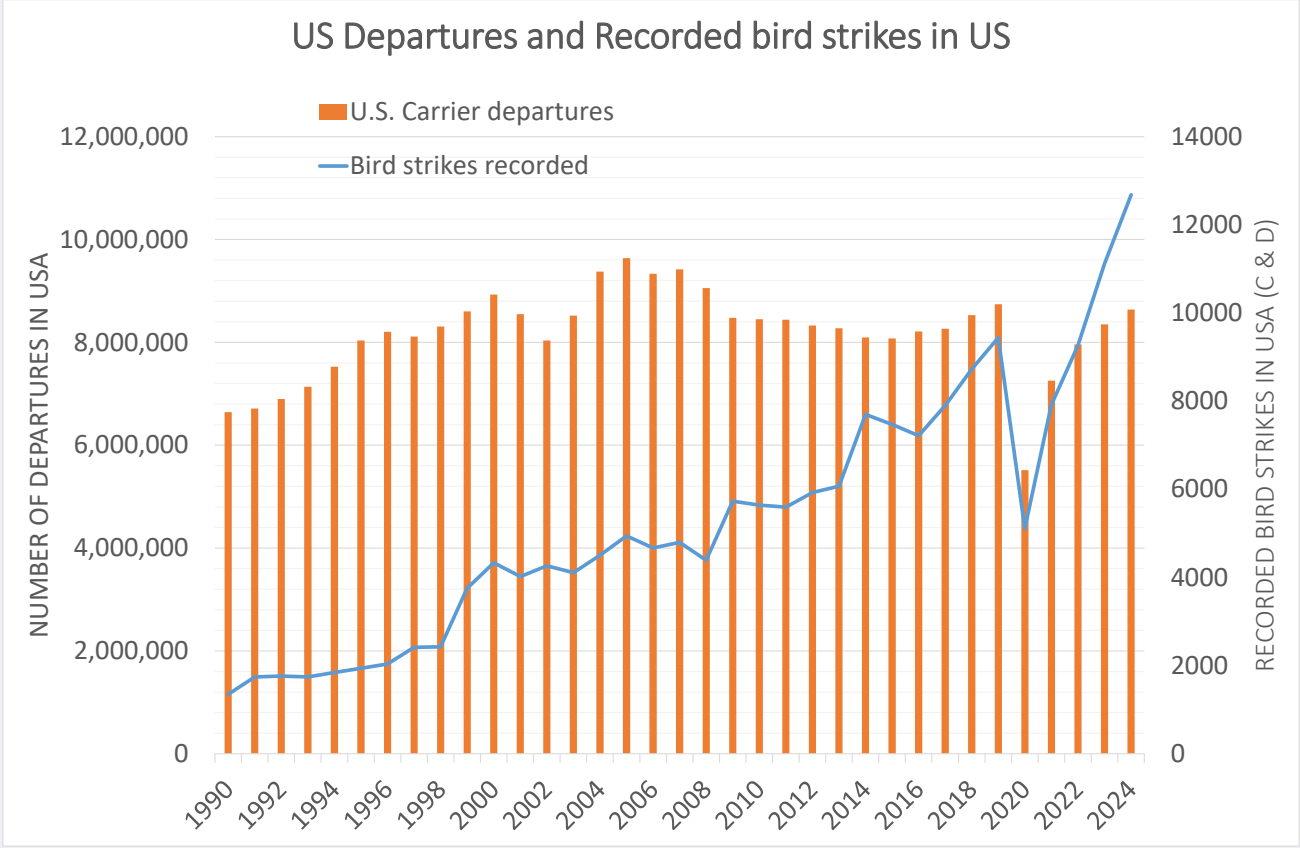
- CS-25.631: 4lb bird striking anywhere at cruise (approx. 450kts)
- FAR-25.631: 8lb bird striking empennage structure at cruise (approx. 450kts)

Engine regulations

- CS-E800(b): 8lb bird ingestion, max take-off power, 200kts
  requires “no hazardous engine effects”
- CS-E800(d): 2.5lb bird ingestion, max take-off power, critical speed
  requires fulfilling a run on schedule, including achieving 75% thrust

This work assumes that all Large bird events (defined here as >8lb) in recent years have been reported, despite not always knowing the species.

