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Development and Evaluation of a Data Dictionary to Standardize Salmonid Habitat Assessments in the Pacific Northwest

David E. Hamm [a]

[a] Northwest Fisheries Science Center, NOAA Fisheries, 2725 Montlake Blvd. E., Seattle, WA, 98112 E-mail:

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FEATURE
Management

Development and Evaluation of a Data Dictionary to Standardize Salmonid Habitat Assessments in the Pacific Northwest

David E. Hamm

Northwest Fisheries Science Center, NOAA Fisheries, 2725 Montlake Blvd. E., Seattle, WA 98112. E-mail: david.e.hamm@noaa.gov

ABSTRACT: *Restoration ecology and conservation biology have increasingly recognized the need for a common language to facilitate the combining of data sets to help identify threats, degraded habitat, and appropriate restoration response. However, to date no tool exists that can standardize language for large quantities of publicly available information relevant to the analysis and management of threatened and endangered Pacific salmonids. Here, I present a simple and transparent method for integrating assessments of degraded salmonid habitat into a database using a data dictionary. The data dictionary is then used to measure similarity between independently created assessments for subbasins within the Columbia-Cascade region. The relationship between the number of restoration projects and the number of assessed ecological concerns is also compared. This initial investigation illustrates the data dictionary's utility in defining a set of salmonid-specific ecological concerns, providing a means to integrate habitat assessments to encompass a wider area and measure the concordance between different assessments conducted over the same geographical area. The ability to standardize and integrate information on degraded habitat provides an important link in a logical chain connecting habitat conditions to the restoration projects intended to enhance populations of threatened and endangered salmonids.*

Desarrollo y evaluación de un diccionario de datos para estandarizar las evaluaciones de hábitat de salmónidos en el Pacífico noroeste

RESUMEN: *Tanto la ecología de la restauración como la biología de la conservación han reconocido la necesidad de contar con un lenguaje común que facilite la combinación de bases de datos para ayudar a identificar amenazas, hábitats degradados y capacidad de respuesta en términos de restauración. No obstante, a la fecha no existen herramientas que generen un lenguaje uniforme para grandes cantidades de información pública, relevante en el análisis y manejo de las especies amenazadas de salmónidos en el Pacífico. En este trabajo se presenta un método simple y transparente en el que, mediante datos de diccionario, se integran las evaluaciones de degradación de hábitat de salmónidos. Los datos de diccionario son después utilizados para medir la similitud entre evaluaciones creadas de forma independiente para cada sub-cuenca de la región Columbia-Cascade. También se comparó la relación que existe entre el número de proyectos de restauración y el número de evaluaciones ecológicas. Esta investigación primaria ilustra la utilidad de los datos de diccionario en cuanto a la definición de grupos de inquietudes ecológicas específicas para los salmónidos; provee, además, los medios para que las evaluaciones de hábitat integren áreas más grandes, así como también generación de medidas congruentes entre las evaluaciones realizadas en esas mismas escalas espaciales. La habilidad para estandarizar e integrar información acerca de los hábitats degradados, ofrece un importante eslabón dentro de una cadena lógica que conecta las condiciones del hábitat con los proyectos de restauración; encaminados a mejorar las poblaciones de salmónidos en peligro y amenazados.*

INTRODUCTION

The political and policy mandates surrounding the Endangered Species Actlistings of Pacific salmon have resulted in the collection of large quantities of data concerning project implementation, habitat condition, population status, and change. To date there has been no attempt to standardize assessment results in a clear and consistent fashion. This comes at the same time that investigations into the practice of restoration have suggested systematic problems with the ways in which restoration has occurred. However, a clear and consistent way to evaluate restoration for salmon enhancement over a broad area—one comparable to the scale of recovery planning—has yet to be created, and evaluation of restoration at this scale remains to be done.

I propose that in sufficient aggregation, important information about the status of restoration and habitat condition can be extracted from diverse and even incomplete data. A method for collecting and standardizing descriptions of degraded salmonid habitat is a first step in the chain of logic linking restoration action to habitat changes that bring about enhanced fish populations.

The importance of a standardized language, or "lexicon," as a tool for use in analysis and conservation planning has begun to be recognized by the conservation biology community (Salafsky et al. 2008). Given the large number of factors that determine the character of the salmonid environment (geological, hydrological, biotic, and land use history), the use of common descriptors to characterize a region is important to bridge local watershed-scale assessments and management at larger scales, such as the scale of recovery planning, which encompasses whole evolutionary significant units (Waples 1991) spanning multiple subbasins.

