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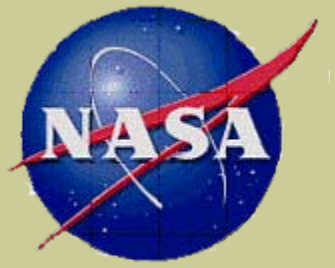

BIRDSTRIKES

An analysis of NAOMS birdstrike data patterns, trends, and structures over the 2001 thru 2003 timeframe yielding useful insights on workable statistical approaches for NAOMS data

LJ Rosenthal, BATTELLE

2004-May-05

Purposes of this Exercise

1. **Provide a case example of NAOMS rate and trend development**
2. **Demonstrate the internal consistency and plausibility of NAOMS data**
3. **Develop a fuller understanding of birdstrike event rates and the factors that influence them**

Here's how we're going to proceed. We will . . .

1. Visually examine and tabulate the raw data to get a feel for its basic properties
2. Evaluate the relative merits of flight Hours vs. Legs as the birdstrike rate base
3. Decide how to partition the data into meaningful subgroups
4. Examine the data in time-series order in a search for trends and seasonal cycles
5. Evaluate factors such as aircraft size that may influence the rate of birdstrike events

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Presentation Sequence

Here's how we're going to proceed. We will:

1. Visually examine and tabulate the raw NAOMS birdstrike data to get a feel for its basic properties
2. Consider the relative merits of Flight Hours vs. Flight Legs as the birdstrike rate base
3. Visually examine the data in time-series order for evidence of long-term trends and seasonal cycles
4. Decide how to partition the data into meaningful subgroups
5. Evaluate factors such as aircraft size that may influence the rate of birdstrike events
6. Specify an initial mathematical model for estimating birdstrike frequencies
7. Estimate model parameters and refine as needed
8. Use the parameterized model to estimate birdstrike frequency in CY03.

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NAOMS Birdstrike Question

Section B, Question AC1:

“During the last 60 days, how many times did an aircraft in which you were a crewmember experience a bird strike?”

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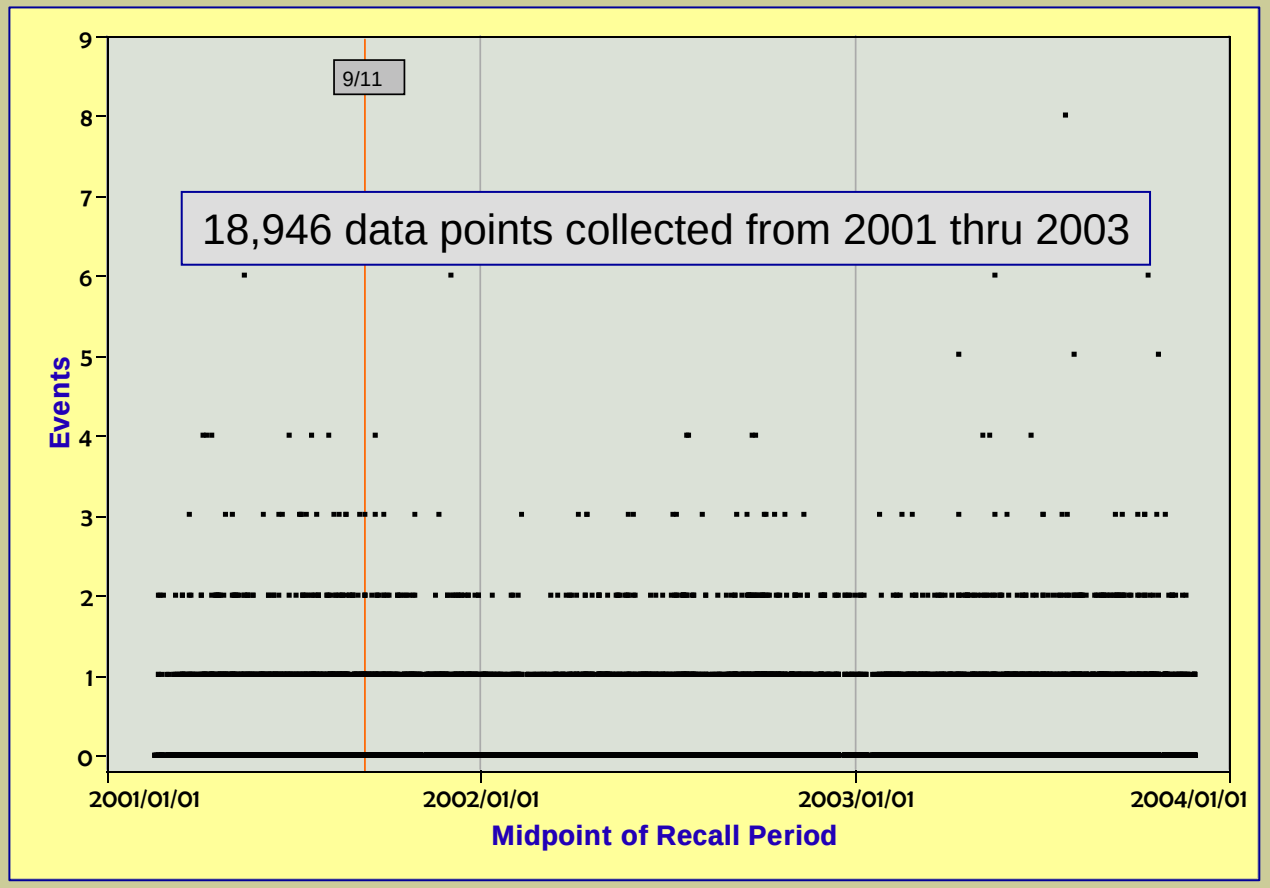
NAOMS Raw Birdstrike Data



Observations:

- Very difficult to see patterns and trends in raw data
- Need different visualization approach
- Data may need to be grouped or accumulated to be meaningfully analyzed.