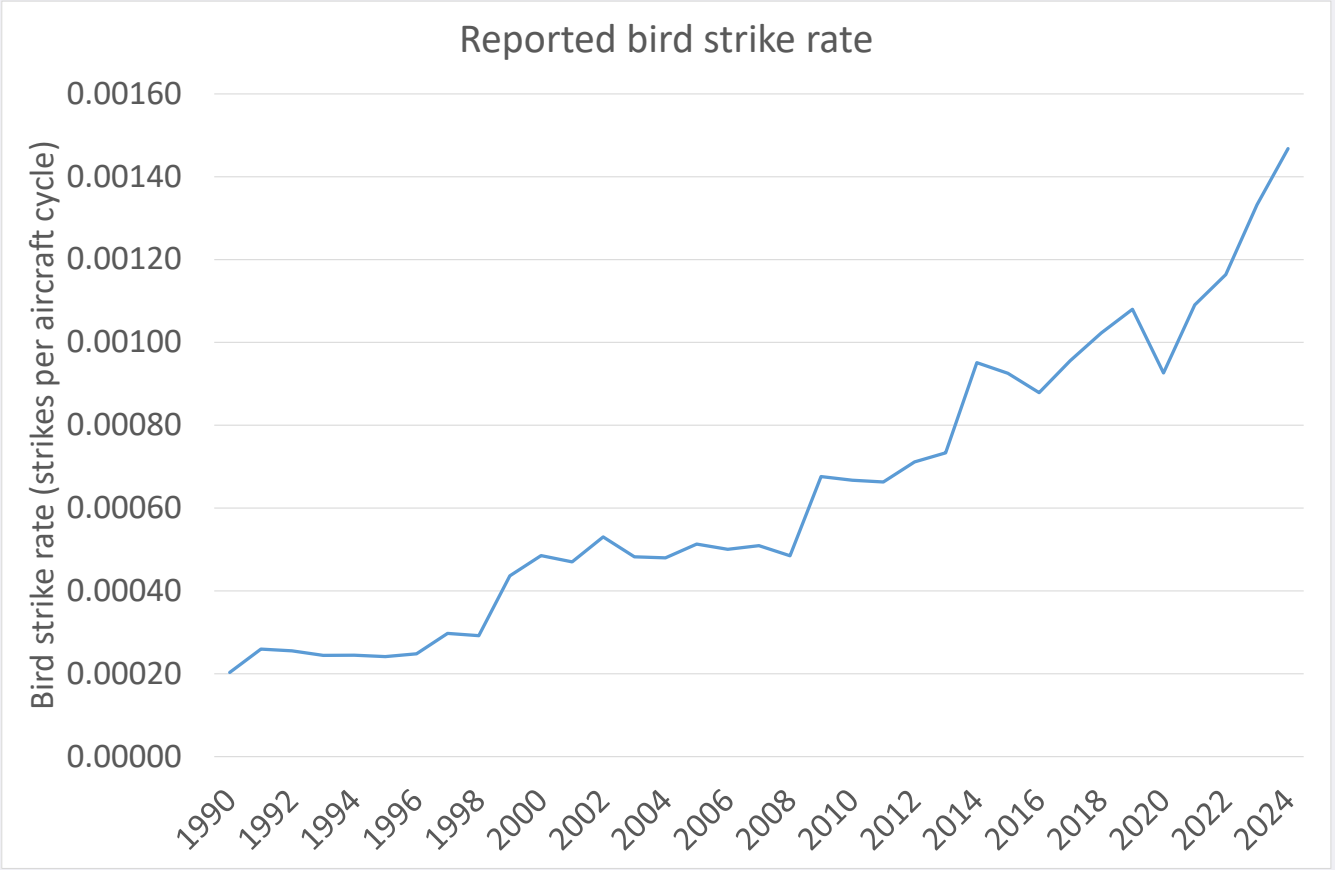
Bird strikes & Flight cycles



- 184,551 events on Turbofan & Turboprop aircraft over 35 years
- Large increase in the number of reported bird strikes per year
- Modest increase in the number of scheduled departures in the USA over the period.

Reference:
U.S. Air Carrier Aircraft Departures, National Transportation Statistics, Bureau of Transportation Statistics (www.bts.gov).

