

**Supplementary material**

## Appendix 1

**Table A1.** Species life-history attributes considered as potential explanatory variables for phenological responses.

Species/Trait	Trophic Level	Niche Breadth	Soaring	Migration Distance	Migration Strategy	Population Size	Generation Time	Population Trend
American Kestrel	a	11	no	short	partial	2,200,000	5.7	decreasing
Bald Eagle	a	11	yes	short	partial	300,000	17.2	increasing
Broad-winged Hawk	a	3	yes	long	complete	1,700,000	9.3	increasing
Cooper's Hawk	b	4	no	short	partial	700,000	7.2	increasing
Golden Eagle	a	9	yes	short	partial	130,000	17.3	stable
Merlin	b	6	no	long	complete	1,300,000	5.7	increasing
Northern Goshawk	b	4	no	short	partial	200,000	7.0	stable
Northern Harrier	a	7	no	short	partial	700,000	7.8	decreasing
Osprey	a	15	no	long	complete	200,000	11.6	increasing
Peregrine Falcon	b	16	no	long	partial	140,000	6.8	stable
Red-tailed Hawk	a	11	yes	short	partial	2,000,000	9.2	increasing
Red-shouldered Hawk	a	3	yes	short	partial	1,100,000	8.3	increasing
Rough-legged Hawk	a	5	yes	long	complete	300,000	10.0	stable
Sharp-shinned hawk	b	9	no	short	partial	500,000	7.2	stable
Turkey Vulture	a	9	yes	short	partial	5,100,000	9.9	increasing

**Table A2** - OLS regression slopes,  $r^2$ , and significance for each species and arrival percentile by site. Significance is coded: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Species/Site	Braddock Bay			Derby Hill			Niagara Point		
	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>
American Kestrel	0.30*, $r^2=0.18$	0.22, $r^2=0.10$	0.29*, $r^2=0.18$	0.12, $r^2=0.06$	0.26*, $r^2=0.15$	0.32**, $r^2=0.23$	0.08, $r^2=0.01$	0.22, $r^2=0.06$	0.06, $r^2=0.01$
Bald Eagle	-	0.52**, $r^2=0.26$	-	-	1.06***, $r^2=0.57$	-	-	-0.46, $r^2=0.12$	-
Broad-winged Hawk	-0.18*, $r^2=0.16$	-0.21*, $r^2=0.16$	-0.28*, $r^2=0.15$	-0.14, $r^2=0.21^*$	-0.14*, $r^2=0.17$	-0.15, $r^2=0.09$	-0.06, $r^2=0.01$	-0.11, $r^2=0.03$	-0.11, $r^2=0.06$
Cooper's Hawk	0.04, $r^2=0.00$	0.05, $r^2=0.00$	0.01‡, $r^2=0.00$	-0.15, $r^2=0.10$	-0.11, $r^2=0.06$	-0.06, $r^2=0.02$	-0.47***, $r^2=0.46$	-0.34*, $r^2=0.27$	0.04, $r^2=0.01$
Golden Eagle	-	0.00, $r^2=0.00$	-	-	-0.15, $r^2=0.04$	-	-	0.69, $r^2=0.09$	-
Merlin	-	-0.11†, $r^2=0.03$	-	-	-0.07, $r^2=0.02$	-	-	-0.11, $r^2=0.04$	-
Northern Goshawk	-	0.57***, $r^2=0.39$	-	-	0.21, $r^2=0.05$	-	-	-0.3, $r^2=0.04$	-
Northern Harrier	0.03, $r^2=0.00$	0.14, $r^2=0.04$	0.02, $r^2=0.00$	0.07, $r^2=0.02$	0.17‡*, $r^2=0.12$	-0.02‡, $r^2=0.00$	-0.16, $r^2=0.03$	-0.06, $r^2=0.00$	0.01, $r^2=0.00$
Osprey	-0.35*, $r^2=0.22$	-0.27‡*, $r^2=0.15$	-0.17‡, $r^2=0.11$	-0.18*, $r^2=0.14$	-0.03, $r^2=0.00$	-0.03, $r^2=0.00$	-0.18, $r^2=0.14$	-0.23, $r^2=0.17$	-0.18†, $r^2=0.16$
Rough-legged Hawk	-0.12, $r^2=0.01$	-0.13, $r^2=0.01$	-0.12, $r^2=0.02$	-0.04, $r^2=0.00$	-0.15, $r^2=0.03$	-0.13, $r^2=0.02$	-0.11†, $r^2=0.01$	-0.25†, $r^2=0.04$	-0.40, $r^2=0.11$
Red-shouldered Hawk	0.05, $r^2=0.01$	0.05, $r^2=0.01$	0.08, $r^2=0.02$	-0.01, $r^2=0.00$	-0.02, $r^2=0.00$	-0.03, $r^2=0.00$	-0.14, $r^2=0.04$	-0.22, $r^2=0.10$	-0.09, $r^2=0.02$
Red-tailed Hawk	0.27*, $r^2=0.15$	0.25, $r^2=0.09$	0.13, $r^2=0.03$	0.20, $r^2=0.12$	0.22, $r^2=0.11$	0.15, $r^2=0.09$	0.01, $r^2=0.00$	0.01, $r^2=0.00$	-0.11*, $r^2=0.30$
Sharp-shinned Hawk	-0.24, $r^2=0.10$	-0.22, $r^2=0.10$	-0.15‡*, $r^2=0.13$	-0.19*, $r^2=0.10$	-0.07, $r^2=0.02$	-0.01, $r^2=0.04$	-0.30, $r^2=0.12$	-0.16, $r^2=0.04$	-0.22, $r^2=0.12$
Turkey Vulture	-0.12, $r^2=0.09$	-0.12, $r^2=0.08$	-0.07, $r^2=0.01$	-0.13, $r^2=0.16$	-0.15*, $r^2=0.17$	-0.15*, $r^2=0.11$	-0.21, $r^2=0.14$	-0.19, $r^2=0.13$	-0.37***, $r^2=0.49$

