Scientific Experiments

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Avian Body Weight

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Non-Intrusive Measurement of Avian Weight

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Weight of birds is typically determined for captured birds as one component of a banding procedure. Here we describe an alternative approach where the bird to be measured voluntarily steps on a scale as his weight is recorded by a remote observer. See a demonstration of the method on this video on YouTube:
https://youtu.be/AC4ZVp-Kv8M

I. Design and Deployment of the Avian Weighing Apparatus

After an extensive search of various scale types (scientific, postal, jewelry, culinary, etc.) and the purchase and evaluation of several, we arrived at the culinary scale shown in Fig. 1 (see www.smartchef.me). This scale has a range of 3000 g and a resolution of 0.1 g. It is not waterproof but can withstand mist and light rain if dried promptly after exposure. It can be read out remotely at a distance of up to 30 feet on a paired cellphone via a Bluetooth link, the necessary App included in the purchase price of the unit. The scale is powered by an internal Lithium polymer battery that is good for over 12 hours of continuous operation (even at temperatures below 20 F) and can be recharged with a standard USB charger. On/off, 0-reset, and units select switches can be operated manually at the scale. The Bluetooth connection provides the weight value every second or less on the cellphone display and also allows the user to remotely switch between g, kg, or ounces at the cellphone display. There is in addition a remote option for an audio output of the indicated weight.

Figure 1: Scale used for avian weight measurements, Bluetooth connected to an iPhone, and being charged through its USB port.

The scale is positioned as shown in Figure 2. It is mounted on a wooden bracket that is attached with 1/4 - 20 carriage bolts and wing nuts to a horizontal wooden platen at the top of a 6-foot-high bird feeder pedestal. Squirrel-proofing is achieved with a baffle fashioned from a 2-foot-long x 6 inch diameter duct pipe as shown. A food cup consisting of a 4 inch x 4 inch by 2 inch high plastic container is firmly held on the top surface of the scale's stainless steel weighing plate with a coin-shaped Neodymium refrigerator magnet situated at the bottom of the food cup. The magnet has been found to have no impact on the operation of the scale. The container is filled to a depth of ~ ½ inch with sunflower seeds, favored by House Finches, Blue Jays, Tufted Titmice, Dark-eyed Juncos, Black-capped Chickadees, etc., but not so much by House Sparrows.

(a) (b) (c)

Figure 2: (a) Vertical bird feeder pedestal with squirrel baffle and mounting platen, (b) same bird feeder pedestal with scale mounted on top, and (c) blowup showing more detail of the scale, mounting components, thermal sensor and top of the aluminum squirrel baffle.

The configuration of the yard area where the bird weight measurements are made is shown in Figure 3. The scale is usually positioned on feeder pedestal #2 which is symmetrically located 16 feet in front of a bay window behind which (inside the house) is a desktop along with the Bluetooth-connected iPhone readout of the scale. The observer sits in the chair in back of the desktop and records bird arrivals and departures along with times, temperatures, and scale readings. The sheltered bottle feeder (and also sometimes a suet feeder) about six feet off the ground and hanging from a lower limb of one of the nearby Hemlock trees serves as a major attractor of birds. Occasionally a bird comes over from there to the nearby and more exposed scale to eat sunflower seeds from the food cup. Frequently a bird will also just drop down to the scale's food cup from within the vegetation of the higher limbs of the nearby Hemlock trees. It is additionally possible

to mount the scale on feeder pedestal #1 or on a step ladder (when squirrels are not present) not far from the bottle feeder, while still maintaining the Bluetooth connection. Operationally the bird arrival rate seems to be most manageable with the scale located on feeder pedestal #2. Figure 4 shows the experimental set up as viewed from inside behind the desk.

