

Trap behavior of *Zonotrichia leucophrys oriantha* at different elevations in the West Elk Mountains, Colorado

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ABSTRACT

High-alpine ecosystems are particularly vulnerable to climate change. Thus, many ecosystem patterns are shifting due to warming temperatures, extreme weather events, and seasonal changes. This becomes an issue for birds that breed and live in high-elevation environments, as they may not be able to co-adapt quick enough to rapid shifts in mountain conditions and habitat. *Zonotrichia leucophrys oriantha* or the Mountain White-Crowned Sparrow (henceforth called: *oriantha*) is a native, migratory species that resides in Gunnison County, CO, USA. *Oriantha* can serve as a model species because it lives and breeds across an elevational range, allowing for life-history differences in the population to be observed. Our hypothesis states that if there are variations in life-history traits along an elevational gradient, than trap-behavior will also show variation. Within this study, our aim was to determine whether there were differences in *oriantha* behavior across elevation by gauging the level of trap-activity at different elevations. We predicted such differences would exist between elevations. We tested for variables including sex, fat, tarsus length, recapture count, and whether the bird was previously banded. The most significant effects on the activity index of trapped birds were elevation and recapture counts, while sex, fat, tarsus length, and previously banded showed no significant effects. Although stress-induced energetics may account for different trap-activity levels, a more thorough and direct examination needs to be conducted in order to explain the causal mechanisms of such differences and how elevation plays a role in trap-behavior.

1. INTRODUCTION

Mountain ecosystems are subject to harsh and variable weather conditions, therefore making them more vulnerable to effects of climate change (Messerli and Ives 1997, Thomas 2002, Diaz et al. 2003). Such effects can have implications for avian communities and consist of rising temperatures, changes in species elevational limits, and shifts in habitat compositions (Sekericioglu et al. 2007). High-elevation breeding birds already endure environmental stresses such as inclement weather, short breeding seasons, cold temperatures, and atmospheric conditions (Morton 2002, Scott 2011, Martin 2015). As a result of climate change, these avian communities are predicted to experience significant population decreases in the future, making increased conservation an imminent concern. In tropical mountain ecosystems, the Escalator to Extinction (EE) phenomenon explains how lower-elevation species have begun to shift their habitat ranges upward in elevation in response to climate change (Pounds et al. 1999, Shoo et al. 2005a). The results of such range-shifts lead lower-elevation species to out-compete and

displace higher-elevation species. The ranges of higher-elevation species completely diminish as they are continually pushed upwards, in turn changing the organization, order, and selected niches of the ecosystem (Williams et al. 2003; Pimm et al. 2006, Wernberg et al. 2016). The consequences of such effects could result in the disappearance of many higher-elevation species (Thomas et al. 2004, 2006.) Despite these concerns, there remains a scarcity of knowledge on how temperate bird species differ across elevations.

Avian species exhibit heterogeneous shifts in elevation ranges due to factors such as temperature, precipitation, and region (Tingley et al. 2012). Ecological and life history traits determine a bird species response to extreme meteorological events (Sandercock et al 2005, Wilson and Martin 2010.) Past studies have shown that elevational gradients indirectly influence morphological, behavioral, and life history traits (Cody 1996, Boyce 1979, Berven 1982a, Mathias and Andrews 1995, Badyaev 1997a, c.) Furthermore, a trade-off between greater parental care and annual fecundity at high elevations suggests that higher-elevational birds focus more on offspring quality and less on offspring quantity (Badyaev 2001 & 1997).

Passerine life histories are favored and selected by a suite of ecological factors which vary with elevation, including climate, breeding season length, predation, and food limitation (Cody 1996, Boyce 1979, Kovshar 1981, Krementz and Handford 1984).

