Non-navigable streams and adjacent wetlands: addressing science needs following the Supreme Court's *Rapanos* decision

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In June of 2006, the US Supreme Court ruled in two cases concerning jurisdiction under the Clean Water Act (CWA). The decisions suggest that hydrological permanence of non-navigable streams and adjacent wetlands (NNSAWs) and their effects on the chemical, physical, and biological integrity of navigable waters ("significant nexus") are relevant in determining CWA jurisdiction. This has increased the need for scientific information to support regulatory determinations and to inform future policies, rule making, and legislation. Here, we propose an approach for addressing these science needs. We define a metric – maximum duration of continuous flow – to assess hydrological permanence. We also define two metrics to evaluate significant nexus: proportion of total benefit to the navigable water contributed by an NNSAW class, and proportion of time that a navigable water receives benefit from an NNSAW. These metrics could be useful in implementing the Court's new legal standards.

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The Clean Water Act (CWA) protects "navigable waters", defined as "waters of the United States" (33 USC § 502[7]). Regulations by the US Environmental Protection Agency (EPA) and US Army Corps of Engineers (Corps) further define what are considered "waters of the US" (33 CFR § 328.3[a] and 40 CFR § 230.3[s]). Prior to 2001, any tributary to a navigable-in-fact water (including waters that are used in interstate or foreign commerce) and virtually all delineated wetlands (wetlands whose hydrology, soils, and vegetation meet regulatory requirements) were regarded as jurisdictional (ie considered a water of the US) under the CWA, because of their potential to serve as migratory bird habitat. Two Supreme Court cases changed this perspective. In *Solid Waste Agency of Northern Cook County (SWANCC)*, the Court held that the presence of migratory birds was an insufficient sole basis for asserting CWA jurisdiction over isolated, intrastate, non-navigable waters (*Solid Waste Agency of Northern Cook County v US Army Corps of Engineers* 2001). However, the Court did not invalidate the regulations defining "waters of the US". The reasoning in *SWANCC* could suggest that waters need some relationship with a navigable-in-fact body of water to be afforded protection under the CWA. By introducing the term "isolated" into the issue of CWA jurisdiction, *SWANCC* has encouraged research on the relative connectivity among wetlands and other waters (Leibowitz and Nadeau 2003).

In a nutshell:

- Recent US Supreme Court cases have created new legal standards for determining jurisdictional waters under the Clean Water Act (CWA)
- Addressing the science needs prompted by these cases will require that the various waters be regarded as components of integrated hydrological and ecological systems
- Based on this view, we define metrics of hydrological permanence and "significant nexus" (the effects of non-navigable streams and adjacent wetlands on the chemical, physical, and biological integrity of navigable waters)
- Application of these metrics could help to determine whether waters are protected under the CWA

Five years after *SWANCC*, the Supreme Court explored CWA protections for tributaries and adjacent wetlands in *Rapanos v United States* and *Carabell v United States* (these two cases were consolidated into one decision, *Rapanos v United States* [2006]). In June of 2006, the Justices issued five opinions in *Rapanos*, with no single opinion commanding a majority. As a result, the scope of "waters of the US" will be determined by the interpretation of these decisions by the EPA, the Corps, and the courts. It is clear, however, that the *Rapanos* opinions establish new data and analytical requirements for determining whether a particular water is protected under the CWA.

Justice Antonin Scalia (joined by three other Justices) opined that "waters of the US" extend beyond navigable-

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in-fact waters to include "relatively permanent, standing or flowing bodies of water" (Figure 1). Scalia indicated that the phrase includes "seasonal rivers" having continuous flow during some months of the year, and some waters that dry up during drought. However, it would not include "ordinarily dry channels through which water occasionally or intermittently flows" or "streams whose flow is '[c]oming and going at intervals…[b]roken, fitful'…or 'existing only, or no longer than, a day'". The opinion also asserts that only wetlands with a continuous surface connection to other jurisdictional waters are considered "adjacent" and protected by the CWA.

Justice Anthony Kennedy's opinion takes a different approach. Kennedy concludes that "waters of the US" include wetlands that "possess a 'significant nexus' to waters that are or were navigable in fact, or that could reasonably be so made". He suggests that wetlands and other waters have significant nexus if the waters "either alone or in combination with similarly situated lands in the region, significantly affect the chemical, physical, and biological integrity of other covered waters more readily understood as 'navigable'" (Figure 1). Such a nexus must be more than "speculative or insubstantial". Kennedy also observes that, in some circumstances, the absence of a hydrological connection may create a significant nexus (eg by allowing a wetland to retain floodwaters or pollutants).