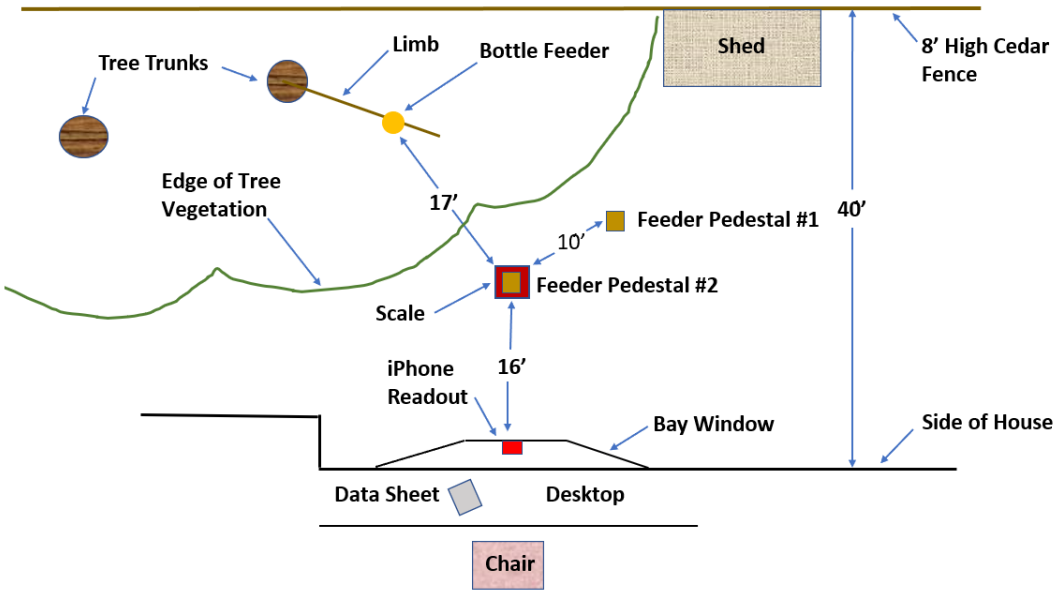


Figure 3: Configuration of area where bird weight measurements are conducted.

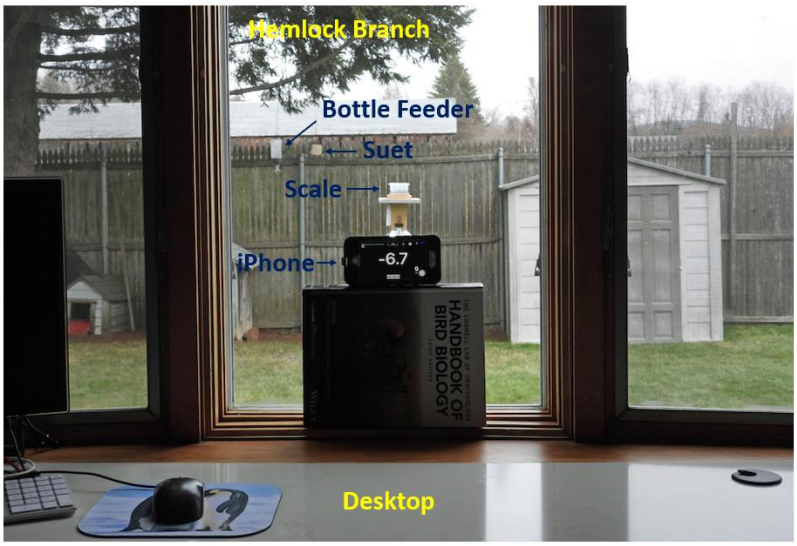


Figure 4: View from inside of the experimental set up.

II. Methodology and Practical Considerations

Figures 5 and 6 show photographs of representative participants at the scale. All measurements are taken under no-wind conditions since even a light wind introduces significant variability in scale readings as discussed along with other sources of error in Appendix A. We have found it possible to conduct 30 - 50 weight measurements under favorable conditions over the period of an hour or two beginning at about sunrise. Bird weight is determined as a difference between two measurements, made either just before and after arrival, or just before and after departure. Ideally a single avian volunteer gently arrives alone at the scale's food cup, eats one or more sunflower seeds (or holds one in its mouth), and then gently departs. This sometimes happens, but often things are more complex. Even in the case of a single bird, the arrival, presence, and departure can all be somewhat tumultuous. Rapid movements and associated accelerations with the bird on the scale lead to fluctuations in scale reading. The observer must either estimate some average value or record the reading in a time interval (of order 2 seconds) when the bird is momentarily at rest. It is also best if the entire visit of the bird be short, so there is no

(a) (b)

Figure 4: (a) House Finch and (b) Northern Cardinal weighing in.