Mountain White-crowned Sparrows (*Zonotrichia leucophrys oriantha*; hereafter, *oriantha*) breed at 2,438-3,657 meters above sea level, from sub-alpine to alpine environments. The breeding season for *oriantha* is compressed and reproductive success varies with annual differences in abiotic conditions such as snowmelt, storm frequencies, temperature, and precipitation (Morton 2002, Martin et al. 2017). *Oriantha* can serve as a model species for understanding effects of elevation on life-history traits, as they live and breed along an elevational gradient. Past data and confirmed genetic evidence shows that *oriantha* genetics and life-history traits vary consistently from lower to higher elevations (Welke and Conover unpubl., Welke and Burg unpubl.) Past studies have attempted to connect species-specific elevation range movements to life-history traits with limited success (Perry et al. 2005, Moritz et al. 2008, Pöyry et al. 2009, Tingley et al. 2012), yet no studies have endeavored to ask whether there are potential behavioral changes in a conspecific species across different elevations.

As past studies have shown that behavioral strategies may indirectly affect how birds adapt and survive to a variety of ecological pressures (Badyaev and Ghalambor 2001, Bear et al. 2009), there is an increasing need to better understand the traits and strategies of birds such as *oriantha*. If there are effects of elevation on the life histories of conspecific species, than behavioral phenotypic plasticity may be possible to observe within *oriantha* as well. Within this study, our aim is to determine whether there are differences in *oriantha* behavior across elevation by gauging the level of trap-activity at different elevations. We predict that there will be a difference in trap-activity between elevations. If such a difference exists, our second aim is to cross-analyze differences in trap activity with other potential covariates which potentially explain or confound the proposed effects of elevation. By determining whether there are variations in *oriantha* behavior across elevation, we can contribute to better understanding how such behavioral traits influence the evolution of *oriantha* life history strategies across elevation.

2. METHODS

Study Site

This year stood as the third consecutive year of collecting trap-behavior data on *oriantha* (2016-2019). This study was conducted in the White River National Forest and West-Elk Mountain Range of Colorado, USA. Study sites ranged in elevation (9498-11699 ft.) and were delineated as suitable habitat areas for *oriantha*. There were a total of eight sites, with four low-elevation sites in the East River Valley at 9498-9799 ft. (38°59'18.9"N -107°00'37.6"W), one mid-elevation site in Schofield Park at approx. 10498 ft. (39°00'58.6"N -107°02'57.1"W), and one high-elevation site each at Virginia Basin (38°58'13.4"N -106°57'54.6"W), Paradise Basin (39°01'19.91"N -107°05'17.85"W), and North Pole Basin (39°02'00.86"N -107°08'30.16"W) from 10977-11699 ft. (**Map 1**).

The temperatures within this climate range from 23°C during the day and 8°C at night from early June to early August, while stochastic weather events such as snow storms and lightning storms are not uncommon. The growing season varies annually and is typically shorter at higher elevations.

The vegetation suitable for *oriantha* habitat consisted dominantly in a variety of *Salix spp.*, *Potentilla spp.*, and *Veratrum californicum*. Other herbaceous species such as *Delphinium*, *Aconitum*, and *Heracleum* comingle amongst the *oriantha* habitat. The general vegetation of the study areas included trees such as *Picea engelmanni* and *Populus tremuloides*.

Data Collection

Potter traps (Wingfield and Farmer 1976) were used to trap *oriantha*, while baked and store-bought birdseed comprised of white proso millet, black oil sunflower seed, and calcium carbonate was used as bait. Potter traps were opened from approximately 0700 to 1200 from late May to early August. Traps were checked every 45-60 min. There were shorter periods of time between trap checks on days with higher temperatures to avoid heat exhaustion of *oriantha*. All un-banded birds were banded with a three-color darvic band combination as well as a sliver USGS band, size 1B.

While observing and taking behavioral data, traps with only one *oriantha* were taken as data points, as two *oriantha* in one trap skewed the behavior of each bird. The observer stood a minimum of 10 meters away to avoid influencing bird behavior. The behavior of trapped *oriantha* was observed for approximately ten seconds, each behavior counting for a second, with a sum of ten behaviors in ten seconds. *Oriantha* behavior was categorized into the following sections: feeding, still, cling, cling flap, flap ram, and bill ram. An explanation was associated with each behavior. Feed indicated that the trap had no effect, while still was associated with awareness, cling with curiosity, flap with alarm, cling flap with mild distress, bill ram with moderate distress, and flap ram with high distress. Once behavior was observed, *oriantha* were removed as quickly as possible from the cage in order to avoid the bird from self-inflicting damage due to the stress of being approached.