† Pre-whitened to correct for significant autocorrelation; ‡ removed linear trends correlating to SOI or NAOI

**Table A3 cont.** - OLS regression slopes,  $r^2$ , and significance for each species and arrival percentile by site. Significance is coded: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Species/Site	Port Huron			Thunder Cape			Whitefish Point		
	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>
American Kestrel	-	-0.65*, $r^2=0.25$	-	-	-0.64*, $r^2=0.27$	-	-0.06, $r^2=0.01$	-0.07, $r^2=0.02$	-0.21*, $r^2=0.14$
Bald Eagle	-	-	-	-	-	-	-	0.28*, $r^2=0.17$	-
Broad-winged Hawk	0.12, $r^2=0.05$	-0.21, $r^2=0.00$	-0.14, $r^2=0.05$	-	-	-	-0.07, $r^2=0.03$	-0.22, $r^2=0.11$	-0.19, $r^2=0.06$
Cooper's Hawk	-0.57, $r^2=0.20$	-1.02***, $r^2=0.55$	-0.48*, $r^2=0.24$	-	-	-	-0.15, $r^2=0.04$	0.13‡, $r^2=0.04$	0.19‡, $r^2=0.08$
Golden Eagle	-	-	-	-	-	-	-	0.13, $r^2=0.01$	-
Merlin	-	-	-	-	-0.17, $r^2=0.06$	-	-	-0.09, $r^2=0.02$	-
Northern Goshawk	-	-	-	-	-	-	-	0.32*, $r^2=0.16$	-
Northern Harrier	-0.19, $r^2=0.01$	-0.29, $r^2=0.05$	-0.12, $r^2=0.05$	-	-	-	-0.17, $r^2=0.08$	-0.17, $r^2=0.06$	-0.23, $r^2=0.10$
Osprey	-	-	-	-	-	-	-0.05, $r^2=0.02$	-0.13, $r^2=0.05$	-0.24‡*, $r^2=0.13$
Rough-legged Hawk	-0.73*, $r^2=0.13$	-0.78*, $r^2=0.17$	-0.77*, $r^2=0.28$	-	-	-	-0.31**, $r^2=0.25$	-0.33**, $r^2=0.25$	-0.12, $r^2=0.03$
Red-shouldered Hawk	-0.22, $r^2=0.05$	-0.30, $r^2=0.05$	-0.54, $r^2=0.01$	-	-	-	0.13, $r^2=0.05$	0.38**, $r^2=0.19$	0.07, $r^2=0.00$
Red-tailed Hawk	-0.47, $r^2=0.06$	-1.11***, $r^2=0.57$	-0.53‡*, $r^2=0.21$	-	-	-	-0.14, $r^2=0.07$	-0.29*, $r^2=0.18$	-0.16, $r^2=0.03$
Sharp-shinned Hawk	-0.83**, $r^2=0.39$	-0.38*, $r^2=0.23$	-0.12, $r^2=0.04$	-0.26*, $r^2=0.20$	-0.21*, $r^2=0.15$	0.05, $r^2=0.05$	-0.16, $r^2=0.07$	-0.15‡*, $r^2=0.08$	-0.22*, $r^2=0.22$
Turkey Vulture	-0.59*, $r^2=0.34$	-0.67**, $r^2=0.44$	-0.56*, $r^2=0.23$	-	-	-	-0.47***, $r^2=0.52$	-0.49***, $r^2=0.44$	-0.16, $r^2=0.05$

