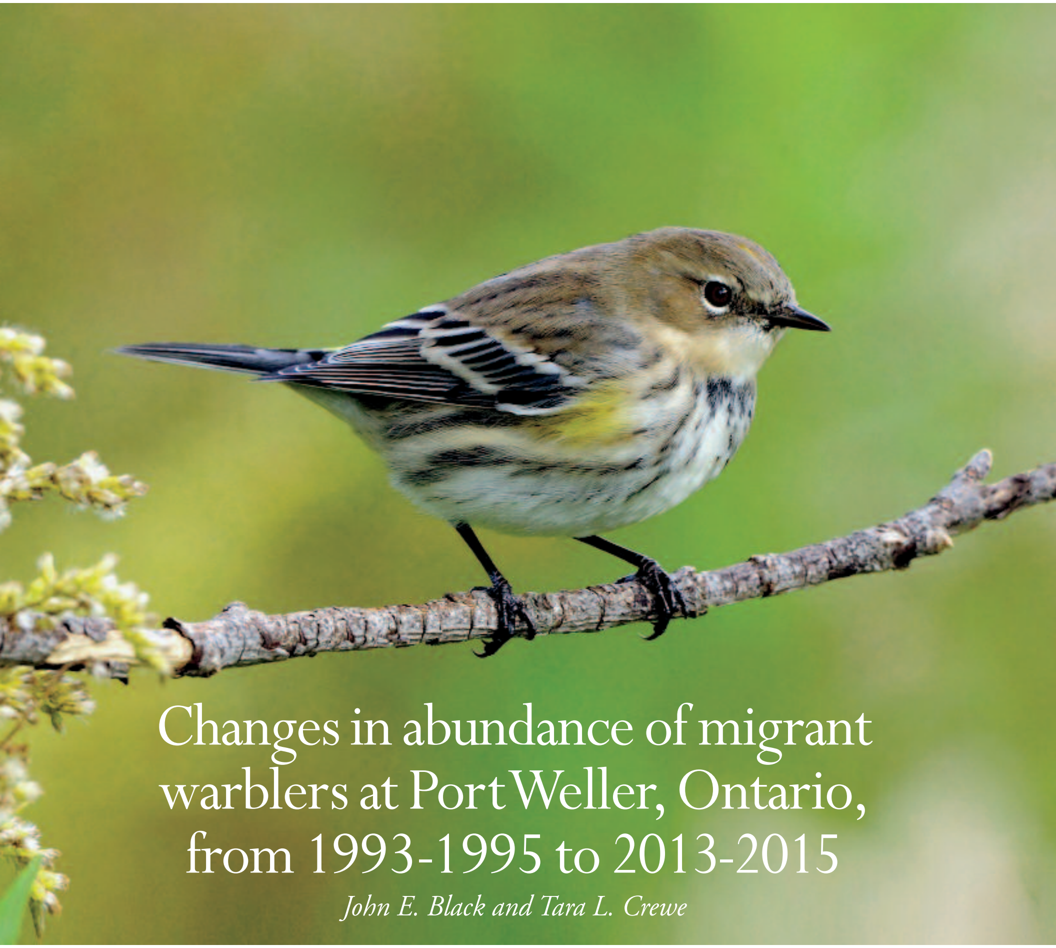


Changes in abundance of migrant warblers at Port Weller, Ontario, from 1993-1995 to 2013-2015

John E. Black and Tara L. Crewe

Yellow-rumped Warbler. *Photo: Homer Caliwag*

Introduction

Testing how bird populations have changed over time is a primary goal of many long-term monitoring programs, including the Breeding Bird Surveys (BBS)(Environment Canada 2014), Christmas Bird Counts (Link *et al.* 2008), Canadian Migration Monitoring Programs (Crewe *et al.* 2008), Niagara Peninsula Hawkwatch (Hawk Migration Association of North America) and Breeding Bird Atlases (Cadman *et al.* 2007). This testing is typically accomplished by counting the number of birds detected during breeding, on the wintering grounds, or passing a particular geographic location during migration. Counts collected in the same way over time can then be used to assess if and how the count population has changed.

Construction of the fourth Welland Canal began in 1913 and was completed in 1932. As part of the construction, two piers stretching 1.3 km into Lake Ontario were built to provide a harbour at the proposed northern end of the canal, where a natural harbour did not exist. The small community that grew up around the piers was named Port Weller after John Weller, an engineer on the first Welland Canal. Known as the Port Weller West (PWW) and Port Weller East (PWE) piers, they have long been known as a migrant stopover site and thus a good spot to observe birds during migration.

From 1993 to 1997, a study was conducted to estimate the abundance and diversity of bird species using the Port Weller piers during spring migration. This was an attractive study for local birders because it allowed them access to PWW, which is not open to the public. Each morning during the month of May, observers recorded the number of birds (primarily passerine migrants) seen and/or heard on PWW and PWE. Results from that original study were summarized in Black and Roy (2010). More than 13,000 individuals of 97 species were observed. The species with the most individuals observed were Yellow-rumped Warbler (*Setophaga coronata*), Yellow Warbler (*Setophaga petechia*) and American Goldfinch (*Spinus tristis*), each with over 1,000 sightings over the five-year period.In order to explore whether the number of individual migrants at Port Weller has changed over time, we repeated the 1993-1997 count methods in 2013-2015 at PWW. While sampling every 20 years cannot provide information on the cause or pattern of change in the count population over time, it can be used to gauge whether mean counts or species assemblage has changed between time periods, as is done with breeding bird data collected by breeding bird atlases over a larger number of sites (Bird Studies Canada *et al.* 2006).