Figure 5: House Finch waiting his turn as House Sparrow is weighed.

(a) (b)

Figure 6: (a) Dark-eyed Junco and (b) Common Grackle at the scale.

significant opportunity for any other changes to occur between the two scale readings that are used to determine the weight, and the observer does not ultimately tire of trying to determine the most appropriate scale reading. In some cases when the bird decides to just stay and continue feeding, clapping or tapping on the window will incite him to leave. Occasionally a visit is so brief that the observer is unable to record a stable reading with the bird on the scale. In general, a visit of 15 – 30 seconds works well.

In other situations, multiple birds arrive at the same time. One may feed while the other waits his turn, or both may be on the scale at the same time. Although infrequent, three or more birds may arrive simultaneously with a subsequent mobbing event playing out and no opportunity for meaningful measurements. Although birds generally consume a negligible fraction of total body weight during a visit, some occasionally manage to throw a lot of seeds out of the cup in a short time (as much as a gram or more in the case of a rambunctious Blue Jay), much to the delight of other birds or a squirrel on the ground at the base of the feeder pedestal. This underscores the importance of keeping the before and after measurements as close together in time as possible. There is also ambiguity concerning repeat visits. In most cases it is not possible to know for sure whether or not the bird has been previously measured.

A set of test weights has been obtained to enable experiments to determine scale accuracy as well as sensitivity to position on the weighing plate. These findings are included in Appendix A along with the discission of sources of error.

III. Initial Measurements and Analysis

As a proof of concept, preliminary measurements on eight bird species have been made thus far: House Finch, House Sparrow, Black-capped Chickadee, Tufted Titmouse, Northern Cardinal, Blue Jay, Mourning Dove, and Common Grackle. Weight measurements of individual birds have been possible for about 2/3 of the visits. Figure 7 shows a summary of over 190 weight measurements, not including the Common Grackle where only a single measurement was made. Data were taken under no- or very-low-wind

conditions on eight different days at temperatures ranging from 19 F to 54 F. Here no attempt was made to correct for calibration errors, noise sources, or repeat visits, although several points reflecting obvious recording errors were removed. The measured weights are within the range of those reported in the Cornell Lab of Ornithology's Birds of the World website.

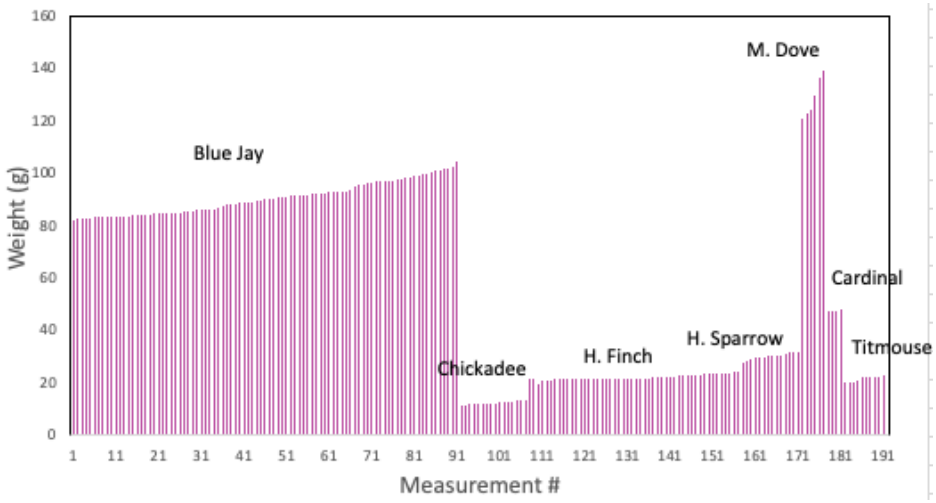
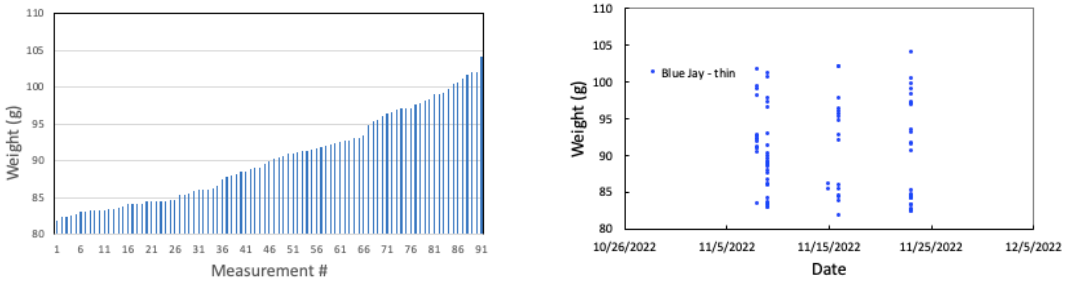


