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Supplementary material

Appendix A1. Modeling detection probabilities of individuals with chick bands.

Individuals wearing chick bands could not be positively identified through resighting and had to be physically captured during nesting to achieve positive identification. Therefore, chick-banded plovers had zero probability of being detected prior to transition from non-breeder to breeder, and after they transitioned to become breeders they had lower detection probabilities than birds marked with adult color-band combinations, which could simply be observed with spotting scopes. We assigned each individual a series of 19 occasion-specific covariates (CB94, CB95, … CB12) that indicated years when an individual was wearing chick bands (e.g., CB95 = 1 means an individual wore chick bands in 1995) versus adult bands (CB95 = 0). For example, a chick first marked in 1994 and recaptured as a breeding female and banded with adult bands in 1998 and seen again in 1999, 2000, 2002, 2003 and 2004 would have the following capture history:

01000333033300000000

and the following 19 occasion specific covariates (covariates begin in year 2 since individuals are not resighted in year 1):

CB94	CB95	CB96	CB97	CB98	CB99	CB00	CB01	CB02	CB03	CB04	CB05	CB06	CB07	CB08	CB09	CB10	CB11	CB12
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note that individual covariates are specified as 1 from the year of first marking as a chick up to and **including** the year when individuals were first nest trapped as an adult. These individual covariates allowed us to estimate each individual's (*i*) encounter probability during each year (*j*) by estimating an offset from the detection probability for adult banded birds:

$$\text{logit}(p_{ij}) = \beta_0 + \beta_1 * CB_{ij}$$

Note that when CB = 0, β_0 estimates detection of color-banded adults (year effects could be included with j-2 additional parameters). The design matrix coding for this model in Program MARK would look like Figure A1 (note that even though this model does not estimate year-specific detection probabilities, that each year is included as a separate row to accommodate the year-specific covariates).

Figure A1. Design matrix in Program MARK including the CB covariate used to designate whether an individual was wearing chick bands or adult bands.

1	0	0	58:p 1:Chick
0	1	CB94	59:p 2:AdM
0	1	CB95	60:p 2:AdM
0	1	CB96	61:p 2:AdM
0	1	CB97	62:p 2:AdM
0	1	CB98	63:p 2:AdM
0	1	CB99	64:p 2:AdM
0	1	CB00	65:p 2:AdM
0	1	CB01	66:p 2:AdM
0	1	CB02	67:p 2:AdM
0	1	CB03	68:p 2:AdM
0	1	CB04	69:p 2:AdM
0	1	CB05	70:p 2:AdM
0	1	CB06	71:p 2:AdM
0	1	CB07	72:p 2:AdM
0	1	CB08	73:p 2:AdM
0	1	CB09	74:p 2:AdM
0	1	CB10	75:p 2:AdM
0	1	CB11	76:p 2:AdM
0	1	CB12	77:p 2:AdM

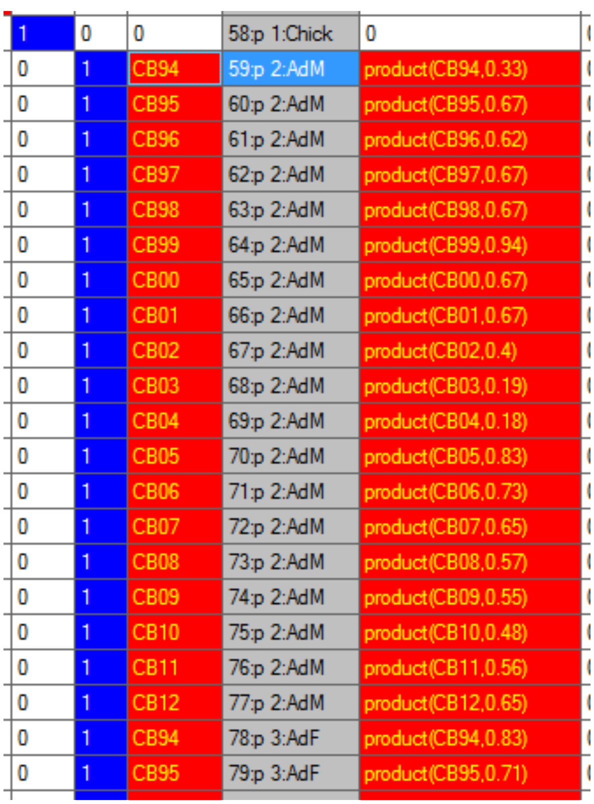
Annual variation in the detection of breeding adults marked only with chick bands is a function of annual trapping success, defined as the proportion of unmarked or partially marked individuals that are successfully nest-trapped and banded with full complements of color-bands (Table A1). Failure to trap and remark individuals can occur for a number of reasons (i.e., nests fail before trapping can occur, individuals are trap shy and will not enter traps, or logistic difficulties precluded capture attempts) and the variable for trapping success (Trap) accounts for all three potential sources of trapping failure. We summarized trapping success separately for males and females by tallying the total number of unmarked or partially marked individuals that were observed nesting during each field season, and calculating the proportion of these individuals that were captured and uniquely banded during each year, 1994–2012. We included unmarked individuals (~ 24% of the total) because we had no reason to suppose that their capture probabilities were different from birds wearing only chick bands, and they increased the sample size for estimating trapping success, especially in early years. We tallied results separately by sex in case there were gender differences in trapping success, but aside from considerable annual variability owing to small sample sizes, trapping success did not differ by sex. We considered models using either sex specific trapping rates (antepenultimate and penultimate columns) or pooled trapping rates (last column), and created an additional annual covariate that applied only to birds wearing chick bands by modeling the interaction of CB*Trap (when birds had adult band combinations with CB = 0, this product was also equal to zero). Design matrix coding of this interaction effect is illustrated for males and the first 2 (out of 19) years of females in Fig. A2.