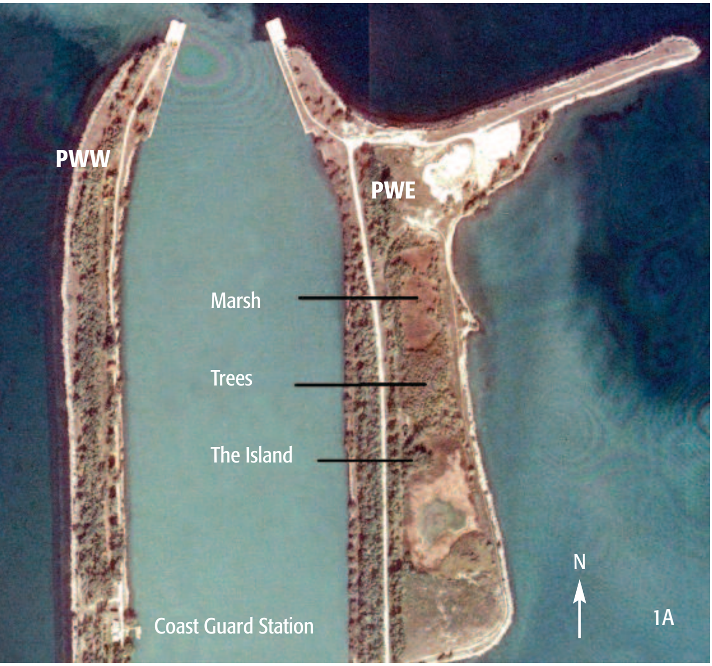
In this article, we discuss only Wood Warblers (hereafter "warblers"). We compare the 1993-1995 and 2013-2015 counts collected at PWW to examine whether there is evidence of a change in the number of individuals by and across warbler species detected using the pier over the past 20 years, and whether the direction of change corresponds with trends in these species detected over similar time periods using alternative bird surveys. We also compare the 1993-1997 counts at PWW with counts collected during the same time period at nearby PWE for evidence of habitat effects on stopover probability, and with counts collected at Long Point, to determine whether annual fluctuations in counts corresponded among sites.

Methods

Count Site Descriptions

Port Weller West Pier

The count area at PWW extends 750 m northward from a Canadian Coast Guard Station to the end of the pier; the station is located at about the midway point of the pier (Figures 1A and 1B). The east side of the PWW count area contains two passageways: a dirt and



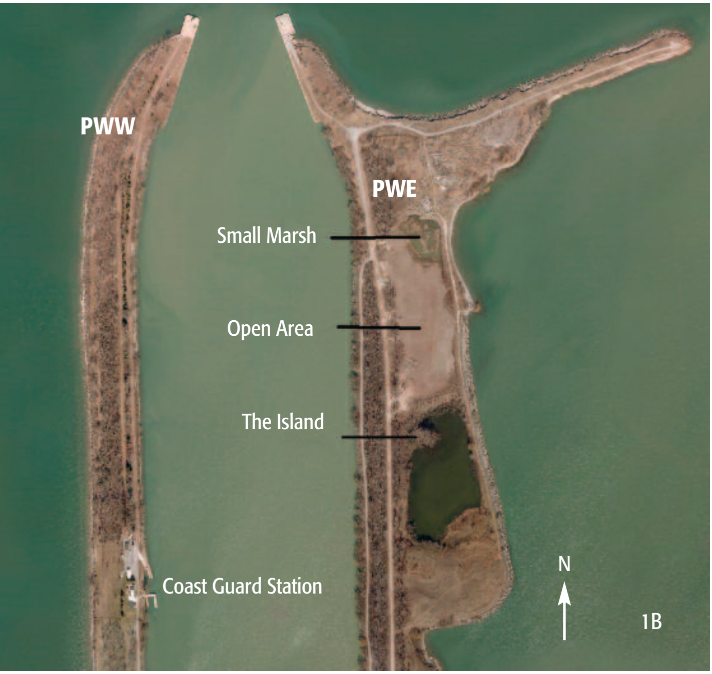


Figure 1A. The Piers, September 1995.

Figure 1B. The Piers, April 2010.

Photos courtesy of Colleen Beard, Brock University Map, Data and GIS Library.

gravel roadway 7 m from the canal (Figures 2A and 2B) and a 12 m wide grassy mowed strip to the west of the road, which converges with the roadway as one nears the tip (Figures 3A, 3B, 4A and 4B). Willow trees along the east side of the road (i.e., adjacent to the canal) were present in 1993-1997 and remained more-or-less unchanged for the 2013-2015 count. In 1993-1997, the mowed strip held poles and wires from a power line that was no longer in use. The wires and poles were removed prior to 2013. West of the mowed strip, an uneven canopy of aging 40-foot poplar trees, punctuated by cedar and spruce trees, was established as a result of plantings in 1932. Since 1997 a number of these poplars have died and there has been an appearance of shorter trees and shrubs. Additional comments on the habitat on the west pier are included in Black and Roy (2010).