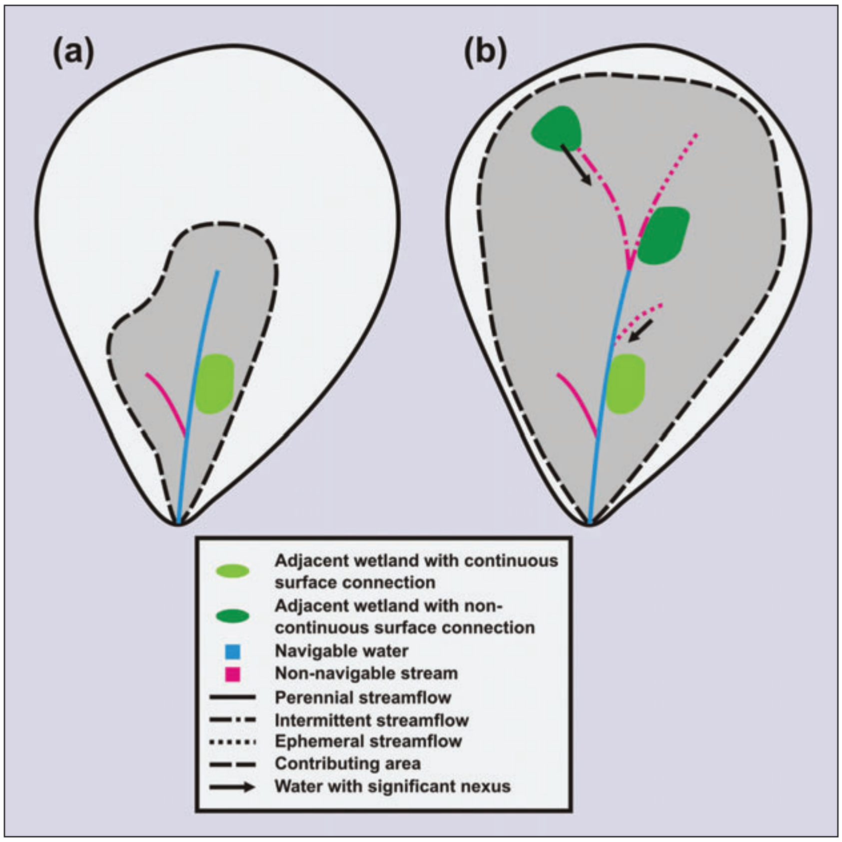

Figure 1. *Hypothetical watershed illustrating concepts relevant to* Rapanos *for (a) baseflow and (b) flood conditions. Examples of significant nexus are for purposes of illustration only; significant nexus must be determined based on actual relationships with downstream, navigable waters.*

Justice John Paul Stevens, in an opinion joined by three other justices, indicated that a water may be found jurisdictional if it meets *either* the Scalia or Kennedy standard. The agencies developed field guidance (www.epa.gov/owow/wetlands/guidance/CWAwaters.html) that indicates that the EPA, Corps, and Department of Justice have adopted this position. The EPA and Corps are encouraging field staff to include in their jurisdictional files information relevant to both the Scalia and Kennedy standards, not because both standards must be met, but because the legal landscape is potentially evolving.

Rapanos poses challenges to EPA and Corps field staff and to the regulated community (eg businesses or individuals who require a permit to discharge into waters of the US) as they seek to determine whether a particular water is jurisdictional under the CWA. The research community is in a position to help ensure that those determinations are well-grounded in science, both by clarifying relationships among waters and by developing protocols that readily identify and document such relationships. Before these protocols can be developed, basic research must address the fundamental hydrological and ecological relationships underlying the Scalia and Kennedy standards. This research could also inform future decision making.

Here, we address the characteristics of non-navigable streams and adjacent wetlands (NNSAWs, pronounced "en-saws") and their relationship to the physical, chemical, and biological integrity of navigable-in-fact waters (hereafter, "navigable waters"). Non-navigable streams occur upstream from, and may ultimately discharge into, navigable waters. Adjacent wetlands border, are contiguous to, or neighbor a jurisdictional water. To address the issues raised by *Rapanos*, we provide a background for understanding NNSAWs and their relationships with navigable waters. Then, we present several metrics that could be useful in implementing the new legal standards. Although our approach does not resolve all the complexities of these issues, the simple metrics presented here illustrate how the *Rapanos* standards can be addressed scientifically. Finally, we discuss how future research can more fully address the Court's decision.