‡ Pre-whitened to correct for significant autocorrelation; † removed linear trends correlating to SOI or NAOI

**Table A3.** Marginal mean changes in spring arrival dates ( $\Delta$  days/year) and standard error for each species after accounting for interspecific variability, geography, and random effects by means of mixed models. Changes in each migration percentile are presented for the 10 most abundant species ( $> 20$  in all years), while changes in median arrival dates are presented for rare species. Phenological responses significantly different than zero are in bold ( $\alpha = 0.05$ )

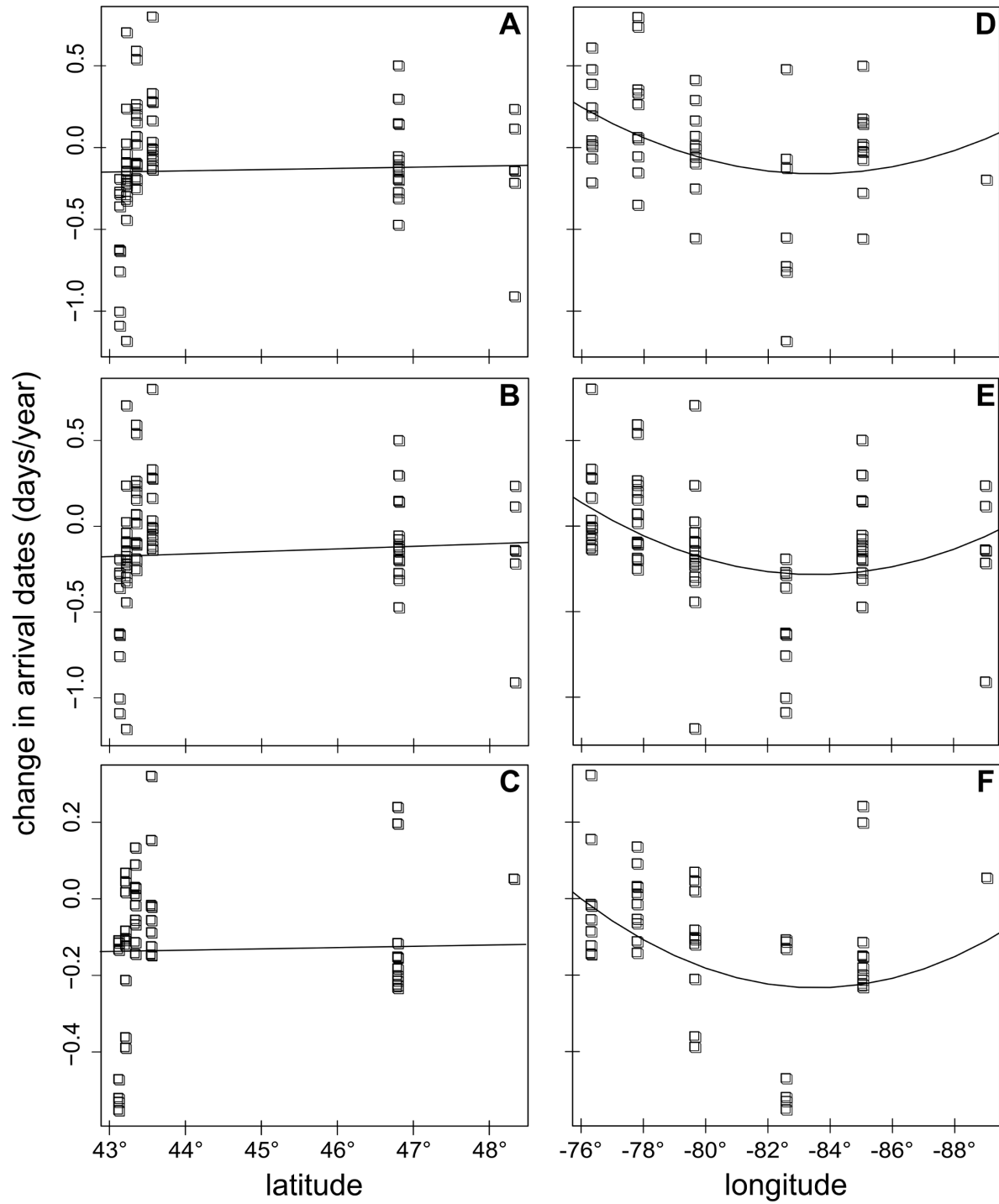
Species	25 <sup>th</sup>	50 <sup>th</sup>	75 <sup>th</sup>
American Kestrel	0.11 (0.08)	0.07 (0.16)	0.05 (0.11)
Bald Eagle	-	0.25 (0.21)	-
Broad-winged Hawk	<b>-0.13 (0.06)</b>	<b>-0.25 (0.13)</b>	<b>-0.12 (0.03)</b>
Cooper's Hawk	<b>-0.32 (0.11)</b>	-0.25 (0.20)	-0.06 (0.11)
Golden Eagle	-	0.08 (0.17)	-
Merlin	-	<b>-0.18 (0.02)</b>	-
Northern Goshawk	-	0.10 (0.19)	-
Northern Harrier	<b>-0.15 (0.05)</b>	-0.04 (0.07)	-0.06 (0.05)
Osprey	<b>-0.33 (0.06)</b>	<b>-0.26 (0.05)</b>	<b>-0.16 (0.04)</b>
Rough-legged Hawk	<b>-0.32 (0.15)</b>	<b>-0.33 (0.12)</b>	<b>-0.24 (0.07)</b>
Red-shouldered Hawk	-0.10 (0.06)	0.00 (0.14)	-0.06 (0.11)
Red-tailed Hawk	-0.09 (0.13)	-0.18 (0.24)	-0.10 (0.12)
Sharp-shinned Hawk	<b>-0.39 (0.10)</b>	<b>-0.19 (0.05)</b>	<b>-0.12 (0.04)</b>
Turkey Vulture	<b>-0.36 (0.10)</b>	<b>-0.32 (0.11)</b>	<b>-0.26 (0.09)</b>