Figure 2A. 6 May 1993. Looking north at the road at start of the count area.

Figure 2B. 10 May 2013. Looking north at the road at start of the count area.
Photos: John Black

Above: **Figure 3A. 6 May 1993. PWW view looking northwest on grassy strip 50 m north of start of the count area.**

Right: **Figure 3B. 10 May 2013. PWW view looking north on grassy strip 50 m north of start of the count area.**
Photos: John Black

Port Weller East Pier

From 1993-1997, a small wooded island (hereafter "Island") existed between a north pond and south pond to the east of the road on PWE (Figure 1A). At PWE (1993-1997), the count area was a road beside a 36 m wide hedgerow to the west of the Island, and a 15 m wide path off the road east of the hedgerow beside the Island. Unfortunately, as a result of work on the canal, the habitat at the Island on PWE changed dramatically since the 1993-1997 study (Figure 1B). Counts were thus not performed there from 2013 to 2015. Additional comments on the habitat and how the habitat changed over the years on PWE are included in Black and Roy (2010).

Far Left: **Figure 4A. 7 May 1993. PWW view looking south along dirt road 75 m south of the north end of the pier.**

Left: **Figure 4B. 27 May 2013. PWW view looking south along dirt road 75 m south of the north end of the pier.**
Photos: John Black

Migrating Bird Counts

Birds observed using PWW were counted daily during the month of May (1993-1997, 2013-2015). The count coordinator (J. E. Black) identified a compiler for each day, who then selected one or two people to accompany him or her on the count. Thus, one to three participants, but preferably two to three, conducted counts together each day. It was relatively easy to find people to count on weekends but harder to find counters for weekdays when many birders were working. Because there was a range of skills in the counters, efforts were made to ensure that at least one counter each day was familiar with the local birds and able to recognize most, if not all, of the songs of migrants on the pier, and that at least one counter was able to hear the high frequency calls of species like the Blackpoll Warbler (*Setophaga striata*). The narrow pier and low bird densities at the count sites made it possible to find, identify and count all birds present during the count period, including those whose songs were unfamiliar to the counters.

At PWW, observers counted all birds detected (i.e., seen or heard) on the mowed strip and the dirt road while walking northward from the Coast Guard Station to an automated weather station at the end of the pier. Surveys began as close to 08:00 as possible, with start times ranging between 07:00-08:30. Surveys lasted one to one-and-a-half hours depending on the number of birds present, but as close to one hour as possible. All birds detected were recorded on a predesigned checklist, which contained species deemed appropriate for the 1993 study (Black and Roy 2010). In the 2013-2015 study, the compiler entered the counts in a predesigned Excel data entry file each day, and emailed the file, along with comments on any unusual encounters, to the coordinator and the other participants in the study. At PWE, counts of all birds seen or heard in the hedgerow and Island were collected between 09:30 and 10:00. See Black and Roy (2010) for more details on count methods.

Change in Count Size Over Time

Port Weller West Pier

We tested whether the number of warblers (by and across all species) detected on PWW changed between time periods by fitting hierarchical linear regression models (Kéry and Royle 2016). Note that we included only warbler species where at least five individuals were observed in one

Bird Count Observers

During the 1993-1997 surveys at PWW and PWE, over 25 persons contributed some time to counting. Eight of these counters were involved on a regular basis from 1993 to 1995. The average age of these eight observers was 57, with a range from 35 to 80. During the 2013-2015 surveys at PWW, over 15 persons contributed some time to counting. Twelve counters were involved on a regular basis, including four individuals that participated in 1993-1997. The average age of these twelve counters was 58, with a range of 31 to 83.

of the time periods or at one of the locations. We calculated 99% migration "windows" (Francis and Hussell 1998) independently for each species to remove excess zero-observation counts at the beginning and end of migrations by excluding data that fell outside the inner 99% of non-zero observation days over time. Regression models (negative binomial distribution) were fit in a Bayesian framework (Rue *et al.* 2009). Raw daily counts were the response variable, and year group (1993-1995 or 2013-2015) and second-order polynomial effects for day of the year were fixed and continuous predictor variables, respectively. First- and second-order effects for day of the year were calculated using a Legendre transformation, which results in independent and orthogonal polynomial effects. The regressions also included a hierarchical (random) term for year to account for random variation in annual counts, which assumed independent and identically distributed errors. A difference in counts between year groups was strongly supported when 95% credible intervals excluded zero. Bayesian posterior probabilities (Kéry and Royle 2016) were used as additional support for or against a change in count size between year groups; e.g., a posterior probability of 0.50 would suggest little support for a change in count size between year groups; a probability > 0.95 would suggest strong support for an increase in count size between year groups; and a probability < 0.05 would suggest strong support for a decline in count size between year groups, even if 95% credible intervals included zero.

Correspondence Among Sites

Comparison of trends

We compared the direction of change in counts detected at PWW for each species with the direction of change detected using other Ontario surveys.

1. Long Point Bird Observatory (LPBO) on Lake Erie, which has collected counts of birds during spring migration since 1961. We include trends (% change/year) estimated for the time period of 1993-2012 (Canadian Migration Monitoring Network 2015).
2. Breeding Bird Survey trends for the province of Ontario, estimated for two time periods, 1970-2012 and 2002-2012 (Environment Canada 2014).