Integrated hydrological–ecological systems

The physical, chemical, and biological integrity of any ecosystem is the synergistic product of processes operating at many spatial and temporal scales. Stream networks

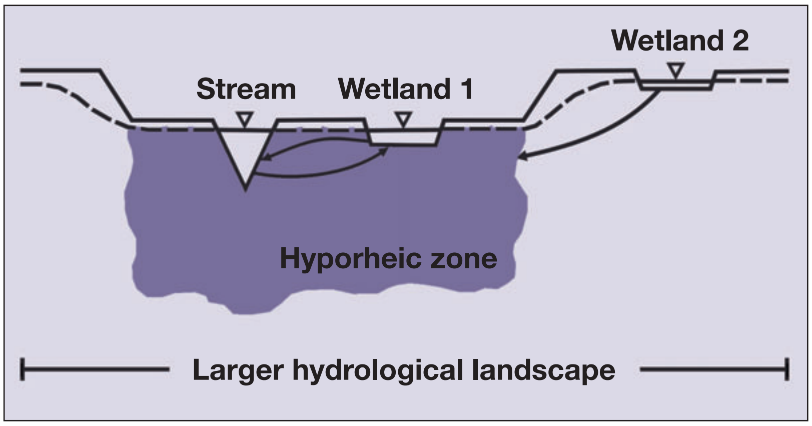

Figure 2. Hydrological connectivity between wetlands and streams. Wetland 1 is located within the hyporheic zone (shaded area), so water from the stream can move into the wetland and return to the channel. Wetland 2 is outside the hyporheic zone, and so connections between it and the stream occur through unidirectional groundwater flow. Both wetlands can also be connected to the stream during over-bank flooding.

are special cases, because hydrological and ecological connectivity allow for the exchange of materials (eg mass, energy, organisms) longitudinally, laterally, vertically, and temporally throughout the basins and underlying aquifers (Ward 1989). Therefore, NNSAWs and navigable waters are best considered elements of integrated hydrological–ecological systems (Nadeau and Rains 2007; Figure 1). Within these systems, materials are passively transported as water flows down-gradient from NNSAWs to navigable waters, and are actively transported as organisms move down-gradient, up-gradient, or overland between NNSAWs and navigable waters (Alexander *et al.* 2007; Meyer *et al.* 2007). Consequently, NNSAWs cumulatively contribute to the integrity of the navigable waters by performing a variety of functions.

Non-navigable streams can be perennial, intermittent, or ephemeral (Figure 1). During a typical year, perennial streams flow year-round, intermittent streams cease to flow during dry periods, and ephemeral streams flow for short durations in direct response to precipitation (Mosley and McKerchar 1993). This widely accepted hydrological definition of "intermittent" differs from Justice Scalia's usage, which implied that intermittent includes flow that is "broken and fitful" and does not occur continuously for months. From a scientific perspective, intermittent streams have widely varying hydrographic characteristics (Poff *et al.* 2006) and can include both the "seasonal rivers" that may pass the Scalia standard and "ordinarily dry channels", which might not.

Adjacent wetlands are proximal to jurisdictional streams and may include slope wetlands on hillslopes and depressional, slope, fringe, or riverine wetlands on valley bottoms (Brinson 1993). Adjacent wetlands may have continuous surface-water connections to nearby streams, or they may be geographically isolated (Leibowitz and Nadeau 2003). However, the latter can have intermittent surface-water connections to streams through over-bank flooding or spillage. They may also have perennial, intermittent, or ephemeral connections to streams through groundwater flow.

Both surface-water and groundwater flow paths connect individual elements between separate NNSAWs and between NNSAWs and navigable waters. Groundwater connections, though more difficult to observe and quantify than surface-water connections, can be equally or more influential in maintaining the integrity of stream networks. Another important type of hydrological connection occurs in the hyporheic zone, where stream water and groundwater can mix. Hyporheic flow consists of water from the stream channel that enters subsurface materials of the streambed and bank and then returns to the stream (Bencala 2005). This definition emphasizes the potential importance of hyporheic flow to downstream waters, including navigable waters. The dimensions of the hyporheic zone are controlled by the distribution and characteristics of alluvial deposits and by hydraulic gradients between streams and local groundwater (Morrice *et al.* 1997). If wetlands are located in settings with active hyporheic exchange, materials may be transferred between streams and wetlands (see Wetland 1 in Figure 2). Streams and wetlands within hyporheic zones are integrally connected; neither can function properly if the other is impaired. For example, much of the nutrient cycling in streams occurs during flow excursions through hyporheic zones (Hill *et al.* 1998; Hill and Lymburner 1998).

