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Development of a zoning-based environmental-ecological-coupled model for lakes to assess lake restoration effect

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Environmental/ecological models are widely used for lake management as they provide a means to understand physical, chemical and biological processes in highly complex ecosystems. Most research focused on the development of environmental (water quality) and ecological models, separately. Limited studies were developed to couple the two models, and in these limited coupled models, a lake was regarded as a whole for analysis (i.e. considering the lake to be one well-mixed box), which was appropriate for small-scale lakes and was not sufficient to capture spatial variations within middle-scale or large-scale lakes. This paper seeks to establish a zoning-based environmental-ecological-coupled model for a lake. The Baiyangdian Lake, the largest freshwater lake in Northern China, was adopted as the study case. The coupled lake models including a hydrodynamics and water quality model established by MIKE21 and a compartmental ecological model used STELLA software have been established for middle-sized Baiyangdian Lake to realize the simulation of spatial variations of ecological conditions. On the basis of the flow field distribution results generated by MIKE21 hydrodynamics model, four water area zones were used as an example for compartmental ecological model calibration and validation. The results revealed that the developed coupled lake models can reasonably reflected the changes of the key state variables although there remain some state variables that are not well represented by the model due to the low quality of field monitoring data. Monitoring sites in a compartment may not be representative of the water quality and ecological conditions in the entire compartment even though that is the intention of compartment-based model design. There was only one ecological observation from a single monitoring site for some periods. This single-measurement issue may cause large discrepancies particularly when sampled site is not representative of the whole compartment.
The coupled models have been applied to simulate the spatial variation trends of ecological condition under ecological water supplement as an example to reflect the application effect in lake restoration and management. The simulation results indicate that the models can provide a useful tool for lake restoration and management. The simulated spatial variation trends can provide a foundation for establishing permissible ranges for a selected set of water quality indices for a series of management measures such as watershed pollution load control and ecological water transfer. Meanwhile, the coupled models can help us to understand processes taking place and the relations of interaction between components in the lake ecosystem and external conditions.
Taken together, the proposed models we established show some promising applications as middle-scale or large-scale lake management tools for pollution load control and ecological water transfer. These tools quantify the implications of proposed future water management decisions.