Project Title: Demography of birds breeding in an urban environment: identification of source and sink populations

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Project Time Period: April 2004 through July 2006

Project Description:

Urban development has proceeded at a rapid rate in the United States and elsewhere and is a significant contributor to species endangerment (Czech and Krausman 1997). Expectations are that current trends will continue well into the next century (Marzluff 2001). The "car culture" of the United States permits current urban centers to spread over much larger areas than cities of the past, and as a result, loss, fragmentation and degradation of wildlife habitat across North America has become a major conservation concern. Moreover, in the U.S. (and elsewhere), urbanization tends to occur in areas of the highest primary productivity and the richest soils (Imhoff et al. 2001). Thus, as cities grow, wildlife habitat inevitably becomes more fragmented and degraded (e.g. Theobald 2000), and it has become critical that we begin to study and better understand the behavior and population dynamics of native wildlife that reside in urban environments. Only after we understand the impact of habitat fragmentation on urban-dwelling wildlife will it be possible to manage those species both for their persistence and to avoid potential negative human-wildlife interactions. With the growth of cities, and continued loss of habitat, it is conceivable that an increasing proportion of species will depend heavily on urban parks and greenspaces (P&GSs) for their continued existence.

From April 2002 through January 2004 my graduate students and I conducted research (supported by the USFWS and METRO's Greenspaces Program) with the objectives to document vertebrate species richness in Portland's urban P&GSs, and to evaluate the extent to which species richness varied with the physical features (e.g., size, shape, topography), habitat characteristics (e.g., plant community composition) and structure of the landscape surrounding each P&GS (e.g. proportion of land composed of forest, residential development, open spaces, etc.). One of the more important findings of that research was that species richness and general abundance of Neotropical migrant birds tended to increase with P&GS area, but 10 ha appeared to be a critical size because total bird species richness reached peak values at P&GSs of this size. We therefore proposed in 2004 to begin demographic studies of birds in an attempt to understand fundamental aspects of the population biology of birds in small- to medium-sized parks. Detailed demographic studies of animals in urban environments are virtually nonexistent and therefore we do not know if urban populations are self-sustaining or dependent on immigration from areas outside the city for their persistence. Recent analyses suggest that habitat fragmentation in nonurban landscapes has negative impacts on forest bird populations out to a radius of 20 km due to negative effects of brood parasites and nest

predators on production of young (Lloyd et al. 2005). Birds in urban areas may show substantial spatial variation in nest loss and brood parasitism (Phillips et al. 2005), possibly because urban areas have reduced populations of predators. It is therefore possible that urban P&GSs might actually serve as areas of high productivity that feed the surrounding landscape, but no data exist to test this hypothesis.

Expected goals and actual accomplishments

Our finding that P&GSs with an area in the range of 10 ha were able to support a high diversity of birds (and other vertebrates) suggested the possibility that management for vertebrate diversity might benefit by the maintenance of P&GS of this size. Our 2004 proposal to the USFWS was funded so that we could begin demographic studies of birds to attempt to understand why 10 ha appeared to be a critical size. We proposed to study four species (2 residents and 2 long-distance migrants) and collect data to permit estimation of population growth rates, including adult survival rates and total seasonal productivity of young. However, for two reasons, we were forced to forego our original plan and focus on a single representative species, the Spotted Towhee (*Pipilo maculatus*). The extremely time-intensive nature of the work and the difficulty of accessing nests of other species (generally placed very high in trees), and of capturing adults made the proposed analyses of other species intractable. We chose towhees as our focal species because they are abundant, nests are placed on the ground (and therefore exposed to most of the predators of concern in P&GSs), and adults were captured "relatively" easily. Moreover, towhees are not a typical urban bird: they rarely breed in managed landscapes. We therefore reasoned that a detailed demographic study of towhees would shed much light on the potential for native species to persist in urban landscapes in which parks are managed to maintain native plant species composition and structure. Although our results do not encompass as many species as planned originally, we have conducted a comprehensive population study that included demographic analyses, an examination of the impact of trails on reproductive success, reproductive (song) behavior, and analyses of microgeographic (i.e. among park) variation in the microbes carried by breeding females. Each of these is described in detail below.

(A) Population and behavioral ecology: source-sink dynamics

Our research was conducted in four P&GSs (Table 1) that (a) our earlier work showed supported towhees, (b) fell within the range of parks sizes deemed appropriate, and (c) were at least theoretically connected by dispersal of the birds. Two additional small sites (1-2 ha) that were undeveloped sites within neighborhoods (Table 1) were also included. The P&GSs thus formed a

TABLE 1. Names and area of P&GSs used in the study of Spotted Towhee demography.

Park and Greenspace	Area (ha)
31st Court Greenspace	~1
PCC Woodlot	2
Maricara Nature Park	10
Lesser Park	11
West Portland Park	16
Springbrook Park	24

network of parks located mostly within the Tryon Creek watershed, and all were characterized by closed canopy forests comprised of mixed conifer-deciduous trees. All P&GSs are located within the City of Portland, with the exception of Springbrook (Lake Oswego). Research took place between the first of April and mid-August in 2004, 2005, and 2006. Our goal was to find nests and individually mark as many pairs as possible in all P&GSs to enable us to determine average seasonal productivity per pair, and to document survival and dispersal of adults and fledglings to evaluate whether or towhee populations were self-sustaining.