Groundwater connections between more isolated wetlands and streams may also occur through local or regional groundwater flow systems outside hyporheic zones, but within larger hydrological landscapes (Winter 2001). In these groundwater flows, materials may be transported from wetlands to streams but not from streams to wetlands (see Wetland 2 in Figure 2). These groundwater flows can also play important roles in material fluxes between wetlands and streams (eg Triska *et al.* 2007).

Organisms can move between NNSAWs and navigable waters by hydrological, terrestrial, and aerial pathways. This biological connectivity allows NNSAWs to function as refugia from predators, competitors, invasive species, and adverse conditions such as extreme temperature and flow (Meyer *et al.* 2007). Exchanges between NNSAWs and navigable waters also help to maintain populations (eg through gene flow and recolonization following local extinctions). In addition, biological connectivity can represent an important pathway by which nutrients are transported to up-gradient sites (Gresh *et al.* 2000; Naiman *et al.* 2002).

The importance of connections between NNSAWs and navigable waters to the integrity of navigable waters typically varies with landscape setting, watershed characteristics, and stream network characteristics. Quantifying the

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importance of these connections is challenging, in part because of natural temporal variation in flow regimes (Poff *et al.* 1997; Izbicki 2007). Temporal variability can result in intra- and interannual expansion and contraction (Figure 1) and subsequent changes in surface and subsurface connectivity (Junk *et al.* 1989; Stanley *et al.* 1997; Rains and Mount 2002; Wigington *et al.* 2005; Izbicki 2007). Because this affects processing and delivery of materials and movement of organisms, the benefits that NNSAWs provide to navigable waters may also vary with time.

Approach

We developed metrics for hydrological permanence and significant nexus that reflect the hydrological and ecological characteristics implied by the Scalia and Kennedy opinions. Our focus is not on the individual NNSAW, but on classes of NNSAWs. Classes of NNSAWs might, for example, be groups of NNSAWs in the same hydrogeomorphic class (Brinson 1993) that occur in the same hydrologic-landscape region (Wolock *et al.* 2004) or ecoregion (Omernik 1987). Defining NNSAW classes will require development of classification approaches that are dualistic and hierarchical, because characteristics of both NNSAWs and downstream navigable waters must be included at various spatial scales.

Hydrological permanence

According to Justice Scalia, a stream NNSAW would be considered jurisdictional if it was relatively permanent. Because stream and hyporheic waters are so integrally linked, including hyporheic water when addressing hydrological permanence could still be consistent with Scalia's approach. This would mean that a dry stream channel might still be considered relatively permanent if the duration of hyporheic flow were sufficient.

To evaluate whether a stream is relatively permanent, we define $D_{max,q}$ as the maximum duration (in days) of continuous surface or hyporheic flow. This metric can be evaluated, in part, from a stream's hydrograph (Figure 3). Biological indicators might also be useful in evaluating duration of flow (Fritz *et al.* 2006). A related metric, $D_{max,c}$, can be defined as the maximum duration of continuous surface or hyporheic connection between an adjacent wetland and a jurisdictional stream. While the Scalia standard does not explicitly require a hydrological connection for adjacent wetlands, $D_{max,c}$ could be useful in determining whether such a wetland has significant nexus.

Significant nexus

Significant nexus is more complex than hydrological permanence. It involves not only the hydrological characteristics of the NNSAW, but also its physical, chemical, and biological attributes. Furthermore, significant nexus is not a property of the NNSAW alone, but reflects characteristics of the combined stream network. Our approach is to consider the ways that NNSAWs alter material fluxes so as to contribute to the integrity of the navigable water. These include:

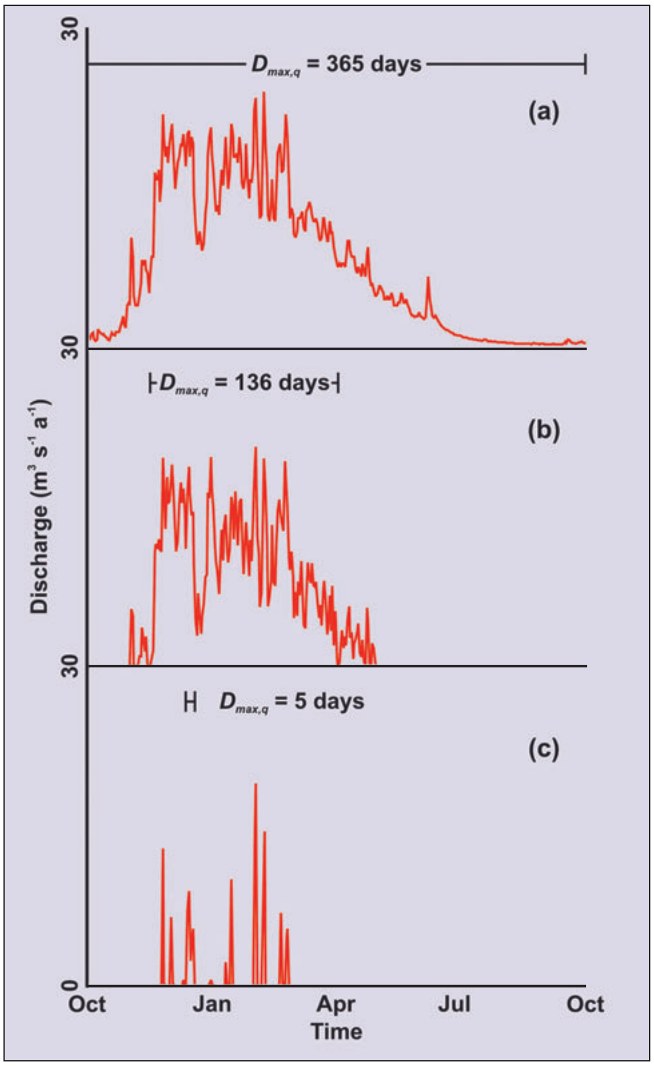

Figure 3. *Hypothetical hydrographs illustrating* $D_{max,q}$ *values for (a) perennial, (b) intermittent, and (c) ephemeral streams.* $D_{max,q}$ *is the maximum duration (in days) of continuous stream or hyporheic flow. Note that the hydrographs do not consider hyporheic flow; including days when the channels were empty but hyporheic flow occurred would increase* $D_{max,q}$ *values. Examples are for purposes of illustration only, and* $D_{max,q}$ *values do not necessarily represent the actual values for those classes of streams.*

(1) *Supplying beneficial materials (source function)*: NNSAWs can be sources of energy, inorganic nutrients, organic matter, and organisms. Source functions include net growth that occurs when NNSAWs serve as spawning and rearing habitat for migratory fish. NNSAWs are also sources of water, maintaining flow regimes by delivering water from the watershed and by storing and releasing stormwater.

(2) *Removing harmful materials (sink function)*: NNSAWs can serve as sinks of harmful materials such as sedi-

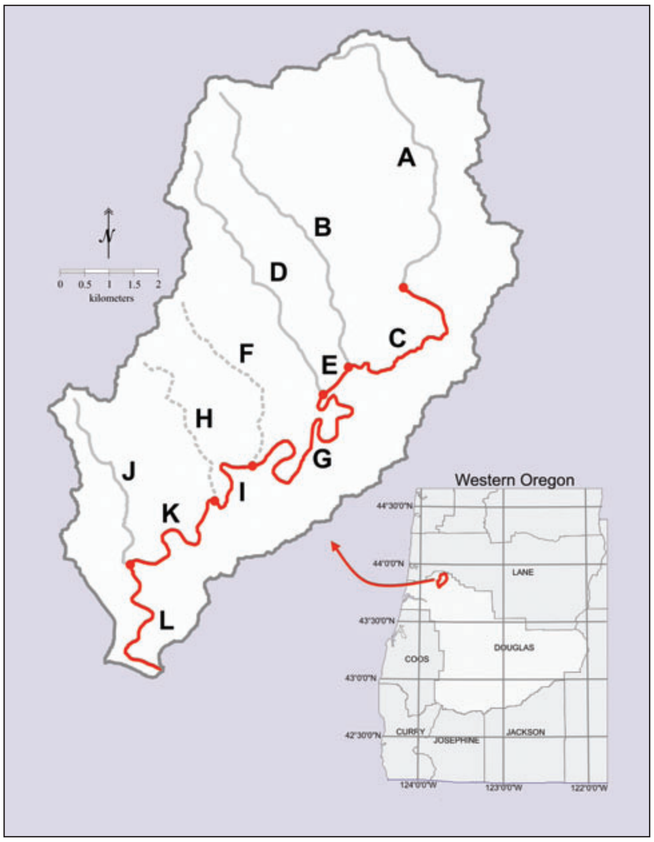

Figure 4. *Watershed and stream network for the West Fork Smith River, Oregon. Gray-colored streams are perennial (solid) or intermittent (dotted) NNSAWs. Red-colored reaches represent the mainstem river. Letters correspond to intermittent and perennial streams and mainstem reaches in Table 1.*

