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Articles

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Abstract

Many National Wildlife Refuges (Refuges) have impaired water quality resulting from historic and current land uses, upstream sources, and aerial pollutant deposition. Competing duties limit the time available for Refuge staff to identify and evaluate potential water quality issues. As a result, water quality–related issues may not be resolved until a problem has already arisen. This study developed a geospatial approach for identifying and prioritizing water quality issues affecting natural resources (including migratory birds and federally listed species) within Refuge boundaries. We assessed the location and status of streams pursuant to the Clean Water Act in relation to individual Refuges in Oregon and Washington, United States. Although twelve Refuges in Oregon (60%) and eight Refuges in Washington (40%) were assessed under the Clean Water Act, only 12% and 3% of total Refuge stream lengths were assessed, respectively. Very few assessed Refuge streams were not designated as impaired (0% in Oregon, 1% in Washington). Despite the low proportions of stream lengths assessed, most Refuges in Oregon (70%) and Washington (65%) are located in watersheds with approved total maximum daily loads. We developed summaries of current water quality issues for individual Refuges and identified large gaps for Refuge-specific water quality data and habitat utilization by sensitive species. We conclude that monitoring is warranted on many Refuges to better characterize water quality under the Clean Water Act.

Keywords: Clean Water Act; geographic information systems; National Wildlife Refuge System; total maximum daily loads; trust resources; water quality assessment

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Introduction

The National Wildlife Refuge System, administered by the U.S. Fish and Wildlife Service (FWS), includes 550 National Wildlife Refuges (Refuges) encompassing 150 million acres, 37 wetland management districts, and 30,000 waterfowl production areas. The mission of the National Wildlife Refuge System is to manage these lands and waters for the conservation, management, and restoration of biological resources and their habitat for the benefit of present and future generations of Americans. Legal mandates on National Wildlife Refuge System lands include the amended National Wildlife Refuge System Administration Act for Refuge purpose and water quality protection (16 U.S.C. 668dd–668ee); the Migratory Bird Treaty Act (16 U.S.C. 703–711), the Endangered Species Act (16 U.S.C. §§ 1531–1544, December 28, 1973, as amended 1976–1982, 1984 and 1988), and the Marine Mammal Protection Act (16 U.S.C. 1361–1471h) for addressing FWS biological resources;

Table 1. Water quality standard attainment categories based on U.S. Environmental Protection Agency guidance (USEPA 2003).

Category	Description
1	All designated uses are met
2	Some designated uses are met but insufficient data for remaining designated uses
3	Insufficient data to determine if any designated uses are met
3B	Insufficient data but some data indicate nonattainment of criterion and a potential concern
4A	All total maximum daily loads needed for attainment of applicable water quality standards have been approved
4B	Other pollution control requirements are expected to address all pollutants and will attain water quality standards
4C	Impairment is not caused by a pollutant
5	Water is impaired or threatened and a total maximum daily load is needed

and FWS Manual Chapter 601 FW 3-Biological Integrity, Diversity, and Environmental Health for maintaining and restoring biological integrity, diversity, and environmental health (www.fws.gov/policy/manuals/). In addition, management guidance documents related to water quality, including comprehensive conservation plans and water resource assessments, are being developed for individual Refuges.

The Clean Water Act was established in 1972 to restore and maintain the chemical, physical, and biological integrity of surface waters in the United States (Code of Federal Regulations 2005). Water quality standards, the conceptual basis for the surface-water pollution-control program of the Clean Water Act, define the goals for a water body by designating its uses (e.g., drinking water supply, primary or secondary contact recreation, aquatic life use support), setting criteria to protect those uses, and establishing antidegradation provisions. Under Clean Water Act Section 305(b), states are required to prepare biennial water quality assessment reports that identify where and why navigable water bodies are not meeting state water quality standards. Water bodies that do not meet water quality standards are considered ''water quality–limited'' and placed on the impaired waters list under Clean Water Act Section 303(d). Impaired water bodies are placed into one of five categories representing different levels of water quality standard attainment based on U.S. Environmental Protection Agency (USEPA) guidance (Table 1; USEPA 2003). Once a water body is listed as 303(d) impaired, the Clean Water Act requires the state to develop a total maximum daily load (TMDL) for the impaired water to protect beneficial uses by minimizing further degradation. After the TMDL is approved by the USEPA, an implementation plan is prepared and initiated by the state. A TMDL is an estimate of the maximum amount of a pollutant that a water body can receive and still meet the water quality standards. It is calculated as the sum of 1) waste load allocation, which is the amount of pollutant from all existing point sources (e.g., sewage treatment plant; industrial facility), 2) load allocation, which is the amount of pollutant from existing nonpoint sources and natural background (e.g., runoff or atmospheric deposition), and 3) a margin of safety that reflects uncertainty associated with the TMDL estimate. A TMDL commonly targets anthropogenic sources such as agriculture, silviculture, industry, and urban centers (e.g., stormwater runoff). In addition, discharges from natural and managed wetlands or other aquatic habitats (e.g., meadows) are also affected by load-limit regulations. Because reporting on the status of implementation is not required under the Clean Water Act or by USEPA, it is often difficult to assess progress toward meeting a TMDL.