Note that the time period, method of analysis and method of determining statistical significance differed among survey types, so they are not directly comparable. Regardless, if all surveys are monitoring the same population, and counts from each survey reflect change in the underlying monitored population, then the direction of change should correspond.

Comparison of annual counts

We compared count size trends between PWW and other Ontario survey sites by first fitting a separate linear regression model (INLA; Martino and Rue 2008) to data for each species at each site to estimate annual indices of count population size, following the methods used to estimate annual indices of count size for the Canadian Migration Monitoring Network and LPBO (Crewe *et al.* 2008).

The regression model was similar to the model described above, but with year as a categorical predictor. The regression coefficient estimates for the year terms (on the log scale) were used as annual indices of abundance, and were compared for correspondence among survey sites using Pearson correlation. Using this method, annual indices for PWW (1993-1997) were compared with annual indices from PWE (1993-1997) and LPBO (1993-1997); and annual indices from PWE (1993-1997) were also compared with annual indices from LPBO (1993-1997) to determine whether the pattern of fluctuation in counts was similar between sites. Methods used to derive annual indices at LPBO are described elsewhere (Canadian Migration Monitoring Network 2015); annual indices for Long Point were accessed online through NatureCounts (www.naturecounts.ca).

Results

Counts were conducted on all dates in May at PWW in each year. At PWE, counts were not conducted during one day in 1994 (26 May) due to inclement weather, and counts were not conducted 3 May and 25 May-31 May in 1997.

A total of 31 warbler species was observed on PWW during 1993-1995 and 2013-2015. Copies of interim reports for all species counted for the years 2013-2015 are available on the Brock University web site (http://www.brocku.ca/tren/niagarabirds). All comparisons and analyses were restricted to 22 warbler species that met the minimum requirement of five individuals detected in at least one time period (Table 1). Note that seven of the 22 species with the largest numbers over both studies accounted for 86% of the total individuals. Nine species seen in smaller numbers and thus not indexed for comparisons were: Golden-winged Warbler (*Vermivora chrysoptera*), Prothonotary Warbler (*Protonotaria citrea*), Hooded Warbler (*Setophaga citrina*), Yellow-breasted Chat (*Icteria virens*), Pine Warbler (*Setophaga pinus*), Blue-winged Warbler (*Vermivora cyanoptera*), Prairie Warbler (*Setophaga discolor*), Orange-crowned Warbler (*Oreothlypis celata*) and Cerulean Warbler (*Setophaga cerulea*).

We included Yellow Warbler and Yellow-rumped Warbler counts in the regression examining change in total warbler abundance over time. Total warbler counts for each year and period are presented in Table 1 with and without Yellow Warbler and Yellow-rumped Warbler. We did this because counts of these two species were extremely large, and any change in total warbler counts would largely reflect any change in these species. Yellow Warblers breed in Niagara and in the vicinity of PWW, and our counts were thus likely to include both resident and migrant individuals. Changes in Yellow Warbler counts over time might therefore reflect changes in the local breeding population as opposed to changes in the overall migrating population. Further, Yellow-rumped Warblers typically migrate through Niagara in mid-April, before our survey began, and, while sampling the entire migration may not be necessary to estimate an unbiased trend using migration counts (Crewe *et al.* 2016), we felt that our survey did not adequately sample their entire migration

Table 1. Total number of individuals of each warbler species detected at Port Weller West Pier during May, 1993-1995 and 2013-2015. Total warbler counts are shown with and without Yellow Warbler (YEWA) and Yellow-rumped Warbler (YRWA).

Species	Scientific Name	1993	1994	1995	2013	2014	2015	1993-1995	2013-2015
Ovenbird	*Seiurus aurocapilla*	4	5	7	4	1	2	16	7
Northern Waterthrush	*Parkesia noveboracensis*	2	5	2	7	12	6	9	25
Black-and-white Warbler	*Mniotilta varia*	9	3	30	10	17	14	42	41
Tennessee Warbler	*Oreothlypis peregrina*	3	2	2	9	6	5	7	20
Nashville Warbler	*Oreothlypis ruficapilla*	3	6	15	6	46	5	24	57
Mourning Warbler	*Geothlypis philadelphia*	2	0	0	3	1	2	2	6
Common Yellowthroat	*Geothlypis trichas*	40	24	33	47	59	60	97	166
American Redstart	*Setophaga ruticilla*	72	37	59	40	49	65	168	154
Cape May Warbler	*Setophaga tigrina*	32	31	9	2	7	9	72	18
Northern Parula	*Setophaga americana*	1	11	3	6	16	20	15	42
Magnolia Warbler	*Setophaga magnolia*	62	29	33	40	77	92	124	209
Bay-breasted Warbler	*Setophaga castanea*	42	13	10	3	14	17	65	34
Blackburnian Warbler	*Setophaga fusca*	6	1	11	3	13	20	18	36
Chestnut-sided Warbler	*Setophaga pensylvanica*	38	12	33	24	29	28	83	81
Blackpoll Warbler	*Setophaga striata*	22	9	7	64	17	100	38	181
Black-throated Blue Warbler	*Setophaga caerulescens*	18	26	47	11	22	27	91	60
Palm Warbler	*Setophaga palmarum*	43	44	24	60	98	84	111	242
Black-throated Green Warbler	*Setophaga virens*	8	9	13	13	8	10	30	31
Canada Warbler	*Cardellina canadensis*	5	1	3	6	1	7	9	14
Wilson's Warbler	*Cardellina pusilla*	13	3	7	12	17	11	23	40
Total (excl. YEWA, YRWA)		425	271	348	370	510	584	1044	1464
Yellow-rumped Warbler	*Setophaga coronata*	295	276	226	139	271	372	797	782
Yellow Warbler	*Setophaga petechia*	268	208	208	373	761	950	684	2084
Total (incl. YEWA, YRWA)		988	755	782	882	1542	1906	2525	4330
Total Number of Species		22	21	21	22	22	22	22	22

