Reply to Feeley and Machovina: Trophic ecology complements estimates of land use change due to food production

Feeley and Machovina assert that even though humans occupy a low trophic level, we have larger ecosystem impacts than any other species because of the sheer volume of food consumed (linked to population size) and the inefficiency of its production (1). The authors argue that large differences in the impact on resource use exist between dietary preferences (e.g., differing proportions of beef, pork, or poultry in a diet), even if human diets are represented by the same trophic level.

We are in complete agreement that humans have among the largest ecological impact of any species and that the human trophic level (HTL) (2) does not capture all aspects of these impacts, in particular, variations in dietary preferences of the same HTL. Feeley and Machovina investigate this topic by defining the land use necessary to produce different meat products, using conversion rates of agricultural production (1). We suggest that trophic ecology theory to calculate the primary production required (3) for different dietary preferences could give complementary results. The 10% law states that between each trophic level, only 10% of energy is integrated as organic matter, with the rest lost to respiration or incomplete digestion (4). This means that two individuals can have a trophic level of 3.5: one eating 1 kg C of trophic level 2 (equivalent to 10 kg C of primary production, PP) and 1 kg C of trophic level 3 (100 kg C of PP), totaling 110 kg C of PP, and the other eating 2 kg C of trophic level 2.5, equivalent to 63.2 kg C of PP (i.e., almost half the PP of the first example). Thus, the relationship between HTL and human impacts is not linear.

Both methods have the same issue of data availability. For this reason, we assumed the trophic levels of particular species were globally identical, but their diets can obviously differ based on different agricultural techniques. The same problem presents itself for calculations of land use. For example, the calculations given by Feeley and Machovina use a conversion factor established for Dutch agricultural production in the 1990s [refs. 3 and 4 of Feeley and Machovina (1)] and apply it to China and the United States in the present day (1). This approach presents a potential bias, as it has recently been shown that even within Europe, land use for the production of the same animal can vary more than twofold (5). These points illustrate the fact that efforts should be made to collect more information such that more accurate estimates can be made of human impacts on the Earth's ecosystem.

We fully agree that humans have a dominant role in the food web, and that the combined increase in meat consumption (indicated by a 40% increase of median global HTL; i.e., a rise from 2.15 to 2.21 with a base HTL of 2), preference for inefficient meat products, and the sheer number of humans will have large global impacts. Thus, the future challenge remains to better quantify the impact of changing diets on the extraction of Earth's resources.

Sylvain Bonhommeau[a,1], Anne-Elise Nieblas[a], Emmanuel Chassot[b], David M. Kaplan[b], Laurent Dubroca[b], Carlos Manacorda[c], Julien Barde[b], and Olivier Le Pape[d]

[a]Biological Resources and Environment Department, Institut Français de Recherche pour l'Exploitation de la MER, Unité Mixte de Recherche (UMR) Exploited Marine Ecosystems (EME-212), 34203 Sète Cedex, France; [b]Environment and Resource Department, Institut de Recherche pour le Développement, UMR EME-212, Centre de Recherche Halieutique Méditerranéenne et Tropicale, 34203 Sète Cedex, France; [c]Instituto de Biotecnología, Centro de Investigación en Ciencias Veterinarias y Agronómicas, Instituto Nacional de Tecnología Agropecuaria Castelar, Hurlingham, 1686 Buenos Aires, Argentina; and [d]Fisheries and Aquatic Sciences Center, UMR ESE-985 Agrocampus Ouest–Institut National de la Recherche Agronomique, F-35042 Rennes, France

1 Feeley KJ, Machovina B (2014) Increasing preference for beef magnifies human impact on world's food web. *Proc Natl Acad Sci USA* 111:E794.

2 Bonhommeau S, et al. (2013) Eating up the world's food web and the human trophic level. *Proc Natl Acad Sci USA* 110(51): 20617–20620.

3 Pauly D, Christensen V (1995) Primary production required to sustain world fisheries. *Nature* 374(6519):255–257.

4 Lindeman RL (1942) The trophic-dynamic aspect of ecology. *Ecology* 23(4):399–418.

5 de Ruiter H, Kastner T, Nonhebel S (2014) European dietary patterns and their associated land use: Variation between and within countries. *Food Policy* 44:58–166.

Author contributions: S.B., A.-E.N., E.C., D.M.K., L.D., C.M., J.B., and O.L.P. wrote the paper.

The authors declare no conflict of interest.

[1]To whom correspondence should be addressed. E-mail: sylvain.bonhommeau@ifremer.fr.