Results

Nest success. - We monitored a total of 76, 150, and 136 nests in 2004 through 2006, respectively (Table 2). The greater number in 2005 and 2006 reflected our increased familiarity with the species habits and expansion of the study into new habitats. Nest success, calculated as the percentage of nests to produce at least one fledged young, varied somewhat among years from a low of 57% in 2005 to high values of 68% and 71% in 2006 and 2004, respectively, but on average, nearly two-thirds of the nests that we observed fledged young (Table 2). Regardless of year, nest predation was the main cause of nest loss, followed distantly by the complete starvation of young or nest abandonment (Table 2). Brown-headed Cowbird (*Molothrus ater*) brood parasitism was never observed.

TABLE 2. Statistics describing nest search efforts and nest success of Spotted Towhees in Portland P&GSs. Data are a composite of results from 2004, 2005, and 2006.

Park	Total	Successful	Depredated	Starved	Abandonded
Lesser	71	51	17	3	0
Maricara	87	54	28	2	3
Springbrook	120	70	42	2	6
West Portland	73	49	21	2	1
PCC Woodlot	7	5	2	0	0
31st Court	4	4	0	0	0
Total (%)	362 (100)	233 (64.4)	110 (30.4)	9 (2.5)	10 (2.8)

However, unless all nests are found prior to egg-laying, using the percentage of nests to fledge young generally overestimates success because nests that failed prior to being detected are not included in the total. We therefore utilized Mayfield logistic regression (Hazler 2004) to account for differences in exposure time of nests to generate daily nest survival rates, and from this, estimates of nest success. Over all three years and sites, the probability of daily survival was 0.966 (CI 0.963-0.969), and assuming that a full nest cycle requires 27 days (3.4 days laying, 13.3 days incubating, 10 days feeding nestlings = ~27 days), our predicted nest success rate was 39.3%% (CI 36.1%-42.7%). The large difference between “apparent” nest success (i.e. % of successful nests [Table

2]) and success estimated by properly accounting for exposure time was substantial (64% vs. 39%) and reflects the frequent loss of towhee nests early in the nest cycle.

TABLE 3. The daily probability of Spotted Towhee nest survival, the corresponding percentage of successful nests (at least one offspring fledged) and confidence intervals (CI) for each measure. The two smallest parks (PCC Woodlot and 31st Court) were excluded due to small sample sizes.

Park/Greenspace	Daily survival Rate (DSR)	95% CI DSR	% Successful nests (% SN)	95% CI (% SN)
Lesser Park	0.970	0.963-0.976	43.9	36.1-51.9
Maricara Park	0.971	0.965-0.976	45.2	38.2-51.9
Springbrook Park	0.959	0.953-0.965	32.3	27.2-38.2
West Portland Park	0.967	0.962-0.972	40.4	35.1-46.4

Comparisons of nest success based on exposure days among P&GSs (Table 3) suggested that birds at Springbrook Park were significantly more likely to lose nests than were pairs from other parks. Nest success ranged between roughly 40% and 45% at Lesser, Maricara and West Portland, but at Springbrook just below a third of nests could be expected to fledge young. Trails within parks potentially act as travel routes for nest predators, or expose birds to humans and their pets. We therefore also tested for an influence of proximity to trails on the daily survival rate by distinguishing between nests placed less than and more than 10 m from a trail. The Mayfield logistic regression detected a significant ($P < 0.05$) negative influence of proximity to trails on nest success: nests placed within 10 m of a trail were more likely to fail than nests located more than 10 m from the nearest trail.

Annual Reproductive Success. – Towhees are multi-brooded and a single pair may fledge young from as many as three nests in one season. Hence, estimates of annual reproductive success require the monitoring of all nesting attempts of each towhee pair throughout the summer. We documented all successful nesting attempts for 31, 62, and 51 towhee pairs in 2004, 2005, and 2006, respectively, and determined the total number

TABLE 4. Comparisons of annual productivity of pairs at all parks over the three year study period.

Park/Greenspace	Pair	2004	2005	2006	Average
Lesser Park	29	3.25	2.90	4.73	3.69
Maricara Park	37	3.64	3.06	2.80	3.16
Springbrook Park	46	3.25	2.47	2.80	2.78
West Portland Park	26	n/a	3.43	4.00	3.69
PCC Woodlot	4	n/a	5.0	2.00	3.50

n/a = not available

of fledglings that were produced. For these 144 pairs, the number of fledglings per year ranged from 0 to 9 young, and over all three years, averaged 3.3 fledglings (2004: 3.4 fledglings/pair/year; 2005: 3.0 fledglings/pair/year; 2006: 3.5 fledglings/pair/year). The number of fledglings per pair differed between the six P&GS (Table 4), but there was no apparent relationship between annual productivity and size of the P&GS. Springbrook is the largest park and it had the lowest productivity (due to high nest predation rates [Table 3]), while West Portland and Lesser, the next largest park and smallest parks, respectively, showed equivalent average productivity/female (Table 4).