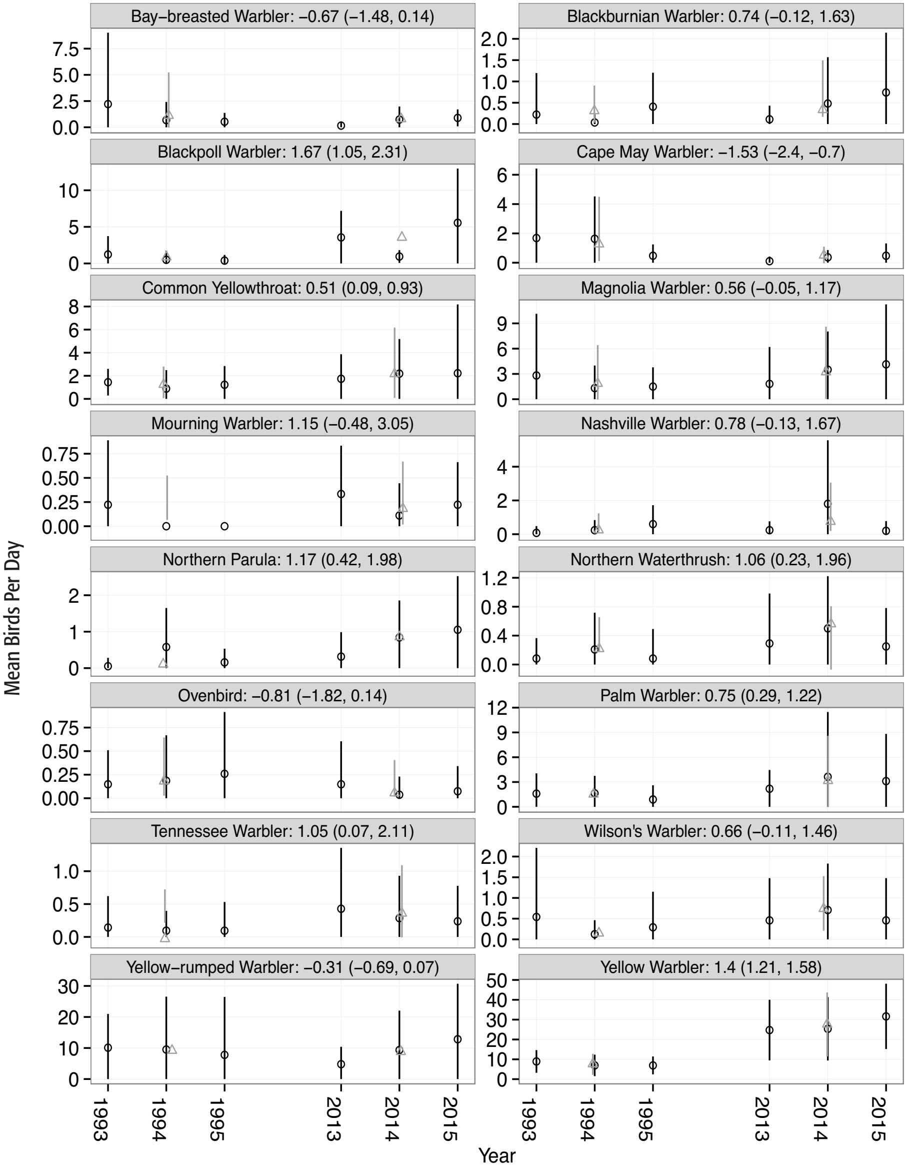


Figure 5. Mean count (standard deviation) by year (black circles) and across years in a year group (grey triangles) for species at Port Weller West Pier where the posterior probability supported a 95% probability that counts increased or declined over the 20-year period between 1993-1995 and 2013-2014. Effect size and 95% credible intervals are shown for each species.

Common Yellowthroat. *Photo: Tom Thomas*

for the purposes of this study. Most other warblers detected during this study typically migrate through Niagara during May when counts were collected (Black and Roy 2010).

Change in Count Size over Time - Port Weller West Pier

The total number of warblers counted was larger in 2013-2015 (4,330; Table 1) than in 1993-1995 (2,525) and this increase in counts between time periods was supported by the regression analysis (positive mean with credible intervals that excluded zero; Table 2). Even if we remove the large numbers of Yellow Warblers (our most common summer resident) and the very abundant Yellow-rumped Warblers, an increase in counts of warblers was observed from 1,044 in 1993-1995 to 1,464 in 2013-2015 (Table 1).