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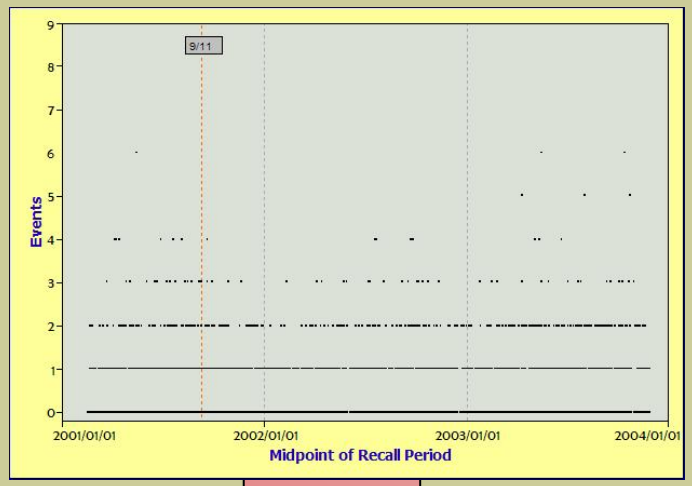
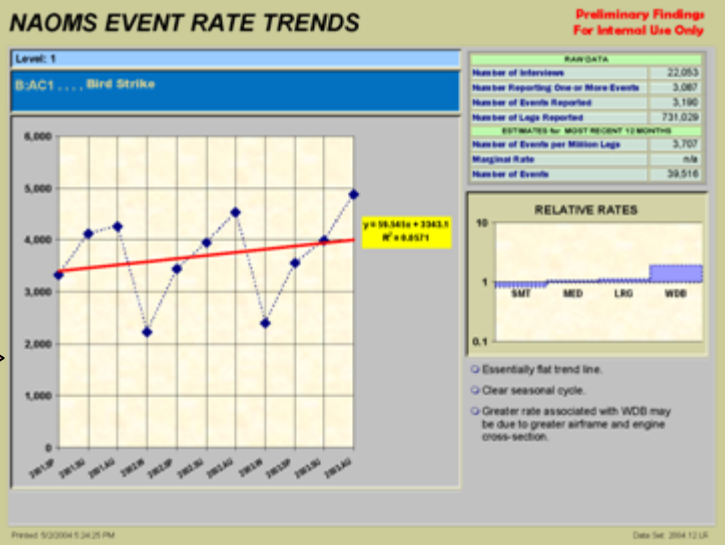
We need to get from . . .

Here



to Here



and Beyond

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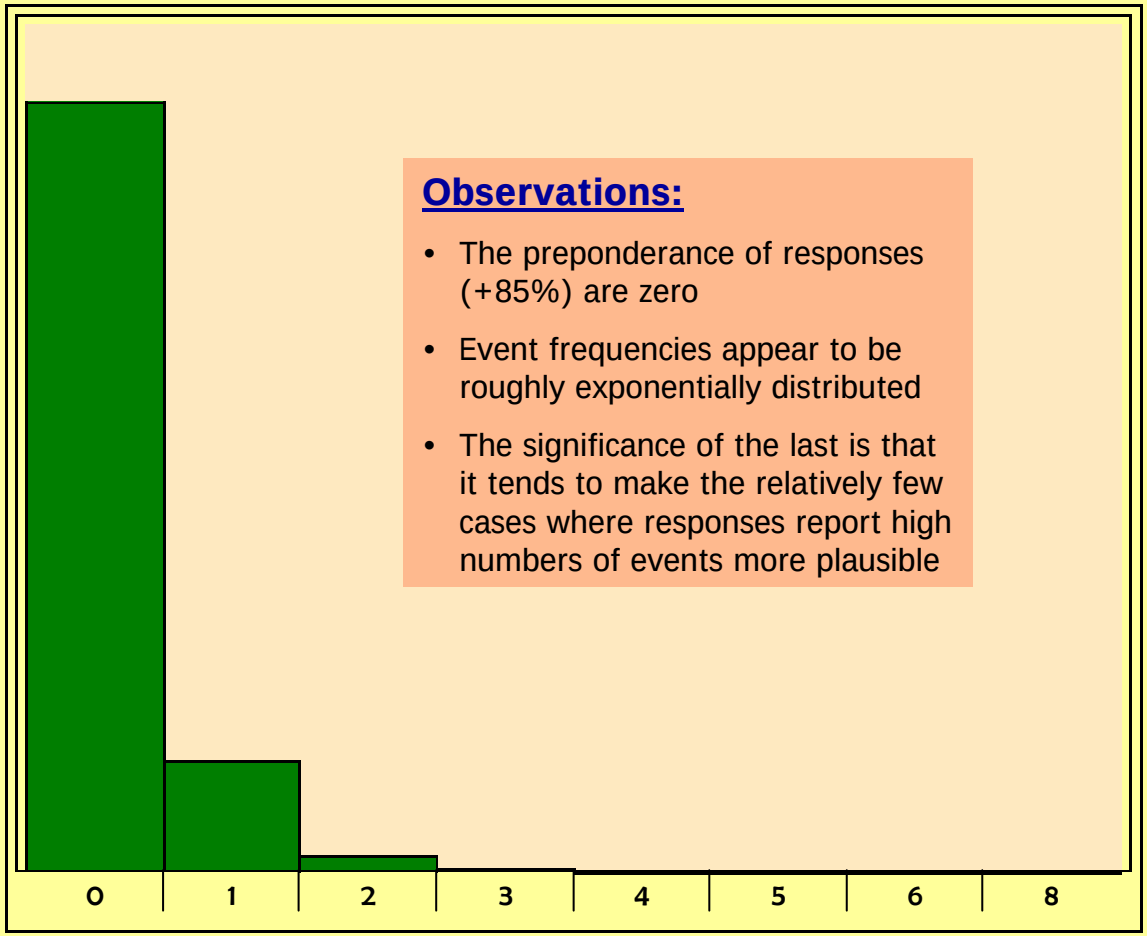
Birdstrike Frequencies