ments and pollutants, and they can attenuate high flows through temporary storage of water.

(3) *Preventing removal of beneficial materials (refuge function)*: NNSAWs can reduce mortality of migratory organisms, particularly fish, by providing refugia from threats, such as predators or extreme temperatures (refugia effects on resident organisms are implicitly incorporated into the source function). NNSAWs can also help to form refugia in other waters (eg by providing cold or warm water to downstream reaches).

To evaluate these functions, we define a metric that assesses the relative benefit provided by an NNSAW of class *i*:

$$B_i = b^*_i / \Sigma b^*_j$$

where B_i is the proportion of total benefit to the navigable water contributed by $NNSAW_i$ for a given material, b^*_i is the benefit the navigable water receives from $NNSAW_i$, and Σb^*_j is the total benefit the navigable water receives from all NNSAW classes and the navigable water itself. Benefits are changes in a beneficial or harmful material provided by source, sink, or refuge functions. An implication of this equation is that the relative benefit of a given b_i value increases as the benefit received from the navigable water itself decreases (causing a decrease in the denominator).

The variable b^* is dependent on b, the net change in material that is or can be caused by the class, and k, the proportion of the altered amount that is or would be transferred downstream to the navigable water:

$$b^* = bk$$

The variables b and k are only measured or estimated if b^* cannot be determined directly. The transfer coefficient, k, can be estimated in various ways (eg through tracer studies, mass balance calculations, or by extrapolating from similar systems). Note that the actual value of k is not needed to calculate B; the relative value compared to other NNSAW classes is sufficient, as illustrated below.

In the following examples, we separately interpret b for source, sink, and refuge functions, and illustrate how the metric could be applied.

For source functions, b represents the net amount of material (ie output minus input) supplied by an NNSAW. We provide an example of how B can be estimated from a study in the West Fork Smith River (WFSR) basin in coastal Oregon (Figure 4). For the purposes of this illustration, we assume that the mainstem WFSR meets the legal definition of a navigable water. Wigington *et al.* (2006) reported tagging 400, 1214, and 3977 juvenile coho salmon (*Oncorhynchus kisutch*) in 2003 within intermittent and perennial NNSAWs and the WFSR mainstem, respectively. The number of fish in an NNSAW (b) is equal to the number of tagged fish divided by the sampling efficiency (e). If e and k do not vary across classes, then B for the intermittent class is:

$$(400k/e) / (400k/e + 1214k/e + 3977k/e) = 7\%$$

Perennial and mainstem values are 22% and 71%, respectively. If fish are sampled in the mainstem half as efficiently as in the intermittent and perennial NNSAWs, and if fish from intermittent NNSAWs have a 25% lower chance of surviving their migration to the navigable water, then B for the intermittent class would be:

$$(400 \times 0.75k/e) / (400 \times 0.75k/e + 1214k/e + 3977k/[0.5e]) = 3\%$$

Under these conditions, perennial and mainstem classes provide 13% and 84% of the benefits, respectively.

For sink functions, b could represent the net amount of material removed by an NNSAW. As an example, Alexander *et al.* (2007) calculated N removal in the northeastern US. They estimated that total nitrogen loads in fourth- and higher-order streams were reduced by 3–4% through headwater stream denitrification. There are two problems with using this approach for determining CWA

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jurisdiction. First, using total nitrogen as the denominator means that the benefit of a given NNSAW nitrogen reduction would decrease as nitrogen in the navigable water (the denominator) increased from other sources. Determining significant nexus with such a metric would result in degraded navigable waters having fewer jurisdictional waters than less impacted waters. Second, using actual removal for *b* means that NNSAWs with relatively pristine catchments would remove less N, and provide less benefit, than NNSAWs with degraded catchments having high loads. Yet, the former can still have the capacity to remove harmful materials, should they be present in the future. Such a capacity helps to maintain the integrity of the navigable water.