Return rate and dispersal. - Our netting efforts have thus far yielded a total of 277 banded adults (Table 5) and 617 banded nestlings. Preliminary analyses of survival, without correcting for failure to resight banded birds that returned and were missed, indicated that 49.3% of males (37 of 75) and 60.0% of females (24 of 40) banded in 2004 returned to breed in 2005. In 2006, 60.6% of females and 72.5% of males banded in 2005 returned to breed. We did not detect any instances of dispersal of adults between P&GSs. Less than 5% of the nestlings we banded have been resighted, but delayed breeding may occur and additional years are required to eliminate this possibility. Proper analyses of adult survival requires at least three years of data to correct for failure to detect survivors that were not resighted (White and Burnham 1999). We will conduct these analyses this coming year, but the results presented below (Table 5) are conservative and represent *minimum* rates of survival that will increase once failure to resight survivors is accounted for.

TABLE 5. Total number of adults banded in each park and the return rate between years for the sexes combined.

Park and Greenspace (n)	2004-05	2005-06	Average
Lesser (47)	44%	60%	51%
Maricara (77)	46%	64%	55%
Springbrook (80)	62%	71%	67%
West Portland (64)	65%	67%	66%
Small sites (1-2 ha) (9)	50%	80%	78%

Demographic analyses. – In an attempt to evaluate the capacity of the parks to sustain themselves, we developed a simple simulation model to calculate population growth rate (lambda, λ) using the empirical estimates of adult return rate (S_A; average of the sexes), mean number of young produced/pair/year (F), and juvenile survival (S_J). Our low juvenile return rate, which is typical of landbird populations, forced us to make the common assumption that S_J was roughly half of S_A. We assumed that $S_J = 0.30$. We attempted to develop a level of realism in the model by permitting both S_A and F to vary randomly between the low and high values recorded at each park over the course of the study. The model was iterated 100 times and values for all parameters were used to calculate λ using Pulliam's (1988) equation:

$$\lambda = S_A + ((F*0.5)*S_J))$$

(F is multiplied by 0.5 so that the estimate of growth rate is based on female births) to estimate growth rate. A λ of 1.0 indicates a stable population, whereas values below and above 1.0 indicate declining and growing populations, respectively.

Results of the simulation suggest that every park in the system was self-sustaining (Fig. 1). Maricara was the only population to occasionally exhibit growth rates below replacement levels (Fig. 1), but the 95% confidence interval (CI; 1.029 to 1.056) surrounding the mean rate (λ = 1.04) did not include 1.0. Hence, growth rate was significantly above replacement. The West Portland population exhibited the highest growth rate (λ = 1.19, 95% CI = 1.172 to 1.190), and the 95% CI did not overlap the average λ of either Springbrook (1.10, 95% CI = 1.088 to 1.105) or Lesser (1.09, 95% CI = 1.082 to 1.096), and therefore West Portland's estimated growth rate was significantly higher than both. Growth rates at Springbrook and Lesser did not differ significantly from each other. The smallest parks (< 2 ha) were highly productive and thus were self-sustaining, but more data are needed for small P&GSs to confirm this result.

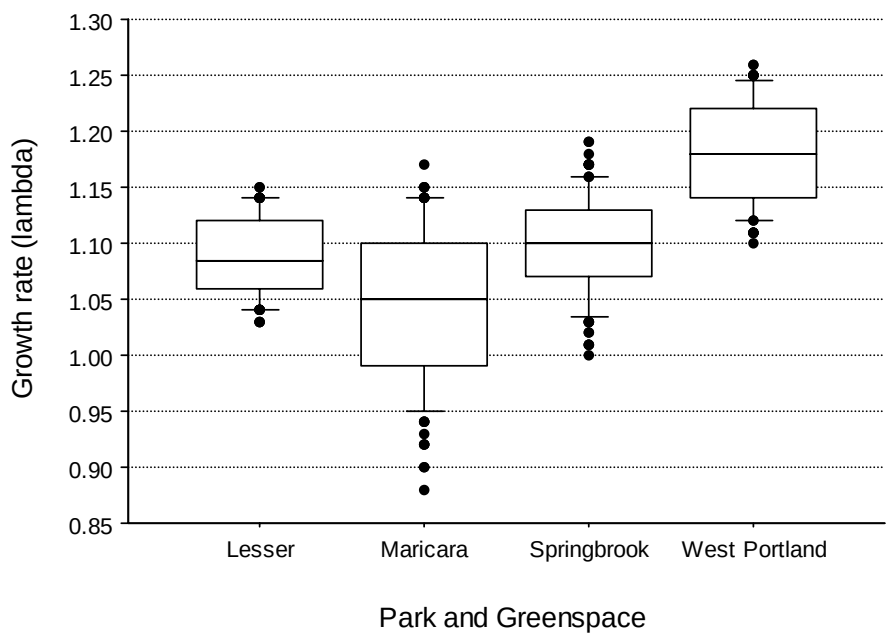

Fig. 1. Box plots describing variation in estimated growth rate at the four primary study sites. The boxes enclose the middle 50% of observations, the horizontal line within the box is the median, the vertical bar extends from the 10th to the 90th percentile of observations, and filled circles represent extreme individual values. The data are based on simulation models that used empirical results from our field studies.

