

Article

Reproductive Success of Tree Swallows at Abandoned Mine Drainage Treatment Ponds

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Simple Summary: Abandoned underground coal mines collect ground water that eventually finds its way to the surface. A common way to treat pollutants and sediments from this mine water is to create passive treatment ponds that remove contaminants before the water enters a surface stream. Tree Swallows and many other birds and wildlife live and breed near these treatment ponds, with potentially detrimental effects. We monitored 63 nests over two breeding seasons (2022–2023) to determine if nests located next to the ponds had better or worse reproductive outcomes than nests farther away. We found that nests close to the ponds (<70 m) had higher numbers of young that survived to the age of fledging than nests that were built farther away from the ponds (>820 m). While this suggests that the treatment ponds provided meaningful resources for Tree Swallows to reproduce, the numbers of offspring were unusually low compared to what was found in studies by other investigators at other sites. More research will be needed to determine why.

Abstract: Abandoned mine drainage treatment ponds could have contrasting effects on the reproductive success of birds living in the vicinity. The ponds and associated vegetation may, like any other body of freshwater, provide beneficial habitats for the insects that the birds use to feed their young; or instead, the ponds may act as an ecological trap, attracting the birds to a habitat that is poor in quality and negatively impacting their productivity. We monitored nests of an aerial insectivore, the Tree Swallow (*Tachycineta bicolor*), to determine whether the distance between the ponds and the nests affected various reproductive parameters including clutch size, hatch rate, number of nestlings, nestling size and mass, number of fledglings, fledging rate, and fledge date. Data were collected over two breeding seasons (2022 and 2023) from a swallow population in southwestern Pennsylvania, USA. We found that the nests closest to the treatment ponds had significantly more nestlings and fledglings, earlier fledge dates, and a better fledging rate when compared to nests that were more distant from the ponds. However, all these parameters were well below previously published values, which suggests that the mine drainage ponds provide good nesting habitats relative to what is available in the region but that they do not represent high-quality habitats for this species overall.

Keywords: clutch size; *dermanyssus*; fledging rate; habitat quality; mites; nesting success; nestling mass; reproduction; *Tachycineta bicolor*; water quality



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1. Introduction

Subsurface coal mines quickly fill with groundwater after mining operations cease. Such mine water can be contaminated from a process by which sulfur-containing rocks interact chemically with water to form sulfuric acid [1]. The acid leaches minerals like iron, manganese, and aluminum from rock layers and finds its way to the surface, where there can be detrimental effects on bacteria, plants, and animal life [2–4]. Treatment of mine drainage through the construction of passive settling ponds can improve water quality before it enters surface waterways [5]. A successful example of this system is found on the campus of Saint Vincent College in Latrobe, PA, USA, where a connected series of three

abandoned mine drainage (AMD) ponds with multiple dikes were built between 1997 and 1998 [6].

There are thousands of AMD treatment facilities around the world, wherever coal has been mined, including Sweden, Slovakia, the Philippines, Australia, and the United Kingdom [5]. Many have passive settling ponds like the ones at Saint Vincent College. By design, the pond receiving mine inputs is far more polluted than the pond further downstream in the treatment system [2]. The polluted fraction of water can inhibit insect populations by depressing larval development stages [3,7]. For example, aquatic life can be poisoned by heavy metals, reproductively inhibited by fluctuating pH, and suffocated from the high amounts of metal particulates in the mine water [8]. In untreated waters, depressed insect populations can impact the vertebrate populations that rely upon them for food [9,10].

It is unclear whether AMD treatment ponds can be a valuable ecological asset for species that rely on aquatic insect life for food. Numerous scientific studies of bacteria and other simple organisms in AMD settling ponds have been published [4], but few have centered on birds. One study measured avian diversity at treatment ponds in comparison to natural wetlands and found that AMD ponds had reduced diversity of bird species [11]. Another study showed that AMD treatment ponds hosted a greater diversity of bird species at the ponds in comparison to natural wetlands nearby [12]. Neither of these studies investigated the reproductive success of the birds, such as the number of fledged offspring per nesting attempt. Measures of species diversity are not adequate to establish the value of a habitat. An AMD pond habitat could be an ecological trap, a common circumstance seen in disturbed areas in which animals settle in a particular habitat but do not have adequate levels of health and reproduction to replace themselves over their lifetimes [13–15].

This study measured bird productivity along a geographical gradient from the AMD ponds to more than 1 km away from the ponds. Bird productivity was defined by life history parameters like number of chicks per nest, egg laying date, and nestling size and weight. Prior studies have shown that birds that lay eggs earlier in the season have better reproductive success than those who delay [16,17]. Higher nestling weights near the time of fledging also correspond to better reproductive outcomes [18], and of course, if parents have more offspring, they will usually have better lifetime success than those who have few.