The regulatory requirements associated with a TMDL represent one of the ultimate challenges for adaptive management on Refuges. States prepare and apply TMDL implementation plans that allocate contaminant load limits among all discharges within a watershed (including wetlands) to maintain or improve water quality. Although wetland and water management on Refuges may be affected by or contribute to the establishment and implementation of a TMDL, many Refuges are not prepared to adapt to an existing or proposed TMDL. Specifically, a TMDL may force alterations of Refuge water-management programs (e.g., no wetland drawdowns after 01 April) that can affect the quantity and quality of Refuge aquatic habitats. As a result, a Refuge could fail to achieve habitat and wildlife objectives. In addition, new or existing invasive plant issues could develop or expand due to altered water regimes, especially considering climate change predictions. A TMDL may also impact FWS-coordinated efforts for resource management with conservation partners in larger landscapes beyond Refuge boundaries.

Consistent with the Clean Water Act, the overarching goal of this study was to identify and anticipate water quality issues that might affect the integrity of water bodies on Refuges. The FWS initiated this study jointly with the USEPA and the U.S. Geological Survey to improve their understanding of water quality and potential risks involving impaired water bodies on the public lands they manage. Oregon and Washington were chosen as pilot states to develop and test the approach. Our specific objective was to develop a geospatial analysis to identify water quality issues for each Refuge in Oregon and Washington.

Methods

Study area

The Refuges in Oregon and Washington (n = 40; Table 2) are diverse in size, habitat, and management goals. Although most were established to broadly

Table 2. National Wildlife Refuges located in Oregon (OR) and Washington (WA), United States. The area represents the size of the approved Refuge boundary. Predominant land use–land cover is from the National Land Cover Data Set (Homer et al. 2004).

Refuge name	State	Year established	Area (km^2)	Adjacent large water body	Predominant land use–land cover
Ankeny	OR	1964	11.4	Willamette River	Agriculture
Bandon Marsh	OR	1983	4.1	Coquille River	Saltwater marsh
Baskett Slough	OR	1965	10.2	None	Agriculture
Bear Valley	OR	1978	17	Klamath River	Forest
Cape Meares	OR	1938	0.6	Pacific Ocean	Forest
Cold Springs	OR	1909	12.6	None	Open water, agriculture
Hart Mountain	OR	1936	1,150	None	Shrub
Julia Butler Hansen	OR	1971	27	Columbia River	Wetlands, agriculture
Klamath Marsh	OR	1958	190	Klamath River	Wetlands
Lewis and Clark	OR	1971	136	Columbia River	Wetlands
Malheur	OR	1940	774	Donner und Blizten	Open water, shrub
McKay Creek	OR	1929	7.4	None	Open water, shrub
Nestucca Bay	OR	1991	15	Pacific Ocean	Wetlands
Oregon Islands	OR	1935	1,854 islands	Pacific Ocean	Rocks, reefs, islands
Siletz Bay	OR	1991	8.0	Pacific Ocean	Wetlands
Three Arch Rocks	OR	1907	9 coastal rocks	Pacific Ocean	Rocks
Tualatin River	OR	1992	29.8	Tualatin River	Agriculture
Umatilla	OR	1968	122	Columbia River	Open water
Upper Klamath	OR	1928	99	Klamath River	Wetlands
William L. Finley	OR	1963	23	Willamette River	Wetlands, agriculture
Columbia	WA	1944	159	Columbia River	Shrub
Conboy Lake	WA	1964	44	None	Wetlands, agriculture
Flattery Rocks, Copalis, and Quillayute Needles	WA	1907	870 islands	Pacific Ocean	Rocks, reefs, islands
Dungeness	WA	1915	5.8	Pacific Ocean	Sand spit, wetlands, forest
Franz Lake	WA	1990	2.9	Columbia River	Open water, wetlands
Grays Harbor	WA	1990	7.0	Pacific Ocean	Open water, wetlands
Little Pend Oreille	WA	1939	265	Little Pend Oreille	Forest
McNary	WA	1953	68	Columbia River	Open water, wetlands, shrub
Nisqually	WA	1974	46	Nisqually River	Wetlands
Pierce	WA	1983	1.6	Columbia River	Wetlands
Protection Island	WA	1982	1.5	Pacific Ocean	Shrub
Ridgefield	WA	1965	27	Columbia River	Wetlands
Saddle Mountain	WA	1953	801	Columbia River	Shrub
San Juan Islands	WA	1975	1.8	Pacific Ocean	Rocks, reefs, islands
Steigerwald Lake	WA	1987	5.7	Columbia River	Wetlands, agriculture
Toppenish	WA	1964	51	Yakima River	Agriculture
Turnball	WA	1937	244	None	Shrub
Willapa	WA	1937	66	Pacific Ocean	Wetlands