**Table A4** - OLS regression slopes between arrival date and the Southern Oscillation Index, as a proxy for ENSO activity. Analyzed migration percentiles are shown for species with a significant correlation ( $\alpha = 0.05$ ) at least one site. Sites are: BB, Braddock Bay; DH, Derby Hill; NP, Niagara Peninsula; PH, Port Huron; TC, Thunder Cape; WP, Whitefish Point. Dashes indicate non-significant correlations while "na" indicates that a species/percentile was not analyzed at a given site.  $R^2$  coefficients denoted in parenthesis and significance is coded: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Species/Site		BB	DH	NP	PH	TC	WP
American Kestrel	25 <sup>th</sup>	-	-	-	na	na	-
	50 <sup>th</sup>	-	-	-	-	-2.5** (0.32)	-
	75 <sup>th</sup>	-	-	-	na	na	-1.9* (0.18)
Cooper's Hawk	25 <sup>th</sup>	-	-	-1.3** (0.31)	-	na	-
	50 <sup>th</sup>	-	-	-	-	na	-1.8* (0.16)
	75 <sup>th</sup>	-	-	-	-	na	-
Osprey	25 <sup>th</sup>	-1.8* (0.15)	-	-	na	na	-1.8* (0.15)
	50 <sup>th</sup>	-1.4* (0.15)	-	-	na	na	-
	75 <sup>th</sup>	-1.6*** (0.26)	-	-0.7* (0.22)	na	na	-
Red-tailed Hawk	25 <sup>th</sup>	-	-	-	-	na	-
	50 <sup>th</sup>	-	-	-2.1** (0.16)	-	na	-
	75 <sup>th</sup>	-	-	-	-	na	-
Sharp-shinned Hawk	25 <sup>th</sup>	-	-	-	-	-	-
	50 <sup>th</sup>	-	-	-	-	-1.1* (0.31)	-
	75 <sup>th</sup>	-	-	-	-	-	-
Turkey Vulture	25 <sup>th</sup>	-	-	-	-	na	-
	50 <sup>th</sup>	-	-	-0.8* (0.26)	-	na	-
	75 <sup>th</sup>	-	-	-	-	na	-

