TECHNICAL COMMENT

SUSTAINABILITY

Comment on "Designing river flows to improve food security futures in the Lower Mekong Basin"

John G. Williams

Sabo *et al*. (Research Articles, 8 December 2017, p. 1270) use sophisticated analyses of flow and fishery data from the Lower Mekong Basin to design a "good" hydrograph that, if implemented by planned hydropower dams, would increase the catch by a factor of 3.7. However, the hydrograph is not implementable, and, if it were, it would devastate the fishery. Further, the analyses are questionable.

In a methodological tour de force, Sabo *et al.* (*1*) relate components of the flow regime of the Mekong River, quantified as stage at Stung Treng, to catch in the important Dai fishery on the Tonle Sap River, Cambodia. They use these empirical relationships to design a "good" flow regime proposed as an "ecological objective function" for the operation of controversial dams planned for the Mekong River. They project that this flow regime would increase yield of the Dai fishery by a factor of 3.7. However, simple flow routing considerations show that the "good" regime could not be implemented, and if it were, it would devastate the Dai fishery.

Sabo *et al.* also depict the historical flow regime and a "bad" regime as plots of stage over time (Fig. 1). The plot of the "good" regime is a roughly rectangular wave, with long low-flow periods connected to shorter high-flow periods by transitions ~15 days long. The transitions are more gradual in the "bad" regime.

Stung Treng is several hundred kilometers upstream from the Tonle Sap–Mekong confluence. The Tonle Sap connects the Mekong to a large natural lake and adjacent floodplains that support large populations of many fishes (*2*). Water flows up the Tonle Sap to the Great Lake during high flows in the Mekong, and back down the Tonle Sap to the Mekong during low flows. Flow in the Mekong is a major driver of stage in the Great Lake, but the Great Lake receives ~40% of its water from tributaries and rainfall (*3*), and the stage records differ substantially (Fig. 2).

Sabo *et al.* state that "…we used estimated hydrologic drivers of the historical bag net, or 'Dai,' fishery on the Tonle Sap River—the largest commercial fishery in the Mekong—to design better fisheries futures by comparing designed flows to current and pre-dam (natural-flow) regimes," and they hypothesize that "Flow variation (high and low) may drive production by controlling redox conditions in floodplain soils, …" This implies that they intend their "good" flow regime for the Tonle Sap–Great Lake system, and perhaps for other reaches of the lower Mekong with large floodplains.

Implementing the "good" flow regime would entail managing releases from the most downstream dam, well upstream from the Tonle Sap–Mekong confluence. During the high-flow period, releases would be large and the floodplain would be inundated. At the end of the high-flow period, releases from the dam would be cut to create the desired decrease in stage. Downstream from the dam, water would drain from the floodplain to the channel as soon as releases were cut, reducing the rate of decrease in stage (and discharge) in the channel farther downstream. The opposite would happen, more strongly because of downstream overland flow, at the end of the low-flow season, prolonging the transition from dry to wet conditions. The situation is too complex for simple analysis, but based on hydrodynamic modeling, about 35 km^3 of water flowed onto the left bank of the Mekong upstream and