Figure 7: Preliminary bird weight measurements.

In Figure 8 (a) we show a replotting of the Blue Jay data from Figure 7 with a zero-offset that emphases the variations in measured values from about 82 g to 104 g. During any given measurement session, it was obvious to the observer that there were typically only 2-4 individual Blue Jays making multiple visits to the scale.



(a) (b)

Figure 8: (a) Replotting of the Blue Jay data in Figure 7 with an 80 g 0-offset, and (b) plotting of that same data as a function of date with each measurement now represented as a point.

On any particular date the data show clumping, with each clump associated with one of the Blue Jays. This provides insight into the net variability in the weight measurements of individual Blue Jays. It does not provide information on day-to-day variability since the Blue Jays measured one day are not necessarily the same as those measured on another.

Appendix A – Calibration and Sources of Error

The scale calibration was checked with a set of calibration weights (Wokape precision steel scale calibration weight kit, part No. W434) both inside on the tabletop and outside with the scale positioned on the feeder pedestal. The weights are in denominations of 10 g, 20 g, 50 g, 100 g and 200 g, conveniently covering the range of measured bird weights (including the additional weight of the food cup, magnet, and sunflower seeds – for a total of an additional approximately 100 g). Measurements inside were done at ~68 F. Outside calibration measurements, conducted under zero wind conditions, ranged thus far down to 15 F, over 50 F degrees below room temperature. Figure A1 shows the scale with calibration weights undergoing tests on the tabletop without the food cup.

Figure A1: Scale undergoing calibration check inside at 68 F.

The scale as received from the manufacturer is found to be well calibrated over the full range of weights investigated when measured inside at 68 F. Tables A1 and A2 show measurement results for two different sets of experiments over a range of temperatures with no food cup and magnet present. The manufacturer assures scale functionality down to 32 F, but suggests that recalibration at such a low temperature would likely be required. A procedure for this is provided using test weights in 100 g steps, however, no procedure is provided to correct for nonlinearity between the 100 g increments.

From the results shown in Tables A1 and A2 we observe that calibration errors always manifest as measured weights a bit greater than the standard test weights. We see that at measured temperatures of 29 F and above the calibration of the scale is good to 1% or better for weights ≥ 50 g, while at 20 g the error increases to as much as 2%, and at 10 g it can be as much as 4 %, all for temperatures ≥ 29F. Since the error is always positive one could add half the likely maximum difference to the measured values to obtain weights accurate to ± half of the likely positive excursion, for example ± 1% at 20 g, etc. At temperatures below 29 F one approach could be to occasionally perform an on-the-fly

calibration check to obtain approximate correction values to apply to the measured bird wights to obtain more accurate values. With some experience it should be possible to obtain corrected bird weight values of, for example, ± 1% or better at 20 g down to 15 F.