protect waterfowl and other migratory birds, several Refuges were created to manage specific species (e.g., Julia Butler Hansen Refuge for the Columbia White-tailed Deer, Hart Mountain National Antelope Refuge). Land-use characteristics of these Refuges range from high urbanization, to intense agriculture, to relatively undeveloped. Multiple Refuges are located along the Columbia River (n = 10) and the Pacific Coast (n = 10; Figure 1). We completed a summary for each Refuge to provide an overview of the most current water quality issues from a regional and Refuge perspective. We also included chemical contaminant data for each Refuge by querying the Environmental Conservation Online System – Environmental Contaminants Data Management System of the FWS and conducting a literature search (based on Refuge name) of various databases including Cambridge Scientific Abstracts, Institute for Scientific Information Web of Knowledge and libraries of the FWS,

Figure 1. National Wildlife Refuges (in green) in Oregon and Washington, United States.

U.S. Geological Survey, National Park Service, U.S. Forest Service, and National Agriculture Library. We considered coastal rock-island Refuges separately in our analyses, because few have navigable water and they are generally not included in the 303(d) listing activities for Oregon and Washington. However, there are 303(d) impairments for some marine coastal waters surrounding these Refuges. In addition, some Refuges adjacent to the Columbia River (Lewis and Clark, Julia Butler Hansen, Pierce, Franz Lake, McNary, Ridgefield, and Steigerwald Lake) did not include parameters listed as impaired for the Columbia River reaches nor was the Columbia River included in the calculation of assessed waters in individual Refuge summaries.

Geospatial data acquisition and analysis

We acquired geospatial data sets (layers), including approved Refuge boundaries, water-related data sets from USEPA and states, and land cover, from various sources (Table 3). The approved Refuge boundary data layer depicts the external boundaries and parcels designated as acquired (fee-title ownership or managed by FWS) or under private ownership. Understanding water quality issues on private parcels is important so that Refuge staffs are aware of potential impairments after the land comes under FWS management. The most recent 303(d) impaired waters spatial data were obtained from state Geographic Information System (GIS) clearinghouses. For Washington, the 303(d) data layer was a polygon shape-file with locations of attainment category 5 impaired waters (those requiring a TMDL), and the 305(b) data layer was a polygon shape-file documenting locations of all sampled waters. The National Land Cover Database is a 30-m-resolution land-cover data layer of the conterminous United States from 2001 Landsat 5 and Landsat 7 imagery (Homer et al. 2004).

We determined the water quality assessment status of water bodies within approved Refuge boundaries. Under the Clean Water Act, water bodies can be listed as impaired, not impaired, or not assessed. We identified stream reaches (parts of a stream between designated tributaries) within Refuge boundaries assessed as impaired for one or more parameters based upon their inclusion in a state's 303(d) list. Listing criteria for 303(d) impaired waters are based on state water quality standards, which are grouped into key elements that include beneficial uses, narrative and numeric criteria, and antidegradation policies (WSDE 2006; ODEQ 2007).

Table 3. Geospatial data sets and their sources used in the ArcGIS module to summarize water quality issues on National Wildlife Refuges in Oregon and Washington.

Data set name	Online linkage	Description
Refuge boundary	http://www.fws.gov/GIS/data/CadastralDB/index.htm	Polygon data set representing areas approved for acquisition by the U.S. Fish and Wildlife Service
Land ownership in Oregon	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml	Layer representing the stewardship–management of Oregon
Land ownership in Washington	http://fortress.wa.gov/dnr/app1/dataweb/dmmatrix.html	Layer representing ownership parcels for Federal, State (excluding Washington Department of Natural Resources), County, and City lands within the State of Washington
Washington Department of Natural Resources parcels	http://fortress.wa.gov/dnr/app1/dataweb/dmmatrix.html	Layer representing areas in which the Washington Department of Natural Resources holds some interest
National Hydrography Dataset for Oregon	http://gis.oregon.gov/DAS/EISPD/GEO/alphalist.shtml#S	Line data set that uniquely identifies stream reaches of Oregon's surface-water drainage system
National Hydrography Dataset for Washington	ftp://nhdftp.usgs.gov/SubRegions/High/FileGDB	Line data set that uniquely identifies stream reaches of the Washington's surface-water drainage system
Waterbodies	http://www-atlas.usgs.gov/atlasftp.html	Polygon data set representing water features of Washington and Oregon
Urban areas	http://www-atlas.usgs.gov/atlasftp.html	Polygon data set representing urban areas of Washington and Oregon
303(d)[a] impaired waters	Not available online, Doug Norton (U.S. Environmental Protection Agency)	Line and polygon data sets representing the spatial locations of 303(d) impaired waters of the United States in 2002
303(d)[a] impaired waters for Oregon	http://www.oregon.gov/DAS/EISPD/GEO/alphalist.shtml	Line data set representing the spatial locations of 303(d) impaired waters of Oregon in 2004/2006
303(d)[a] impaired waters for Washington	http://www.ecy.wa.gov/services/gis/data/data.htm	Line data set representing the spatial locations of 303(d) impaired waters of Washington in 2008
305(b)[a] assessed waters for Washington	http://www.ecy.wa.gov/services/gis/data/data.htm	Polygon data set representing locations of "all categories" of sampled waters of Washington in 2008
Waters with a total maximum daily load	http://epamap32.epa.gov/radims/	Line data set representing waters that are not supporting their designated uses