To avoid these problems, we define *b* for sink functions as the maximum net amount of material an NNSAW could remove if sufficient amounts of the material were present. To illustrate this, we estimate nitrogen removal capacity for the NNSAW classes in the WFSR (Figure 4). We assume that maximum loadings would occur if the entire basin were covered with nitrogen-fixing alder. We then use a first-order decay equation (Alexander *et al.* 2007) to calculate N removal (Table 1). Assuming that this represents nitrogen that would have been transported to the mainstem were it not removed (ie k = 1), then b^* values for intermittent, perennial, and mainstem classes are 11, 43, and 59 metric tons, respectively. This gives *B* values of 10%, 38%, and 52%, respectively.

Table 1. Estimated maximum annual nitrogen delivery, retention, and downstream export (in metric tons) for intermittent and perennial streams and mainstem reaches of the West Fork Smith River, Oregon

Map location[1]	*Reach type*	*Local delivery*[2]	*Upstream delivery*[3]	*Total retention*[4]	*Downstream export*[5]
A	Perennial	295	0	18	277
B	Perennial	172	0	12	160
C	Mainstem	131	277	15	393
D	Perennial	159	0	5	154
E	Mainstem	6	553	2	557
F	Intermittent	92	0	6	86
G	Mainstem	122	711	9	824
H	Intermittent	89	0	5	84
I	Mainstem	53	910	7	955
J	Perennial	102	0	8	93
K	Mainstem	68	1040	13	1095
L	Mainstem	70	1188	13	1245

Notes: [1]Letters correspond to locations in Figure 4. [2]The maximum N load to the incremental drainage area (reach drainage area minus the drainage area of upstream reaches). Maximum N loadings estimated as the amount of N that would be delivered if the entire basin were covered with nitrogen-fixing alder, using a rate of 200 kg ha^{-1} yr^{-1} (Wigington *et al.* 1998). [3]Equal to downstream export from reaches that feed directly into the target reach. [4]Sum of N retention from local and upstream delivery. Retention from each of these sources is equal to the product of the delivery and retention rates. Retention rates estimated as first-order decay processes (Alexander *et al.* 2007), equal to $1 - \exp(-0.0513Z^{-1.319}T)$, where *Z* is mean water depth and *T* is time of travel. *T* estimated as a function of drainage area, discharge, and slope based on Jobson (1996). Time of travel for local delivery taken as one-half of the reach value (ie local delivery is assumed to be introduced at the reach midpoint). [5]Equal to local plus upstream N delivery minus total N retention.

For refuge functions, *b* represents the net output of organisms from waters other than the NNSAW class, given the presence of NNSAW refugia, minus the output if the refugia were absent. As an illustration of this function, Labbe and Fausch (2000) found that 85% of sampled pools in NNSAWs that were refugia from northern pike (*Esox lucius*) contained Arkansas darter (*Etheostoma cragini*), compared to 36% of pools in NNSAWs where pike were present. Combining such data with densities and estimates of *k* could be used to calculate *b*.

The flux of materials between NNSAWs and navigable waters varies over time (Figure 1). Some NNSAW functions that occur infrequently can still have important effects on navigable waters if the benefits are long-lasting. For example, infrequent flood events can provide persistent habitat benefits through the supply of gravel and large woody debris. For such an infrequently occurring function, the following metric could be used along with *B* to evaluate its significance:

$$\tau = \min(d/r, 1)$$

where τ is the proportion of time that a navigable water receives benefits from an NNSAW, *r* is the recurrence