Bird strike rate



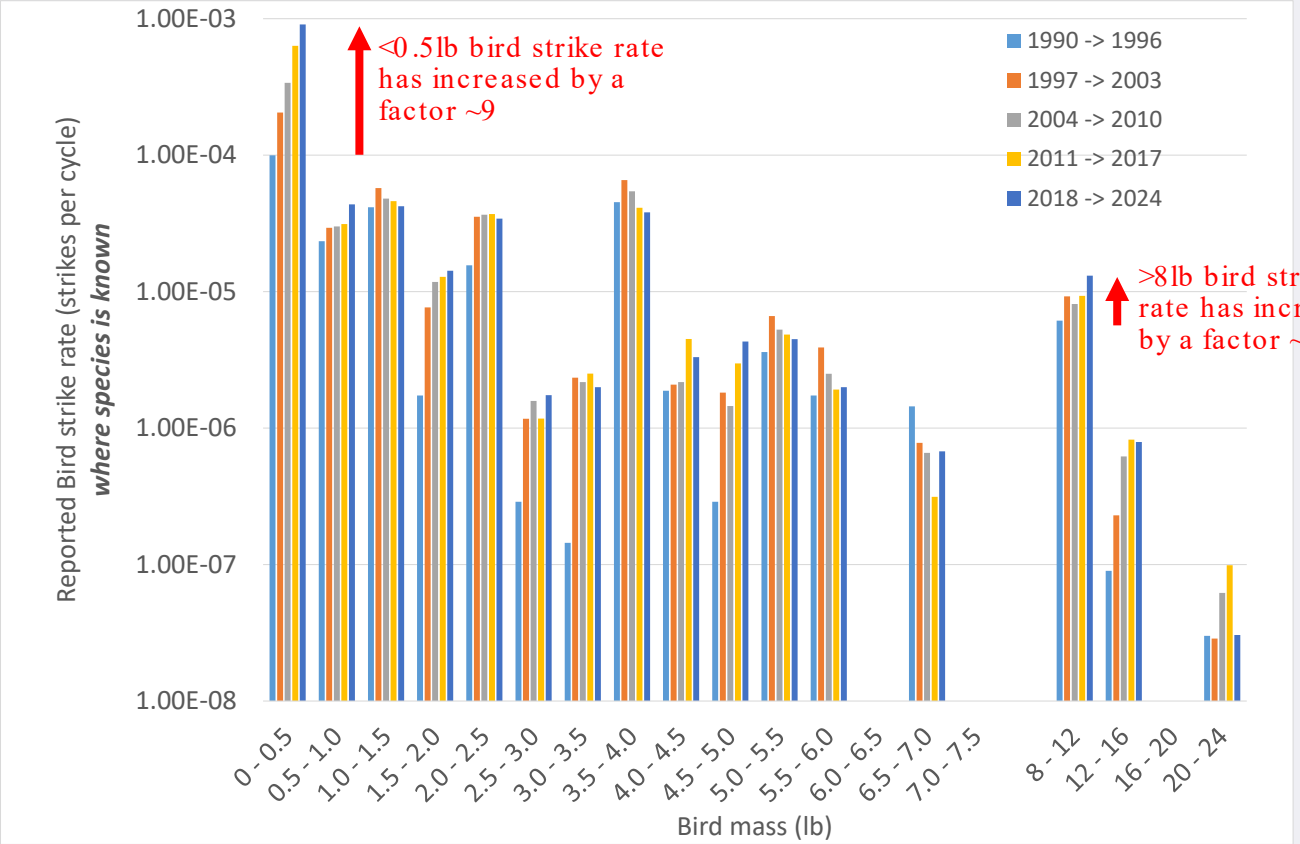
- Large increase in the reported bird strike rate
- Suspicion is that this is mostly owing to better reporting…

Reported Bird strike rate, for events of known species

Events of Known species

(36% of total)