[a] USEPA (2003).

The specific parameters considered in state water quality standard assessments differ. Oregon and Washington both have water quality standards for bacteria, dissolved oxygen, pH, phosphorus, temperature, total dissolved gas, toxic substances, and turbidity. Oregon also has standards for aquatic weeds or algae, biological criteria, chlorophyll *a*, and sedimentation (ODEQ 2007), and Washington has standards for bioassessment and contaminated sediments (WSDE 2006). We categorized a stream reach as assessed but not impaired if 305(b) data (assessed waters) did not overlap with 303(d) data (impaired waters). We considered stream reaches not assessed if they had no corresponding 305(b) or 303(d) data. Determining total stream length within the Refuge boundary allowed for the calculation of the percent of total Refuge waters that have 303(d) impaired waters and, perhaps more importantly, the percent of Refuge waters that were assessed under the Clean Water Act. Such information allows for 303(d) impaired waters data to be kept in perspective of total water resources available within a Refuge.

We conducted spatial overlay analysis in ArcGIS 9.3. The 303(d) impaired water data sets had different data structure (impaired streams are lines in Oregon and polygons in Washington) and required separate analysis. The National Hydrography Dataset streams in Oregon within approved Refuge boundaries were clipped, visually inspected, and refined to prevent unintentional exclusion of segments that were coincident with the Refuge boundary. We then calculated clipped stream reach lengths (km). We matched the stream centerlines from state 303(d) impaired water data and the National Hydrography Dataset to compare impaired and not impaired stream reaches. The National Hydrography Dataset streams in Washington within the approved boundary were clipped as described for Oregon, except that the 2008 water quality data were obtained as two polygon shapefiles, 303(d) impaired waters and 305(b) assessed waters. We extracted the National Hydrography Dataset stream centerlines within the boundaries of these two polygon data sets using the intersected function of ArcGIS. We then imported results from the analysis into Microsoft Access to build a relational database. An example of the raw data from the spatial analysis can be found in the *Supplemental Material* (Data S1, http://dx.doi.org/10.3996/112010-JFWM-043.S1).

Results

We determined the water quality assessment status for Refuges in Oregon and Washington. Overall, 12 Refuges

Table 4. Water quality assessment status of Refuges in Oregon (n = 20) and Washington (n = 20), United States. Waters were designated as not assessed under 305(b), 303(d) impaired, not 303(d) impaired, or not considered for assessment under the Clean Water Act (e.g., coastal island Refuges). The development status of total maximum daily loads (TMDL) for watersheds in which Refuges are located is also presented. Percentages (%) are given in parentheses.

Assessment status	Oregon	Washington
Total number of Refuges[a]		
Not assessed under 305(b)	6 (30)	7 (35)
303(d) impaired	12 (60)	3 (15)
Not 303(d) impaired	0 (0)	5 (25)
Not considered	2 (10)	5 (25)
Total Refuge stream length (km)		
Not assessed under 305(b)	1,887 (88)	2,889 (97)
303(d) impaired	262 (12)	52 (2)
Not 303(d) impaired	0 (0)	31 (1)
TMDL development status for Refuge		
Approved	14 (70)	13 (65)
Underway	2 (10)	2 (10)
No development	2 (10)	0 (0)
Not considered	2 (10)	5 (25)

[a] A Refuge was designated as impaired if at least one stream reach was on the state's 303(d) impaired waters list.

in Oregon (60%) and 8 Refuges in Washington (40%) were assessed under 305(b) activities of the Clean Water Act (Table 4). All Refuges assessed in Oregon had at least one stream reach designated as 303(d) impaired, and three of the eight Refuges assessed in Washington had waters that were designated as 303(d) impaired. Only a small percentage of streams on Refuges in Oregon (12%; 262 km) and Washington (3%; 83 km) have been assessed under 305(b) activities (Table 4). The length of 303(d) impaired streams of individual Refuges ranged from 0.8 to 102 km in Oregon and 4.1 to 15 km in Washington (Table 5). As a percentage of total stream length for a Refuge, the 303(d) impaired length was 0 to 86% in Oregon and 0 to 32% in Washington (Table 5). Relatively small proportions (<14%) of Refuge streams in Washington were assessed as not 303(d) impaired; the length of these nonimpaired streams ranged from <0.1 to 9.4 km (Table 5). Two coastal rock island Refuges in Oregon (10%) and five in Washington (25%) have not been included in 303(d) listing activities because they generally lack navigable water (Table 4).