Our analysis also supported an increase in counts between time periods for seven of 22 species (Blackpoll Warbler, Common Yellowthroat, Northern Parula, Tennessee Warbler, Northern Waterthrush, Palm Warbler, and Yellow Warbler; Figure 5) and a decline in counts for Cape May Warbler (negative means with credible intervals that excluded zero; Table 2). If we consider species with a posterior probability ≥ 0.95 (increase in counts) or ≤ 0.05 (decline in counts), our results further supported an increase in count between time periods for Magnolia Warbler, Nashville Warbler, Blackburnian Warbler and Wilson's Warbler, and a decline in count for Bay-breasted, Ovenbird and Yellow-rumped Warblers. In the case of the Yellow-rumped Warbler, the apparent decline was likely the result of a decline in extreme counts between time periods, as opposed to a decline in the median or mean count over time.

Table 2. Total count at Port Weller West Pier in each year group (1993-1995 and 2013-2015), mean, standard deviation (SD), lower 95% credible interval (LCI), upper 95% credible interval (UCI) and posterior probability (Post. Prob.) for a regression that tested whether mean count increased (positive mean) or declined (negative mean) between year groups for each species and across all warbler species. Strong support for a change in count size between time periods is suggested by credible intervals that do not include 0 (shown in bold), but also by a posterior probability ≤ 0.05 for a decline in counts or ≥ 0.95 for an increase in counts, even when credible intervals did include 0 (shown in italics).

	Total Counts						
Species	1993-995	2013-2015	Mean	SD	LCI	UCI	Post. Prob.
Ovenbird	*16*	*7*	*-0.81*	*0.5*	*-1.82*	*0.14*	*0.05*
Northern Waterthrush	**9**	**25**	**1.06**	**0.44**	**0.23**	**1.96**	**0.99**
Black-and-white Warbler	42	41	0.01	0.43	-0.84	0.86	0.52
Tennessee Warbler	**7**	**20**	**1.05**	**0.52**	**0.07**	**2.11**	**0.98**
Nashville Warbler	*24*	*57*	*0.78*	*0.45*	*-0.13*	*1.67*	*0.96*
Mourning Warbler	2	6	1.15	0.90	-0.48	3.05	0.91
Common Yellowthroat	**97**	**166**	**0.51**	**0.21**	**0.09**	**0.93**	**0.99**
American Redstart	168	154	-0.17	0.21	-0.58	0.24	0.21
Cape May Warbler	**72**	**18**	**-1.53**	**0.43**	**-2.4**	**-0.7**	**0.00**
Northern Parula	**15**	**42**	**1.17**	**0.4**	**0.42**	**1.98**	**1.00**
Magnolia Warbler	*124*	*209*	*0.56*	*0.31*	*-0.05*	*1.17*	*0.96*
Bay-breasted Warbler	*65*	*34*	*-0.67*	*0.41*	*-1.48*	*0.14*	*0.05*
Blackburnian Warbler	*18*	*36*	*0.74*	*0.44*	*-0.12*	*1.63*	*0.95*
Chestnut-sided Warbler	83	81	-0.02	0.3	-0.6	0.57	0.48
Blackpoll Warbler	**38**	**181**	**1.67**	**0.32**	**1.05**	**2.31**	**1.00**
Black-throated Blue Warbler	91	60	-0.29	0.26	-0.79	0.21	0.12
Palm Warbler	**111**	**242**	**0.75**	**0.24**	**0.29**	**1.22**	**1.00**
Black-throated Green Warbler	30	31	-0.03	0.4	-0.82	0.76	0.48
Canada Warbler	9	14	0.43	0.5	-0.55	1.43	0.80
Wilson's Warbler	*23*	*40*	*0.66*	*0.4*	*-0.11*	*1.46*	*0.95*
TOTAL (excl. YEWA, YRWA)	*1044*	*1464*					
Yellow-rumped Warbler	*797*	*782*	*-0.31*	*0.19*	*-0.69*	*0.07*	*0.05*
Yellow Warbler	**684**	**2084**	**1.4**	**0.09**	**1.21**	**1.58**	**1.00**
TOTAL (incl. YEWA, YRWA)	**2525**	**4330**	**0.59**	**0.19**	**0.19**	**0.99**	**0.99**

Correspondence among Sites

Comparison of trends

Direction of detected change in mean counts over time at PWW corresponded with the direction of population trend detected for LPBO for 14 of 22 species, and with the direction of trend detected for BBS for 11 of 22 species (across both BBS surveys), and with LPBO and both BBS time periods (i.e., across all surveys) for 7 of 22 species (Table 3).

Bay-breasted Warbler. *Photo: Claude King*

Table 3. Comparison of the direction of change in counts (+ suggests an increase in counts and - suggests decline in counts) of each warbler species detected at Port Weller West (PWW) Pier during 1993-1995 and 2013-2015, compared with the direction of change detected for LPBO and BBS.

* suggests strong support for the change: for PWW, 95% credible intervals excluded 0; for BBS, strong support was suggested by the "overall reliability high" rating; and for LPBO, we considered a trend to have strong support when p ≤ 0.05. Species where direction of change corresponded among all surveys are shown in bold. For example, the Northern Waterthrush showed an increase in columns 1, 2 and 4 and a decrease in column 3; there was strong support for the increase in column 1.