Parental feeding rates and nestling growth. – Preliminary analyses suggested that conditions for rearing young differed among parks, and that the ability of parents to provision young adequately may have affected nestling quality. We recorded food

deliveries to dependent young in nests in ~ 70 and ~80 nests 2005 and 2006, respectively, using video recorders in 1 to3 hour long sessions. Average feeding rates (trips/hr) from a random sample of nests from Maricara (11.7, standard error = 1.31 trips/hr, n = 9 nests) and Springbrook (8.1, standard error = 1.43 trips/hr, n = 8 nests) parks in 2005 suggest that parents at Maricara were able to deliver food at higher rates than at Springbrook (t = 1.83, P = 0.088). The differences in delivery rate suggested low food availability at Springbrook, and this is supported by comparisons of the size of young at the point of fledging (i.e. leaving the nest). Data from 2005 on nestling body mass, and lengths of the tarsometatarsus (= "tarsus"; the lowest major leg element) and 5th primary feather of the wing all suggest that young at Springbrook were relatively poorly fed (Table 6). In general, young from Maricara and Springbrook tended to be the smallest, but Springbrook birds in particular were the lightest and had the shortest primary feathers on days 8-9 of the nestling period (Table 6). West Portland birds, on the other hand, were consistently heavy, had long tarsi, and long primary feathers (Table 6), suggesting that the highest quality nestlings were produced at West Portland park.

TABLE 6. Comparisons of nestling body mass (g) and lengths (mm) of the tarsometatarsus ("tarsus") and 5th primary feather at ~8 days of age. Slight differences in nestlings age were removed statistically. Parks that share a letter under each column did not differ statistically from one another (analysis of variance).

	Mass	Tarsus length	5th primary
Lesser	26.5 A	25.1 AB	11.6 A
Maricara	25.2 AB	24.7 B	8.1 BC
Springbrook	24.0 B	25.2 AB	5.6 C
West Portland	27.0 A	25.6 A	10.7 AB

(B) Additional research: microbial ecology, song behavior, and extra-pair mating system of towhees

In addition to the demographic research described in the initial proposal, we conducted research on towhees in other subject areas that also had the potential to address the impacts of human interactions on birds in urban environments.

Microbial ecology. – The negative influence of microbes on birds and other animals is well known (Faustino et al. 2004), but birds and microbes may also evolve mutually beneficial relationships. Recent studies suggest that birds acquire internal microbes through both their diet, and through copulations. Access through copulatory behavior is possible because the cloaca, the common opening through which all wastes are eliminated and gametes exchanged, can receive microbes during copulation that can become established within recipient birds. Bird-microbe interactions are thus viewed as being part of the normal outcome of social interactions of birds. However, human may

alter these relationships because of potential inputs from our activities. Dietary sources may come from bird feeders, and incidental inoculations may occur as consequence of fecal contamination arising from contact between birds and wastes from domestic pets. To investigate these possibilities, a graduate student (Jennifer Klomp) conducted a study of the cloacal microbial community of Spotted Towhees in 2005.

Klomp conducted her research in the Lesser, Maricara, Springbrook and West Portland parks, and the two small woodlots. She assisted in all phases of the demographic work (located nests, helped capture and band adults, etc.), but also swabbed the cloacas of 46 females using sterile procedures. The swabs were then transported to the laboratory where molecular methods were applied to allow her to quantify cloacal microbial species diversity, and to test for microgeographic variation among parks. She detected a total of 57 different species of microbes in the cloacas of the 46 females, and found that microbial species richness and diversity varied among parks. By all measures, microbial diversity was higher at Maricara and Springbrook than other parks (Table 8).

TABLE 8. Comparisons of species richness, Shannon-Wiener diversity (*H'*), and species richness estimated by rarefaction ($S_{rarefacted}$) for cloacal microbes sampled from breeding female spotted towhees in four parks within Portland, OR.

	Park[a]			
	Lesser	Maricara	Springbrook	West Portland
Richness (S)	22	44	36	31
Diversity (*H'*)	3.84 D	4.82 A	4.44 B	4.13 C
(95% CI)	(3.56 to 4.08)	(4.63 to 5.00)	(4.18 to 4.66)	(3.84 to 4.39)
$S_{rarefacted}$[b]	21.6 C	27.4 A	25.5 AB	23.1 BC
(95% CI)	(20.4 to 22.7)	(23.5 to 31.9)	(21.8 to 29.1)	(19.7 to 26.6)

[a] Parks that share letters did not differ significantly from one another based on the widths of the 95% confidence intervals.
[b] Richness was estimated assuming that all parks were sampled at the intensity of Lesser (40 microbes/park).

The actual species composition of the microbes found at different parks also differed substantially, but proximity of parks did not appear to explain microbial community similarity. For instance, Maricara and West Portland are only 0.4 km apart at their closest point, but microbial communities at West Portland were more like those found at Springbrook (located nearly 3 km away). Further work is needed to understand why cloacal microbial communities differ among parks, but we suspect that intensity of human use is potentially an important contributor. Maricara and Springbrook were the two parks most actively used by people and their pets, and they also had the highest microbial diversity. We suspect that humans and their pets brought birds into contact with an unusually high number of microbes due to foot traffic and pet wastes.