Despite the lack of water quality assessment in Refuge waters, 14 Refuges in Oregon (70%) and 13 in Washington (65%) are located in watersheds with approved TMDLs (Tables 4 and 5). Bear Valley and Siletz Bay in Oregon and Ridgefield and Turnball in Washington are in watersheds where TMDL development is underway (Table 5). Two Refuges in Oregon with 303(d) impaired waters, Hart Mountain and Malheur, are located in watersheds with no TMDL development (Table 5). In general, the absence of a TMDL indicates that the watersheds have had little assessment under Clean Water Act activities, rather than an absence of water quality issues.

Refuge water quality summaries were designed to be standalone documents for Refuge staff (see example in *Supplemental Material*, Data S1; http://dx.doi.org/10.3996/112010-JFWM-043.S1). Summaries were organized to provide information on Refuge background (purpose, species of concern, boundary, and ownership), TMDL status and 303(d) impaired water listings (changes in listings between reporting cycles, impaired stream reaches, parameters responsible for impairment, and prioritization of impairment), and additional information (other biological, chemical, and physical data available). Drafts of the data sets are available in the *Supplemental Material* (Data S2, http://dx.doi.org/10.3996/112010-JFWM-043.S2; Data S3, http://dx.doi.org/10.3996/112010-JFWM-043.S3; Data S4, http://dx.doi.org/10.3996/112010-JFWM-043.S4; Data S5, http://dx.doi.org/10.3996/112010-JFWM-043.S5). Individual Refuge summaries provide information for Refuge staffs to be proactive in addressing water quality issues by providing current 303(d) impaired waters and TMDL issues, web links and contacts for 303(d) lists and TMDL development status, TMDL implementation schedules, and potential involvement in TMDL planning teams.

Discussion

Identifying Refuge stream reaches designated as not impaired or not assessed is important to understand the water quality assessment status of Refuges. Overall, little is known about the water quality of stream reaches within Refuges in Oregon and Washington. Consequently, it cannot be assumed that water quality is good or not impaired for Refuges that have not been assessed under the Clean Water Act given the diverse acquisition history of some properties (e.g., former military facilities, farmland). The lack of water quality assessment on Refuges is not related to sampling design. Neither ODEQ nor WSDE exclude Refuges or other public lands from their 303(d) sampling activities, but much of the sampling is collaborative. More waters on Refuges might be assessed if state and Refuge staff could coordinate water quality monitoring activities. In addition, certain parameters including pharmaceuticals, surfactants, household cleaners, and plasticizers are currently not regulated under the Clean Water Act, but have been associated with deleterious effects to water quality and aquatic biota. Therefore, other water quality issues may exist on FWS properties outside of those identified by 303(d) impaired waters activities.

Listing strategies for 303(d) impaired waters need to be considered when interpreting water quality data. The exceedance of a water quality standard that triggers an impairment in a water body can differ among states. For example, the freshwater acute criterion for *p,p'*-DDE is 1,050 μg/L in Oregon and 1.1 μg/L in Washington. Although this may be an extreme case, the between-state differences in water quality standards that lead to a 303(d) listing must be considered when interpreting data

Table 5. The length (km) and percent (% in parentheses) of stream reaches assessed as 303(d) impaired, not 303(d) impaired, not assessed under 305(b) for National Wildlife Refuges in Oregon and Washington, United States (USEPA 2003). The status of total maximum daily load (TMDL) development in the watershed in which the National Wildlife Refuge is located is also presented. Coastal rock island Refuges were not included because they are generally not considered for assessment under 305(b).