(based on a 60-day interviewee recall period)

Events



Observations:

- The preponderance of responses (+85%) are zero
- Event frequencies appear to be roughly exponentially distributed
- The significance of the last is that it tends to make the relatively few cases where responses report high numbers of events more plausible

Frequencies

Level	Count	Prob
0	16240	0.85717
1	2322	0.12256
2	308	0.01626
3	54	0.00285
4	14	0.00074
5	3	0.00016
6	4	0.00021
8	1	0.00005
Total	18946	1.00000

N Missing 0

8 Levels

Outliers

- Ten outlying values excluded
- 10 (2)
- 12 (2)
- 20 (1)
- 30 (3)
- 33 (1)
- 90 (1)
- The last three (30, 33, 90) almost certainly typos

Note: Based on NAOMS data collected through 2003/12/31

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Birdstrike Data Grouped by Month

Observations:

- Pronounced seasonal pattern
- Great deal of variability in the data
- Calculating rate as reported events per survey interview not operationally meaningful

Note: Based on NAOMS data collected through 2003/12/31

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Rate Denominator Question

- **NAOMS data analyses are rate focused**
- **Aviation safety rates usually calculated**
  - per Hour, or
  - per Leg
- **Which is best suited for birdstrike rate calculations?**

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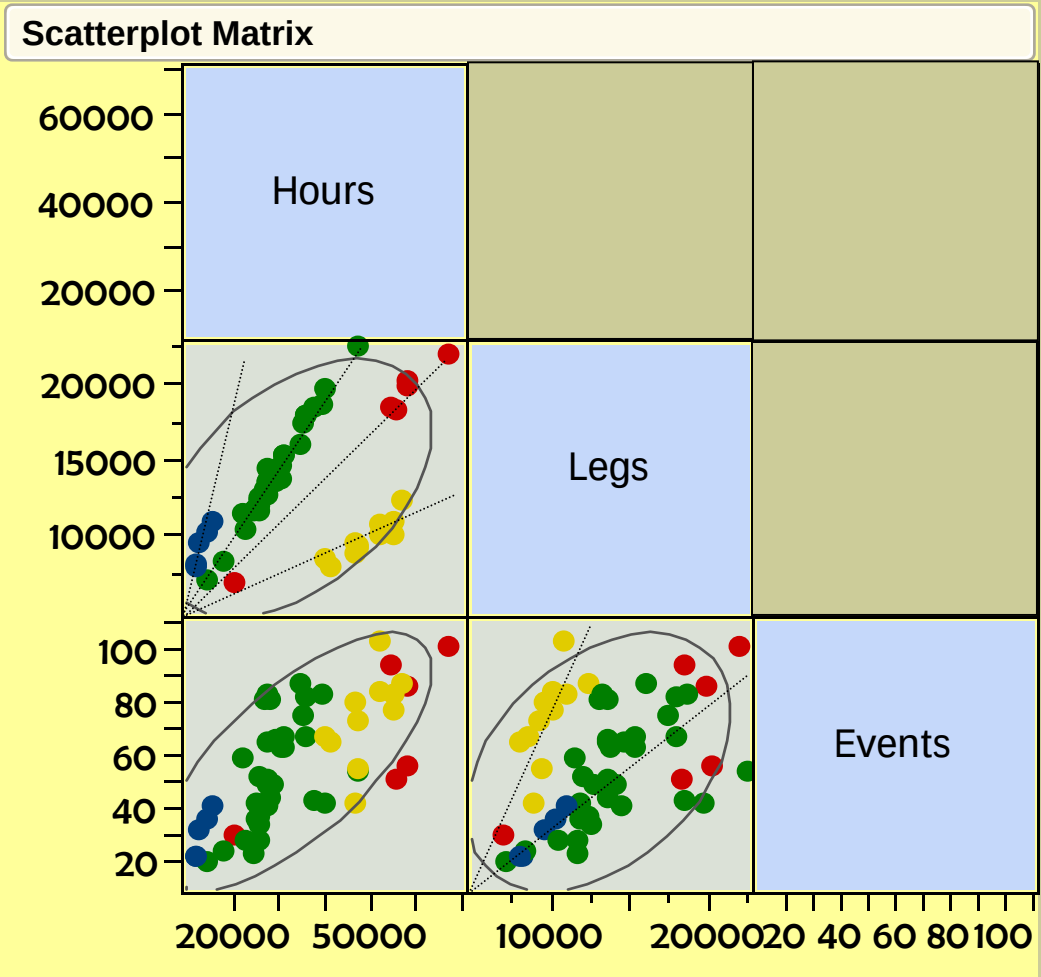
Relationships among Hours, Legs, & Events



Correlations

	Sample Size	Hours	Legs	Events
Sample Size	1.0000	0.9786	0.3310	0.6832
Hours	0.9786	1.0000	0.4544	0.7007
Legs	0.3310	0.4544	1.0000	0.3958
Events	0.6832	0.7007	0.3958	1.0000

Observations:

- Stronger relationship between Hours and Events than between Legs and Events
- Aircraft size a probable complicating factor in relationship between Legs and other variables