We chose to study the productivity of Tree Swallows (*Tachycineta bicolor*), as they readily nest in artificial wooden boxes that facilitate data collection. Further, food delivered to nestling Tree Swallows consists predominately of flying invertebrates that have aquatic larval stages, such as damselflies (order *Odonata*) and mayflies (order *Ephemeroptera*) [19]. This fact has led to the frequent use of Tree Swallows in studies of environmental contamination, since pollutants impacting water quality can have adverse effects on the organisms that live in the water, as well as those that depend on them in higher trophic levels [20]. Tree Swallows rarely travel more than 400 m from an active nest to find food [21], so individuals living near polluted waterways are likely to offer contaminated or otherwise impacted prey to their nestlings.

Our hypothesis was that birds locating their nests in boxes placed near Saint Vincent's AMD ponds will show poorer productivity compared to birds that locate their nests farther away. We reasoned that the insect prey that parents use to produce eggs and feed their nestlings would be of a poor quality and quantity near the ponds due to the contamination and sediments found in the water. The reduced nutrient supply would be reflected in those birds' reproductive outputs, including nestling size and mass [22,23].

2. Materials and Methods

2.1. Study Site

The study site was located near Saint Vincent College, a small residential institution with approximately 1400 students enrolled. The campus is in a suburban area about 53 km SE of the city of Pittsburgh, PA, USA. The nearest town to the college, Latrobe, has a population of 28,000 and is spread across 193 km² at a density of 147 per km².

The site is in the Köppen–Geiger humid continental climate zone with hot summers and no dry season [24]. Temperatures at the nearest airport range from a mean daily low temperature of -5.9 °C in winter (January) to a mean daily high temperature of 28.3 °C in summer (July) [25]. The college campus is composed of tightly packed academic buildings and residence halls sited on top of a hill, with an adjacent cemetery and athletic fields positioned directly west and south, respectively (Figure 1). Going further in those directions, agricultural fields predominate, with small muddy hedgerows between them. The hedgerows do not contain permanent surface waters but are wet enough year-round to support cattails (*Typha* spp.), other wetland plants, and possibly the insect prey of Tree Swallows. Down the campus hill and to the north are the series of AMD ponds which drain into a stream carrying water affected by AMD entering from mines further west. An adjacent 4.9 ha recreational lake is relatively free from AMD and supports fish. Surprisingly, point-count surveys of birds at the lake that we conducted for a separate, concurrent study rarely recorded Tree Swallows (only 1 of 429 individual birds identified during point counts was a Tree Swallow) [26]. Land coverage within a 2.5 km radius of the site includes 38% forest; 33% human development or other non-agricultural cover; 21% croplands planted in corn; 6% soybean, wheat, or cover crops; and 1% bodies of water [27]. The forest canopy is composed of mixed oak and maple species, characteristic of the Eastern Temperate Forest ecoregion of North America [28]. The understory is dense with invasive shrubs, including several varieties of bush honeysuckle (*Lonicera* spp.).

The AMD ponds are spread over 9 ha of land. Water tests indicate that the water entering the ponds during May–July in 2022 and 2023 averaged above the local authority’s maximum water quality criteria in total iron, manganese, and sulfate and below the water quality criteria for dissolved oxygen (DO) (Table 1).

Table 1. Chemical properties of pond water found at study site and allowable concentrations according to Pennsylvania Water Quality Standards. Shaded cells indicate parameters outside of water quality standards.

Parameter	Site Sample Mean \pm SD Concentration ¹	Water Quality Standard ²
DO ³	4.9 \pm 3.3 mg/L	5.0 mg/L minimum
Alkalinity	175 \pm 3 mg/L	20 mg/L minimum
TDS ⁴	873.2 \pm 119.1 mg/L	750 mg/L maximum
pH	6.28 \pm 0.37	6.0 minimum
Total Al	<0.3 mg/L	NA
Total Cl	61.9 \pm 2.2 mg/L	250 mg/L maximum
Total Fe	48.4 \pm 2.8 mg/L	1.5 mg/L maximum
Total Mn	1.93 \pm 0.03 mg/L	1.0 mg/L maximum
Total Mg	35.3 \pm 1.6 mg/L	NA
NO ₃	<0.04 mg/L	NA
Total K	3.6 \pm 0.1 mg/L	NA
Total SO ₄	560.3 \pm 35.8 mg/L	250 mg/L maximum
Total Zn	<0.03 mg/L	NA

¹ Unpublished data collected by B. Bollinger, Lab Manager at Saint Vincent College, and staff of the Pennsylvania Department of Environmental Protection. Means \pm SD of each parameter were calculated from water tests conducted on 3 May, 1 June, and 7 July in 2022 and 18 May and 18 July in 2023 from the input of mine effluent into the upper pond (input pipe to Wetland #2). ² PA Title 25 Chapter 93.7. Standards for aluminum, magnesium, nitrate, potassium, and zinc are not listed. ³ Dissolved oxygen. ⁴ Total dissolved solids.