State, National Wildlife Refuge name	303(d) impaired, km (%)	Not 303(d) impaired, km (%)	Not assessed under 305(b), km (%)	TMDL status
Oregon				
Ankeny	3.0 (29)	0 (0)	7.4 (71)	Approved
Bandon Marsh	0 (0)	0 (0)	11 (100)	Approved
Baskett Slough	0 (0)	0 (0)	16 (100)	Approved
Bear Valley	0 (0)	0 (0)	25 (100)	Underway
Cape Meares	0 (0)	0 (0)	1.3 (100)	Approved
Cold Springs	5.6 (42)	0 (0)	7.6 (58)	Approved
Hart Mountain	99 (10)	0 (0)	935 (90)	No development
Julia Butler Hansen	0 (0)	0 (0)	50 (100)	Approved
Klamath Marsh	37 (18)	0 (0)	170 (82)	Approved
Lewis and Clark	0 (0)	0 (0)	83 (100)	Approved
Malheur	102 (15)	0 (0)	555 (85)	No development
McKay Creek	6.4 (86)	0 (0)	1.0 (14)	Approved
Nestucca Bay	4.1 (7)	0 (0)	55 (93)	Approved
Siletz Bay	6.1 (30)	0 (0)	15 (70)	Underway
Tualatin River	43 (47)	0 (0)	48 (53)	Approved
Umatilla	21 (30)	0 (0)	49 (70)	Approved
Upper Klamath	0.8 (<1)	0 (0)	146 (>99)	Approved
William L. Finley	20 (47)	0 (0)	24 (53)	Approved
Washington				
Columbia	5.5 (2)	9.4 (4)	230 (94)	Approved
Conboy Lake	0 (0)	0 (0)	97 (100)	Approved
Dungeness	0 (0)	0 (0)	1.6 (100)	Approved
Franz Lake	0 (0)	0 (0)	6.2 (100)	Approved
Grays Harbor	0 (0)	0 (0)	1 (100)	Approved
Little Pend Oreille	0 (0)	0.8 (<1)	532 (>99)	Approved
McNary	15 (32)	0 (0)	31 (68)	Approved
Nisqually	0 (0)	11 (14)	66 (86)	Approved
Pierce	0 (0)	0.6 (13)	3.9 (87)	Approved
Ridgefield	0 (0)	0 (0)	53 (100)	Underway
Saddle Mountain	4.1 (<1)	4.1 (<1)	1,235 (99)	Approved
Steigerwald Lake	0 (0)	1.2 (12)	8.9 (88)	Approved
Toppenish	0 (0)	0 (0)	131 (100)	Approved
Turnball	0 (0)	0 (0)	336 (100)	Underway
Willapa	0 (0)	<0.1 (<1)	103 (>99)	Approved

among states. Moreover, not all 303(d) impaired waters are listed because of water concentration exceedances. Washington also lists waters as impaired when fish tissue contaminant concentrations exceed criteria of the National Toxics Rule (Code of Federal Regulations 1992) for the protection of human health. In addition, each state has discretion as to which attainment categories are designated 303(d) impaired. Different strategies for determining which water quality standard attainment categories are included in the 303(d) impaired waters list can affect the perceived water quality status among states (Figure 2). For example, waters with categories 2–5 are on the 303(d) list in Oregon; however, Washington includes only those waters designated as category 5. Once a water quality standard is exceeded, procedures to list water bodies as impaired differ among states. In Washington, 303(d) impaired waters are listed using either a segmentation system (1-mi[1.6-km] segments of smaller rivers and streams) or a grid cell system (larger rivers and lakes over 1500 acres [607 ha]) system (WSDE 2006). Entire tributaries in Oregon are designated as impaired if any sample in the reach does not meet numeric criterion (ODEQ 2007). These differences in listing procedures have contributed to Oregon having more 303(d) impaired waters by stream length than Washington (Figure 2).

