Anabranching reaches juxtaposed with lowland meandering rivers in the midwestern United States: morphological characteristics and power regimes

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Abstract

Geomorphic heterogeneity is a primary characteristic of real rivers. An important, yet overlooked aspect of geomorphic heterogeneity of rivers in intensively managed agricultural landscapes of the midwestern United States is spatial variability in channel planform. In particular, these otherwise meandering rivers often contain anabranching reaches characterized by multiple channels separated by stable, vegetated islands. Morphologically, these anabranching reaches appear to differ from anabranching forms previously reported in the literature in terms of island shape and bifurcation angle (Figure). This research quantitatively characterizes the morphological characteristics of anabranching reaches within meandering river systems based on number of channels, island shape and size, bifurcation angles, and cross-sectional geometry across the channel belt. A combination of high-resolution imagery and LiDAR elevation data is used to construct a three-dimensional classification scheme (planform + bed profile) to better characterize anabranching river types. Although differences in planform types have been explained as a function of stream power, which represents the energy of a river to perform geomorphic work, the environmental domain of anabranching rivers has yet to be defined precisely, especially in relation to other planform types. Plotting of anabranching and meandering reaches on slope-discharge plots reveals that both types of reaches generally have similar power regimes – a finding consistent with the notion that the development of anabranching in these systems probably occurs through top-down (floodplain incision) rather than bottom-up (bar growth into islands) mechanisms. The study is a first attempt at characterizing juxtaposed anabranching-meandering systems and provides the basis for further process-oriented fieldwork exploring the role of natural versus human-induced processes on the formation and evolution of mixed planform river characteristics in intensively managed agricultural landscapes.

Prevalence and morphological characteristics of anabranching reaches juxtaposed with lowland meandering rivers in the Midwestern US

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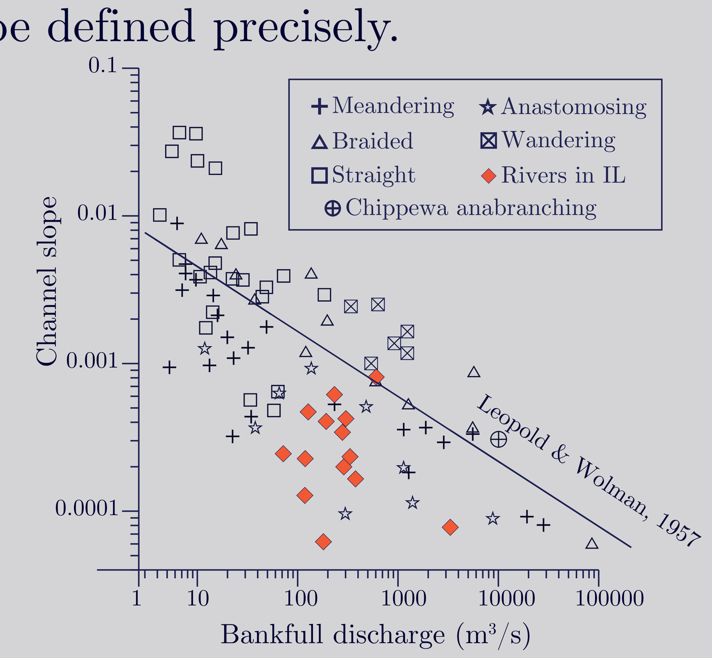
1. Introduction: spatial variablity in channel planform