We also found that the number of microbes detected in the cloaca of individual female towhees varied predictably with female morphology. Small females (i.e., birds with short tails, narrow bills, and in the case of one park, short leg elements) exhibited higher microbial species richness. And, after statistically removing the effects of these variables, we found that microbe richness varied directly with female body condition: relatively heavy birds supported more microbes (Fig. 2).

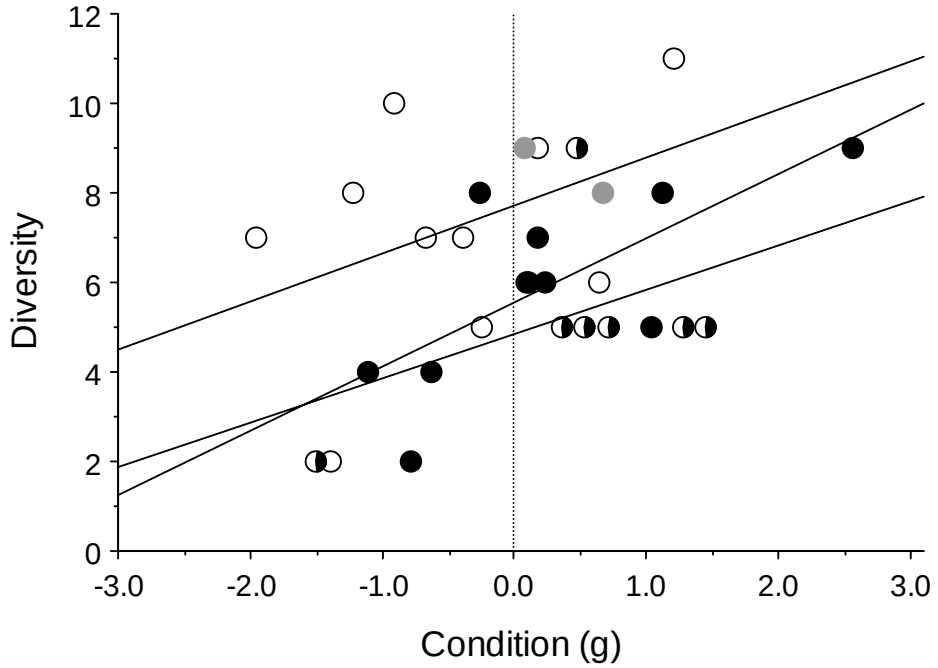

Fig. 2. Microbial richness (number of species) versus female body condition (size corrected body mass) for females captured at Lesser (half-filled circles), West Portland (filled circles) and Springbrook (open circles).

The basis for the positive relationship between female body condition and microbial diversity (Fig. 2) is unclear, but two possibilities exist. First, high microbial richness might improve digestion and/or absorption of food and nutrients, resulting in overall higher body mass and condition. Second, the relationship may exist because of independent effects of towhees taking food from bird feeders. Humans near parks often maintain feeders, even during the summer months, and research indicates that birds obtain microbes from their diet. Feeder locations may concentrate bird activity and facilitate transfer of microbes from the environment to birds. Hence, birds that use feeders may tend to be heavy because of the supplemental food, but they may also acquire higher loads of microbes while feeding. Additional work will be needed to sort through these possibilities.

Towhee singing behavior. - Song is a fundamentally important means of communication among birds that functions in the maintenance of normal social relationships. Recent studies have established that ambient urban noise alters the singing behavior of birds (Patricelli and Blickley 2006, Wood and Yezerinac 2006), and may potentially affect reproductive success. Towhees are very versatile singers and our

anecdotal observations suggested strongly that vocal dialects exist, and that parks exhibited distinctive song types. Jennifer Richardson, a new graduate student at PSU, chose to investigate the song behavior of Spotted Towhees for her Masters work, and in the 2006 field season she began recording songs and sing behavior of towhees. In addition, she was fully involved with the demographic study and contributed to nest searches, capture of adults, and monitoring of nests.

Richardson collected data from 65 individually marked males, and given that individual identities were known (because they were banded), she was able to obtain at least 200 different songs from all 65 males. With these data she will be able to calculate singing rates and diurnal patterns of singing, and to compare song behavior of males in high and low ambient noise environments (i.e., edge versus interior of parks). Over the course of the next academic year (September through May) she will use a sonograph to quantify and describe all recorded songs so that she will be able to (a) determine if song dialects exist and differ among parks, and (b) measure song repertoire size of individual males. Knowledge of the latter will enable her to determine if males in low and high noise environments maintain different repertoires, and to relate repertoire size to male age, physical characteristics (size, condition), and reproductive success. She plans to return for another field season in 2007 to address additional questions, such as the repeatability of male song repertoires and evaluate the stability of the presumed song dialects.

Extra-pair mating systems. – As a consequence of our sampling of adult and nestling blood to evaluate body condition through measurement of hematocrit, we also were able to obtain DNA samples for use in studies of parentage. Much research over the past two decades has established that socially monogamous songbirds regularly obtain copulations outside of their pair bond, but why this is so is still very much debated. Sarah Smith has begun molecular genetic studies to measure the frequency of extra-pair paternity in towhees using a set of four variable microsatellite loci. Towhees have never before been examined in this context, and her preliminary studies show that towhees in Portland show relatively high frequencies of extra-pair paternity for a mostly resident songbird.