Test Mass	Measure @68 F	Measure @15 F 8:25 AM	Measure @19 F 9:30 AM	Measure @22 F 10:00 AM	Measure @26 F 11:00 AM	Measure @29 F 11:40 AM	Measure @30 F 12:10 PM	Measure @33 F 12:40 PM	Measure @35 F 3:30 PM
200.0	200.0	201.7	201.4	201.2	200.7	200.7	200.0	200.0	200.0
100.0	100.0	101.3	101.2	100.9	100.6.	100.6	100.0	100.0	100.0
50.0	50.1	51.2	51.0	50.8	50.6	50.2	50.3	50.3	50.3
20.0	20.0	21.7	20.9	20.5	20.4	20.3	20.2	20.2	20.3
10.0	10.0	10.8	10.8	10.7	10.4	10.2	10.1	10.2	10.2

Table A1: Results of a calibration check experiment with all readings in g. The first measure column is representative of standard room temperature performance. The subsequent columns are the results of an experiment on December 12, 2022 in which the unloaded scale with a reading of 0.0 g was placed atop pedestal #2 at 7:25 AM when the measured temperature was 10 F, under zero-wind conditions. Within one hour the reading had stabilized at -14.7 g while the measured temperature had increased to 15 F. The scale reading was reset to 0.0 and subsequent measurements were made over the morning and afternoon.

Test Mass	Measure @69 F 11:30 PM	Measure @35 F 7:00 AM	Measure @35 F 7:00 AM reset	Measure @29 F 8:00 AM	Measure @29 F 8:00 AM reset	Measure @29 F 8:00 AM reset w 100 g	Measure @32 F 9:05 AM	Measure @32 F 9:05 AM reset	Measure @37 F 10:55AM
200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.6	200.0	200.0
100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.1	100.0	100.0
50.0	50.1	50.4	51.3	50.5	50.4	50.0	50.4	50.3	50.1
20.0	20.0	20.3	20.2	20.4	20.3	20.1	20.4	20.2	20.2
10.0	10.0	10.3	10.1	10.4	10.4	10.0	10.3	10.2	10.1

Table A2: A second calibration check, with all readings in g. The first measure column shows measurement values taken inside at 11:30 PM the evening of December 15, 2022. The next two measure columns show values taken in an unheated porch the following morning at 7:00 AM. The unloaded scale reading had remained at 0.0 g, but resetting the scale gave some minor changes nevertheless. After the 7:00 AM measurements the unloaded scale with a reading of 0.0 g was placed atop pedestal #2 under zero-wind conditions. There was no evidence of drift over the subsequent three hours. For the last set of readings at 8:00 AM the scale was reset to 0.0 g with a 100 g load present and the standard set of weights sequentially added in the usual fashion.

Another concern is the robustness of the calibration as a function of the position of the weight to be determined on the weighing plate. For example does a bird sitting on the edge of the food cup measure the same as one standing in the sunflower seeds inside the cup? The Experimental findings reveal a surprising resiliency to variations in weight position. Figure A2 depicts the results for placement of a 100 g test weight at five different positions on the weighing plate for the scale without food cup on the table-top at 68 F. This experiment gives identical results if the scale is inclined at an angle of 5 degrees with respect to horizontal, additionally verifying insensitivity to out-of-level positioning.

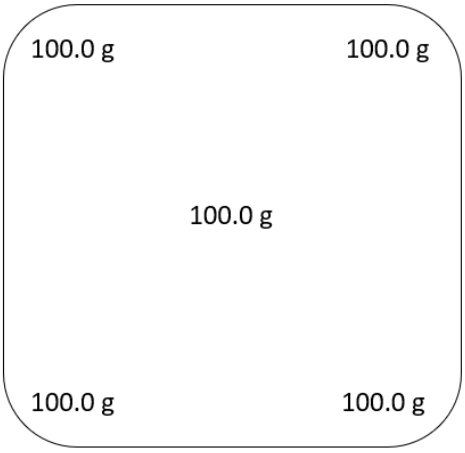


Figure A2: Measurement results for placement of 100 g test weight at five different locations on the scale's weighing plate. Results were unchanged when the scale assembly was inclined 5 degrees with respect to horizontal along either the X- or Y- axis.