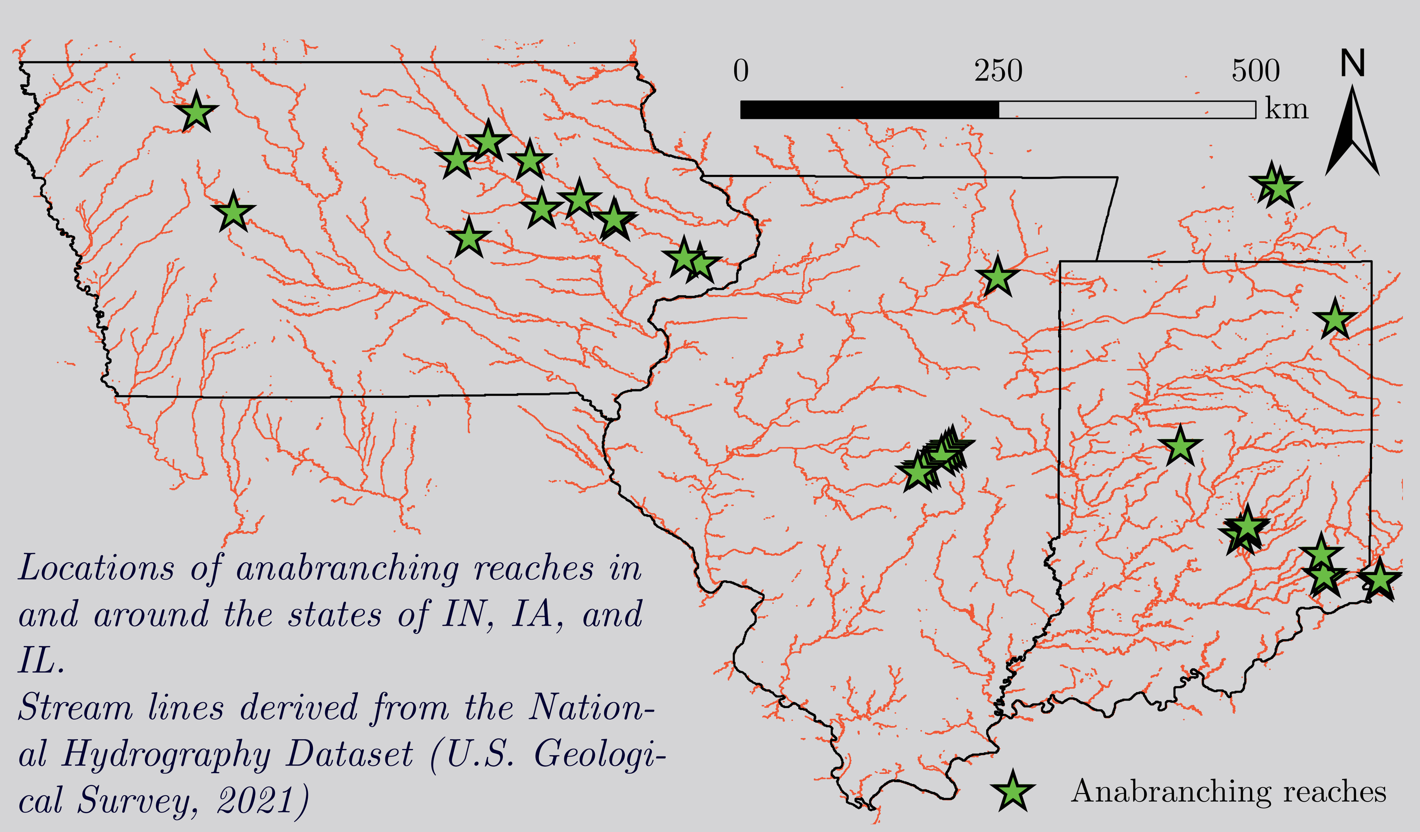
- Variability in channel planform indicates differing boundary conditions, evolution trajectories and underlying processes.
- Plotting the channel slope with bankfull discharge for different river types separated meandering and braided rivers, indicating they occur in distinct energy regimes (Leopold & Wolman, 1957). However, the energy domain of anabranching rivers (Nanson & Knighton, 1996) is yet to be defined precisely.



- Quantification of channel planform using reach scale metrics gives an indication of the (self-) similarities or differences in underlying processes between rivers of different character (Kelly, 2006; Hundey & Ashmore, 2009; Meshkova & Carling, 2013).
- The purpose of this paper is to capture the diversity of anabranching forms in midwestern US, where spatial transitions in planform occur without associated changes in valley width.

2. Regional setting

- This study focuses on anabranching reaches found in Illinois, Indiana, and Iowa. This region has gone through cycles of glaciation and is currently under intensive agriculture.
- The topography is relatively flat and end moraines are distributed throughout the landscape - an indication of the region's glacial past. Windblown loess overlies most glacial deposits.
- An extensive search for anabranching reaches along meandering rivers is being conducted using Google Earth Imagery (leaf-off). As of now we have identified 16 rivers containing a total of 38 anabranching reaches. The dataset is growing and more locations will be added as we search other midwestern states.



