Comment on "Cumulative biophysical impact of small and large hydropower development in Nu River, China" by Kelly M. Kibler and Desiree D. Tullos

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Received 3 July 2013; revised 6 November 2013; accepted 20 December 2013; published 13 January 2014.

Citation: Jager, H. I., and R. A. McManamay (2014), Comment on "Cumulative biophysical impact of small and large hydropower development in Nu River, China" by Kelly M. Kibler and Desiree D. Tullos, *Water Resour. Res.*, *50*, 758–759, doi:10.1002/2013WR014378.

[1] Small hydropower projects are often considered to have fewer environmental impacts than large, main-stem projects. *Kibler and Tullos* [2013] set out to test this assumption in a study of dams in the Nu River Basin, Yunan Province, China. The authors estimated the cumulative biophysical impacts of hydropower projects on mainstems and tributaries by using a suite of 14 indicators normalized by energy production. These results were summarized for 31 hydropower projects considered by the authors to be small (<50 MW) and four large (>50 MW) projects. The authors note that, in the United States, 50 MW projects are not considered small (those with less than 25 MW are considered small).

[2] The primary result reported was that the "small dams generate greater cumulative biophysical effects per megawatt of installed capacity than large dams" and, more specifically, that "biophysical impacts of small hydropower may exceed those of large hydropower, particularly with regard to habitat and hydrologic change." According to the authors, "This trend is demonstrated for 9 of 14 investigated metrics." These findings were highlighted in at least two press releases. The American Geological Union (AGU) headline of 28 May 2013 stated that "Small dams on Chinese River harm environment more than expected, study finds" (http://news.agu.org/press-release/small-dams-on-chinese-river-harm-environment-more-than-expected-study-finds/). On 21 June 2013, the Columbia Basin Bulletin reported the headline: "Study: Certain cumulative environmental damage caused by small dams is worse than larger dams" (http://www.cbbulletin.com/427136.aspp).

[3] We have two main concerns about the reported conclusion. First, high impact estimates for six of the nine metrics were a result of dewatering of diversion or bypass reaches below <50 MW dams in the Nu River Basin. This single factor likely produces the result that "small" dams have larger cumulative negative impacts than large ones. Because these metrics are not independent, counting and comparing the number of metrics is misleading. Furthermore, the term "cumulative impacts" is misleading as there is nothing accumulated—distributions presented represent values for individual dams. The term "cumulative" implies that something is added or that the spatial compounding of up and downstream effects of hydropower development has been considered by the metrics presented.

[4] It is fair to conclude that diverting all or most flow from bypass reaches into canals or penstocks that carry water to a downstream powerhouse has multiple adverse consequences. However, to draw conclusions by counting metrics that derive from a single underlying cause (diverting all flow) measured several different ways is misleading. It would be helpful to measure the contributions of dewatered bypass reaches to each of these metrics separately. This would help readers to generalize their results to countries or river basins where small hydro is not synonymous with diversion and diversion is not synonymous with dewatering. This brings us to our next concern. Although the authors note that the Nu River Basin is a unique morphological setting and this should be taken into account when considering the transferability of the results to policy outside the immediate basin, we are concerned that readers in other countries or basins could draw the wrong conclusion from the study. Readers may assume that the primary result highlighted (small dams having larger impacts than large dams on a per-unit-energy basis) holds true generally for hydropower in the USA and other countries. This could mislead for two reasons:

[5] 1. The number of small dams with diversion reaches is unusually high in the Nu River Basin because of the steep topography of headwater subbasins. To compare the situation in the US, we reviewed 328 hydropower licenses issued by the US Federal Energy Regulatory Commission between 1996 and 2005. Only 42% of dams in this sample involved diversion reaches and these occurred at about the same rate for dams above and below the 50 MW threshold (Table 1).

[6] 2. Not all countries allow dewatering of diversion reaches. Among US dams for which we extracted information related to flow requirements, minimum flows in bypass reaches were specified for 88 dams (95%), whereas only five dams had no minimum flow requirements. We hope to extract bypass flow information from more licenses in future, but our estimate based on this subset indicates how

This article is a comment on *Kibler and Tullos* [2013] doi:10.1002/wrcr.20243.

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0043-1397/14/10.1002/2013WR014378

Table 1. Review of Information Extracted From Hydropower Licenses Issued to Private Dam Owners by the US Federal Energy Regulatory Commission Between 1996 and 2005[a]

	Rating Capacity <50 MW	Rating Capacity >50 MW
Total dams	237	91
With Diversions		
Number	101	37
Percent	43%	41%
With Bypass Flow Required		
Number	70	18
Percent	70%	49%

[a]Statistics about bypass flow requirements were based on requirements noted in a comments field for a subset of dams.

the situation in the USA compares. Specifically, dewatering of diversion reaches is rarely allowed.

[7] Because the study, and the claim that small dams cause more biophysical damage is receiving attention in the popular media, our concern is simply that counting correlated metrics influenced by a practice that is rarely allowed in some countries like the US, and that furthermore may not be associated with plant size, could mislead casual readers. To be fair, the authors emphasize the relevance of their results for countries where regulation is lax or absent. Rather than focus on the question of small versus large, we suggest that the appropriate take-home message from the study is that dewatering diversion reaches below hydropower dams can have negative effects on multiple indicators, highlighting a need for minimum flows in reaches below dams where flows are diverted.

[8] Another relevant point is that a trade-off exists between constructing larger dams with integral powerhouses and smaller dams with diversions and downstream powerhouses. In the first case, inundated reservoir area and flow alteration will be greater, whereas in the second case, dewatering of a bypass reach is a concern. The indicators presented could perhaps help to quantify this trade-off in terms of sustainability indicators.

[9] By pointing out these issues, we do not wish to downplay the significance of this study. Understanding the costs and benefits of large versus small dams is an important and understudied research question that deserves attention. The use of energy-normalized metrics is also commendable. We hope that this conversation will stimulate others to examine sustainability metrics in different situations and geographic locations, leading to context-specific guidelines [see *Efroymson et al*., 2013]. One hallmark of a good sustainability indicator is whether it clarifies the benefits of alternative mitigation actions (e.g., bypass flows) that lead to more sustainable outcomes, and those proposed by the Kibler and Tullos paper could perhaps be tailored to do this. Sustainability indicators are currently being used by the US Department of Energy's Biomass Energy Technology Office to measure progress and guide industry toward more sustainable practices for developing energy and protecting ecosystem services. In future, studies like this one could lead to similar guidance for the hydropower industry.

[10] **Acknowledgments.** Preparation of this comment was supported by the United States Department of Energy's (DOE) Energy Efficiency and Renewable Energy Office, Wind and Water Power Technologies Program and conducted by Oak Ridge National Laboratory (ORNL), which is managed by UT-Battelle, LLC, for the DOE under contract DE-AC05-00OR22725. The opinions expressed are those of the authors and do not reflect those of DOE or ORNL. We appreciate the review provided by the associate editor.

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