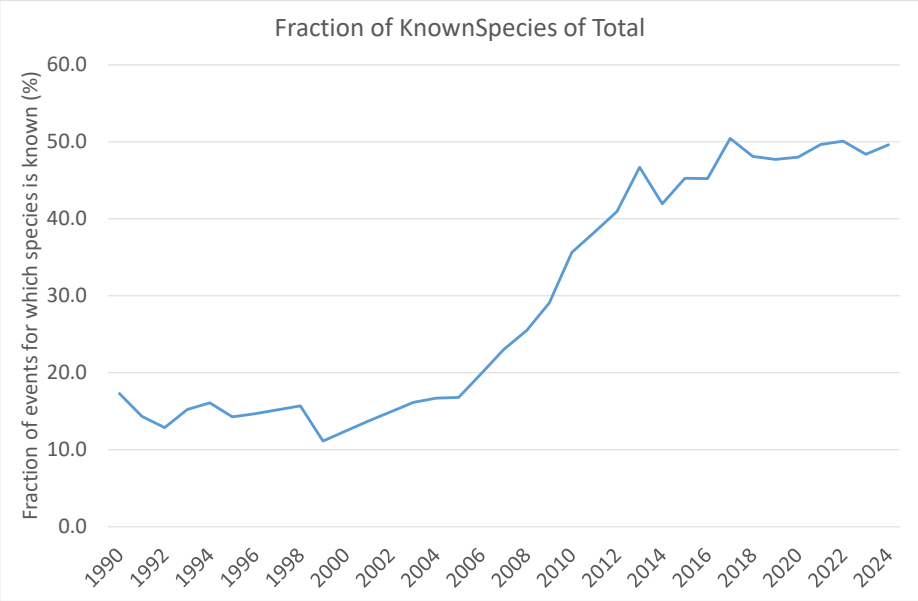
- Chosen to break the 35 years into 5 equal time periods of 7 years (too little data for year by year).
- Considering the 66,479 events (36% of total) where the species was identified:

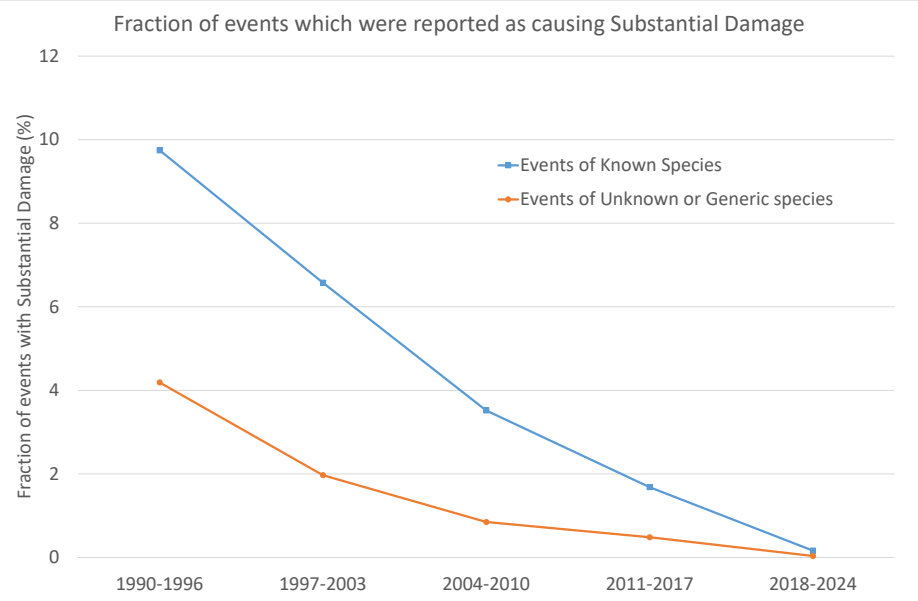


Unknown / Generic birds

Events of Unknown species (64% of total)

- In the 1990s, only about 15% of reported events were attributed to a specific species. Over the last 10 years, this has been around 50%.
- The generic level of damage sustained by the aircraft (& engines) is recorded. Fraction of events with Substantial Damage is dropping.