Bird Morphology and Condition

Physiological and reproductive features such as wing chord, tail length, culmen length, tarsus length, central crown stripe width, and total crown width were measured in millimeters with digital calipers. Abdominal fat, furculum cavity fat, brood patch development, and total mass (g) were measured. A scale of 0-5 was used to measure furculum and cavity fat, with 0 being none, 1 showing traces of fat, 2 showing streaks, 3 showing partially filled or thin covering, 4 showing prominent, filled or thick covering, 4 showing bulging or bulging slightly, and 5 showing bulging fat deposition (Morton 2002). Brood patch development ranges from a 0-4, with 1 being feathers present, 2 defeathering, and 3 complete vascularization being where the dermal tissue becomes edematous and thickened (Morton 2002).

Data Analysis

Within recapture counts of 0-4, higher-elevation sites (Virginia, Paradise, and North Pole Basin) had a sample size of 61, while the mid-elevation site (Schofield Park) had a sample size of 86, and lower-elevation sites (1-4 of East River Valley) had a sample size of 296.

An activity index was created for the trap behavior of each *oriantha*, with each behavior scaling in value from 0-3 (**Table 1**). The activity index (AI) for each bird was cumulative, 0 being the lowest and 30 being the highest. A higher AI was indicative of higher behavioral activity within the trap.

Our independent factor was elevation, while our dependent factor was the trap behavior (AI) of *oriantha*. Our statistical analyses were computed in Jmp and considered confounding variables such as sex, body fat, tarsus length, whether *oriantha* have been captured multiple times that year (recapture counts), and whether an *oriantha* was banded in previous years. Data from *oriantha* that were recaptured more than four times were excluded from analysis in order to prevent bias and repeated individuals. Linear regression was used to analyze the effects of recapture, elevation, fat, tarsus length, and previously banded. One-way ANOVA's analyses were used for looking the effects of fat versus no fat on AI. Multiple Regression analyses were used to determine whether sex and recapture counts interacted with the effects of elevation.

3. RESULTS

We found that there was a significant positive relationship between activity index (AI) and elevation across recapture counts 0-4 (leverage plot, $P < .0001$, **Fig. 1**). This was found to be true whether each bird was recaptured once, twice, three, or four times (**Table 2**). *Oriantha* exhibited lower AI within the trap as recapture counts increased (leverage plot, $P < 0.0026$, **Fig. 2**).

Because of this, we did a multiple regression analyses to determine whether the effects of recapture confounded the effects of elevation. When we combined recapture counts of 0-4 and excluded recapture counts of 5 or higher from the data, a multiple regression analysis indicated that the effects of recapture did not interact with the effects of elevation (**Fig. 3**)

Oriantha with a recapture of 0 and any detectable level of fat have higher AI's with a mean of 15.2889 (N=227), while *oriantha* without fat have a mean of 14.3391 (N=236) (one-way ANOVA, **Fig. 4**). Yet, there is no effect of fat on AI within elevation when the sum of fat on each *oriantha* is taken into account (linear regression, $P < 0.1828$, $F = 11.1189$, $N = 220$, **Fig. 5**).

We analyzed the effects of sex on AI with 0 recaptures to ensure that recapture count did not confound our results. A linear regression showed that sex had insignificant effects on AI ($P = 0.1623$, $F = 5.870$, $N = 221$ **Fig. 6**). Females were more active than males across all elevations with 0 recaptures (multiple regression, **Fig. 7**). Tarsus length had no effect on AI ($P < 0.61280$, $F = 0.149$, $N = 221$, **Fig. 8**). *Oriantha* that were banded in previous years did not have varying AI's and did not show any signs of habituation ($P < 0.70014$, $F = 0.257$, $N = 221$, **Fig. 9**).