**Table A5-** OLS regression slopes between arrival date and the North Atlantic Oscillation Index. Analyzed migration percentiles are shown for species with a significant correlation ( $\alpha = 0.05$ ) at least one site. Sites are: BB, Braddock Bay; DH, Derby Hill; NP, Niagara Peninsula; PH, Port Huron; TC, Thunder Cape; WP, Whitefish Point. Dashes indicate non-significant correlations while "na" indicates that a species/percentile was not analyzed at a given site. R<sup>2</sup> coefficients denoted in parenthesis and significance is coded: \* p<0.05, \*\*p<0.01, \*\*\* p<0.001.

Species/Site		BB	DH	NP	PH	TC	WP
American Kestrel	25 <sup>th</sup>	-	-	-	na	na	-
	50 <sup>th</sup>	-	-	-	-	1.5* (0.23)	-
	75 <sup>th</sup>	-	-	-	na	na	-
Bald Eagle	25 <sup>th</sup>	-	-	-	na	-	-1.2 (0.21)
Cooper's Hawk	25 <sup>th</sup>	-	-	-	-	na	-
	50 <sup>th</sup>	-	-	-	-	na	1.3 (0.18)
	75 <sup>th</sup>	0.9* (0.15)	-	-	-	na	-
Golden Eagle	50 <sup>th</sup>	-	-	-	-	-	-1.7* (0.16)
Northern Harrier	25 <sup>th</sup>	-	-	-	-	na	1.1* (0.20)
	50 <sup>th</sup>	-	-	-	-	na	-
	75 <sup>th</sup>	-	-	-	-	na	-
Osprey	25 <sup>th</sup>	-	0.9* (0.15)	-	na	na	-
	50 <sup>th</sup>	1.3** (0.27)	-	-	na	na	-
	75 <sup>th</sup>	0.8* (0.16)	-	-	na	na	1.1* (0.15)
Rough-legged Hawk	25 <sup>th</sup>	-	-	-	na	na	1.1* (0.21)
	50 <sup>th</sup>	-	-	-	-	na	-
	75 <sup>th</sup>	-	-	-	na	na	-
Red-tailed Hawk	25 <sup>th</sup>	-	-	-	-	na	1.0* (0.21)
	50 <sup>th</sup>	-	-	-	-	na	1.3* (0.22)
	75 <sup>th</sup>	-	-	-	-	na	1.3* (0.15)
Sharp-shinned Hawk	25 <sup>th</sup>	-	-	-	-	-	1.0* (0.16)
	50 <sup>th</sup>	-	-	-	0.9* (0.23)	-	-
	75 <sup>th</sup>	0.8* (0.15)	-	-	-	-	-
Turkey Vulture	25 <sup>th</sup>	-	-	-	-	na	1.1* (0.17)
	50 <sup>th</sup>	-	-	-	-	-	1.3* (0.18)
	75 <sup>th</sup>	-	-	-	-	na	-



**Figure A1.** Geographic trends in phenological responses ( $\Delta$  days/year OLS slopes) of the 25<sup>th</sup> (A,D), 50<sup>th</sup> (B, E) and 75<sup>th</sup> (C, F) migration percentiles as identified by mixed model analysis.