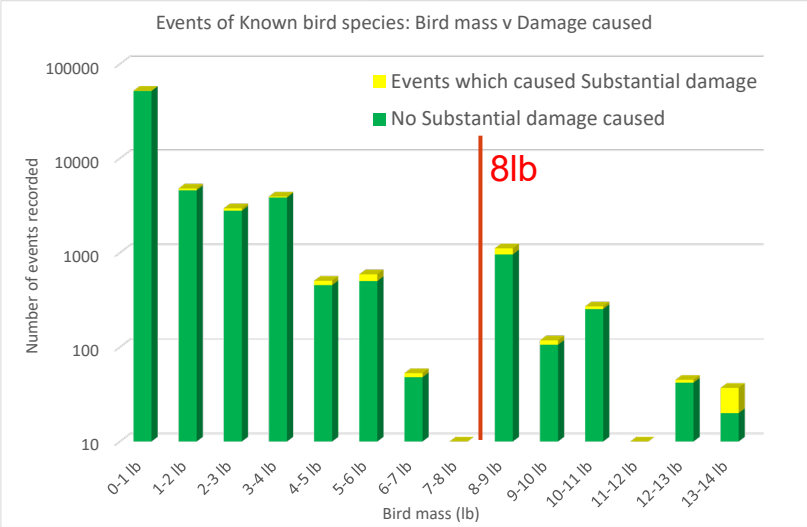


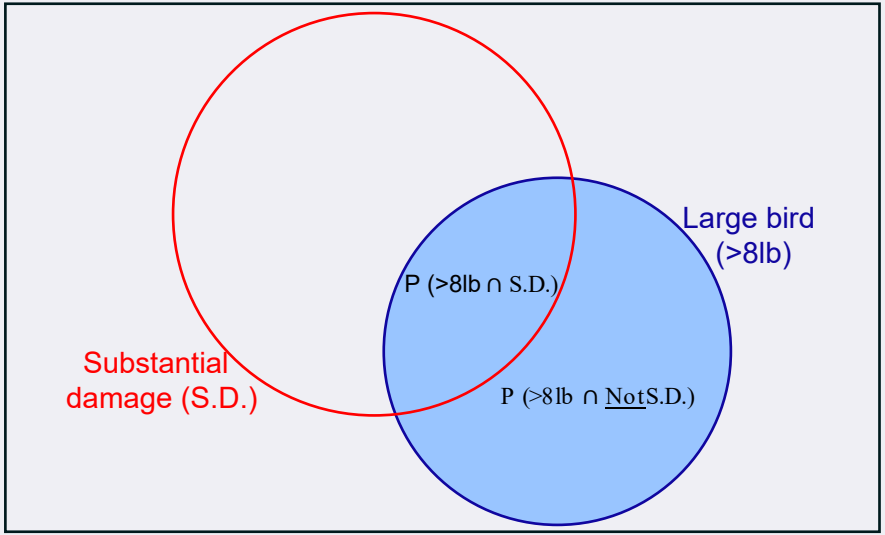
- The damage caused will be used to estimate (in broad terms) the bird mass of these Unknown/generic events . . .

Unknown / Generic birds

Events of Unknown species (64% of total)

- Some Large bird (>8lb) events cause Substantial damage, some don't.
- Some <8lb events cause Substantial damage, most don't.
- A structured approach was taken in estimating these groups:





$$P(>8\text{lb} \cap \text{S.D.}) = P(>8\text{lb} \,/\, \text{S.D.}) * P(>8\text{lb})$$

$$P(>8\text{lb} \cap \underline{\text{Not}}\text{S.D.}) = P(>8\text{lb} \,/\, \underline{\text{Not}}\text{S.D.}) * P(>8\text{lb})$$

Data sourced from FAA bird database

Data sourced from Callaghan model, P(>8lb) = 1.05%

Unknown / Generic birds – estimates of bird masses

Events of Unknown species (64% of total)

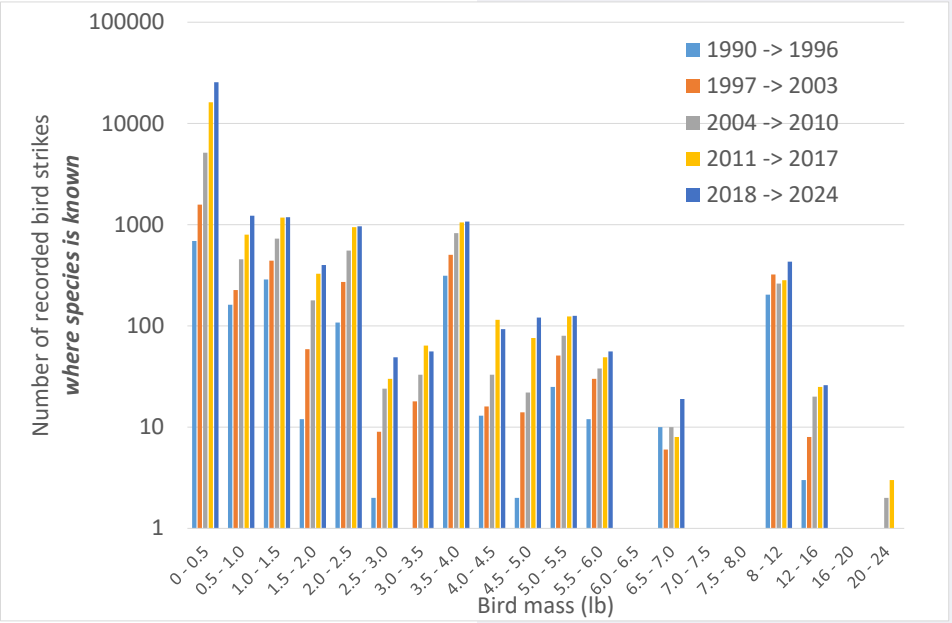
	1990-1996	1997–2003	2004 – 2010	2011-2017	2018–2024
# Known bird events >8lb	208	331	284	311	458
# Unknown birds predicted to be >8lb	111	229	276	280	345
# Known bird events <8lb	1,639	3,227	8,128	20,954	30,939
# Unknown birds predicted to be <8lb	10,462	21,537	25,989	26,333	32,510
TOTAL birds >8lb	319	560	560	591	803
TOTAL birds <8lb	12,101	24,764	34,117	47,287	63,449