4. DISCUSSION

We hypothesized that if the life history traits of passerines vary with elevation, so will the trap-behavior of *oriantha* at different elevations. As predicted, our results demonstrate that elevation had a strong effect on the trap behavior of *oriantha*. *Oriantha* were more active within the trap at higher elevations.

Recapture count, or how many times a bird had been recaptured within the year, also had a significant effect on trap behavior. Birds that were recaptured more frequently had lower trap activity. This result can be explained by the idea that *oriantha* became increasingly habituated to the trap the more frequently they were recaptured, therefore decreasing their activity within the trap when recaptured more than once. Since lower-elevation sites had a larger sample size, there was a concern with whether recapture counts confounded the effects of elevation. Because of this concern, we ran a multiple regression analysis in Jmp to determine whether recapture counts interacted with the effects of elevation on AI. Recapture counts did not confound the effects of elevation on AI, and that AI or trap activity drops with increased numbers of recapture at every elevation (**Fig. 3**).

Sex did not have a significant effect on trap behavior, although females were found to be more active in the trap on the initial capture (0 recapture.) We used a multiple regression analysis to confirm that females were more active upon the initial capture across all elevations (**Fig. 7**).

We were curious to see whether tarsus length co-varied with AI, but found a negligible and non-significant correlation between the two (**Fig. 8**). We found that *oriantha* which were banded in previous years did not show a difference in AI compared to *oriantha* that were not previously banded.

Total fat or sum of fat also had a negligible affect on AI, yet *oriantha* with any level of detectable fat had slightly higher AI's. Amounts of fat across elevations could indicate bird energetics. Since furculum fat is difficult to observe by technicians, it is possible that more accurate estimates of energetics can be measured through a combination of mean body mass and fat (Morton 2002.) If this study is to be continued in the future, we would recommend determining whether trap-behavior co-varies with the different stages of the breeding season, and if such a covariance exists, whether it does so across elevation. This would give better insight into whether energetics play a role in trap

behavior, and if such a factor could be explained by reproductive status or food limitation.

This study is the beginning of a larger question concerning the causal mechanisms of such difference in trap behavior. Four causal mechanisms that could help us better understand the sources of this difference in trap behavior are climate, breeding season length, predation, and food limitation (Cody 1996, Boyce 1979, Kovshar 1981, Krementz and Handford 1984). Badyaev (1997) shows that nest predation rates decrease with elevation. This suggests that perceived risk behavior caused by higher nest predation rates is an unlikely explanation for our results.

Food limitation and more specifically stress-induced energetics of birds at different elevations, is the most likely explanation for differences in trap behavior. Resource abundance is limited and habitat is more spatially segregated at higher elevations (Kovshar 1981, Badyaev 1987, 1993, 1994).

Although sex ultimately did not have an effect on AI in our study, females were shown to be more active upon the first recapture across all elevations. This could be accounted for by the fact that females reduce their nest provisioning rates during incubation due to the colder climates and spatially wider habitats at higher elevations (Kovshar 1981, Badyaev 1993, 1994), suggesting that females are more food-stressed than males, therefore exhibiting higher AI's with trap behavior.

Corticosterone, a dominant stress hormone found in birds (Holmes and Philips 1976) is induced by physiological and psychological stressors (Harvey et al. 1984). The most well known physiological stressor is inclement and harsh weather, a factor that is known to reduce food availability. Corticosterone has been implicated to affect the feeding behavior of birds (Wingfield 1988, 1985). Hence, our results and discussion point towards the idea that physiological and psychological stress, caused by limitations in food and more inhospitable climates at higher elevations, may explain the differences in trap behavior across elevations in *oriantha*. More specifically, the hormone corticosterone may have an effect on the amount of activity in the trap. If we were to test for corticosterone at different elevations and find a positive relationship, this would point towards the hypothesis that *oriantha* experience more stress at higher elevations.

A more direct examination of stress-induced energetics and possible causal mechanisms of trap behavior could be conducted by testing for corticosterone plasma levels at different elevations, as well as by increasing the sample size of higher-elevation *oriantha*. This is recommended for future studies.