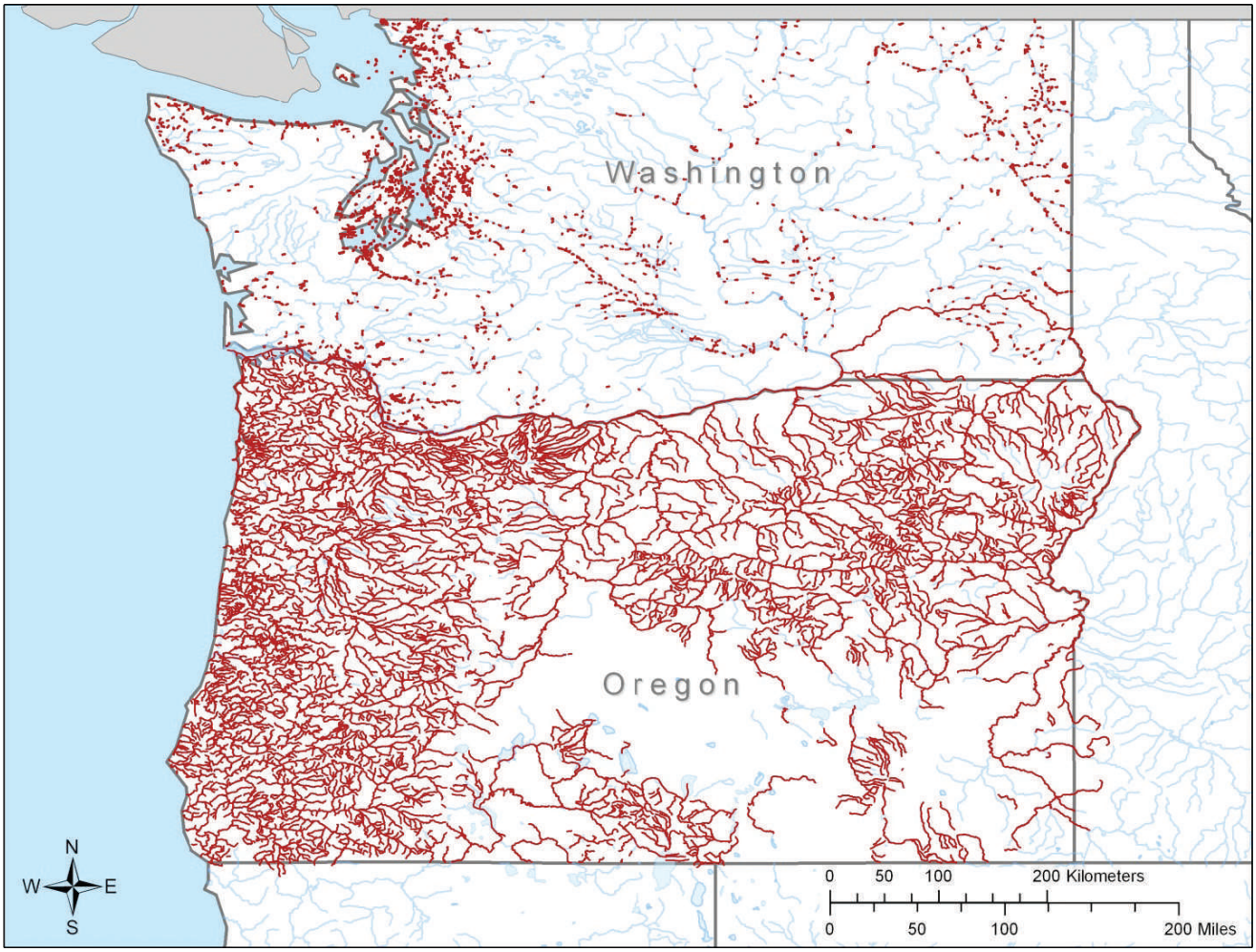

Figure 2. Water bodies in Oregon and Washington, United States, that do not meet water quality standards and are listed as impaired (in red) under Clean Water Act Section 303(d) (Code of Federal Regulations 2005).

The FWS needs to be able to prioritize water quality issues for remediation based on Refuge management objectives and with fiscal responsibility. Competing obligations limit staff time for tracking potential water quality issues, and water quality–related issues may not be dealt with until a problem has already arisen. Therefore, this study created a template to summarize current water quality issues for individual Refuges. Water quality information is pertinent for completing water resource inventories and assessments on Refuges. Specifically, these data can be used to define water quality and condition and to identify threats to water quality outlined in water resource assessment documentation. Data from this study will minimize the data acquisition phase for these components in the water resource assessments for Oregon and Washington. Identification of water quality impairments on Refuges will be directly applicable to sensitive species and habitats of concern as identified in comprehensive conservation plans. Parameters resulting in water quality impairments will differ in their potential threat to species of concern and warrant consideration when management decisions regarding species and their habitats are made.

Multiple factors need to be considered when evaluating 303(d) impaired waters for a Refuge. Defining a single set of ranking factors for all Refuges would be ineffective because management goals differ; therefore, the prioritization of parameters will depend on the species of interest and habitat dynamics. Management objectives for species and habitats, as well as the toxicity of impaired parameters to biota, could guide the prioritization process. In addition, the specific parameter for which a stream reach is considered impaired, especially one with an approved TMDL, could also influence the prioritization. The 303(d) impaired waters listing strategy also has to be considered. For example, parameters listed as impaired in attainment category 2, 3, 3B, or 4C are of lower concern than category 4A or 5 in Oregon. The magnitude of a water quality standard exceedance is also important to consider, but can be difficult to derive because states differ in the data they make publically available or the data may not be electronic (e.g., ODEQ 2010; WSDE 2010).

Species utilization of particular water bodies is also an important factor. Stream reaches, wetlands, and other water bodies that are known to host sensitive species are important because they relate directly to management

goals of the Refuge. Examples include spawning habitat for salmon and nesting habitat for migratory birds. In addition, different parameters listed as 303(d) impaired may have greater influence on certain species than others; an impairment related to sedimentation may be more important to consider for a sensitive species of mussel compared to an impairment based on *Escherichia coli*. Site-specific inventories of sensitive species are not complete for many Refuges; therefore, resource managers may list the entire Refuge area as habitat used, which further highlights the need for inventory and monitoring of sensitive species.

