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Ecological relevance of current water quality assessment unit designations in impaired rivers

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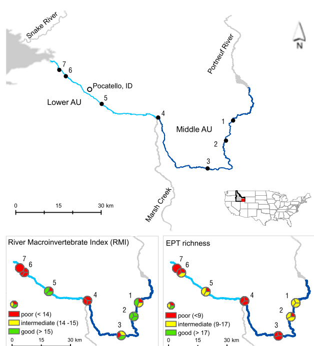
HIGHLIGHTS

- Tested ecological relevancy of water body assessment units (AU) in impaired river.
- Evaluated ecological similarity amid reaches within AUs and defined alternate AUs.
- Biological conditions had greater variability within than between AUs.
- Multivariate analyses identified alternative AUs that reduced this variability.
- Provide a framework for identifying AU boundaries based on local-scale measures.

GRAPHICAL ABSTRACT



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ABSTRACT

Managers often nest sections of water bodies together into assessment units (AUs) to monitor and assess water quality criteria. Ideally, AUs represent an extent of waters with similar ecological, watershed, habitat and land-use conditions and no overlapping characteristics with other waters. In the United States, AUs are typically based on political or hydrologic boundaries rather than on ecologically relevant features, so it can be difficult to detect changes in impairment status. Our goals were to evaluate if current AU designation criteria of an impaired water body in southeastern Idaho, USA that, like many U.S. waters, has three-quarters of its mainstem length divided into two AUs. We focused our evaluation in southeastern Idaho's Portneuf River, an impaired river and three-quarters of the river is divided into two AUs. We described biological and environmental conditions at multiple reaches within each AU. We used these data to (1) test if variability at the reach-scale is greater within or among AUs and, (2) to evaluate alternate AU boundaries based on multivariate analyses of reach-scale data. We found that some biological conditions had greater variability within an AU than between AUs. Multivariate analyses identified alternative, 2- and 3-group, AUs that reduced this variability. Our results suggest that the current AU designations in the mainstem Portneuf River contain ecologically distinct sections of river and that the existing AU boundaries should be reconsidered in light of the ecological conditions measured at the reach scale. Variation in biological integrity within designated AUs may complicate water quality and biological assessments, influence management decisions or affect where monitoring or mitigation resources are directed.

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1. Introduction

Biological and physical monitoring and assessment efforts are used to document the integrity and track the status of inland waters worldwide. Because more waters exist than can be effectively monitored, managers in the United States and European Union (EU) often nest sections of water bodies together into assessment units (AUs) to monitor and assess water quality criteria (United States Enivonrmental Protection Agency and USEPA, 1997; Barbour et al., 1999; EU WFD, 2000). For example, over half of lotic systems in the US are included in large AUs and lack site specific monitoring (US EPA, 2015) and in the EU there is approximately two times the number of water bodies as monitoring sites (EEA, 2012). Ideally, AUs are comprised of waters with similar watershed, habitat and/or land-use characteristics in the U.S. (US United States Enivonrmental Protection Agency and USEPA, 1997) or are discrete waters with no overlapping ecological, hdyrological and geological characteristics with other waters (EU WFD, 2000). In the U.S., more often, AUs are based on political or hydrological boundaries which allow for a consistent classification system for monitoring across basins and states. However, this approach shifts the focus away from measurable changes in ecological conditions and may not capture the finer scale processes that produce biological patterns observed at smaller scales (Snelder and Biggs, 2002; CoreTeam, 2014).

In the U.S., once AU boundaries are designated, biological indices (e.g., macroinvertebrate communities) and environmental features are often sampled at only a few sites within AUs and are used to make inferences about the condition of the entire unit often because of limited resources (Barbour et al., 1999). Therefore, aggregating large sections into a single AU (and only sampling a few sites within AUs) may underestimate ecological complexity present within unit boundaries, especially in impaired waters. Impairments occur at various spatial scales ranging from local point-source inputs to landscape-scale land-use patterns; these multi-scale stressors influence biological communities and ecological processes in complex ways. Current AU designations in impaired water bodies were intentionally designed to document the cumulative effects of varying impacts (Barbour et al., 1999), but may misrepresent or be too large to capture local-scale variation in biological and environmental conditions. Designation of AU boundaries based on local-scale biological and environmental patterns (e.g., reach or sampling location) may allow managers to more accurately identify impairments and changing conditions.

The EU framework, with an understanding of the limitations of large-scale water body designations, recommends that AU designations should reflect changing ecological conditions and recommends that sampling sites within AUs reflect these changing conditions (European Union Water Framework Directive, 2011). Locations and quantity of sampling sites under the EU framework are meant to reflect point or non-point source inputs or physical alterations (EU WDF, 2011). Ultimately though, individual nations within the EU determine water body classifications and sampling protocols and more research is needed to address discrepancies in water body assessments including site selection because, in many instances, like in the U.S., few sampling locations are used to represent entire AUs (Birk et al., 2012; Hering et al., 2010).