Table A1. Annual trapping success of adult male and female Great Lakes piping plovers during 1994-2012. 'Both' refers to both sexes combined.

	Total unmarked or chick bands			Total newly banded			Annual trapping rate		
YEAR	Males	Females	Both	Males	Females	Both	Males	Females	Both
1994	6	6	12	2	5	7	0.33	0.83	0.58
1995	9	7	16	6	5	11	0.67	0.71	0.69
1996	13	13	26	8	7	15	0.62	0.54	0.58
1997	9	9	18	6	5	11	0.67	0.56	0.61
1998	12	13	25	8	10	18	0.67	0.77	0.72
1999	16	21	37	15	14	29	0.94	0.67	0.78
2000	9	12	21	6	10	16	0.67	0.83	0.76
2001	18	22	40	12	18	30	0.67	0.82	0.75
2002	25	21	46	10	13	23	0.40	0.62	0.50
2003	21	16	37	4	2	6	0.19	0.13	0.16
2004	22	30	52	4	9	13	0.18	0.30	0.25

2005	35	41	76	29	30	59	0.83	0.73	0.78
2006	26	24	50	19	16	35	0.73	0.67	0.70
2007	31	28	59	20	16	36	0.65	0.57	0.61
2008	28	28	56	16	19	35	0.57	0.68	0.63
2009	42	30	72	23	21	44	0.55	0.70	0.61
2010	25	21	46	12	11	23	0.48	0.52	0.50
2011	18	21	39	10	7	17	0.56	0.33	0.44
2012	23	30	53	15	21	36	0.65	0.70	0.68
Average	**20.4**	**20.7**	**41.1**	**11.8**	**12.6**	**24.4**	**0.58**	**0.62**	**0.60**

Figure A2. Design matrix in Program MARK illustrating interaction effect of individuals wearing chick bands (CB) and annual trapping rate.



1	0	0	58:p 1:Chick	0
0	1	CB94	59:p 2:AdM	product(CB94,0.33)
0	1	CB95	60:p 2:AdM	product(CB95,0.67)
0	1	CB96	61:p 2:AdM	product(CB96,0.62)
0	1	CB97	62:p 2:AdM	product(CB97,0.67)
0	1	CB98	63:p 2:AdM	product(CB98,0.67)
0	1	CB99	64:p 2:AdM	product(CB99,0.94)
0	1	CB00	65:p 2:AdM	product(CB00,0.67)
0	1	CB01	66:p 2:AdM	product(CB01,0.67)
0	1	CB02	67:p 2:AdM	product(CB02,0.4)
0	1	CB03	68:p 2:AdM	product(CB03,0.19)
0	1	CB04	69:p 2:AdM	product(CB04,0.18)
0	1	CB05	70:p 2:AdM	product(CB05,0.83)
0	1	CB06	71:p 2:AdM	product(CB06,0.73)
0	1	CB07	72:p 2:AdM	product(CB07,0.65)
0	1	CB08	73:p 2:AdM	product(CB08,0.57)
0	1	CB09	74:p 2:AdM	product(CB09,0.55)
0	1	CB10	75:p 2:AdM	product(CB10,0.48)
0	1	CB11	76:p 2:AdM	product(CB11,0.56)
0	1	CB12	77:p 2:AdM	product(CB12,0.65)
0	1	CB94	78:p 3:AdF	product(CB94,0.83)
0	1	CB95	79:p 3:AdF	product(CB95,0.71)

Model[a]	ΔAIC_c	Deviance	k

Appendix A2. Modeling steps and rankings for multi-state capture-recapture models.

