Mass or weight: What is measured and what should be reported?

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Status and trends in demography of Northern Spotted Owls, 1985–2003. Wildlife Monographs, no. 163.

BUCHANAN, J. B., R. J. GUTIÉRREZ, R. G. ANTHONY, T. CULLINAN, L. V. DILLER, E. D. FORSMAN, AND A. B. FRANKLIN. 2007. A synopsis of suggested approaches to address potential competitive interactions between Barred Owls (*Strix varia*) and Spotted Owls (*S. occidentalis*). Biological Invasions 9:679–691.

DARK, S. J., R. J. GUTIÉRREZ, AND G. I. GOULD, JR. 1998. The Barred Owl (*Strix varia*) invasion in California. Auk 115:50–56.

ELLIOTT, K. 2006. Declining numbers of Western Screech-Owls in the lower mainland of British Columbia. British Columbia Birds 14:2–11.

GILLETT, N. P., A. J. WEAVER, F. W. ZWIERS, AND M. D. FLANNIGAN. 2004. Detecting the effect of climate change on Canadian forest fires. Geophysical Research Letters 31:L18211.

GREMEL, S. 2005. Factors controlling distribution and demography of Northern Spotted Owls in a reserved landscape. M.S. thesis, University of Washington, Seattle.

HAYWORTH, A. M., AND W. W. WEATHERS. 1984. Temperature regulation and climatic adaptation in Black-billed and Yellow-billed magpies. Condor 86:19–26.

HOUGHTON, R. A., J. L. HACKLER, AND K. T. LAWRENCE. 2000. Changes in terrestrial carbon storage in the United States. 2: The role of fire and fire management. Global Ecology and Biogeography 9:145–170.

HOUSTON, C. S., AND K. J. MCGOWAN. 1999. The westward spread of the Barred Owl. Blue Jay 57:190–195.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. 2007a. Climate change 2007: The physical science basis. Contributions of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (S. Soloman, D. Qin, M. Manning, M. Marquis, K. Averyt, M. M. B. Tignor, H. L. Miller, Jr., and Z. Chen, Eds.). Cambridge University Press, Cambridge, United Kingdom.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. 2007b. Climate change 2007: Impacts, adaptation and vulnerability. Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (M. Parry, O. Canziani, J. Palutikof, P. van der Linder, and C. Hanson, Eds.). Cambridge University Press, Cambridge, United Kingdom.

JOHNSON, N. K. 1994. Pioneering and natural expansion of breeding distributions in western North American birds. Pages 27–44 *in* A Century of Avifaunal Change in Western North America (J. R. Jehl, Jr. and N. K. Johnson, Eds.). Studies in Avian Biology, no. 15.

JOSEPHSON, J. R., AND S. G. JOSEPHSON. 2003. Abductive Inference: Computation, Philosophy, and Technology. Cambridge University Press, New York.

KELLY, E. G., E. D. FORSMAN, AND R. G. ANTHONY. 2003. Are Barred Owls displacing Spotted Owls? Condor 105:45–53.

LATIFOVIC, R., Z.-L. ZHU, J. CIHLAR, AND C. GIRI. 2002. Land cover of North America 2000. Natural Resources Canada, Canada Center for Remote Sensing, and U.S. Geological EROS Data Center.

MAZUR, K. M., AND P. C. JAMES. 2000. Barred Owl (*Strix varia*). *In* The Birds of North America, no. 508 (A. Poole and F. Gill, Eds.). Birds of North America, Philadelphia.

MEEHAN, T. D., W. JETZ, AND J. H. BROWN. 2004. Energetic determinants of abundance in winter landbird communities. Ecology Letters 7:532–537.

MONAHAN, W. B., AND R. J. HIJMANS. 2007. Distributional dynamics of invasion and hybridization by *Strix* spp. in western North America. Pages 55–66 *in* Festschrift for Ned K. Johnson: Geographic Variation and Evolution in Birds (C. Cicero and J. V. Remsen, Jr., Eds.). Ornithological Monographs, no. 63.

OLSON, G. S., R. G. ANTHONY, E. D. FORSMAN, S. H. ACKERS, P. J. LOSCHL, J. A. REID, K. M. DUGGER, E. M. GLENN, AND W. J. RIPPLE. 2005. Modeling of site occupancy dynamics for Northern Spotted Owls, with emphasis on the effects of Barred Owls. Journal of Wildlife Management 69:918–932.

OLSON, G. S., E. M. GLENN, R. G ANTHONY, E. D. FORSMAN, J. A. REID, P. J. LOSCHL, AND W. J. RIPPLE. 2004. Modeling demographic performance of Northern Spotted Owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039–1053.

PEARSON, R. R., AND K. B. LIVEZEY. 2003. Distribution, numbers, and site characteristics of Spotted Owls and Barred Owls in the Cascade Mountains of Washington. Journal of Raptor Research 37:265–276.

REICHERT, B. K., L. BENGTSSON, AND J. OERLEMANS. 2002. Recent glacier retreat exceeds internal variability. Journal of Climate 15:3069–3081.

ROOT, T. [L.]. 1988. Energy constraints on avian distributions and abundances. Ecology 69:330–339.

ROOT, T. L., D. P MACMYNOWSKI, M. D. MASTRANDREA, AND S. H. SCHNEIDER. 2005. Human-modified temperatures induce species changes: Joint attribution. Proceedings of the National Academy of Sciences USA 102:7465–7469.

SALT, G. W. 1952. The relation of metabolism to climate and distribution in three finches of the genus *Carpodacus*. Ecological Monographs 22:121–152.

TAYLOR, A. L., JR., AND E. D. FORSMAN. 1976. Recent range extensions of the Barred Owl in western North America, including the first records for Oregon. Condor 78:560–561.

U.S. FISH AND WILDLIFE SERVICE. 2007. Draft recovery plan for the Northern Spotted Owl (*Strix occidentalis caurina*): Merged options 1 and 2. U.S. Fish and Wildlife Service, Portland, Oregon.

WRIGHT, A. L., AND G. D. HAYWARD. 1998. Barred Owl range expansion into the central Idaho wilderness. Journal of Raptor Research 32:77–81.

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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*

LITERATURE CITED

BURCHFIELD, R. W., Ed. 1976. A Supplement to the Oxford English Dictionary, vol. II (H–N). Clarendon Press, Oxford, United Kingdom.

CHARDINE, J. W. 1986. Mass or weight: What is measured and what should be reported? Auk 103:832.

DAVIDSON, S., M. PERKIN, AND M. BUCKLEY. 2004. The Measurement of Mass and Weight. Measurement Good Practice Guide, no. 71. National Physical Laboratory, Teddington, United Kingdom.

HODGMAN, C. D., AND N. A. LANGE, Eds. 1927. Handbook of Chemistry and Physics. Chemical Rubber Publishing, Cleveland, Ohio.

KLEIN, H. A. 1974. The World of Measurements: Masterpieces, Mysteries and Muddles of Metrology. Simon and Schuster, New York.

PENNYCUICK, C. J. 1987. Cost of transport and performance number, on Earth and other planets. Pages 371–386 *in* Comparative Physiology: Life in Water and on Land (P. Dejours, L. Bolis, C. R. Taylor, and E. R. Weibel, Eds.). Springer-Verlag, Berlin.

ROGERS, E. M. 1960. Physics for the Inquiring Mind: The Methods, Nature, and Philosophy of Physical Science. Princeton University Press, Princeton, New Jersey.

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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