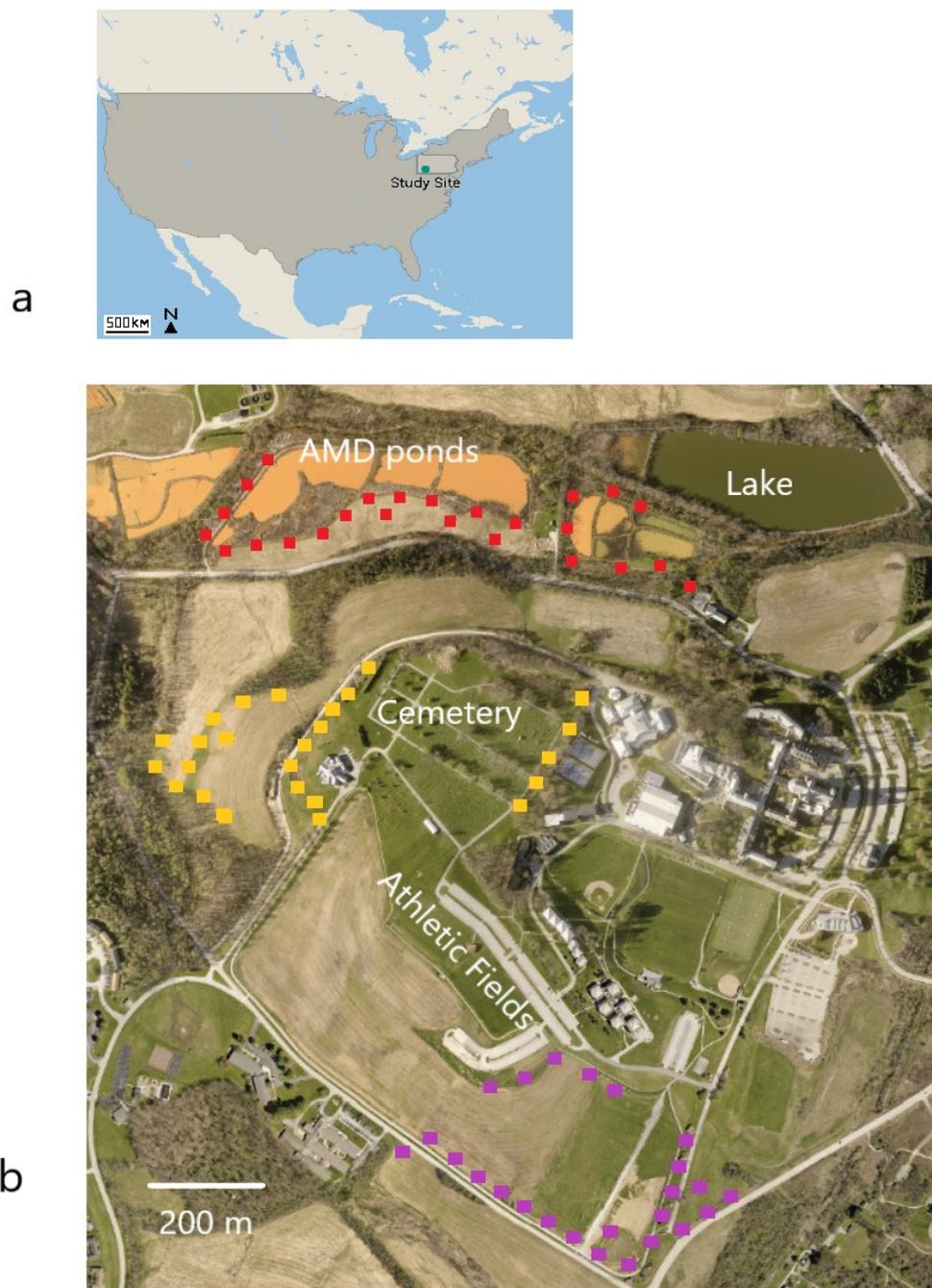


Figure 1. (a) Location of the study site within the United States. (b) Aerial view of the study site. Tree Swallow nest boxes were placed near abandoned mine drainage (AMD) treatment ponds and at locations that were more distant from the ponds. Nest box locations are shown on the map as red squares (NEAR locations), yellow squares (MID locations), and purple squares (FAR locations). Box locations are approximated.