Species	PWW 1993/95-2013/15 (%)	LPBO 1993-2012 (%)	BBS 1970-2012 (%/yr)	BBS 2002-2012 (%/yr)
Ovenbird	-	+*	-*	-*
Northern Waterthrush	+*	+	-	+
Black-and-white Warbler	-	-	-	+
Tennessee Warbler	+*	-	-	-
Nashville Warbler	+	-	+	+
Mourning Warbler	+	+	-*	-
Common Yellowthroat	+*	+	+	+
American Redstart	-	+	-*	-
Cape May Warbler	-*	-	-	-
Northern Parula	+*	+*	+	+
Magnolia Warbler	+	-	+	+
Bay-breasted Warbler	-	-*	-	-
Blackburnian Warbler	+	-	+*	-
Chestnut-sided Warbler	-	+	-	-
Blackpoll Warbler	+*	+*		
Black-throated Blue Warbler	-	+	+*	+
Palm Warbler	+*	+	+	+
Black-throated Green Warbler	+	+	+	-
Canada Warbler	+	+	-	-
Wilson's Warbler	+	+	+	+
Yellow-rumped Warbler	-	-	+	+

Table 4. Pearson correlation coefficient (Corr) of annual indices among sites, estimated for Port Weller West (PWW), East (PWE) Piers and Long Point Bird Observatory (LPBO) during 1993-1997 (n = 5). (Note that significant positive correlations p ≤ 0.05 are in bold.)

Species	PWW-PWE		PWW-LPBO		PWE-LPBO	
	Corr	*p*	*Corr*	*p*	*Corr*	*p*
Ovenbird	0.73	0.17	0.39	0.52	0.28	0.65
Northern Waterthrush	-0.22	0.72	0.64	0.25	0.60	0.28
Black-and-white Warbler	0.80	0.11	-0.37	0.55	-0.46	0.43
Tennessee Warbler	**0.88**	**0.05**	0.72	0.17	0.61	0.27
Nashville Warbler	0.66	0.23	0.41	0.49	**0.96**	**0.01**
Mourning Warbler	0.19	0.76	0.04	0.95	0.26	0.68
Common Yellowthroat	0.32	0.60	0.45	0.44	**0.89**	**0.04**
American Redstart	**0.98**	**<0.01**	-0.34	0.57	-0.43	0.47
Cape May Warbler	**0.97**	**0.01**	0.71	0.18	0.55	0.33
Northern Parula	-0.45	0.45	0.24	0.70	0.29	0.63
Magnolia Warbler	0.74	0.15	0.58	0.30	0.21	0.73
Bay-breasted Warbler	0.6	0.28	**0.88**	**0.05**	0.70	0.19
Blackburnian Warbler	**0.91**	**0.03**	0.70	0.19	0.72	0.17
Chestnut-sided Warbler	**0.97**	**0.01**	0.43	0.46	0.24	0.69
Blackpoll Warbler	**0.99**	**<0.01**	-0.15	0.81	-0.12	0.84
Black-throated Blue Warbler	0.03	0.97	0.76	0.14	0.21	0.73
Palm Warbler	0.68	0.20	0.17	0.78	0.42	0.48
Black-throated Green Warbler	0.46	0.43	0.38	0.52	0.75	0.15
Canada Warbler	**0.99**	**<0.01**	0.56	0.32	0.60	0.28
Wilson's Warbler	0.43	0.47	0.43	0.47	**0.99**	**<0.01**
Yellow-rumped Warbler	0.85	0.07	0.18	0.63	0.00	0.99
Yellow Warbler	-0.65	0.23	0.42	0.48	-0.44	0.45

Comparison of counts among sites

Significant ($p \leq 0.05$) positive correlations of annual indices between PWW and PWE suggest that similar patterns of annual variation in migration counts were observed for 7 of 22 species (Tennessee Warbler, American Redstart, Cape May Warbler, Blackburnian Warbler, Chestnut-sided Warbler, Blackpoll Warbler and Canada Warbler); Yellow-rumped Warbler was near-significant at $p = 0.07$ (Table 4). Similar comparisons between PWW and LPBO (1993-1997) suggest comparable patterns of annual variation for one species (Bay-breasted Warbler, Table 4) and comparisons between

PWE and LPBO (1993-1997) suggest comparable annual fluctuations for only three species (Nashville Warbler, Common Yellowthroat, Wilson's Warbler) (Table 4). However, note that only 5 years of data were used in these comparisons, and that Long Point annual indices were estimated using a regression that included data collected from 1961-2013, and may not be directly comparable (i.e., differences between LPBO and PWW/PWE may be due to differences in detection, analysis or in the population being monitored).

Discussion

Overall, our results suggest that counts of several warbler species and warblers as a group have increased between 1993-1995 and 2013-2015 at PWW. Many factors can influence the number of birds detected by a particular count protocol, including variation in observer skill (Link and Sauer 2002), weather (Francis and Hussell 1998), habitat (Harrison *et al.* 2000), climate (Berthiaume *et al.* 2009, Calvert *et al.* 2009) and population distribution (Paprocki *et al.* 2014). In particular, a systematic change in any factor that influences detection, including climate change, habitat succession, or a change in migratory route or stopover behaviour can bias trends in migration counts if the underlying temporal change in detection is not accounted for (see review in Crewe *et al.* 2015a). Because detection probability was not explicitly estimated at PWW through the use of double-observer sampling or other methods (e.g., Berthiaume *et al.* 2009), we cannot confirm whether any observed change in count size reflects real change in the size of the monitored population or, alternatively, a change in the probability that birds were detected at PWW.