Stage 1: modeling resighting probability			
p(FY = 0, sex × ChickBand × [ChickBand × Trap])	110.3180	4308.11	67
p(FY = 0, ChickBand + [ChickBand × Trap])	109.2620	4313.04	64
Stage 2: modeling probability of first-breeding[b]			
ψ(sex + A2)	109.2620	4313.04	64
ψ(sex + A4)	102.2716	4302.81	64
ψ(sex + A3)	98.9960	4302.77	64
ψ(sex × A2)	92.2416	4296.01	64
ψ(sex × A4)	89.5173	4284.88	68
ψ(sex × A3)	85.5793	4285.15	66
Stage 3a: modeling survival probability			
Φ(FY × t, M × t, F × t)	85.5793	4285.15	64
Φ(FY × t, sex + t)	64.8657	4291.63	51
Φ(FY + t, M + t, F + t)	63.6726	4333.79	30
Φ(A2 + t [FY = M = F])	61.9760	4334.14	29
Φ(A2 × t [FY = M = F])	61.5615	4296.63	47
Φ(FY, M, F)	60.8601	4267.61	12
Φ(× t [FY = M = F])	59.5490	4333.76	28
Φ(A2 [FY = M = F])	50.7348	4359.51	11
Stage 3b: adding annual covariates to Φ			
Φ(FY + BreedTemp, M + F + MerlinEast)	42.4329	4349.18	14
Φ(FY,M + F + MerlinEast)	42.0601	4350.84	13
Φ(FY + BreedTemp, M + F +MerlinTemp + NBTemp)	41.6888	4346.42	15
Φ(FY, M + F + MerlinEast + NBTemp)	41.3412	4348.09	14
Φ(FY + BreedTemp, M + F + MerlinEast + Hurricane)	39.6384	4344.37	15

Φ(FY, M + F + MerlinEast + Hurricane)	39.1927	4345.95	14
Stage 4: adding individual covariates to Φ_{FY}			
Φ(FY + Condition, M + F + MerlinEast +Hurricane)[c]	33.9686	4338.70	15
Φ(FY + Cohort)	30.8583	4335.91	15
Φ(FY + HDate)	25.4429	4330.17	15
Φ(FY + StandardHD)	25.1980	4329.93	15
Φ(FY + HDate + Cohort)	21.3368	4324.04	16
Φ(FY + BandAge)	20.9184	4325.65	15
Φ(FY + StandardHD + Cohort)	20.5615	4323.27	16
Φ(FY + HDate + Condition)	19.8426	4322.55	16
Φ(FY + StandardHD + Condition)	19.2515	4321.96	16
Φ(FY + Cohort + BandAge)	15.4167	4318.12	16
Φ(FY + Condition + BandAge)	14.7977	4317.51	16
Φ(FY + StandardHD + BandAge)	11.2974	4314.00	16
Φ(FY + StandardHD + BandAge)	10.4223	4313.13	16
Φ(FY + StandardHD + BandAge + Cohort)	7.5852	4308.27	17
Φ(FY + StandardHD + BandAge + Condition)	3.6513	4304.33	17
Φ(FY + StandardHD + BandAge + Condition + Cohort)	1.3574	4300.01	18
Stage 4b: adding individual covariates to ψ_1^{12} and ψ_1^{13}[d]			
ψ(sex × A3 + StandardHD)	3.2782	4299.91	19
ψ(sex × A3 + Condition)	0.0000	4296.63	19

Table A2. Sequential modeling steps and AIC-based model rankings for estimates of first-year (FY) apparent survival, adult (M, F) apparent survival, detection probability of adults, and age-specific transition probabilities of Great Lakes piping plovers during 1993–2012.

[a]Refer to Table 1 for covariate abbreviations. + indicates an additive relationship; × indicates a multiplicative relationship.

[b]A2, A3, A4 refer to number of age classes (e.g. 2, 3, 4).

[c]Remainder of Stage 4 models all included an effect of MerlinEast and Hurricane on male and female apparent survival.

[d]Individual covariates added to age one transition probabilities from pre-breeder to breeder.