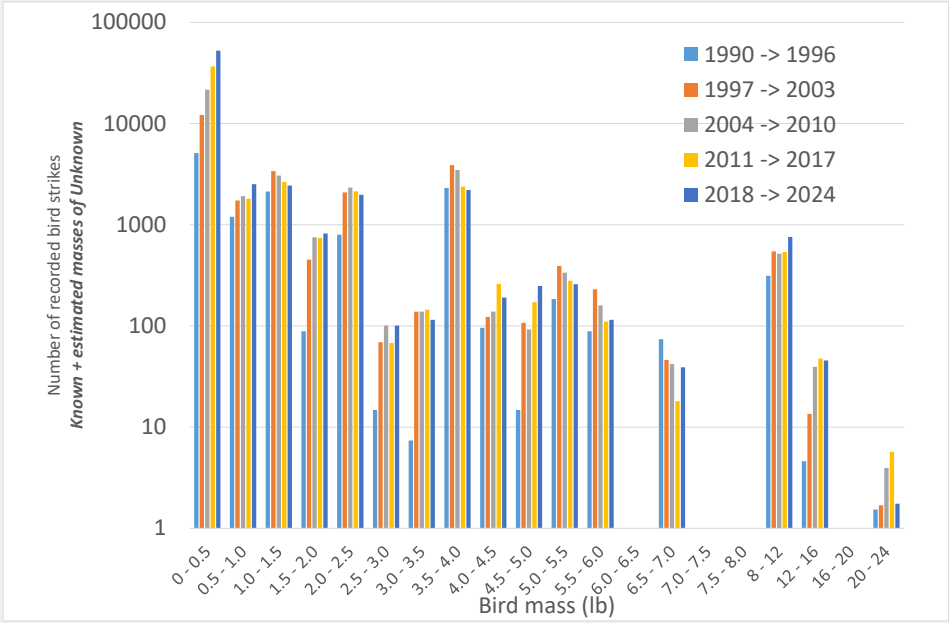
- Assume that the mass distribution of Unknown birds are the same as Known birds. The following factors were used for scaling:

	1990-1996	1997–2003	2004 – 2010	2011-2017	2018–2024
Factor applied to # Known birds >8lb	1.53	1.69	1.97	1.90	1.75
Factor applied to # Known birds <8lb	7.38	7.67	4.20	2.26	2.05