Locations of anabranching reaches in and around the states of IN, IA, and IL.
Stream lines derived from the National Hydrography Dataset (U.S. Geological Survey, 2021)

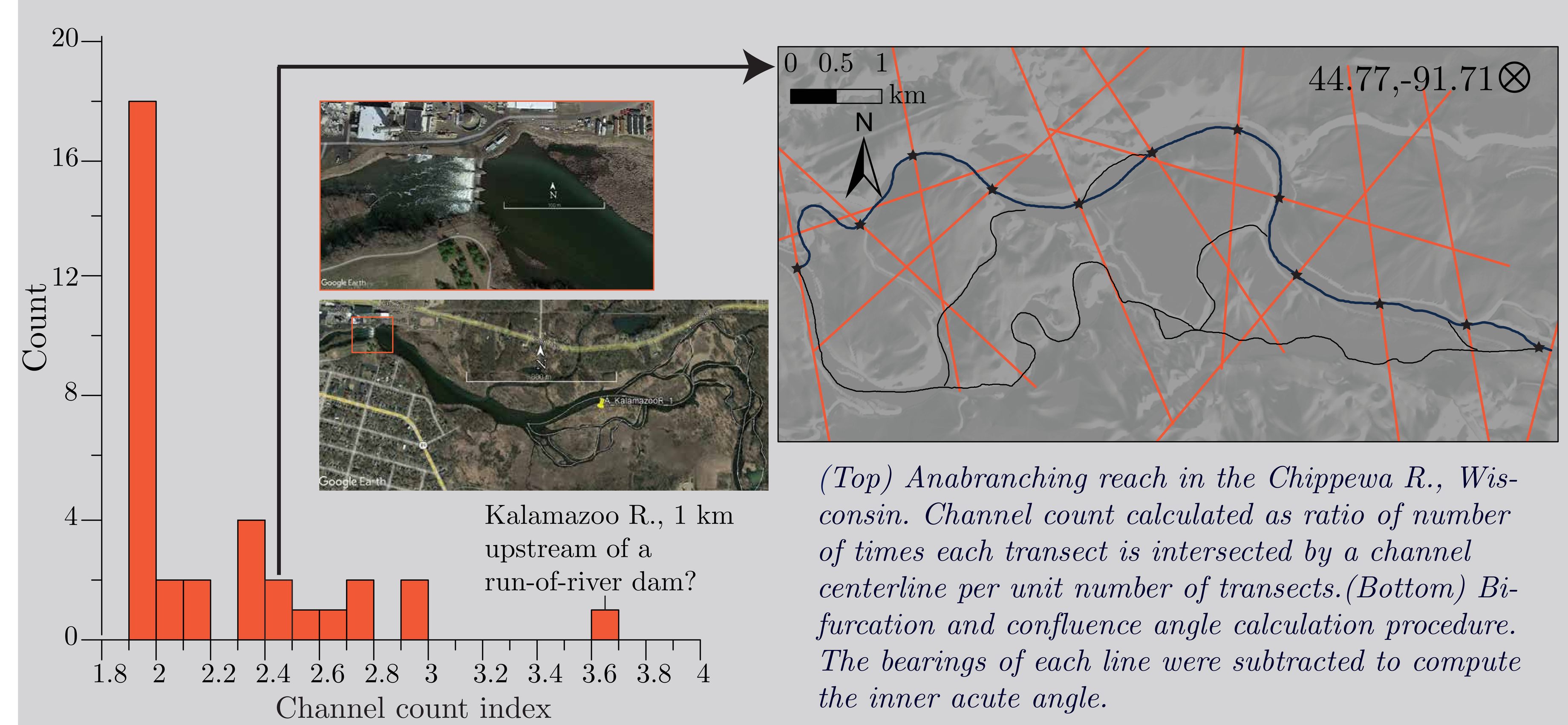
3. Methods: Planform metrics and slope-discharge plots

- Main channel centerline and island polygons were manually digitized on Google Earth and imported into ArcMap 10.8 for further analysis.
- Channel slope was calculated using LiDAR elevation data and bankfull discharge was estimated at USGS gage stations as 2 year flood. Channel slope was plotted as a function of discharge to quantify energy conditions