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Map 1: *Oriantha* study sites within the White River National Forest and West-Elk Mountain Range of Colorado, USA.

TABLE 1: ACTIVITY INDEX AND ASSOCIATED BEHAVIOR

Behavior	Scale	Explanation
Feed	0	no effect
Still	0.5	awareness
Cling	1	curiosity
Flap	1.5	alarm
Cling Flap	2	mild distress
Bill Ram	2.5	moderate distress
Flap Ram	3	high distress

LEVERAGE PLOT OF AI BY ELEVATION ACROSS RECAPTURE COUNTS OF 0-4

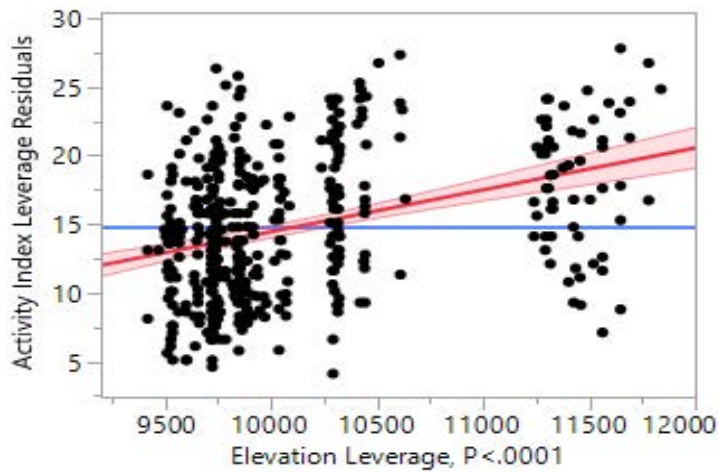


Fig. 1: There is a significant positive relationship between AI and elevation (ft) across, showing that *oriantha* trap-activity increases with elevation.

LEVERAGE PLOT OF AI BY RECAPTURE COUNTS

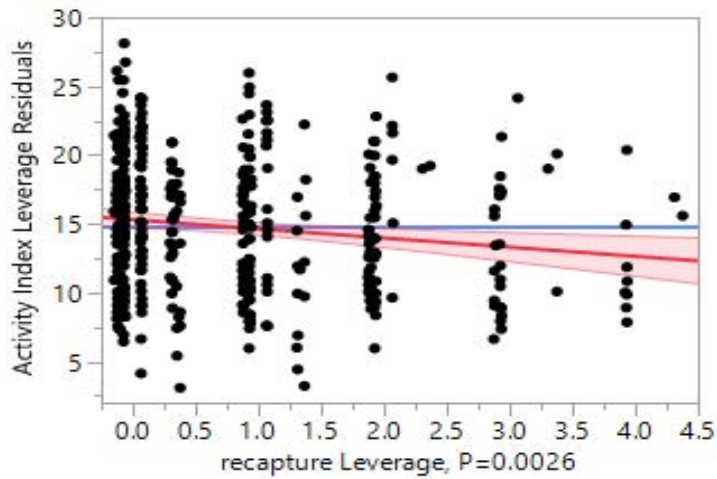


Fig. 2: AI decreases with increasing recapture counts, indicating that *oriantha* become less active in the trap the more times they are recaptured.

TABLE 2: ACTIVITY INDEX BY ELEVATION ACROSS RECAPTURE COUNTS OF 0-4

Recapture Count	N=	F-stat=	P=
0	241	29.4694	<.0001
1	112	7.4884	0.0072
2	53	25.9373	<.0001
3	27	13.5819	0.0011
4	13	13.2405	0.0045
5	5	9.4857	0.0369
6+	13	Not significant	Not significant

A positive relationship holds between AI and elevation (ft) across recapture counts of 0-4.