Note: Based on NAOMS data collected through 2003/12/31

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Rate Denominator Decision

CONSIDERATIONS:

HOURS

PRO: Stronger statistical relationship with Events than alternate

CON: Bird strikes don't happen in cruise

LEGS

PRO: Good operational reasons to believe that the number of legs flown should be a primary driver of birdstrike frequencies

CON: Statistical relationship with Events weaker than alternative

PRO: Plausible explanation of weaker statistical relationship—complicating effects of average stage length differences among aircraft size categories

- **DECISION: Use Legs as the rate denominator**
  - Operational considerations generally trump statistical correlations when structuring models and equations
  - Statistical correlations can be artifacts or chance phenomena

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Grouping Approach

- **Intended to achieve group event frequencies that**
  - Adhere more closely to a normal (Gaussian) distribution
  - Keep group sizes as small as practical so as not to unnecessarily suppress data variation
  - Allow event frequencies to be modeled in terms of aircraft size, season, and trend
  - Ensure that each group contains at least one reported event
- **Experimental Grouping Approach**
  1. Varies for each question depending on the frequency of nonzero responses
  2. First, group by aircraft size category
  3. Second, further subdivide by month, quarter, semi-year, or year
     1. Depending on the average frequency of nonzero responses per year
     2. >= 400 (monthly); >= 200 (quarterly); >=100 (semi-yearly); >= 50 (yearly)
     3. < 50 nonzero responses, do not subdivide
  4. Mark questions with fewer than 100 nonzero responses per year across all aircraft size categories as untrendable

Note: All groups have fuzzy boundaries because NAOMS recall periods cross seasonal boundaries and because about 15% of respondents fly aircraft in more than one size category.

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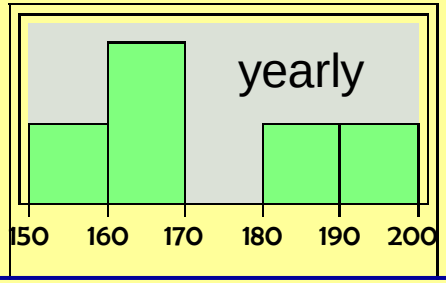
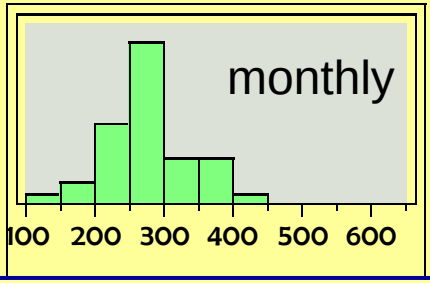
Birdstrike Group Sizes

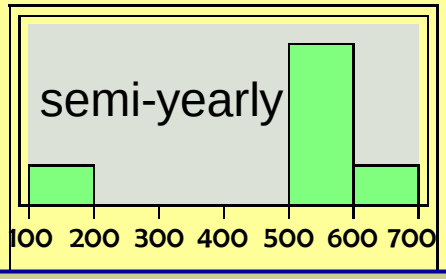
SMT
Small Transport

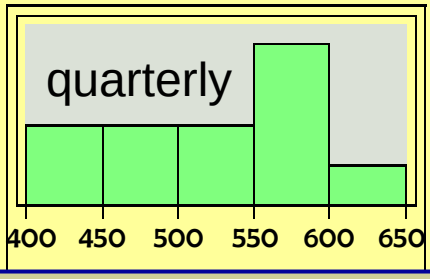




MED
Medium Transport

LRG
Large Transport





WDB
Widebody

Observations:

- Different interview and event reporting frequencies cause each aircraft size group to have a distinct granularity
- Observations or SMT and LRG categories are sparse.

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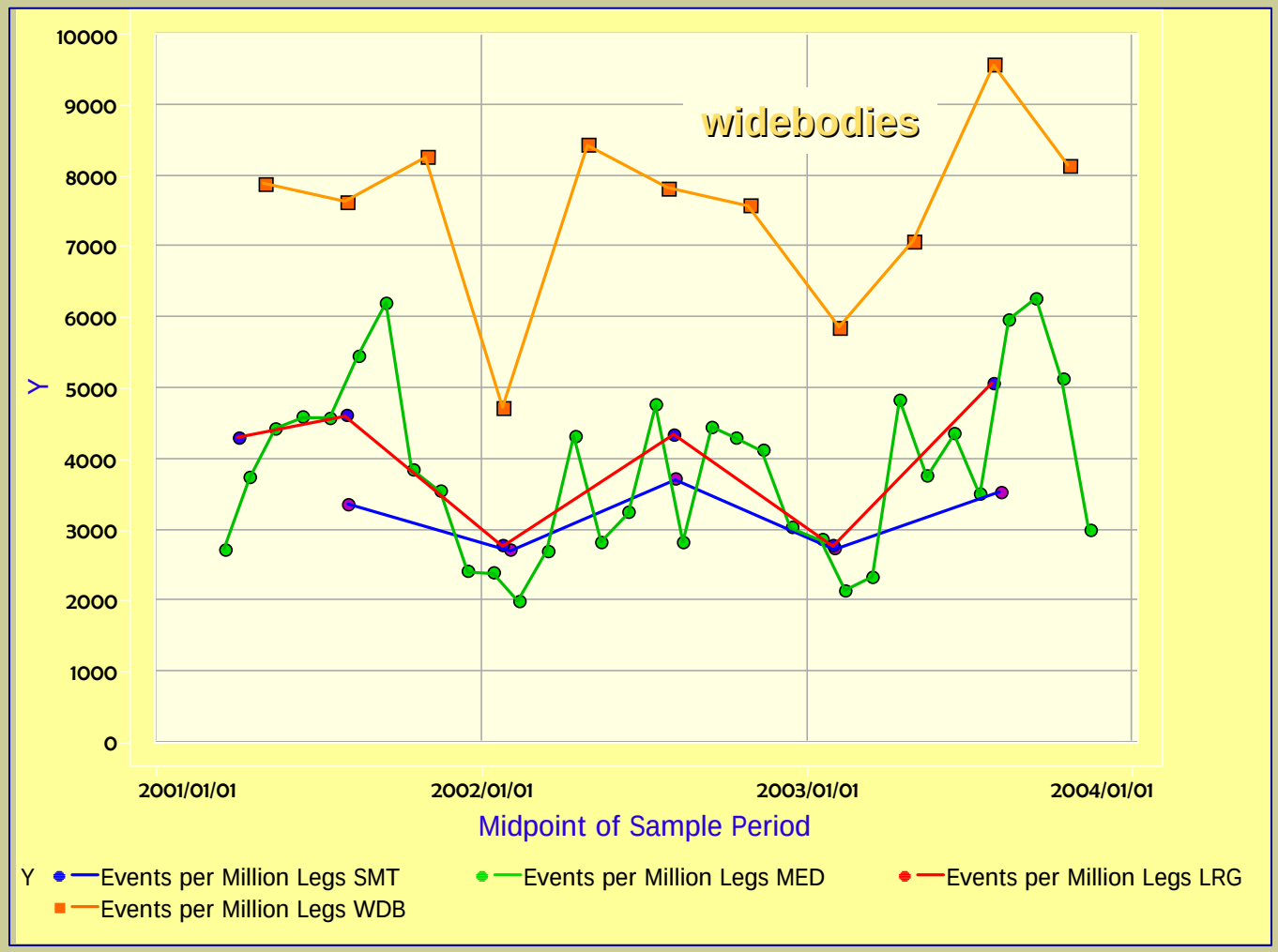
Grouped Birdstrike Rates by Aircraft Size