2.2. Study Species

The Tree Swallow is a North American insectivorous Passerine species in the swallow and martin family (*Hirundinidae*). Different studies in different locations have shown some variation in the diet items consumed during the breeding season, but true flies (order *Diptera*), dragonflies and damselflies (order *Odonata*), mayflies (order *Ephemeroptera*), and caddisflies (order *Trichoptera*) are the most frequent [17]. These insects are typically captured in midair from 0 to 12 m above the ground or water surface, but swallows may forage up to

100 m above these surfaces on occasion [21]. Tree Swallows are obligate migrants; they breed throughout Canada and the northern United States, and following reproduction, they travel to points south from the U.S. southeastern coast to Mexico and Central America. The global population size is estimated to be near 19 million and declining overall [29]. However, populations in Pennsylvania are stable [30]. The species is a secondary cavity nester that readily nests in artificial boxes, a trait that has facilitated many scientific studies [17]. It produces only a single brood per year, with incubation performed only by the female and other parental duties shared between male and female. Tree Swallows are socially monogamous but have one of the highest levels (>80%) of extra-pair paternity recorded among Passerines [17].

2.3. Nest Box Setup and Monitoring

Twenty-five wooden nest boxes were set up in early 2022 along and near (<70 m) the edge of AMD ponds, and another twenty-five were placed near the cemetery and adjacent fields at a distance from the ponds ranging from 260 to 490 m. Another 25 boxes were erected in time for the 2023 breeding season at an even farther distance from the AMD ponds, ranging from 820 to 1700 m. These latter boxes were positioned along a campus fitness path encircling a set of sports practice fields and an agricultural field. Distances were estimated to the nearest 10 m using the measurement tool on Google Maps [31].

All boxes were purchased from the Pennsylvania Game Commission's Howard Nursery (Bellefonte, PA, USA) and featured an entrance hole of 3.6 cm in diameter. The boxes were hung 1.2 m meters above the ground on steel posts. Steel cone predator baffles were installed immediately below each box. The box orientation was set to face east, as that is the Tree Swallow's documented preference [32]. Most boxes were placed in a line with an average of 30 m between each one (10 m minimum). Almost all boxes were used by nesting birds, about half by Tree Swallows. The other half were occupied by non-target species like House Wrens (*Troglodytes aedon*) and Eastern Bluebird (*Sialia sialis*). These other species, unlike the Tree Swallow, do not rely on insects with aquatic larval stages to feed their young [33,34], making them less suitable for our project.

Nest boxes were checked every 2–3 days from 15 March to 8 August each year. We noted the presence of adults, of nest material, completed nests, eggs, and nestlings by inserting a cell phone into a ventilation slot between the front and top panels of a box and taking a photo.

When nestlings were approximately 11 days old (range = 6–16), we opened the box, removed the nestlings, and placed them together in a plastic container for weighing with a digital scale. The average nestling weight was found by dividing the overall mass by the number of nestlings. We selected a single nestling for morphometric measurements to minimize the time spent at the nest. We were careful to avoid any nestling that appeared smaller or larger than the rest. The unflattened wing chord and several other parameters were measured using calipers to the nearest 1 mm. U.S. Fish and Wildlife numbered leg bands were applied to nestlings for use in future studies.

We tried to minimize disturbance by only handling nestlings once during their development, so that banding and measurements would be conducted on the same day. We targeted our visits to coincide with a nestling age between 7 and 12 days old. Leg bands do not often fit nestling Tree Swallows appropriately when they are younger than 7 days, and handling nestlings past day 12 risks premature fledging [22].

Knowing the dates of egg laying, hatching, and fledging was important for the calculation of nestling age, but usually, only two of these dates were known precisely, since we did not visit each nest every day. Nestling age was therefore an estimate, based on known dates when available, and on published species averages when not available. The incubation period for Tree Swallows is around 14 days (range = 11–20), and the average nestling period is around 20 days (range = 15–25) [17]. Tree Swallows have asynchronous hatching, with an average of 28 h between the first-hatched and last-hatched egg [35]. Our estimates of nestling age were based on the date when the first nestling hatched. It is possible that some

nestlings considered here to be X days old may be X-1 days old due to hatching asynchrony, but given our effort to avoid measuring the smallest nestling in each brood, the number of mis-aged nestlings in our dataset should be close to zero.

Between 30% and 24% of nests in 2022 and 2023, respectively, became infested with hematophagous mites (*Dermanyssus* spp.), especially those that had not yet fledged by mid-June of each year. The degree of infestation was not quantified. We did not interfere with the mites, as we did not wish to bias our measurements of nestling health and parental reproductive success by treating some nests differently than others.

2.4. Data Analysis

More nests were monitored in 2023 than in 2022 ($n = 45$ and 20 , respectively) due to the addition of more nest boxes in 2023. Morphometric data were collected on nestlings from only a subset of nests ($n = 24$ in 2023; $n = 5$ in 2022), because we were unable to consistently access nests within the short interval of time when nestlings were aged 7–12 days. This is especially true in 2022 when we were overly cautious with choosing when a nestling was the ideal size and age for handling.