Work Tasks and Project Schedule:

February/March 2004:

Conduct preliminary surveys of parks to establish return time for birds and probable areas of research.

March/April 2004:

Initiate population surveys and begin to locate nests and capture birds for to mark them for survival analyses. Daily visits made to all sites.

May through end of July 2004:

Conduct population study in all parks. Nests were located and monitored on a daily basis. Behavioral observations and capture programs continued throughout the summer.

August 2004:

Habitat sampled at all nests sites and randomly located sites to establish nesting preferences of towhees.

September through December 2004:

Data entry and preliminary take place.

January/February 2005:

Proposals submitted to obtain additional financial support for the research. By the end of the spring term, participants received additional funding from the American Ornithologists' Union (Klomp), Portland State University (Klomp and Smith), and the Environmental Protection Agency (Smith).

March through end of July 2005:

Conduct population study in all parks. Locate previously marked birds to document survival. Conduct nest searches to locate nesting attempts for as many pairs as possible, and then monitor nests on a daily basis. Observations of parental behavior conducted, along with sampling of towhees for cloacal microbes. Capture of adult birds continued throughout the summer.

September through December 2005:

Data entry and additional analyses performed. Molecular genetic analysis of parentage begun.

January/February 2006:

Proposals submitted to obtain additional financial support for the research. By the end of the spring term, participants received additional funding from the American Ornithologists' Union (Smith).

February/March 2006:

Detailed trail maps developed for each park and location of all nests marked using GPS/GIS technology.

April through the end of July 2006:

Conduct population study in all parks. Locate previously marked birds to document survival. Conduct nest searches to locate nesting attempts for as many pairs as possible, and then monitor nests on a daily basis. Observations of parental behavior conducted, and studies of song behavior initiated. Capture of adult birds continued throughout the summer.

Project Staff and Partners (including volunteers):

1. Salaried Staff

Sarah Bartos Smith, Graduate Student and Research Assistant (2004-06)
Jennifer McKay, Graduate Student and Research Assistant (2004-06)
Jennifer Klomp, Graduate Student and Research Assistant (2005)
Jennifer Richardson, Graduate Student and Research Assistant (2006)
Michelle Campbell-Breckon, Field Assistant (2006)
Jina Sagar, Field Assistant (2005)
Nathan Einbinder, Field Assistant (2005)

2. **Volunteers**

John Deshler (2006: PSU undergraduate student)
Laura Bonner (2006: PSU undergraduate student)
Jennifer Richardson (2005: new graduate student)
Luke Redmond (2005: PSU graduate student)
Michelle Campbell-Breckon (2005: PSU undergraduate student)
Susan Kaufman (2005: PSU undergraduate student)
Kara Ryf (2005: PSU undergraduate student)
Corrie Winter (2005: PSU undergraduate student)
Jalene Braun (2005: PSU undergraduate student)
Bridger Cohen (2005: Wilson High School student)
Christy Lee (2004: PSU undergraduate student)
Christina Bentley (PSU undergraduate student)
Ashley Rogers (2004: Reed College)
Adam Smith (2004/05: spouse of staff member)

3. **Partners**

Metro Regional Services
City of Lake Oswego
City of Portland

On-going Tasks and Continued Activities:

The majority of field work has been completed. The only remaining activities will be to (1) wait until this winter (when the leaves fall) so that we can use GPS instruments to measure the location of every nest with greater accuracy, and (2) recensus the populations next spring to obtain a third estimate of adult return rate for use in our estimates of annual survival. Smith and McKay will be conducting extensive data analyses throughout the year in preparation for their Ph.D. and Masters defenses. Murphy will be heavily involved and assist both students in their endeavors. Klomp and Murphy have already completed all laboratory and most of the statistical analyses of the cloacal microbe study and this is being prepared as a manuscript for submission for peer-review and ultimately publication. Smith and McKay will likewise be preparing manuscripts for publication. Richardson will begin her analyses of song behavior this fall and will prepare for a second field season next year.

At present, we have a very well established population study and our goals are to attempt to continue studying towhees and possibly other bird species over the near future. Additional studies of more small sites (1-2 ha) and of natural areas outside of the Urban Growth Boundary would add much valuable information and Murphy will seek additional funding to support both activities.

Summary of Expenditures and Project Costs:

Expenditures

I. Salaries and wages

Sarah B. Smith (graduate student)	$3,840.00
Jennifer McKay (graduate student)	$7,340.00
Jennifer Klomp (graduate student)	$2,000.00
Jennifer Richardson (graduate student)	$3,500.00
Nathan Einbinder (field assistant)	$2,018.00
Jina Sager (field assistant)	$2,000.00
Michelle Campbell-Breckon (field assistant)	$2,060.00
Total salaries and wages	**$22,758.00**
II. Fringe benefits (OPE???)	**$1,208.00**
III. Materials and supplies	**$1,034.00**
Total direct costs (from USFWS)	**$25,000.00**

Match

I. Salary & stipends/tuition remittance (for students)

PI (Murphy) salary @ 10% of 1.0 FTE)	$9,793.31
Student teaching assistant stipends	
Smith (16 Sept. 2004 to 15 June 2005)	$17,500.00
McKay (16 Sept. 2005 to 15 June 2006)	$17,500.00
McKay (16 Sept. 2004 to 15 June 2005)	$17,500.00
Klomp (16 Sept. 2005 to 15 June 2006)	$17,500.00
Richardson (16 Sept. 2005 to 15 June 2006)	$17,500.00
Total salary and graduate student stipends	**$97,293.31**