Combining data from multiple sources is greatly enhanced by the use of standardized language and explicit definitions of data categories (Ziegler and Dittrich 2004; Katz et al. 2007; Al-Chokhachy and Roper 2010). Currently most habitat assessments are "locked" in a text file. The process of translating assessments into an electronic, tabular, or database form enables the synthesis of larger data sets and facilitates data sharing and further analysis. A carefully constructed data dictionary can characterize independently derived habitat assessments in such a way that a consensus on the relevant ecological concerns can be found while retaining sufficient detail that ecological concerns can be related to both appropriate restoration projects and larger scale environmental stressors that produce ecological concerns. The data dictionary could also theoretically be used to compare assessments done at different times to evaluate ecological changes over time.

Here I present the development of an ecological concerns data dictionary. Definitions of data dictionaries vary, but they are generally understood to be both a catalog and repository of information about data, such as its format, meaning, relationships to other data, and suggested usage. Ecological concerns are those specific features of freshwater habitat and ecology that influence the productivity and abundance of salmonids that restoration projects are meant to address (sensu Bernhardt et al. 2007). Once developed, the data dictionary was used to translate habitat assessments from two different sources and synthesize their findings into a database. This process highlights the utility of a simple and standardized method for integrating habitat information using a data dictionary. Counts of data dictionary categories assessed per region then become a simple metric that can be mapped to provide a novel way to visualize habitat condition across a wide region.

This is the first step in creating a data set of ecological concerns to compare against a database of restoration projects in the area. As an example of analysis using the data set, I also present the relationship between the number of ecological concerns identified and the number of restoration projects implemented for each assessment unit in the Columbia-Cascade region of the Pacific Northwest.

DATA DICTIONARY DEVELOPMENT

Based on two ideas, this data dictionary was developed in order to enable the standardization of different habitat assessments and relate habitat degradation to restoration actions: First, that specific features of degraded salmonid habitat could be placed into a well-defined category, called "ecological concern," and that these ecological concerns could be separated from underlying processes and causes such as anthropogenic "stressors" or "threats" that are generally not the direct target of restoration projects. For example, separating threats like "water diversions" from its effects—low water, mortality (due to inadequate screening), and increased temperatures—allows one to link these effects of water diversion to appropriate restoration (e.g., improved screening or buying instream water rights). Clearly distinguishing cause and effect can also highlight data gaps; for example, significant water diversions with no data on the effects. The ecological concern category could then be subdivided in such a way as to consistently bin a variety of terms and descriptions of ecological concerns.

Methods for using particular aspects of the habitat as indicators of the functional integrity of ecological processes have been developed for particular habitat types. For example, the proper functioning condition (PFC) methodology developed by Prichard et al. (1998) and a related methodology, the matrix of pathways and indicators (MPI; often called "The Matrix"; National Marine Fisheries Service 1996), have both been developed and used in a salmon-specific context for making decisions regarding activities that alter the habitat of threatened and endangered species (Section 7 consultations, Endangered Species Act:7(a)(2)). However, these methods, though valuable for this specific use, have been criticized as a tool for overall recovery planning or for guiding habitat assessments (Good et al. 2003), and many categories are too general to be considered useful indicators of ecological processes (T. Good, Northwest Fisheries Science Center, personal communication).

Though numerous assessment methods exist (more than 80 are referenced in the NBII database (National Biological Information Infrastructure, ecological assessment methods database node), the data dictionary's twin goals are to integrate existing habitat data and to relate this data to restoration activity. The distinction between habitat condition and other ecological concerns from underlying processes follows Beechie et al. (2003) with additional guidance from the matrix (National Marine Fisheries Service 1996).

The data dictionary presented here "ecological concern" as changes to the ecological conditions essential for maintaining the long-term viability of a given population of salmonids that cause mortality, injury, reduced health, or diminished reproduction.

Ecological concerns include abiotic features, such as temperature or concentration of dissolved oxygen, that allow the maintenance of essential life functions or features that directly provide for essential needs, such as habitat forms that provide shelter, conditions for reproduction, or habitat for prey species. Ecological concerns also include biotic interactions such as prey condition, disease, predation, and interactions with members of the same species such as competition and reproduction. Ecological concerns all affect abundance and productivity but may or may not determine the upper limits to population abundance (e.g., act as a limiting factor) (Reeves et al. 1989). The intent of the data dictionary then is to capture categorical information about the immediate environment of populations of threatened and endangered Pacific salmon (e.g., excess fines/excess sediment) in such a way that this information can be related to the specific goals of restoration projects (e.g., sediment reduction/erosion control).

