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**Mass or weight: What is measured and what should be reported?**—Many years ago, ornithologists weighed a bird by placing it on a balance and reading the bird's weight from the scale in grams. Chardine (1986:832), however, suggested that “the term mass be used in preference to weight” because “although balances

measure weight, they usually are rescaled so that mass in grams rather than force in Newtons can be read directly." Since then, ornithologists have reported the weight of a bird as its "mass." There are reasons for believing that this argument is incorrect.

Mass is an intrinsic property of matter and is measured in kilograms. The mass of a bird is a constant. A 15-gram bird is 15 grams, whether measured on the Earth, the Moon, or Mars. Weight is a measure of the force of gravity on a physical object and is measured in newtons. The weight of a bird of mass 15 g varies with the magnitude of the gravitational force acting on it and would be considerably different if measured on the Moon, for example, instead of on Earth. In the same way, the International Prototype Kilogram, kept in Paris, would weigh differently (in kilograms, as indicated on the scale of a balance) if measured on the Moon.

The distinction between weight and mass seems straightforward. Why should there be confusion? A problem is that the words "weight" and "mass" are very old, each with several meanings. One meaning of "mass" is "a quantity of matter," and the quantity of matter that one had in the 1700s, mostly for trade in a market, was measured by weight with a balance or scale (in grains, carats, avoirdupois ounces, troy ounces, pounds, stones, shekels, and so on). In the late 1700s, King Louis XVI and the French National Assembly established a committee of savants to determine standards for weights and measures. The committee eventually proposed that the kilogram be the *weight* of one cubic decimeter of water at 4°C (Klein 1974). Subsequently, balances were constructed to measure the quantity of matter (i.e., weight) in kilograms. The distinction between mass and weight that we now make was of no practical significance before the late 1800s, and then only to physicists. The newton, as a measure of the force of gravity on a quantity of matter, was not even proposed until 1904 (Burchfield 1976) and was not accepted by physicists until much later (e.g., the 12th edition of the *Handbook of Chemistry and Physics* [Hodgman and Lange 1927] defined the "unit of weight" as "the dyne"). Clearly, balances have never been designed to measure weight in newtons or dynes. Chardine (1986), however, stated that balances had been rescaled so that mass in grams rather than force in newtons could be read directly, but this is not so. Balance makers did not rescale balances to read mass instead of newtons. Once kilograms of mass and newtons of force were clearly distinguished in the mid-20th century, physicists continued to measure the weight of physical bodies in what are considered "bad" units, kilograms-weight (kg-wt), which have been shortened to "kilograms" (kg). For example, according to Rogers (1960:124–125; italics in original),

Weighing-scales are primarily force-measurers, but are graduated in kg or pounds. As long as we are dealing with forces in equilibrium (e.g., in problems on levers, cranes, pulleys, etc.), we can keep them in 'bad' units, since we are only concerned with ratios. Even so, as a reminder that they are *force* units, we should write them as kg-wt (= kilograms-weight) to distinguish them from plain kg properly used for masses.

We know that our balances measure kilograms of weight, rather than kilograms of mass, because a mass of one kilogram returns readouts of different weights at different places. Also, according to Great Britain's National Physical Laboratory, "The most simple method of weighing is to simply place a test piece on a mass balance and take the displayed reading as its weight" (Davidson

et al. 2004:4). Although the mass of a bird could be measured, if one needed to know it, the method is "tedious [and] difficult" (Rogers 1960). Thus, when we put a bird on a balance, we are measuring its physical weight (in kilograms-weight), not its Newtonian mass. I recommend that we use the correct term, "weight," instead of "mass," even if we continue (as everyone else does) to use the incorrect (i.e., "bad") units, kilograms (or kilograms-weight), instead of newtons. Ornithologists using bad units to indicate the size of a bird, however, does not justify them in using bad units in their work when force units (newtons) are required. For example, Pennycuick (1987) made a point of converting the weight of animals (in grams) to force units (newtons) in his studies on the locomotion of animals.

When deciding between "mass" or "weight" to describe the size of birds, ornithologists seem to have a choice between the advice of physicists (cited above) or the unsubstantiated opinion of Chardine (1986).—BERTRAM G. MURRAY, JR., *Population Dynamics Research, 249 Berger Street, Somerset, New Jersey 08873, USA. E-mail: bmurray@rci.rutgers.edu*

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**Mass or weight: What is measured and what should be reported—Response to Murray (2007).**—In his commentary on Chardine (1986), Murray (2007) advises ornithologists to use the term "weight" in preference to "mass." His argument is largely based on the history of how mass was, and still is, measured. We