II. Volunteer hours

Total volunteer hours = 1,695 @ $6.50 **$11,017.50**

IV. Mileage

Minimum mileage estimates (assumes 5 d/wk for April, May, June and July) for Smith (3 yr; 10 mi roundtrip/day (RT/D), McKay (3 yr; 46 mi RT/D), and both Klomp and Richardson (1 yr each; 10 mi RT/D) = 2,550 mi (Smith), 9,180 mi (McKay), 850 mi (both Klomp and Richardson) = 13,430

Total mileage = 13,430 miles @ $0.34/mile) **$4,566.62**

V. Equipment and supplies

Mist nets	6 @ $110 apiece	$660.00
Color bands	1000 @ $0.20 apiece	$200.00
Sony Video recorders	3 @ $225 each	$775.00
Video tapes		$150.00
Sound recording parabolic disc and Telinga shotgun microphone		$1500.00
CD players, speakers, and batteries		$320.00
Garmin GPS receivers	2 @ $250 each	$500.00
	Total equipment and supplies	**$4,105.00**

Total matching funds (from PSU and volunteers) **$116,982.43**

Summary and Conclusions:

Our results suggest that parks and greenspaces in the Southwest Hills functioned as population sources over the period of our study, and that Spotted Towhees are not only capable of sustaining themselves, but appear also to produce sufficient young to export individuals to surrounding areas. The success of the towhee populations can be attributed to two factors: relatively high annual production of young, and high adult survival. Despite losing roughly 60% of nests, the ability of towhees to replace failed nests and produce up to three broods/season enables most pairs to have at least one and often two successful broods.

Few comparative data are available from other sites, but recent work on towhees from California (Small 2005) suggests much higher nest failure rates: daily nest survival near Sacramento, CA, was 0.928 (95% CI = 0.912 to 0.943), which generated nest success of only 19.3% (95% CI = 13.2% to 27.5%). Nest predators were the primary cause of nest loss in both California and in Portland, but in California, Brown-headed Cowbird brood parasitism and snake predation were relatively common. Both were absent at our site, and we suspect that avian and mammalian predators caused nearly all nest failures, but we are not able to establish their relative importance.

In that we do not know the primary nest predators we have difficulty evaluating risk factors for towhees, but we suspect that domestic pets (and feral cats) are of concern. An additional concern, which we were able to demonstrate statistically, was that large numbers of trails may adversely affect a nest's probability of fledging young. Our results showed that nests located within 10 m of a trail were more likely to fail than nests located more than 10 m from a trail. The mechanism underlying this relationship is unclear, but possibilities include greater exposure to pets, greater disturbance from people (and reduced parental behavior), or use of trails by natural nest predators. Regardless, our data suggest that trails reduce nesting success for towhees, and we suspect the same is true for other species.

Negative impacts of trails may have manifested themselves also through alteration of parental behavior. Springbrook had the highest trail density and received the most traffic of all parks, and we note that parental feeding rates of young were lower at Springbrook than at Maricara. In addition, measurements of body size of young at the point where they left the nest consistently indicated that the lowest quality young were produced at Springbrook, and that the highest quality young came from Lesser and West Portland. The two latter parks had low trail density and human use. These data suggest that parents may have responded negatively to human traffic on the trails and as a consequence produced lower quality young at high use parks.

The average annual percentage of towhees to survive from one year to the next, when averaged across all of our sites (61%), was very similar to estimates from several sites near Sacramento, CA (Gardali and Nur 2006). But like the latter authors, we found variation in apparent survival among sites. The two larger sites (Springbrook and West Portland) exhibited an average annual return rate of about 67%, whereas annual return rate at the two smaller sites (Lesser and Maricara) was in the low to mid 50s (~53%). Doherty and Grubb (2002) also detected a trend towards lower survivorship in small forest fragments. We note that all of these figures underestimate true survival because (1) we have not yet accounted for the probability of resighting surviving birds, and (2) current mark-recapture models do not allow the separation of permanent emigration from true death. But assuming that the same biases apply to all sites, adults appeared to exhibit higher survival at larger parks. We plan to census all parks again in 2007 to provide additional data to bolster our conclusions.

Park size and trail abundance therefore appear to have had important effects on towhee demographics. Nests located near trails were predisposed to failure (and possibly poorer parental behavior) and therefore parks with many trails, regardless of size, tended to have lower nest success. On the other hand, adult survival was generally higher in large parks. The interaction of these two factors appeared to have an influence on potential population growth rate, and the source:sink status of populations (Table 7). Maricara had the lowest potential growth rate, and we speculate that this is likely to have arisen from the combination of it being relatively small (compared to other parks that we studied) and having many trails. West Portland, on the other hand, was 60% larger than Maricara, lacked well-kept trails, and exhibited the greatest growth potential (Table 7).

TABLE 7. A summary of the probable interaction between park size and trail abundance on population growth rate of towhees in Portland, OR.