Observations:

- Widebody rate distinctly higher than rates for other aircraft size category
- Pronounced seasonal pattern evident for all aircraft weight categories

Note: Based on NAOMS data collected through 2003/12/31

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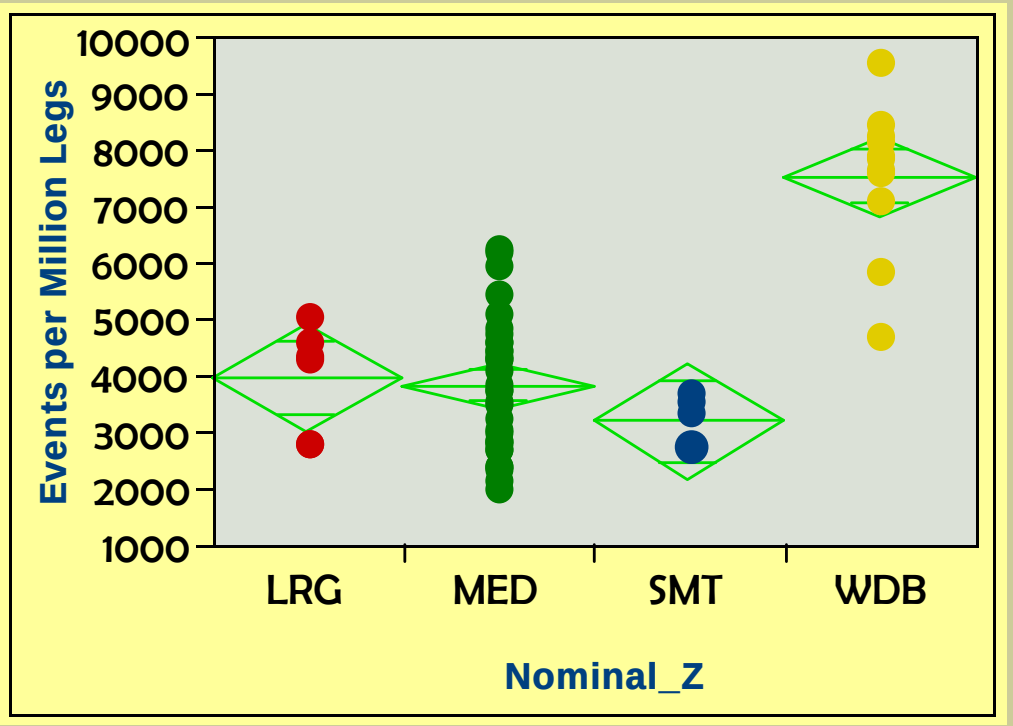
Birdstrike Rate Variation

AIRCRAFT SIZE

NOTE
The green diamonds show the zone where the average is probably located



Observations:

- Widebodies distinctly different from other aircraft size categories
- SMT, MED, and LRG categories are not meaningfully different
- Lot of variation in MED category.