The second idea is that a bottom-up approach, surveying a wide variety of sources and incorporating only preexisting categories, would reflect the priorities and judgments of local experts and standardize the degree of subdivision within categories. This avoids imposing an a priori structure and instead better reflects the information readily available to the creators of habitat assessments. Because there is no central repository of freshwater habitat data, the categories and terminology were collected by searching online for habitat assessment guidelines from state agencies (e.g., Washington Department of Fish and Wildlife, Oregon Watershed Enhancement Board), limiting factor analyses from federal and state agencies (e.g., Washington Conservation Commission), and completed habitat assessments such as subbasin plans, recovery plans for listed salmonids, watershed assessments, and project reporting frameworks from funding agencies. Though data-holding entities often had a single online location for documents, these were occasionally incomplete and some documents were obtained by request. More than 50 documents were examined for inclusion.

The data dictionary is categorical and so implicitly incorporates the ecological concerns prioritized within existing documents. Documents came from federal and state government agencies, tribal organizations, county watershed associations, nonprofit organizations, and for-profit private entities. These documents present the summation of primary data, model outputs, and expert opinion that have been collected and analyzed. Because many organizations use the decision support model ecosystem diagnosis and treatment (EDT; Lestelle et al. 1996) for freshwater habitat assessment, the model's habitat categories were included as well.

The data dictionary is not meant to be used with primary habitat data. Habitat assessments and limiting factor analysis are the primary documents guiding restoration actions and it is the conclusions of these documents that the data dictionary is meant to capture.

Though my data gathering was not exhaustive, care was made to obtain habitat assessments from all major freshwater ecosystems in the Pacific Northwest of the United States, from both the west and east side of the Cascade Mountains across three states (Washington, Oregon, and Idaho). These included large river basins (e.g., Columbia River, Snake River) and small tributaries in urban and rural watersheds, the Puget Sound, Columbia River estuary, and in the marine near shore.

In collecting the categories used to described degraded freshwater I found a wide variety in the number of categories, from 6 (Oregon Department of Fish and Wildlife 2007) to more than 80 (EDT). These categories referred to subjects spanning a range of spatial and temporal scales, from "road density" to "percent fines in the channel substrate."

All categories used to describe ecological concerns were recorded, and as new documents were examined new categories were added. Terms that appeared to refer to existing categories (based on metadata, associated metrics, or definitions from the scientific literature or technical dictionaries) were not added but notable variations on word phrasing were added to the "Additional Categories" section of the dictionary (Table 1).As more documents were read, new categories and terms were more rarely added.

The data dictionary has a hierarchical arrangement of categories with general categories and nested subcategories (Table 1). Assessments use both general and specific terms, such as "water quality" as opposed to the more specific "high water temperatures," included in the same document to describe ecological concerns. A hierarchical arrangement allows the retention of more information in the process of translating a document. Though an increasingly "networked" hierarchy could be made to better reflect ecological processes, the increase in accuracy would require many interconnected layers of terms. Based on my experience with this arrangement, a more complicated data dictionary would be much more difficult to understand and cumbersome to use.

Categories were eliminated if possible to maintain a balance between completeness and ease of use. Categories considered too broad to relate to a particular restoration project or that could be subdivided into constituent categories were eliminated. For example, "high road density" may have important effects such as increased sediment runoff or toxic runoff, depending greatly on the type of roads, geology, and other factors, but road density can be broken into constituent categories such as sediment conditions and toxics that directly affect salmon. High road density alone does not mean the harmful effects of roads are present, and the presence of restoration projects cannot tell you whether the effects of high road density have been mitigated. Next, categories in the data dictionary that were so narrow in scope that they were rarely included in habitat assessments were also eliminated. For example, the contribution of icing to stream bank instability is one of the EDT habitat criteria but was noted (without data) in only a few Northwest Power and Conservation subbasin plans (Northwest Power and Conservation Council 2005) and absent from all other habitat assessments.

This was an iterative process; the definitions for the data dictionary categories were written and revised to refer to broader categories than just the literal definition of the category title. The "Additional Categories" term, the last column in Table 1, reflects the range of terms that were binned in that category. Terms were binned based on similarity of cause or effect on salmonids.