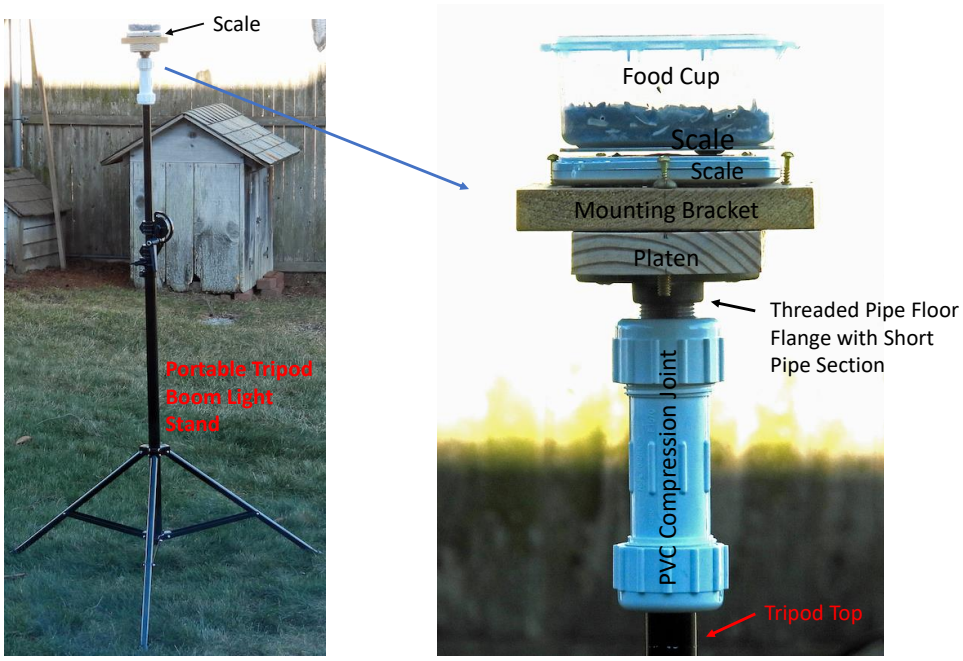
Temperature sensitivity of the scale reading is a concern that remains under investigation. For the experiment described in Figure A1, the initial cool down from 68 F to 15 F resulted in a scale reading change 0.0 to -14.6 g. After being reset to 0.0 g the unloaded scale reading then remained constant over the relatively slow warm up to 33 F over a period of four hours. In the case of the experiment described in Figure A2 the unloaded scale reading remained at 0.0 g during the cool down to from 69 F to 29 F, stayed there as the temperature rose to 35 F over a period of four hours, and further remained at 0.0 g as the scale was brought inside and warmed back up to 69 F. Although the temperature sensitivity is not fully understood, it appears that with before and after scale readings for bird weight measurements taken fairly close to each other in time as they usually are, any temperature related drift will be extremely small and inconsequential, even for small birds.

Sensitivity of the scale reading to movement of a bird while on the scale is a significant concern. For example, the reading can change by ± 2 grams or more for an 85 g Blue Jay as he gyrates around the food cup. The only way to address this has been to wait for the bird to be still momentarily (a couple seconds) or come up with some sort of an average reading on the fly. Practically this is less of an issue for smaller birds like House Finches, and large but quieter birds, like Mourning Doves.

Sensitivity to wind is by far the largest potential source of error. This can be as much as ± several grams in a light gusty situation with no bird present, and even more with a bird on the scale. Thus far the only way around this has been to take data under no-wind conditions, most frequently present in the early morning hours when birds also tend to be active.

Appendix B – Field Deployable Bird Weighing Apparatus

It will be of interest to compare weights of members of a bird species in one geographical area with those of members of the same species in another area, for example House Finches in Hadley, Massachusetts versus House Finches in eastern Maine. To facilitate such comparisons a field deployable bird weighing apparatus has been implemented. Figure B1 shows a photograph of this apparatus in which in which the vertical bird feeder pedestal shown in Figure 2(a) has been replaced with a portable tripod boom light stand (Newer 13 feet/390 cm two-way rotatable Al adjustable tripod boom light stand) configured as shown with a platen fashioned to accept the standard mounting bracket /scale assembly. A cylindrical squirrel guard can be added as necessary.



(a) (b)

Figure B1: (a) Portable tripod boom light stand with standard avian weighing scale mounted on top, and (b) details showing mounting of the scale/food cup assembly.