MULTIPLE REGRESSION ANALYSIS OF ELEVATION AND RECAPTURE COUNTS

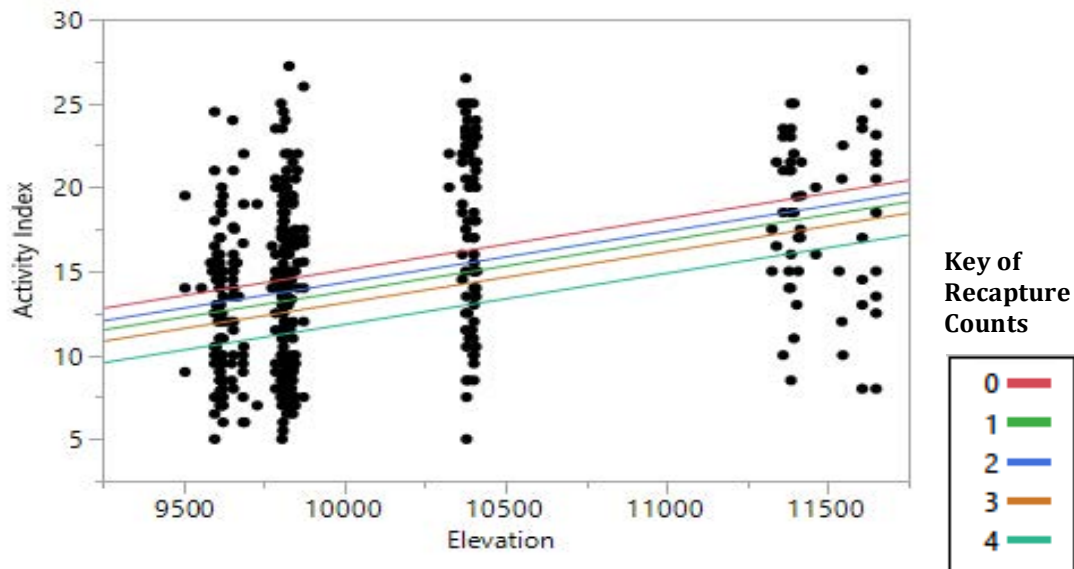


Fig. 3: *Oriantha* that were recaptured multiple times had decreased AI's, yet the effects of recaptures did not vary across elevations (ft). This confirms that the effects of recaptures did not confound or interact with the effects of elevation (ft).

ONE-WAY ANOVA OF FAT VS. NO FAT WITH 0 RECAPTURES

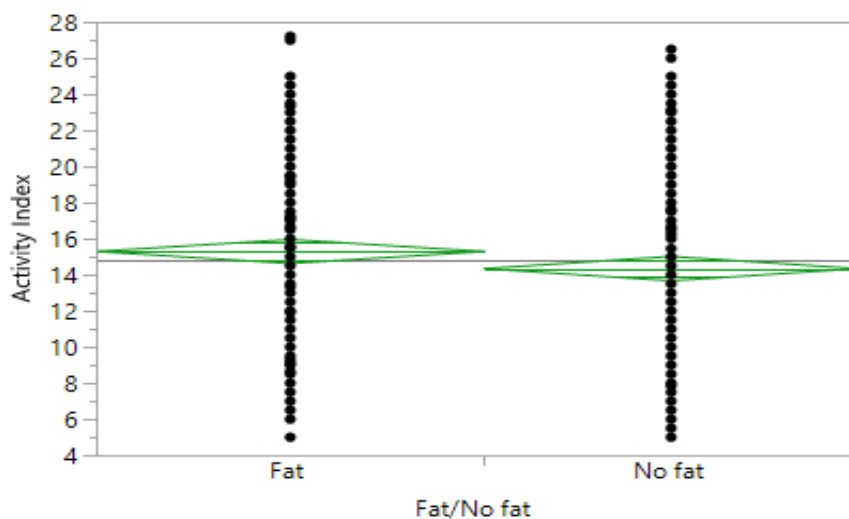


Fig. 4: *Oriantha* with any fat had a mean 15.2889 (N=227) while *orianta* with no detectable fat had a mean of 14.3391 (N=236).