Inclusion of estimated masses for events of Unknown species

Mass distribution of bird events



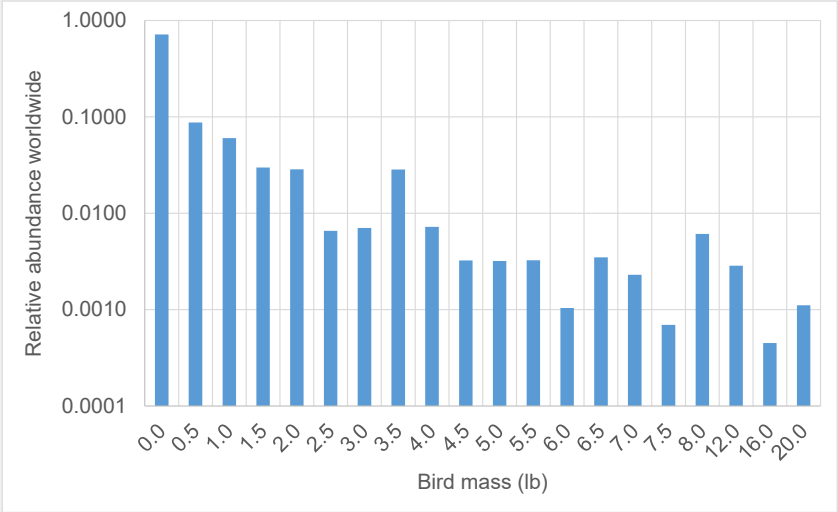


Addition of estimated masses of events for which species was Unknown

Bird abundance model

Callaghan bird abundance model – a reference mass distribution

- To estimate reporting rates, a model of bird abundance has been used.
- Worldwide model of 9,700 bird species, including an estimate of their numbers. After removing flightless birds, total of 50.4 billion birds! Large uncertainty to this, of course.
- Average bird masses known for 8,076 of the 9,700 species (comprising 98.2% of birds).
- Relative abundance of birds, by mass:



- Assume that bird abundance correlates with bird strike risk…

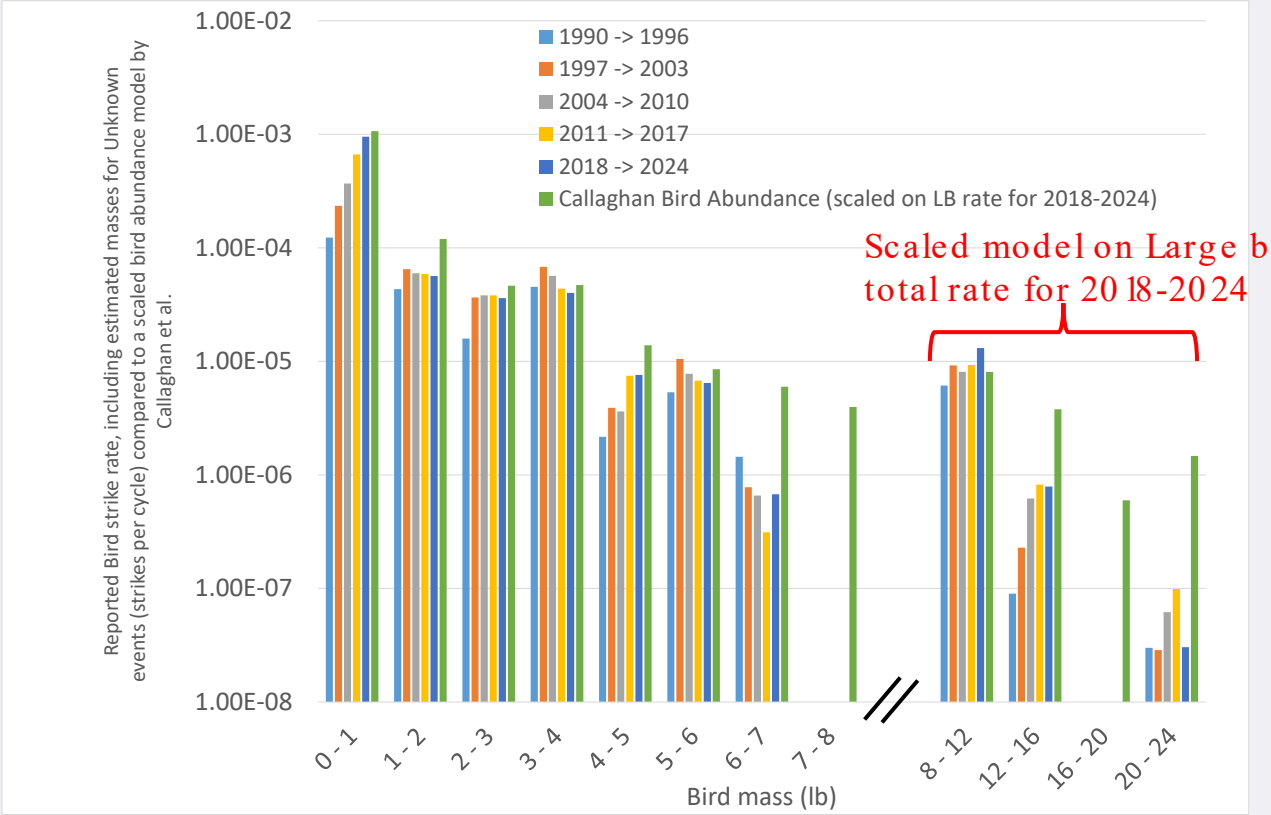
Reference:
"Global abundance estimates for 9,700 bird species", Callaghan, Nakagawa & Cornwell, Proceedings of the National Academy of Sciences, 2021, Vol. 118, No. 21.