Using daily counts of migrating animals to estimate population change, as we did here, relies on the assumption that new birds were detected each day, and that factors affecting the probability of detecting available birds, such as stopover duration or observer skill, did not change systematically over time. At PWW, mean observer age and skill were approximately the same in both time periods, and should not have contributed substantially to any systematic variation in detection over time. Habitat has also remained relatively stable between 1993 and 2013 (Black and Roy 2010). However, we did not collect data on vegetation at or surrounding the sites monitored, thus we cannot ascertain that detection probability did not change over time as a result of habitat succession. This pier has opened up a little with the death of many poplars and the succession and additional appearance of shorter trees and shrubs, which may have influenced the probability that some warbler species used the pier during stopover, and therefore the probability of detecting those species. The habitat is perhaps now more suitable for Yellow Warblers, which were found in much larger numbers not only during migration but also during the breeding period between 2013-2015 and 1993-1995. (See http://www.brocku.ca/tren/niagarabirds.) The increase in counts of other warbler species over time might also be attributed to an increase in detection if the observed changes in habitat resulted in a higher

Northern Parula.
Photo: Tom Thomas

probability that birds stopped at the site, and/or a higher probability that individuals that did stop remained at the site for longer periods of time. If birds were more likely to stop during the latter time period, or more likely to stay for longer time periods before departing again on migration, this could bias estimates of long-term change by increasing the odds that an individual would be counted on one or more observation days (Crewe *et al.* 2015a).

Even if we were to assume that changes in habitat and observer effort did not contribute to differences in warbler numbers between 1993-1995 and 2013-2015, it is still not obvious that we can, from the results above, conclude that more birds migrated through Port Weller in 2013-2015 than in 1993-1995. This might be true if all other factors contributing to the probability that birds will land at the piers, such as weather, migration route, and breeding or wintering distribution, have also not changed over time. The large variation in daily (large standard deviation around annual means, Figure 5) and annual counts (Table 1, Figure 5) observed for some species, for example, might suggest that counts were influenced by factors in addition to temporal changes in the underlying population size. Perhaps weather conditions were such that Blackpoll Warblers were more likely to land at PWW in 2013-2015 than in 1993-1995. Moreover, weather conditions farther south might also influence how many individuals stop at PWW in spring, and on a larger spatial scale, change in habitat structure in the landscape surrounding the Port Weller Piers might influence the probability that birds stopover and are counted during migration.

Regardless, correspondence of fluctuations in annual indices at PWW with PWE for some species suggests that at least for those species, counts are not simply a reflection of site-specific changes in detection probability. A correspondence in the direction of count trends for seven warbler species detected at PWW with LPBO and Ontario BBS (Table 3) also suggests, at least qualitatively, that the small study on the west pier does reflect the overall direction of population change detected for those warbler species across Ontario. The lack of correspondence in direction of trend among surveys for most other species does, however, suggest that counts do likely reflect some site-specific biases (Harrison *et al.*

2000), or differences among surveys in the breeding origin of the migrants detected. Without knowledge of the breeding origin of individuals detected by migration counts, we cannot safely assume that all surveys are monitoring the same population, particularly as distance between sites increases (this might have contributed to the greater correspondence between PWW and PWE annual indices as compared with PWW or PWE with LPBO annual indices). Correspondence of trends in annual migration counts collected at LPBO with Breeding Bird Survey trends have been reported in the past (Francis and Hussell 1998, Crewe *et al.* 2008) and do support the use of seasonal migration counts, such as those collected at PWW, for long-term population monitoring when collected annually over the long term.

Concluding Remarks

In general, we conclude that the type of method used here (sampling three years every 20 years), as opposed to sampling annually over a 20-year time period, can be useful for estimating whether the size of the count population has changed over time, while reducing long term effort required to collect data. Sampling more years (e.g., five years every 20 years) might improve correspondence of annual indices and long-term trends with alternative sites and surveys. The correspondence in direction of trend for some species detected at PWW with direction of trend observed for those species using other bird count datasets suggests that a systematic study of one small area (PWW) can be used to learn not only about birds using a single locality during migratory stopover (e.g., Niagara), but potentially also the direction of population change at a larger spatial scale. For those species with annual indices and trends that did not correspond among sites or surveys, additional data on detection probability would be required to determine if observed changes reflect changes in local factors, such as habitat succession. Daily counts at more sites that sample the same breeding population over the same period of time, as is done with Breeding Bird Atlases (see also Crewe *et al.* 2015b), would also allow us to determine with greater confidence whether site-specific annual fluctuations are evidence of broader-scale population fluctuations. Note that by not counting annually, we did lose information on the trajectory of change over time, and on the long-term variation in annual counts. As a result, it is not possible to determine whether the observed change is outside the normal range of annual variation in population counts. Our study has nevertheless answered the simple question raised in the introduction: "did the number of warblers detected using the west pier during migration change between 1993-1995 and 2013-2015?" We see that the number of warblers detected using the west pier during migration increased! It will be most interesting to see if the conclusions reached here persist when the final two years, 2016 and 2017, of data are included.

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