	Park/Greenspace size	
Trail development	Smaller	Larger
Low	Lesser (λ = 1.09)	West Portland (λ = 1.18)
High	Maricara (λ = 1.04)	Springbrook (λ = 1.09)

Nonetheless, the most important message is that Spotted Towhee populations at all parks showed the capacity to maintain themselves (i.e. $\lambda > 1.0$ at all locations). Moreover, the capacity to produce young was such that "excess" young were probably produced at most parks, and through dispersal, towhee young were probably able to sustain populations in residential areas surrounding the parks. **However, we hasten to also point out that the ability of towhees to persist in these parks was dependent entirely on the absence of development and persistence of native understory vegetation.**

Based on our experiences with towhees, we feel that we can make several management recommendations. **First**, trail development must be planned carefully and implemented cautiously. The primary argument for maintenance of neighborhood parks is that they improve quality of life for humans. Trails provide access for nature appreciation and exercise, and trails must and should exist. However, trails also serve as corridors of movement of predators (both wild and domestic) of wildlife and may serve as entry points for alien species and microbes. Although only correlations, we found several patterns that suggested that parks with large numbers of trails (and human and domestic pet activity) may have negatively affected towhees: nest success, parental feeding rates, and nestling body size were all lowest in parks with many trails. In addition, microbial species richness was greatest in the two parks with the greatest human foot traffic and domestic pet activity. We are as yet unable to prescribe an appropriate trail density, but do recommend careful planning to ensure that all parks have areas that are relatively undisturbed by trails.

Second, and following closely on our first recommendation, domestic pets need to be controlled at all times in parks. Many walkers leash their dog on their daily trip through the park, but violations occur. The impact of dogs on nesting success is probably low, but we note that birds nesting near trails had lower nest success than pairs located more than 10 m from trails.

No laws exist for the restraint of cats and most cat owners appear to believe that cats should naturally be free to move into parks from surrounding homes. It is estimated that there are 64 million domestic cats in the U.S. and that most run free (Winter 2006). Abundant evidence also exists to demonstrate that cats negatively affect small vertebrate populations (Winter 2006). Research from Wichita, KS, estimated that, at a minimum, a roaming cat killed four birds/yr (http://www.geocities.com/the_srco/Article.html). Assuming half the cats in the U.S. roam freely, and that cats elsewhere show similar predation rates, then 128,000,000 birds are killed every year by cats (this ignores the heavier predation by feral cats). We found, not uncommonly, that young in nests experienced partial nest loss (1 or 2 young missing) or that young exhibited puncture wounds. Both suggest predation by predators with low motivation (possibly a well fed cat). We are unable to identify the specific cause for either observation, but cats were observed in parks and we suspect they may have contributed to towhee nest failures. We therefore recommend that ALL domestic pets be treated equally and that cats no longer be allowed to roam freely within the city limits.

Our **third** recommendation concerns the issue of appropriate park size for maintaining a diverse wildlife community. A community of organisms may persist at a site either because they provide enough recruits on site to sustain themselves, or lacking sufficient on-site productivity, it may persist because of immigration of individuals from outside. Previous work by students in Murphy's lab showed that many species dependent on forest habitat first appeared in parks when they covered an area of about 10 ha. Non-forest dependent species also maintained high abundance in parks of this size, and thus, 10 ha appeared to be a critical ***minimum*** size for maintaining biodiversity.

We have shown that one bird species (the Spotted Towhee) is able to sustain populations from on-site production of young in parks in the range of 10-20 ha. Towhees are a forest-edge species, and in retrospect, the parks that we studied provided substantial forest-edge habitat. The park boundary represents a sharp edge between habitats where transitions in the physical and biotic environment occur, and using the commonly assumed "edge effect" (transition zone) of 50 m to 75 m width, then a square 15 ha park would be composed of 44% to 61% edge habitat. That towhees did well in parks in this size range is therefore encouraging, but perhaps not surprising. Whether truly forest-dependent species would also be able to sustain themselves in parks of this size is unknown, but we suspect that they would not. The occurrence of forest-dependent species in parks in the range of 10-20 ha (or smaller) is probably dependent on proximity to larger parks that exist in the landscape, and in the case of our study area, Tryon Creek State Park (~250 ha) is located 1.5 km at its minimum and 4.3 km at its maximum from the parks in our study. We suspect that our results would change radically if Tryon Creek were absent from the landscape. The neighborhood parks surrounding Tryon Creek State Park probably experience spillover effects and local human residents benefit by the opportunities to view wildlife in smaller parks that would otherwise not be present. Therefore, as a policy recommendation, we suggest that planners attempt to preserve at least one large park (> 100 ha) with a network of surrounding parks in the range of 10 ha to 20 ha to maximize possibilities of maintaining biodiversity. Habitat corridors will also be essential for animals with less mobility than birds.

Fourth, and lastly, we have insufficient data to evaluate the importance of parks under 5 ha in area. We followed nest fates and documented adult towhee survival in two parks that were ~1 to 2 ha in area, and birds did well at both sites (i.e. they would be self-sustaining). However, both sites were relatively close to other larger sites, and whether truly isolated sites of this size would have supported birds is unclear. Far more work on the demography of birds (of all species) in small, isolated parks and greenspaces is needed before we can fairly evaluate the demographic significance of such small sites.

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