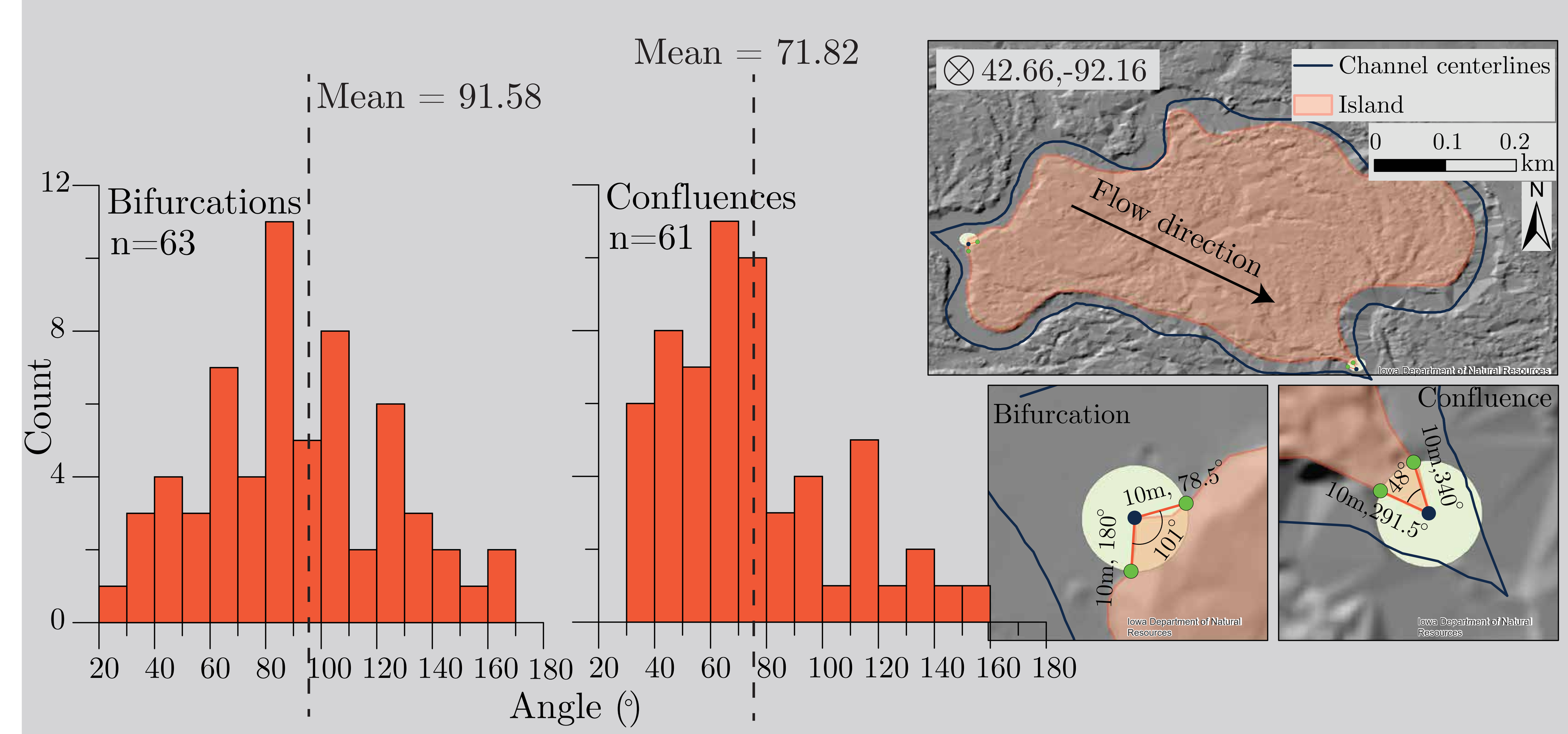
Metric	Physical significance	References	Method
Channel count index	Measure of multiplicity of channels in a reach	Egozi & Ashmore, 2008; Meshkova & Carling, 2013	Number of channels intersecting a transect were measured within an anabranching reach
Island shape and scaling relationships	Similarity or difference in island formative processes	Kelly, 2006; Hundey & Ashmore, 2009	Scaling relationship quantified as power law fit between length and width as well as perimeter and area of islands
Bifurcation and confluence angle	Channel flow and sediment transport patterns	Coffey & Shaw, 2017; Hasthorpe & Mount, 2012	Difference in the bearing of channels on both sides o an island vertex

4. Results: Planform metrics

- Median channel count for all anabranching reaches studied is two. More than 50% of anabranching reaches have two channels, when averaged over the number of transects.
- Some reaches, however, are highly dissected, for example a reach of the Chippewa River, WI where the channel count is 2.4.
- Mean bifurcation angle is 91°±33°), and is not consistent with the theoritical critical bifurcation angle of 72° calculated for stream networks through hydraulic principles (Devauchelle et. al., 2012).