Comparison of Bird strike rates and Bird abundance model

- Assuming that all Large bird events have been recorded (either as Known or Unknown species).
- Scale Callaghan model on 2018-2024 Large bird strike data

Bird strike rate V abundance model

Time period	"Missing" events wrt model
1990-1996	82%
1997-2003	68%
2004-2010	59%
2011-2017	37%
2018-2024	16%



Sensitivity analysis – LB & MB populations in USA are rising…

A changing threat

- There is evidence that Medium & Large bird populations have increased (not from strike data):

Table 3. Estimated change in North American population from 1990 to 2018 for 36 bird species with mean body masses ≥1.1 kg that have been struck by civil aircraft ≥20 times in North America, 1990 to 2018 (see Tables 1, 2, 5 and 6 for data on individual species).

Bird mass	Number of species	Estimated population[a]		Population change[b]	
		1990	2018	Net	Percent
Large (≥1.8 kg)	20	21,621,000	49,448,000	27,827,000	129
Medium (1.1–1.7 kg)	16	33,796,000	40,508,000	6,712,000	20

From "Population increases of large birds in North America pose challenges for aviation safety", Richard Dolbeer, 2020.

Date range	0 -> 2.5 lb	2.5 lb -> 4 lb	> 4 lb
1990-1996	**100%**	**83.4%**	**43.7%**
1997-2003	100%	87.5%	57.8%
2004-2010	100%	91.7%	71.9%
2011-2017	100%	95.8%	86.0%
2018-2024	**100%**	**100%**	**100%**

If all years are judged against 2018-2024 model:

Time period	"Missing" events wrt model
1990-1996	82%
1997-2003	68%
2004-2010	59%
2011-2017	37%
2018-2024	16%

If 2018-2024 model (for Medium & Large birds) is scaled down for earlier periods:

Time period	"Missing" events wrt model
1990-1996	79%
1997-2003	66%
2004-2010	58%
2011-2017	37%
2018-2024	16%

Conclusions

- Assuming that the relative abundance of Large birds v Medium birds v Small birds has changed according to the Dolbeer 2020 study, the “missing bird events” can be interpreted as the following under -reporting:

Time period	Under-reporting rates, assuming Large bird and Medium bird populations have increased
1990-1996	79%
1997-2003	66%
2004-2010	58%
2011-2017	37%
2018-2024	16%

- This work indicates that reporting rates in the FAA’s Wildlife Database have improved significantly since its inception in 1990.

Backup slide

Logic of assigning Unknown/generic events:

Conditional probability sums

	1990-1996	1997–2003	2004 – 2010	2011–2017	2018–2024
# Known bird events >8lb	208	331	284	311	458
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TOTAL birds >8lb	319	560	560	591	803
TOTAL birds <8lb	12,101	24,764	34,117	47,287	63,449

P(SD)	Probability of having Substatial Damage (uses all 184,551 events)	0.0502	0.0262	0.0150	0.0102	0.0010
P(SD / >8lb)	Probability of Substantial Damage, given >8lb bird (from Known events)	0.1635	0.1662	0.1725	0.1801	0.0240
P(>8lb)	From Calaghan model	0.0105	0.0105	0.0105	0.0105	0.0105
P(>8lb / SD)	P(>8lb / SD) = P(SD / >8lb) * P(>8lb) / P(SD)	0.0343	0.0667	0.1212	0.1861	0.2535
P(>8lb & SD)	P(>8lb & SD) = P(>8lb / SD) * P(SD)	0.0017	0.0017	0.0018	0.0019	0.0003
P(notSD)	Probability of NOT Substatial Damage (uses all 184,551 events)	0.9498	0.9738	0.9850	0.9898	0.9990
P(notSD / >8lb)	Probability of NOT Substantial Damage, given >8lb bird (from Known events)	0.8365	0.8338	0.8275	0.8199	0.9760
P(>8lb / notSD)	P(>8lb / notSD) = P(notSD / >8lb) * P(>8lb) / P(notSD)	0.0093	0.0090	0.0088	0.0087	0.0103
P(>8lb & notSD)	P(>8lb & notSD) = P(>8lb / notSD) * P(notSD)	0.0088	0.0088	0.0087	0.0086	0.0103