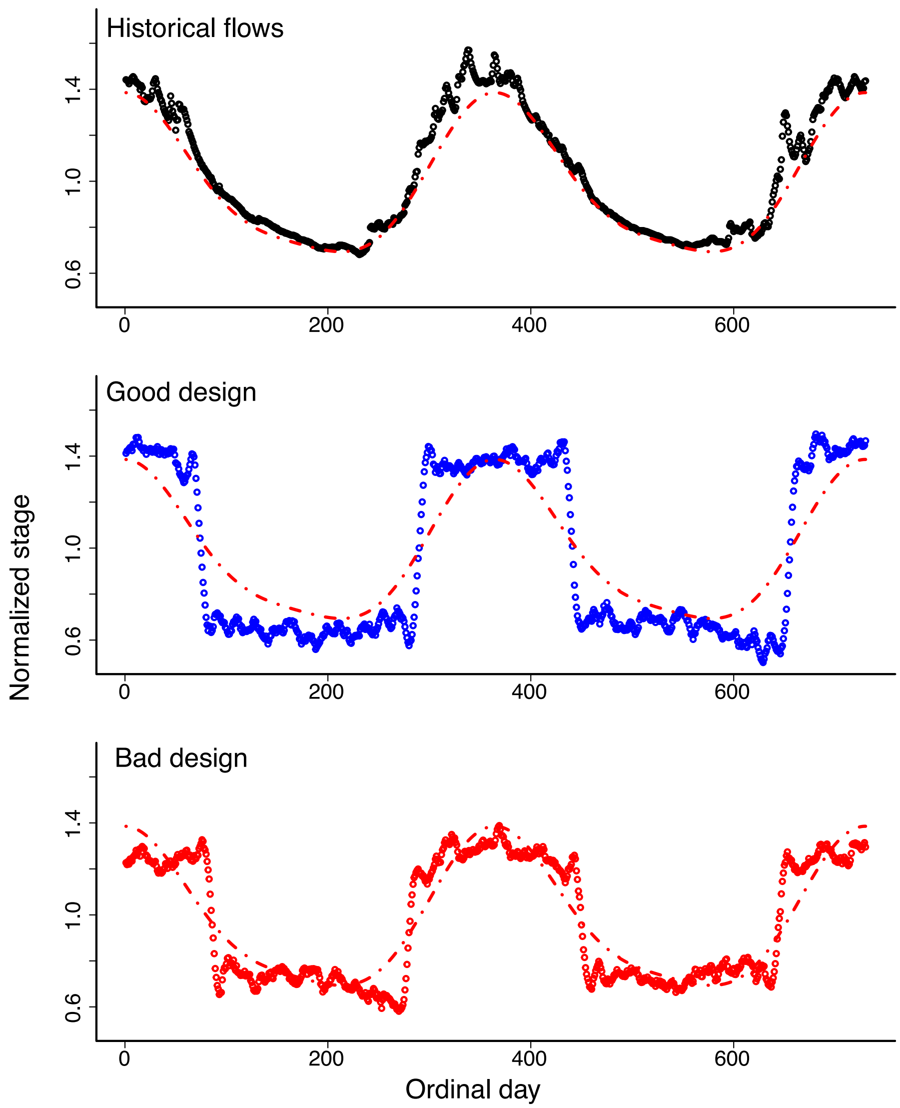

Fig. 1. Illustration of designed flows, including a "good" design and a "bad" design, compared to the reconstructed historical flow regime. [Copied from Sabo *et al.* (*1*)]

Retired consultant. Email: jgwill@frontiernet.net

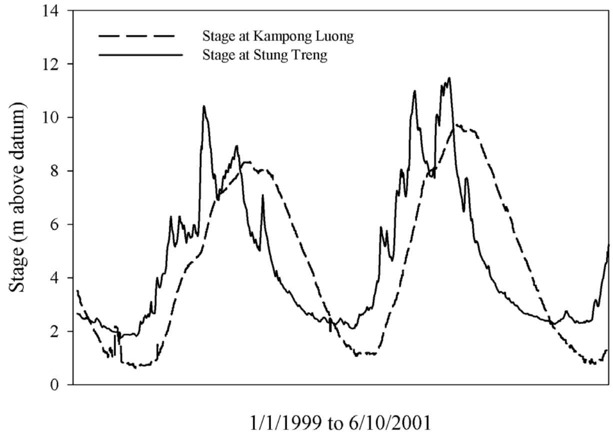

Fig. 2. Stage of the Mekong River at Stung Treng (solid line) and the Great Lake at Kampong Luong (dashed line) for two flood cycles. The flood pulse in the Great Lake lags that at Stung Treng, and high-frequency variation is suppressed. [Data from Sameng Preap, Mekong River Commission]

on the opposite side from the Tonle Sap confluence in 2002 (*4*), so flows between the channel and floodplain are substantial. Thus, the proposed rectangular wave would degrade to something more like the "bad" flow regime as it moved downstream.