Initial analyses began with examining reproductive parameters from nests in three distance categories relating to the AMD ponds: adjacent to the ponds (<70 m, $n = 35$), at an intermediate distance from the ponds (260–490 m, $n = 10$), and at a far distance from the ponds (820–1700 m, $n = 18$). These categories are hereafter referred to as NEAR, MID, and FAR nests, respectively.

Specific parameters calculated and compared across these three distance categories included the number of nests with at least one egg, clutch size, number of hatched nestlings, number of nests with at least one fledgling, earliest fledge date, number of fledglings, and three other measures of productivity (Table 2).

Table 2. Calculations for Tree Swallow reproductive parameters using number of eggs, nestlings, and fledglings.

Parameter	Calculation
Mean Hatch rate (%)	$\bar{X} = \frac{\text{hatched nestlings}}{\text{clutch size}} * 100$
Mean Fledge rate (%)	$\bar{X} = \frac{\text{fledglings}}{\text{hatched nestlings}} * 100$
Mean Nesting success rate (%)	$\bar{X} = \frac{\text{nests with at least one fledgling}}{\text{nests with at least one egg}} * 100$

Each parameter was evaluated for the assumptions of normal distribution using kurtosis, skewness, and F-tests. All distributions were normal except for fledge date, which was consistent with a Poisson distribution. A repeated-measures multivariate analysis of variance (MANOVA) was run using JMP software (version 17.2.0) [36] to determine whether the dependent variables of clutch size, number of hatched nestlings, and number of fledglings could be predicted by the independent variables of year (2022, 2023) and distance to the AMD ponds (NEAR, MID, FAR). A general linear model (GLM) assuming the Poisson distribution for fledge date was used to determine if the fledge date was dependent on the year (2022, 2023) and distance to the AMD ponds (NEAR, MID, FAR).

For morphometric analyses, we used JMP software [36] to create general linear models, testing for relationships among the dependent variables of nestling wing chord and body mass and the dependent variables of nestling age and distance group (NEAR, MID, or FAR). Interaction terms were included each time.

3. Results

3.1. Nest Parameters

All measured life history traits followed the same general pattern: whereas the NEAR group had the most favorable reproductive outcomes, the MID group had intermediate levels, and the FAR group had the least favorable outcomes (Table 3). In the MANOVA test

comparing clutch size, number of hatched young, and number of fledglings to distance group, we found that this variable explained a significant amount of variance ($F = 3.61$, $df = 55$, $p = 0.034$). According to the model, over the three developmental stages of egg, nestling, and fledgling, the NEAR group had the greatest numerical success. The mean clutch size of the three distance groups was similar, varying by only 0.2 eggs (Table 3). However, all three groups showed a significant loss of offspring as time progressed from the nestling stage to the fledgling stage ($F = 31.28$, $df = 54$, $p < 0.001$). There appeared to be an increasing difference in this negative slope among the three groups in the later stages of reproduction (number of nestlings and fledglings) (Figure 2), but our test did not show this interaction to be significant ($F = 1.66$, $df = 108$, $p = 0.166$). There was also no significant effect of year ($F = 0.43$, $df = 54$, $p = 0.517$).

Table 3. Productivity of Tree Swallow nests at three distances from abandoned mine drainage ponds, 2022–2023. NEAR nests were those less than 70 m from a pond edge ($n = 35$), MID nests were those from 260 to 490 m from a pond edge ($n = 10$), and FAR nests were those from 820 to 1700 m from a pond edge ($n = 18$).

Productivity Parameter	NEAR Nests	MID Nests	FAR Nests
Earliest lay date	1 May	10 May	8 May
Mean clutch size (\pm SE)	5.0 ± 0.2	5.0 ± 0.2	4.8 ± 0.3
Mean hatch rate	93%	83%	78%
Mean number of hatched young (\pm SE)	4.7 ± 0.2	4.3 ± 0.5	3.8 ± 0.4
Mean fledge rate	71%	71%	49%
Mean number of fledglings (\pm SE)	3.3 ± 0.3	2.9 ± 0.8	1.8 ± 0.5
Nest success rate	86%	50%	56%
Earliest fledge date	12 June	18 June	22 June
Average fledge date (\pm SE)	$22 \text{ June} \pm 2 \text{ days}$	$6 \text{ July} \pm 9 \text{ days}$	$8 \text{ July} \pm 5 \text{ days}$
Least squares mean nestling mass ¹ (g \pm SE)	18.6 ± 0.7	17.8 ± 1.2	$17.2 \text{ g} \pm 0.7$
Least squares mean wing chord ¹ (mm \pm SE)	48.2 ± 2.9	49.1 ± 4.4	41.4 ± 3.2

¹ Least squares values were output from general linear models and represent estimated nestling measurements at 11 days of age.