LINEAR REGRESSION OF SUM OF FAT WITH 0 RECAPTURES

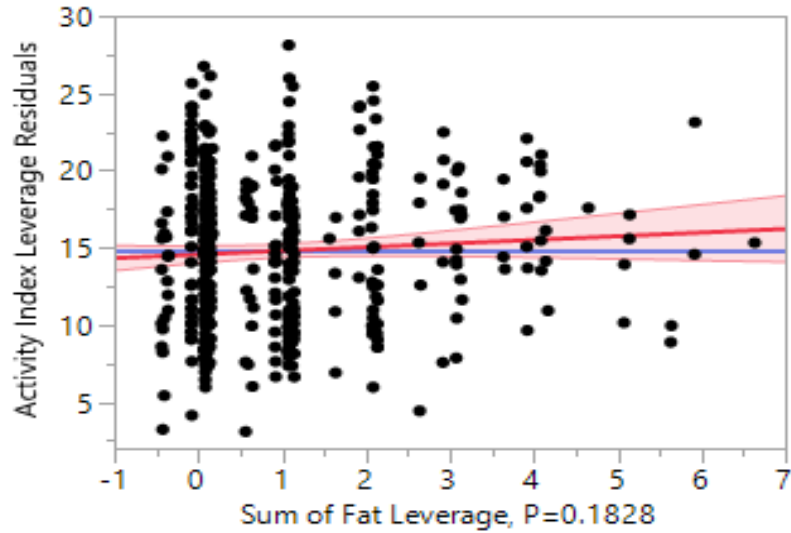


Fig. 5: While *oriantha* with any amount of fat may have higher AI's, there is no significant effect of the sum of fat on AI.

LINEAR REGRESSION OF AI BY SEX WITH 0 RECAPTURES

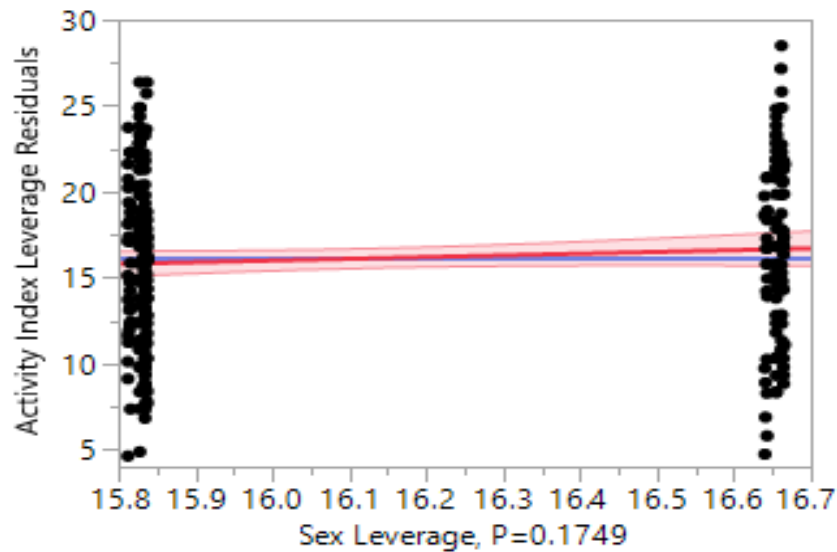


Fig. 6: Sex did not have a significant effect on AI, with female mean= 16.702 while male mean=15.8013.