Regarding the Tonle Sap, the average annual outflow from the Great Lake exceeds 75 km^3 (*3*). Draining this volume in 15 days would require a constant discharge of ~58,000 m^3 s^{-1}, which is almost 6 times the high flow reported in (*2*) and greater than current peak flows in the Mekong. This discharge could not plausibly be carried by the existing Tonle Sap channel.

The Dai fishery uses what are essentially anchored trawls, with mouths facing upstream, that depend on current to function. The nets target fishes migrating out of the Great Lake to the Mekong River with the falling limb of the hydrograph, as the Great Lake drains over 5+ months (*2*). If somehow the "good" flow regime could be implemented, shortening the falling limb of the hydrograph to ~15 days would truncate the period when the nets might be used by a factor of about 11. Until the channel enlarged in response to the higher flows, the flow probably would be too swift to use the fine mesh nets needed to catch the small fishes that make up the bulk of the Dai fishery catch (*2*), even if it were possible to anchor the nets.

Sabo *et al.* "hypothesized that high fisheries yields are driven by measurable attributes of hydrologic variability, and that these relationships can be used to design and implement future flow regimes that improve fisheries yield through control of impending hydropower operations." Indeed, the size of the flood pulse in the Great Lake is a good predictor of the Dai fishery catch (*2*). Sabo *et al.* found associations between several other attributes of variability in stage at Stung Treng and the catch, but whether any are "hydrologic drivers" of catch remains an open question because the flow-catch records are short (17 years); the analysis was not specified in advance (*5*); other important factors such as habitat cover, sedimentation, and net primary production (*6*) were ignored; and it seems improbable that one drastic change in the flow regime would be good for the fishery whereas a modestly different drastic change would be bad (*7*). Intuitively, variation in stage in the Great Lake seems more likely to influence catch in nets targeting fishes migrating out of the lake than does variation in stage in the Mekong River hundreds of kilometers upstream.

Despite the sophistication of the methods used to develop empirical relationships, predictions based on them depend on the assumption of causality and the assumption that all else will remain more or less equal, which clearly will not be true if the proposed dams are built and the hydrograph is radically altered. Complex computer-based analyses can be marvelously powerful tools, but they should be used carefully, and it is always necessary to think clearly about the results.

REFERENCES

1. J. L. Sabo *et al.*, *Science* **358**, eaao1053 (2017).
2. A. S. Halls, B. R. Paxton, N. Hall, N. Peng Bun, L. Lieng, N. Pengby, N. So, "The Stationary Trawl (Dai) Fishery of the Tonle Sap-Great Lake, Cambodia," MRC Technical Paper No. 32 (Mekong River Commission, Phnom Penh, Cambodia, 2013).
3. M. Kummu, J. Sarkkula, *Ambio* **37**, 185–192 (2008).
4. H. Fujii *et al.*, *Int. J. River Basin Manage.* **1**, 253–266 (2003).
5. A. Gelman, E. Loken, *The Garden of Forking Paths: Why Multiple Comparisons Can Be a Problem Even When There Is No "Fishing Expedition" or "p-Hacking" and the Research Hypothesis Was Posited Ahead of Time* (Department of Statistics, Columbia University, 2013); www.stat.columbia.edu/~gelman/research/unpublished/p_hacking.pdf.
6. M. E. Arias *et al.*, *Ecol. Modell.* **272**, 252–263 (2014).
7. J. P. Ioannidis, *PLOS Med.* **2**, e124 (2005).

25 January 2018; accepted 25 May 2018
10.1126/science.aat1225

Comment on "Designing river flows to improve food security futures in the Lower Mekong Basin"

John G. Williams

Science **361** (6398), eaat1225.
DOI: 10.1126/science.aat1225