Summary of Fit

Rsquare	0.652036
Adj Rsquare	0.631567
Root Mean Square Error	1150.77
Mean of Response	4536.184
Observations (or Sum Wgts)	55

Means for Oneway Anova

Level	Number	Mean	Std Error
LRG	6	3977.47	469.80
MED	33	3835.09	200.32
SMT	5	3211.10	514.64
WDB	11	7546.53	346.97

Note: Based on NAOMS data collected through 2003/12/31

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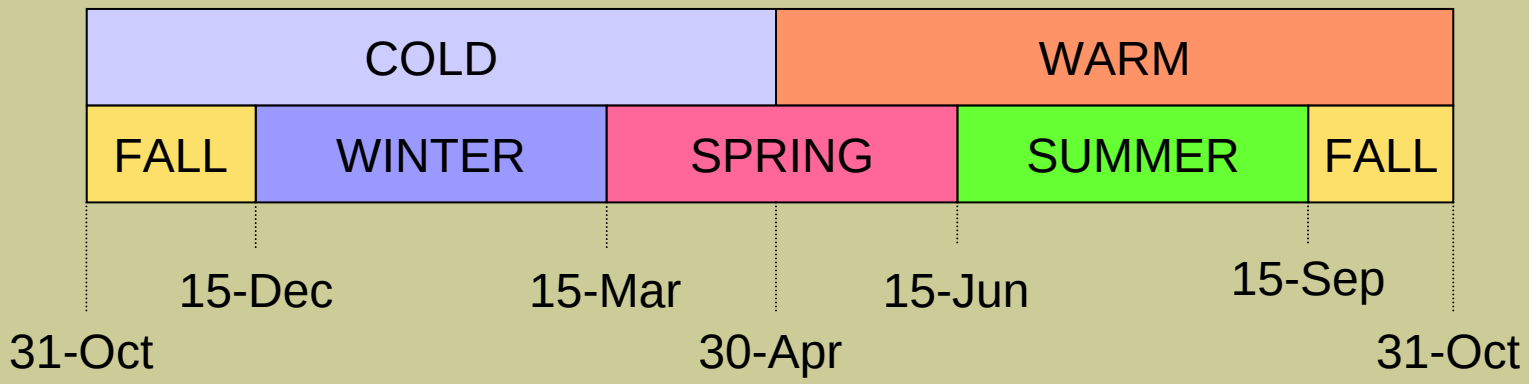
Seasonal Subdivisions



Note: Periods end at 23:59 pm on the dates shown.

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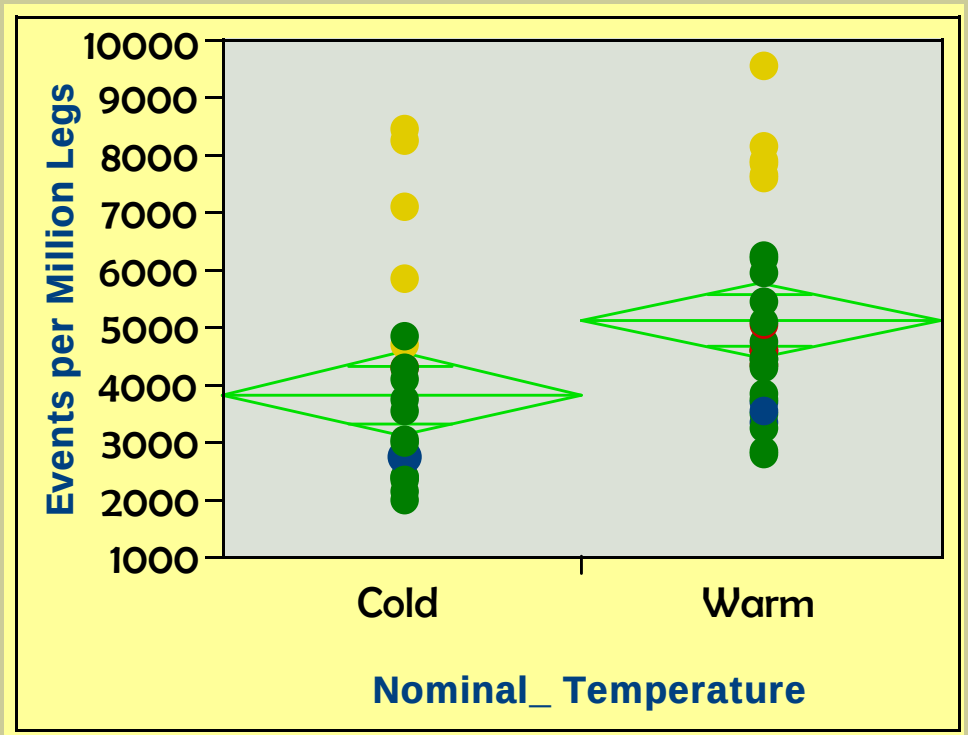
Birdstrike Rate Variation

TEMPERATURE

NOTE
The green diamonds show the zone where the average is probably located



Observations:

- Rates vary between Cold and Warm periods
- Difference not profound.

Summary of Fit

Rsquare	0.117721
Adj Rsquare	0.101074
Root Mean Square Error	1797.511
Mean of Response	4536.184
Observations (or Sum Wgts)	55

Means for Oneway Anova

Level	Number	Mean	Std Error
Cold	25	3830.12	359.50
Warm	30	5124.57	328.18

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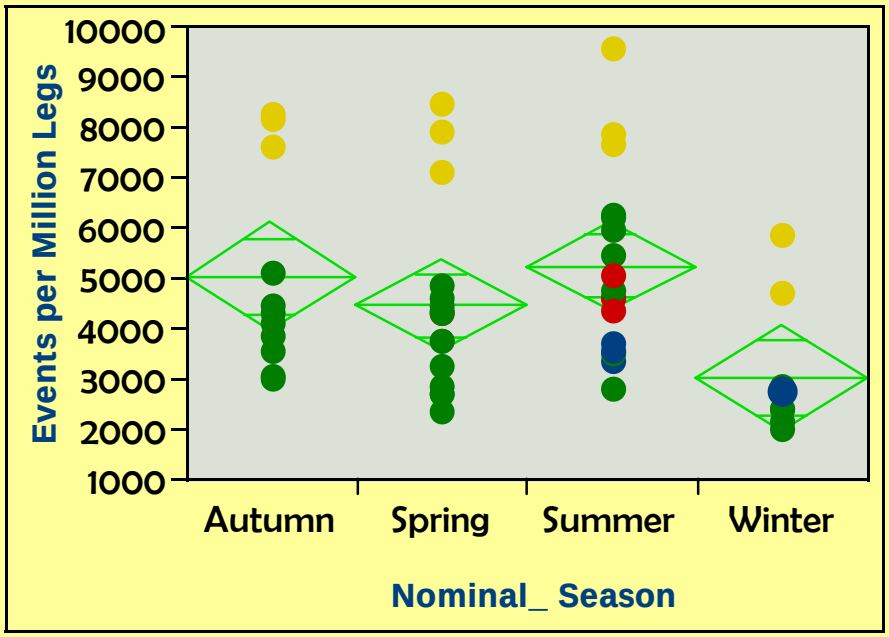
Birdstrike Rate Variation