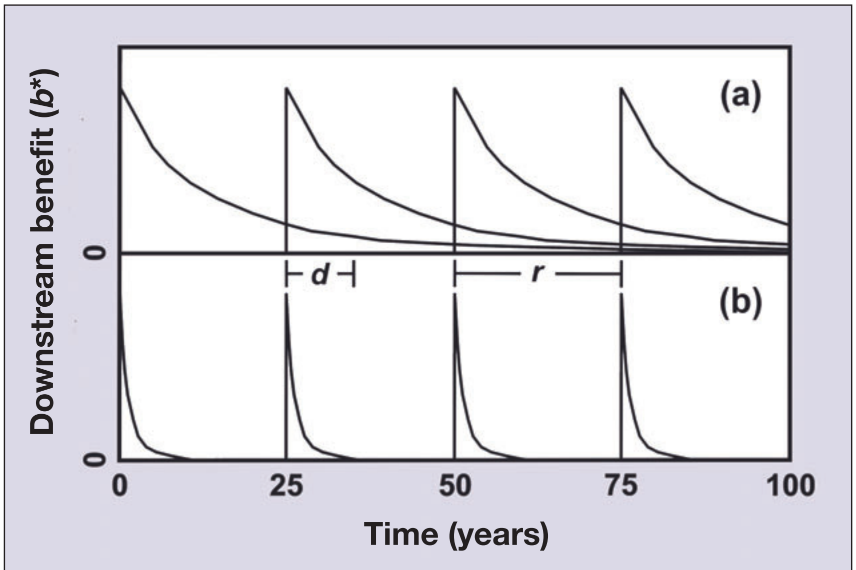

Figure 5. *Timing effects in delivery of downstream benefit from a non-navigable stream and adjacent wetland (NNSAW) class to a navigable water. We define* τ *to be the proportion of time that a navigable water receives benefits from an NNSAW. If the duration of the effect,* d*, is less than the recurrence frequency,* r*, then* τ = d/r*. If* d ≥ r*, then* τ = 1*. (a)* τ = 1 *for a recurrence interval of 25 years and duration of 100 years. (b)* τ = 0.4 *for a recurrence interval of 25 years and a duration of 10 years.*

interval of the function, and d is the duration of the downstream benefit. For example, τ would be equal to one for large woody debris that was delivered on a 25-year frequency, but with a duration of 100 years (Figure 5).

The two metrics we have defined simplify the nexus issue by dealing with the relative benefits of single materials. In applying B and τ, the following should be considered:

- Both metrics evaluate a single material. An NNSAW class processes many different materials. A large benefit from a single material could be sufficient to establish significant nexus. Alternatively, significant nexus might arise from the accumulation of multiple benefits.
- Neither metric addresses the importance of a material to the integrity of a navigable water. For example, $B = 0.4$ for a limiting nutrient could be more significant than $B = 0.8$ for a non-limiting nutrient. Materials must be selected that are known to play important roles in maintaining the integrity of navigable waters.
- We have removed some of the influence of watershed and stream condition by defining b as a capacity, rather than actual removal, for sink functions. This effectively standardizes the landscape for stream loadings. Yet condition can still affect function (eg higher carrying capacities in less degraded waters). These metrics therefore need to be calculated relative to some standard condition (eg current, reference, or restorable condition).
- How to legally define the navigable water to which significant nexus is established will presumably be clarified by the EPA, the Corps, and the courts. For example, significant nexus might have to be established for the entire navigable water or just for the uppermost navigable reach.

Research needs

To be used by regulators, any approach for evaluating hydrological permanence and significant nexus, including our metrics, must be inexpensive and easily applied, with minimal data collection. Meeting these criteria requires two critical areas of research:

- Methods and indicators that vary in level of effort and accuracy are needed for use in evaluating the metrics. These methods include direct measurement, model-based estimates, and indirect indicators (see WebTable 1).
- Dualistic and hierarchical classification approaches are needed to assess hydrological permanence and significant nexus, because it is impractical to evaluate NNSAWs individually and because of the need to focus on aggregate function. Researchers must then describe classes and functions for the NNSAWs in their region.

Research is also necessary in several other areas:

- Fundamental research into the interactions between upstream and downstream components of stream networks, including the factors influencing the integrity of navigable waters at various spatial and temporal scales, and the dependence of navigable waters on NNSAWs.
- Case studies are required within various regional settings that quantify and document hydrological permanence and significant nexus and illustrate application of the metrics.
- Although the metrics can quantify hydrological permanence and significant nexus, the threshold values that would meet the Scalia and Kennedy standards are legal and policy matters. However, research evaluating the consequences of adopting different threshold values could be helpful.

Conclusions

Based on an understanding of integrated hydrological–ecological systems, we have developed three metrics that could help to assess hydrological permanence and significant nexus. We include hyporheic waters in evaluating hydrological permanence because they are so integrally linked to stream waters. Our approach could be generalized and applied to other issues, including jurisdiction of isolated wetlands, managing and establishing TMDLs (total maximum daily loads), and impact assessment. Further research and development of indicators and classification systems will be critical for any successful application. Successfully meeting the challenges of *Rapanos* will also require more research on the functional relationship among upper streams, wetlands, and downstream waters. This information could help inform future policies, rule making, or legislation that might result from the Court's decision.

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