The mean hatch rate, mean fledge rate, and nest success rate all generally followed the same pattern as the numbers of eggs, nestlings, and fledglings. That is, rates were higher in the NEAR group and lower in the FAR group, with mostly intermediate values in the MID group (Table 3). The earliest fledge date in the NEAR group was 10 days earlier than that of the FAR group, and NEAR nests' fledge dates averaged 16 days earlier (Table 3). Values for the MID group were intermediate. The GLM model showed that the distance group explained a significant amount of variance in fledge date ($F = 18.39$, $df = 2$, $p < 0.001$). No significant difference between years was found ($F = 2.48$, $df = 1$, $p = 0.115$).

The above statistics show that some nests in all groups failed to produce hatchlings or fledglings. Six failures were due to a nest being overtaken by a competing species, the Eastern Bluebird (*Sialia sialis*), and nests being destroyed by unknown predators. Ten nests failed due to the unexplained death of all nestlings, which happened in two nests of the NEAR group, two nests of the MID group, and six nests of the FAR group. In 6 of these 10 cases, the dead nestlings were found in a nest infested with hundreds of mites (*Dermanyssus* spp.). However, there were nests that produced fledged young that also had mites, and these were predominately in the NEAR group. Only 1 of 11 (9%) nests in the NEAR group that were infested with mites failed, whereas the failure rate following mite infestation was 100% in the MID group (2 of 2 nests failed) and 60% in the FAR group (3 of 5 nests failed).

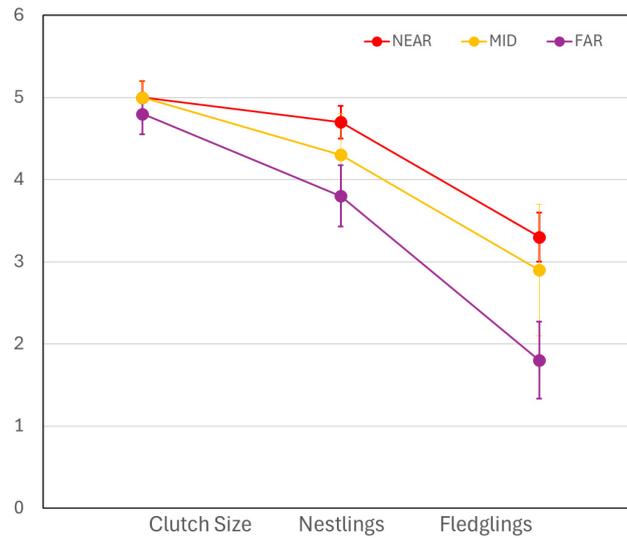


Figure 2. Average numbers \pm SE of Tree Swallow eggs, hatched young, and fledglings at nests NEAR to (red points), at MID distance from (yellow points), and FAR from (purple points) abandoned mine drainage ponds. Overall means of three distance groups were significantly different.

3.2. Morphometrics

Nestling wing length and nestling age were strongly correlated, with the older nestlings showing longer wings (Figure 3; $F = 21.14$, $df = 23$, $p < 0.001$). There was no interaction between age and nest groups ($F = 1.66$, $df = 23$, $p = 0.436$). The distance groups showed no difference in wing length (Table 3; $F = 3.16$, $df = 23$, $p = 0.206$). The nestling body mass increased significantly with nestling age (Figure 4; $F = 9.27$, $df = 23$, $p = 0.002$). There was no difference in average nestling mass between distance groups (Table 3; $F = 1.59$, $df = 23$, $p = 0.451$), and the interaction term was not significant ($F = 4.04$, $df = 23$, $p = 0.132$).