Linking other data related to contaminants in water, sediment, and biota from Refuge studies may be helpful in understanding and interpreting 303(d) impaired water issues. Contaminant concentrations in biota are especially important to consider. Because Refuge management goals focus on biota and their habitats, there is a need to place 303(d) impaired waters into a biological context. The water quality standards, which provide the criteria for listing waters as impaired, may not adequately address impacts to all species and species groups that are management objectives for individual Refuges. Moreover, relating contaminant concentrations (e.g., parameters listed as impaired) in water to contaminant effect thresholds in plants and animals based on tissue concentrations presents uncertainty. Quantifying concentrations of bioaccumulative contaminants in biological samples from Refuges could determine whether parameters listed as 303(d) impaired are of concern for plants and animals, and would provide baseline contaminant information prior to a release (e.g., new permitted discharge, dam removal, oil spill).

We identified significant gaps in Refuge-specific water quality data. Assessment of those Refuge waters that have not been evaluated under Clean Water Act Section 305(b) activities could be a priority to characterize current water quality on a greater proportion of Refuge stream reaches. Many of the 303(d) impaired waters within Refuge boundaries were based on criteria exceedances upstream of the Refuge, and the data from which the listing was initiated were not current (e.g., collected before 2002). Therefore, additional water quality inventory and monitoring is warranted on Refuges.

By following a stepwise process, Refuge managers and contaminant specialists could consider issues associated with impaired water listings, and then move forward in their management plans by characterizing likely sources. Management actions could then be prioritized by considering the biological relevance of the impairment along with impacts to sensitive species. Studies designed to assess the Refuge's contribution to an impaired reach would help direct management strategies to minimize or eliminate such contributions. Conducting mass balance studies or monitoring those parameters for which TMDLs have been proposed or implemented may be informative. Given the potential impacts of off-Refuge inputs to receiving waters, biological resources would benefit from identifying and implementing land management practices that reduce on-Refuge inputs by multiple sources.

Another data gap is high-resolution land use–land cover data, which were not available for all Refuges but would be informative for regional water quality analysis. Available land use–land cover data are dated and the resolution too coarse for smaller Refuges (Homer et al. 2004). Orthoimagery is available (U.S. Department of Agriculture 2010), but land cover percentages cannot be calculated easily from these data. High-resolution land use–land cover data could be used to group Refuges and their surrounding watersheds by dominant land-cover type. For example, these data could match certain parcels with specific management objectives or compare similar habitats among Refuges. Data analyses could determine whether certain parameters listed as impaired are generally associated with a specific land use–land cover type (e.g., pesticides in agricultural areas). This information could be applied to Refuges that have not been assessed to identify potential contaminants of concern.

Creating a GIS-based water quality module for future use by Refuge managers will require staff time devoted to updating the various data layers and communicating with state water quality experts. Expertise in ArcGIS and other database programs will be needed to ensure compatibility of geospatial data. As new geospatial data become available for Oregon and Washington, it will need to be clipped to the Refuge boundaries, visually inspected and refined, and imported into the existing database. Geospatial data layers including Refuge boundary, TMDL, and 303(d) listed waters are continually updated. Maintaining such a module at the regional or national level, rather than the individual Refuge level, would be most efficient because most geospatial data are available at the state level. Regional-level maintenance would also utilize established GIS expertise within the FWS and alleviate the need for special training at the Refuge level. Nevertheless, the framework and established database queries for the GIS module developed in this study provide the foundation for future data updates and could be applied to other regions of the National Wildlife Refuge System.

Supplemental Material

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Data S1. Example of Refuge summaries.

Found at DOI: http://dx.doi.org/10.3996/112010-JFWM-043.S1 (6 MB DOCX).

Data S2. The National Hydrography Dataset for the state of Oregon.

Found at DOI: http://dx.doi.org/10.3996/112010-JFWM-043.S2 (472 MB ZIP).

Data S3. The National Hydrography Dataset for the state of Washington.

Found at DOI: http://dx.doi.org/10.3996/112010-JFWM-043.S3 (819 MB ZIP).

Data S4. Drafts of water quality summaries for individual Refuges in Oregon and Washington. Each

summary was designed to be a standalone document for Refuge staff. Summaries are organized to provide information on Refuge background (purpose, species of concern, boundary, and ownership), total maximum daily load (TMDL) status, 303(d) impaired water listings (TMDL status, changes in listings between reporting cycles, impaired stream reaches, top parameters listed as impaired, prioritization of impairment, and contact list for water quality issues), and additional information (other biological, chemical, and physical data available). Further refinement of Refuge summaries can be achieved through an iterative process with Refuge staff to further incorporate specific management priorities for specific species. These summaries were current as of 2010.

Found at DOI: http://dx.doi.org/10.3996/112010-JFWM-043.S4 (13 MB ZIP).

Data S5. Geographic Information System (GIS) layers, including Refuge boundaries, 303(d) listed waters for Oregon and Washington, 305(b) listed waters for Washington, and waters with total maximum daily loads (TMDLs). These data layers were current as of 2010.

Found at DOI: http://dx.doi.org/10.3996/112010-JFWM-043.S5 (31 MB ZIP).

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