SEASON

NOTE
The green diamonds show the zone where the average is probably located



Observations:

- Rates vary only slightly among Spring, Summer, and Autumn
- Average winter rate distinctly lower.
- Somewhat more explanatory power than just the Cold/Warm distinction.

Summary of Fit

Rsquare	0.186839
Adj Rsquare	0.139006
Root Mean Square Error	1759.178
Mean of Response	4536.184
Observations (or Sum Wgts)	55

Means for Oneway Anova

Level	Number	Mean	Std Error
Autumn	11	5035.73	530.41
Spring	16	4471.21	439.79
Summer	17	5246.93	426.66
Winter	11	3032.73	530.41

Note: Based on NAOMS data collected through 2003/12/31

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Initial Model

The *model* is the equation structure that is expected to capture the relationship between the dependent variable (the Event Rate) and explanatory variables like Trends, Aircraft Size, and Season.

$$\frac{Birdstrikes}{Leg} = \text{BaseRate} \bullet \text{SecularTrend}^{Time} \bullet \text{WDBadj}^{WidebodyPct} \bullet \text{ColdAdj}^{ColdPct} \bullet \text{WinterAdj}^{WinterPct}$$

The practical interpretation of this model is as follows:

1. Establish the birdstrike base rate per flight leg in the base period
2. Adjust a percentage up or down for each following year (long-term trend)
3. Adjust a further percentage up or down if the aircraft is a widebody
4. Adjust a further percentage up or down if the period is cold
5. Adjust a further percentage up or down if it is winter (very cold).

All percentage adjustments are multiplicative (i.e., they compound).

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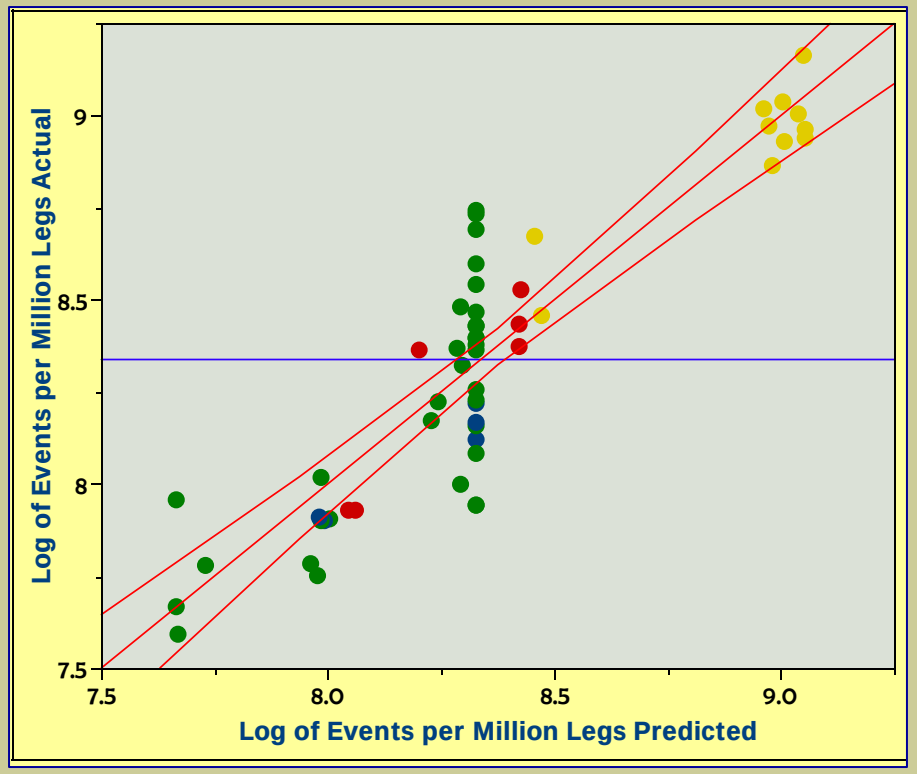
Results of Model Analysis

The rate data were logarithmically transformed and then analyzed using standard regression techniques.



Note: Based on NAOMS data collected through 2003/12/31

Summary of Fit

RSquare	0.810704
RSquare Adj	0.803423
Root Mean Square Error	0.177291
Mean of Response	8.339799
Observations (or Sum Wgts)	55

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	8.3252386	0.031627	263.23	<.0001
Legs_WDB_pct	0.7590829	0.063441	11.97	<.0001
Winter Pct	-0.701932	0.079508	-8.83	<.0001

Observations:

- Eighty percent of statistical rate variation explained
- All retained parameters highly significant from both operational and statistical perspectives
- Significant amount of variability involving MED sized aircraft remains unexplained.