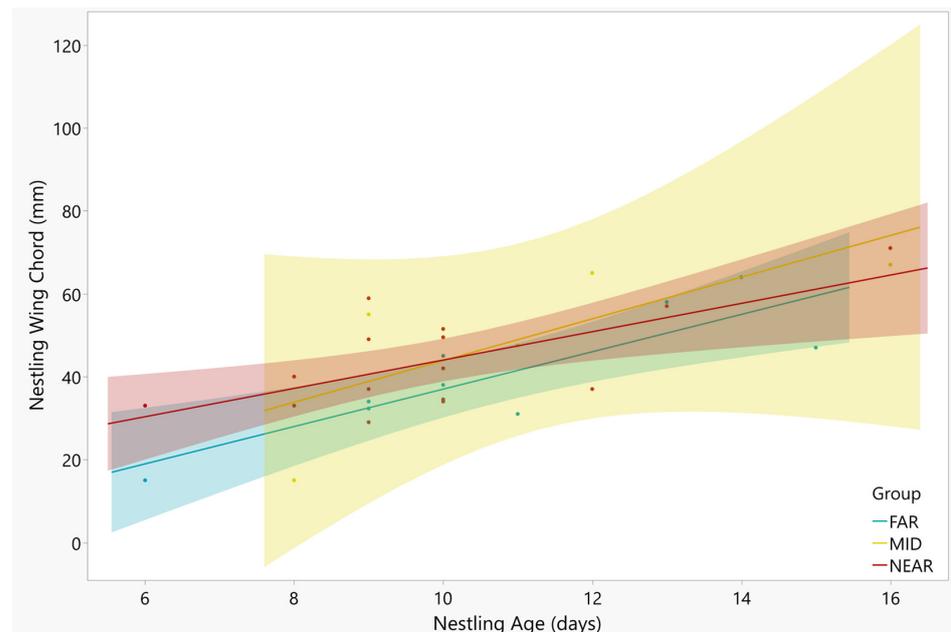


Figure 3. Wing lengths of nestling Tree Swallows and age at time of measurement. Only one nestling was measured per nest. The positive relationship between the two variables was significant ($p < 0.001$), with no difference between slopes of nests in the NEAR (red points), MID (yellow points), and FAR (blue points) groups ($p = 0.436$). Regression lines and 95% confidence intervals are shown for each group. The R^2 values for the regression lines are as follows: NEAR = 0.45, MID = 0.55, FAR = 0.73).

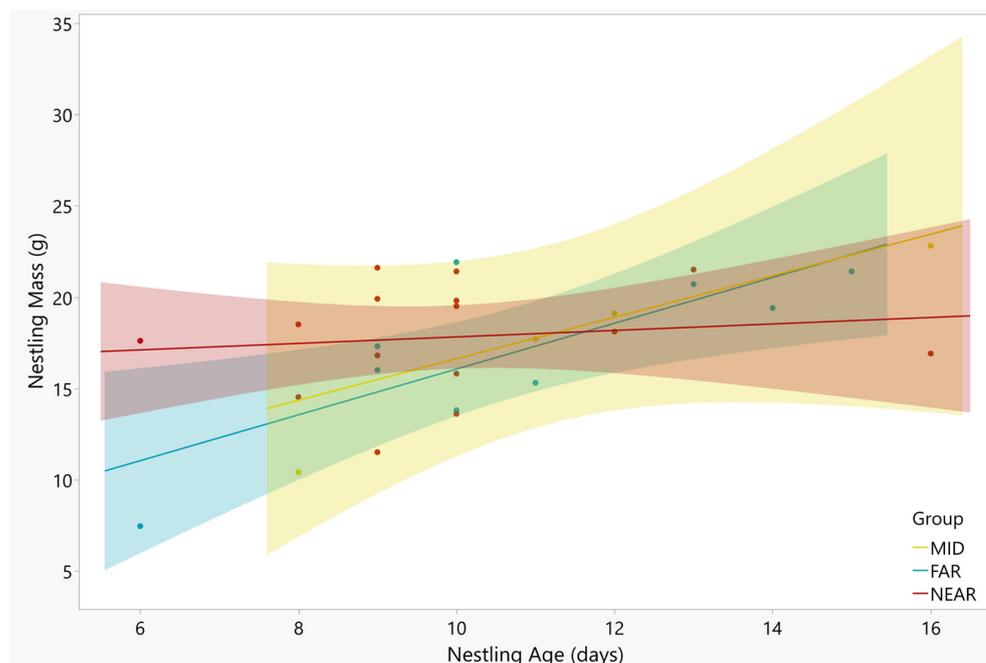


Figure 4. The mass of nestling Tree Swallows and age at time of measurement. Only one nestling was measured per nest. The positive relationship between the two variables was significant ($p = 0.002$), with no difference found between nests in the NEAR (red points), MID (yellow points), and FAR (blue points) groups ($p = 0.451$). Regression lines and 95% confidence intervals are shown for each group. The R^2 values for the regression lines are as follows: NEAR = 0.02, MID = 0.59, FAR = 0.59.

4. Discussion

We predicted that Tree Swallows nesting near the AMD ponds would show reduced measures of nest productivity compared to those that nested farther away from the ponds. The data firmly refute our prediction, since many of the reproductive parameters were higher among the NEAR nests compared to the MID and FAR nests. The differences between nest groups became greater as the stages of the nesting cycle progressed. This pattern suggests that whatever factors led to the reduced nest success in the MID and FAR groups were experienced during the development of hatched young and not at earlier stages.