MULTIPLE REGRESSION OF AI BY SEX WITHIN ELEVATION

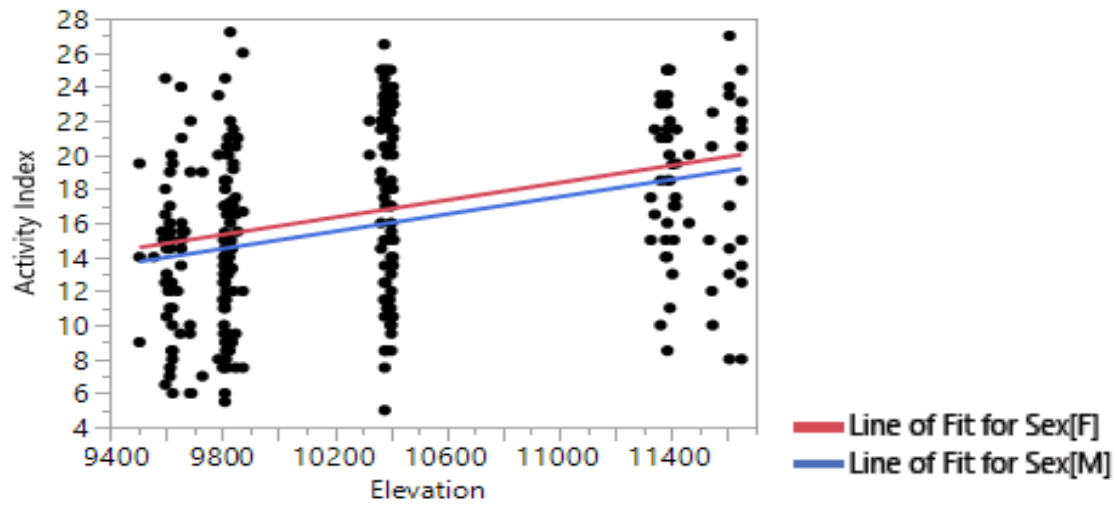


Fig. 7: Females are more active at every elevation with 0 recaptures, but this effect is ultimately unsubstantial.

LINEAR REGRESSION OF AI BY TARSUS LENGTH WITH 0 RECAPTURES

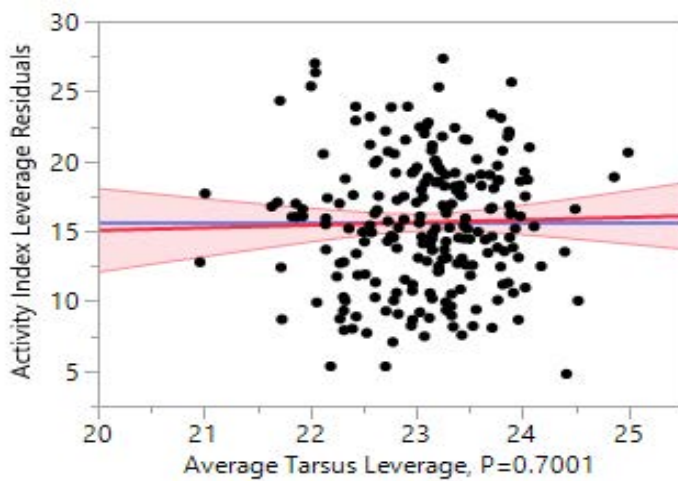


Fig. 8: The tarsus length (mm) of *oriantha* had no effect on AI.

LINEAR REGRESSION OF AI BY PREVIOUSLY BANDED WITH 0 RECAPTURES

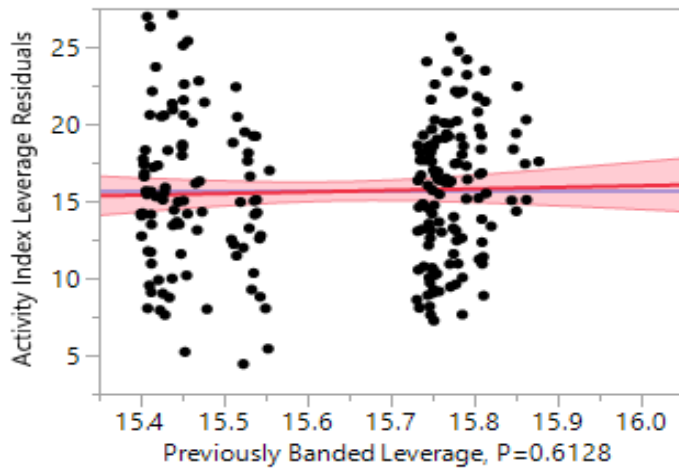


Fig. 9: *Oriantha* that were banded in previous years did not have a varied AI and a mean of 15.3405, while unbanded *orianta* had a mean of 16.0133.