Here we investigate if AU designations represent local-scale ecological (e.g., biological and environmental) conditions in the Portneuf River, an impaired river in the western U.S. The Portneuf River is a 160-km long, fifth-order river in southeastern Idaho and is representative of many waters in the U.S. and Europe because it flows through a catchment with diverse hydrological and land-use characteristics. The Portneuf River is divided into three AUs, over three-quarters of the mainstem Portneuf (134 river km) are nested into two AUs, which are both listed as US EPA impaired by sediment and nutrients. These two AUs were designated by political and hydrological boundary of tribal and public lands and confluences with large tributaries, and one-two representative sampling locations (e.g., reaches) are typically sampled within each AU (IDEQ, 2007, 2011). Because both AUs are impaired, it is critical that AUs represent the conditions of river reaches within the unit boundaries to allow for effective detection of changes in impairment status. We hypothesized that a bottom-up approach, which uses fine-scale distinctions in biological and environmental conditions to nest reaches into AUs, will more accurately define AUs than the current top-down approach, which used political and hydrological boundaries. The specific objectives of this study were to: (1) describe biological and environmental conditions at multiple reaches within each AU, (2) test if the variability of reach-scale biological and environmental conditions is greater within or between AUs, and (3) evaluate alternate AU boundaries based on reach-scale biological and environmental data. We predict that alternate AU boundaries based on reach-scale biological and environmental data may be more suitable AU designations. These analyses provide managers with a framework for identifying more appropriate AU boundaries based on biological and environmental relevance. Though this study focuses on only one impaired river, results are germane to other regions challenged with managing water resources in catchments with diverse hydrological and land-use characteristics.

2. Methods

2.1. Study area

We sampled four reaches in the middle Portneuf AU (89 km long) and three reaches in the lower Portneuf AU (47 km long) located in the Portneuf River basin (4th Field Hydrologic Unit Code 17040208; Fig. 1). Each sampled reach was 150–350 m long. To delineate reaches, existing AUs were stratified using key watershed features identified by previous studies and with Idaho Department of Environmental Quality (IDEQ) staff including natural groundwater influence, human development, land-use variations, confluences with impaired tributaries and locations of major irrigation diversions (Baldwin et al., 2004; Hopkins, 2007; IDEQ, 2010; Hopkins et al., 2011).

The middle AU extends from river km 137 below Chesterfield Reservoir and end of tribal lands to river km 48 just above the confluence of Marsh Creek (a 3rd-order tributary; Fig. 1). Study reaches in the middle AU are referred to as Reach 1 (river km 118), Reach 2 (river km 109), Reach 3 (river km 85) and Reach 4 (river km 48). Rangeland (e.g., pasture, cultivated crops) was the dominant land-use in the middle AU (27.8 $\pm$ 3.1%; mean $\pm$ 1 SD) and development (e.g., impervious surface coverage) made up a smaller percentage of land-use (1.9 $\pm$ 0.1%)[1]. Natural springs influence flow, water temperature and nutrient loading in Reaches 1 and 2 (Minshall and Andrews, 1973; Hopkins et al., 2011). These conditions facilitate high standing stocks of aquatic macrophytes and high macroinvertebrates abundance (Hopkins et al., 2011). Reach 3 is downstream of the town of Lava Hot Springs (population 407; 2010 census data) and the town's wastewater treatment facility. Reach 4 is located downstream of an irrigation diversion dam and the town of McCammon (population 809; 2010 census data), and just upstream of the confluence of the US EPA impaired (identified pollutants: bacteria, nutrients, sediment) Marsh Creek tributary.

The lower AU extends from the confluence of Marsh Creek (river km 47) to the river's mouth at American Falls Reservoir. Study reaches in the lower AU include Reach 5 (river km 25), Reach 6 (river km 9) and Reach 7 (river km 6). Rangeland was the dominant land use in the lower AU (22.1 $\pm$ 0.6%) and development made up a smaller percentage of land-use (3.4 $\pm$ 0.8%). Reach 5 is downstream of the confluence of Marsh Creek and just upstream of Pocatello, Idaho (population 54,255; 2010 census data), the largest urbanized area in the watershed. Downstream of Marsh Creek, turbidity increases and macrophytes decrease (Hopkins et al., 2011). Reach 6 is located downstream of the city center of Pocatello and adjacent to an active and former phosphorus processing facilities. In addition to urban storm water impacts, contamination from phosphorus processing facilities has leached into the