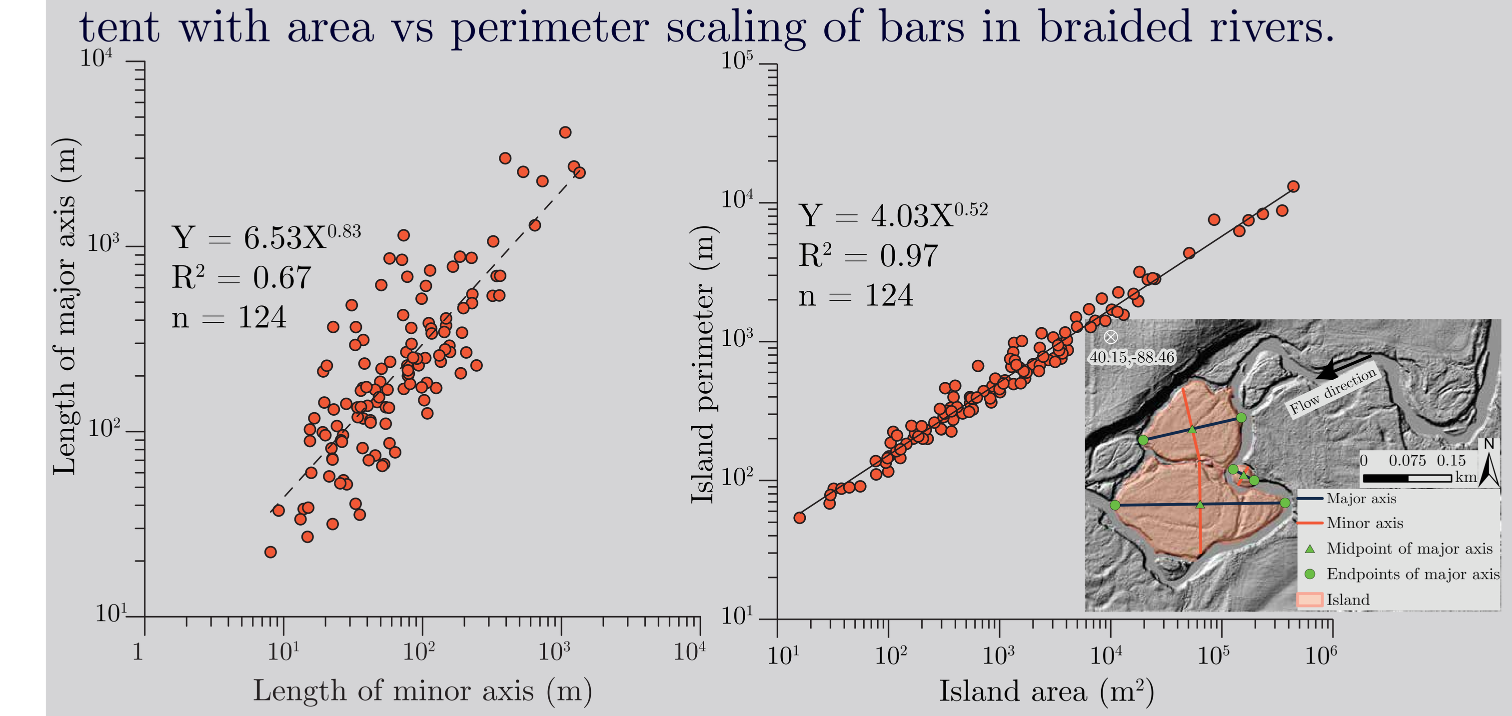


(Top) Anabranching reach in the Chippewa R., Wisconsin. Channel count calculated as ratio of number of times each transect is intersected by a channel centerline per unit number of transects.(Bottom) Bifurcation and confluence angle calculation procedure. The bearings of each line were subtracted to compute the inner acute angle.



5. Results: Planform scaling relationships

- Exponent of width-length scaling for bars in braided rivers is close to unity for major axis length varying over six orders of magnitude, implying a self similar form across scales.
- In anabranching case, the exponent for length scaling is less than unity. Area vs perimeter scaling of anabranching islands is consistent with area vs perimeter scaling of bars in braided rivers.



6. Conclusions

- Otherwise meandering rivers (according to plotting position on slope discharge plot) containing anabranching reaches were identified in and around the states of Illinois, Indiana, and Iowa.
- Channel count (average number of channels per cross section) ranged between 2-3.8, agreeing well with theoretical estimates of two to four channels (Huang & Nanson, 2007; Eaton et. al., 2010) as well as being within the range of recent measurements for large anabranching rivers (Meshkova & Carling, 2013).
- Bifurcation angle estimates (91°±33°), however, are larger than theoretical calculations of 72°, those for large anabranching rivers with bifurcation angle values between 50°-85° (Meshkova & Carling, 2013), as well as for deltaic networks (70.4°±2.6°) (Coffey & Shaw, 2017).
- The study is a first attempt at characterizing juxtaposed anabranching-meandering systems and provides a basis to explore the role of natural versus human induced processes on formation and evolution of mixed planform river characteristics in intensively managed agricultural landscapes.

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8. Acknowledgement

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