4.1. Values of Reproductive Parameters in Comparison to Other Studies

With generally better reproductive outcomes in the NEAR group compared to the MID and FAR groups and no significant difference in nestling size or mass, it is tempting to conclude the AMD ponds had a favorable effect on Tree Swallow's reproductive success. However, the absolute values for fledging rate and number of fledglings were lower than most published studies at non-polluted sites. In our study, the NEAR nests had a fledging rate of 71%, and the mean number of fledglings was 3.3 ± 0.3 . Elsewhere, a long-term study in the neighboring U.S. state of New York with a sample of 5081 nests had a fledging success rate of 88%, and the average number of fledglings was 4.3 [17]. Other studies reported a success rate from 88 to 95%, with the average number of fledglings ranging from 4.0 to 4.9 [17,37–43]. The only studies with average values lower than what was found here are those that took place during periods with unusual temperature regimes or persistent rainfall [44,45] or those with nests exposed to residual mercury pollution in a nearby river [43]. In the latter case, the fledging rate was 80%, and the average number of fledglings was 3.6, figures that are still higher than the NEAR nests of this study.

Numerous studies of Tree Swallows indicate that nesting success is negatively affected by unseasonably cold and rainy weather during the nestling stage [38,44,46]. This was not a factor during our study; temperatures were $< \pm 0.8$ °C from climatic averages in May and

June of 2022 and 2023, and the precipitation was below average during the same months, especially in 2023 [47]. In fact, the rainfall in May 2023 was only 45% of normal [26].

Aside from these population-level parameters, studies show that there are subsets of individuals that have consistently lower values in fledgling success rate and the number of fledglings. These include Tree Swallows that nest in landscapes with high percentages of agricultural monoculture lacking habitat heterogeneity within 5 km of a nest [42]. Our study site did contain corn (*Zea mays*), soybean (*Glycine max*), and wheat (*Triticum aestivum*) fields, but there were many hedgerows, riparian zones, and forest patches that preclude this explanation for the below-normal fledgling numbers. Late-nesting Tree Swallows also have lower fledging rates [16]. This likely explains the lower values we found in our FAR nests, but not the NEAR nests, since those had an earlier average lay date.

In sum, the data presented here for the NEAR nests are lower than expected, given previously published studies. We have rejected explanations relating to weather and habitat structure. It remains possible that polluted waters of the AMD ponds impact the nestling food supply and, ultimately, nestling survival.

4.2. Study Limitations and Suggestions for Future Research

Data on food availability and quality are a missing component of this study. It is not clear whether these variables vary with the distance to the AMD ponds. A related factor is how much nestlings in the NEAR group might have been compromised by metals in their diet due to bioaccumulation [48].

We measured nestlings at each nest only once, so the growth trajectory of individual nests cannot be examined. Significant nestling growth occurs during the first week after hatching [37], but we did not take body mass or wing length data on nestlings less than 6 days of age. With more data on younger nestlings, we might have found a difference in treatment groups or an interaction between them. These would be important data to have, since growth rates can change depending on food resources [23,49]. Such data would help determine whether the development of nestlings in our study differed from nestlings in other studies. Differences could help us understand why the reproductive outputs of NEAR nests were comparatively low. There may also have been internal physiological differences besides mass or structural size that may explain the lower values.

This study only included data from two years, both of which featured numerous nests with mite infestations. The mites can cause nests to fail due to abandonment by parents or the premature fledging of young [47], but many studies fail to find an effect of mite infestation on nestling survival [50–52]. Parasites in general may cause slower nestling growth and have a synergistic effect with other factors that might depress nest survivorship [50,53]. It is therefore possible that the MID and FAR nests, which had more nestling mortality associated with mite infestations, could have had unusually low reproductive outputs during our short study but could have higher values in a year without an abundance of mites. Factors like this, that are unrelated to the AMD treatment ponds, could obscure or reverse the patterns associated with the treatment ponds. Additional years of data collection would help.

The best experimental setup to test effects of AMD would be for one set of nest boxes to be placed around AMD ponds and another set placed around control ponds that contained no AMD. This was not possible at our study site. The FAR nests were farther away, not just from the AMD ponds, but also from any other permanent body of water. The birds nesting near the ponds fared better than the others. However, the limitations of the experimental setup should be considered before refuting the general hypothesis that a polluted waterbody represents an ecological trap and reduces reproductive success.

More research is planned to determine whether other species of birds show the same pattern as the Tree Swallow with regard to how the three distance groups showed different levels of productivity, as well as why those levels were all low compared to studies elsewhere. We will also study how the prey biomass depends on the distance to the treatment ponds and whether nestlings have measurable levels of heavy metals in their tissues.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/birds5030030/s1>: Table S1: Nesting success parameters of Tree Swallow nests, 2022–2023, at different distances from abandoned mine drainage treatment ponds; Table S2: Morphometric parameters of nestling Tree Swallows, 2022–2023, at different distances from abandoned mine drainage treatment ponds.

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Data Availability Statement: This study’s complete dataset is contained within Tables S1 and S2. Water quality data for the AMD ponds in this study are archived at <https://www.datashed.org/project-monastery-run-wetland-2> (accessed on 7 August 2024).

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