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No Long-term Trend Found

An alternate model that was discarded:

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	7.8019333	2.996875	2.60	0.0121
MidPoint	1.799e-10	9.63e-10	0.19	0.8525
Legs_WDB_pct	0.7582259	0.063262	11.99	<.0001
Season Cold Pct	-0.1598	0.107	-1.49	0.1416
Winter Pct	-0.525074	0.14185	-3.70	0.0005

Note: Based on NAOMS data collected through 2003/12/31

Observations:

- When the MidPoint time secular long-term parameter was included, it was not found to be statistically significant
- This does not mean that a long-term trend does not exist
- It does mean that the random data variation, seasonal affects, and other factors made it too difficult to confidently measure a trend with less than three years data using this approach.

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Final Model

Structural Model

$$\frac{Birdstrikes}{Legs} = \text{BaseRate} \bullet \text{WDBadj}^{WidebodyPct} \bullet \text{WinterAdj}^{WinterPct}$$

Parameterized Model

$$\frac{Birdstrikes}{Legs} = 4126.7 \bullet 2.14^{WidebodyPct} \bullet 0.496^{WinterPct} / 1000000$$

Example: Estimated Birdstrikes by Widebodies during CY03

Season	Legs*	Formula	Result
Winter	148,000	**148,000 x 4126.7 x 2.14 x 0.496 / 1,000,000**	**650**
Spring	130,000	**130,000 x 4126.7 x 2.14 / 1,000,000**	**1,145**
Summer	89,000	**89,000 x 4126.7 x 2.14 / 1,000,000**	**788**
Autumn	118,000	**118,000 x 4126.7 x 2.14 / 1,000,000**	**1,043**
TOTAL	**485,428**		**3,626**

Note: Based on NAOMS data collected through 2003/12/31 * Approximations derived from BTS data.

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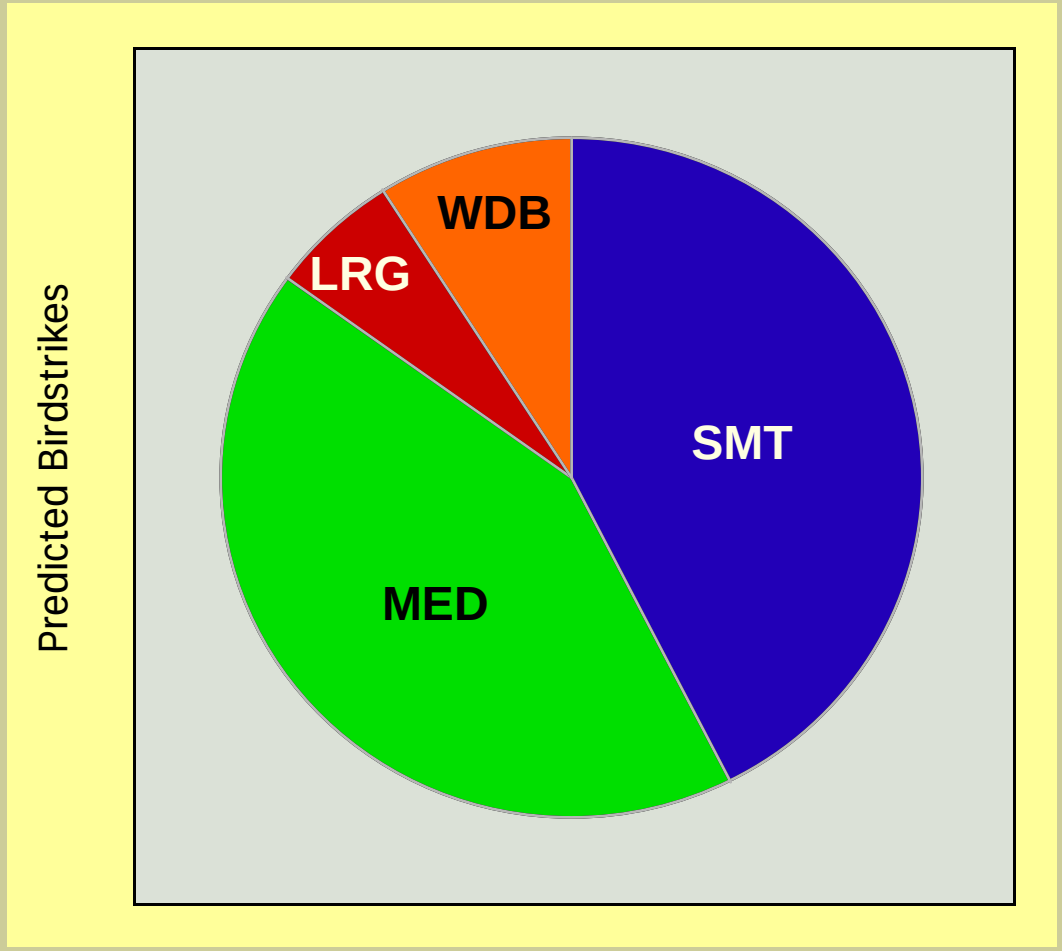
Projection to All Aircraft Sizes



Aircraft Size	Predicted Birdstrikes	Pct
SMT	17,175	43%
MED	17,146	42%
LRG	2,475	6%
WDB	3,626	9%
Total	**40,422**	**100%**

Note: Based on NAOMS data collected through 2003/12/31

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Summary

1. **Approach**
   - A workable approach to modeling and trending NAOMS data was described
   - The process is visually rich and statistically robust
   - It can be implemented with standard statistical tools.
2. **Internal consistency and plausibility of NAOMS birdstrike data**
   - Consistent seasonal cycles are evident in birdstrike data
   - The raw data appeared coherent and did not have any obvious discontinuities.
3. **Fuller understanding of birdstrike events**
   - A model was developed that explained 80% of birdstrike rate variability
   - The model is operationally plausible
   - It can be used to predict future birdstrike event rates
   - After external validation.

Next Step: Validation against external data sources.

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