Fundamentally, data dictionaries are metadata (i.e., data about data). Though they define language and meaning, they may also contain metadata crosswalks. A "crosswalk" is "a table that maps the relationships and equivalencies between two or more metadata schemes" (Dublin Core Metadata Initiative). Explicit rules for relating different data types also make data dictionaries essential components of relational databases. Ecological concerns have been linked using metadata crosswalks to an existing database of restoration projects and to other data dictionaries of more broad-scale processes such as specific ecological and anthropogenic threats and land use changes. These metadata crosswalks can be used to test specific relationships

TABLE 1. The Ecological Concerns Data Dictionary used for this analysis. The data dictionary has been modified based on subsequent analysis. The most current version of the data dictionary is available at http://webapps.nwfsc.noaa.gov/pcsrf

ID	Ecological Concern	Definition	Included Categories	ID	Ecological Concern-Subcategory	Definition	Included Categories
1	Sediment Conditions	Reduction of the quantity or quality of spawning habitat due to changes to the background (natural) quantity and size of sediment inputs to the stream system	Sediment, Stream spawning habitat, Beach spawning habitat (lake), Substrate, Surface Erosion, Siltation	1.1	Sediment Quantity	Harmful changes (increases or decreases) in the amount of sediment discharged to the stream system	Sediment load
				1.2	Sediment Quality	Harmful changes to the size (increases or decreases) of sediment discharged to the stream system	Embededness, Substrate Fines, Sediment size ratio
2	Toxic Contaminants	Exposure to chemical substances capable of causing injury or death		2.1	Water	Direct exposure to toxic substance in the water column	Short-term Toxicity, Stormwater Discharge, Outfalls, Wastewater, Non-Point Pollution, Spills, Marine Debris, Point Pollution, Water Chemistry
				2.2	Biota	Persistent toxic substances in the bodies of plants and animals that are concentrated as they are consumed and move to the next trophic level	Bioaccumulation Toxicity
				2.3	Sediments	Toxic substances found in the sediments harm infaunal creatures, alter ecological relationships and if disturbed may enter the food web	Sediment Contamination
3	Species Interactions	Increased Competition, Predation or Disease. Negative effects due to biological interactions	Invasive species	3.1	Introduced Competitors and Predators	Introduced organisms that either compete for resources with or prey upon, native salmonids	Invasive/Exotic Fish, Invasive/Exotic Plants, Invasive/Exotic Invertebrates
				3.2	Intraspecific Competition	Increased competition for suitable habitatdue to reduced habitat quantity and quality	
				3.3	Increased Native Predation	Changes to the habitat that increase native predator numbers or increase predator success	Native Fish, Native Bird, Native Pinnipeds
				3.4	Pathogens	Introduction of disease causing organisms	
4	Food Web Alterations	Alteration to the trophic structure of the riverine system, includes loss of salmon food and is directly related to the quantity of nutrients available, the primary productivity and the quantity and diversity of animal biomass	Food, Prey	4.1	Detritus Based Food Web Interactions	Disturbance to stream ecological relationships due to lack of plant detritus resulting in insufficient food for growing salmonids	Reduced Macrodetrital Inputs, Reduced Microdetrital Inputs, Macroinvertebrates
5	Channel Stability	Changes to River, Stream, Lake. Estuarine tributary and Distributary channel form, causing bedload movement including the loss (scour) or fill (aggradation) of the channel and associated loss of spawning habitat, disruption to passage and loss of instream ecosystem function	Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload	5.1	Entrenchment	Loss of stream bed material, including loss of spawning habitat, due to increased flow focus	Downcutting, Incising, Bed Scouring
				5.2	stream bank	Loss of sediment from stream or river bank	bank erosion

TABLE 1. (continued)

ID	Ecological Concern	Definition	Included Categories	ID	Ecological Concern-Subcategory	Definition	Included Categories
				5.3	Aggradation	Filling of Channel with sediment due to bedload movement	increased width/depth ratios
				5.4	Confinement	Restriction of stream or river movement due to reinforcement of the banks and associated loss of streambed due to increased flow focus	Bank Hardening, Bank Stabilization, Armoring, Bridge Crossings
6	Channel Modification	Anthropogenic changes to River, Stream, Estuarine tributary and Distributary channel form and associated loss of spawning habitat, disruption to passage and loss of instream ecosystem function		6.1	Filling	Anthropogenic placement of sediment in a watercourse to alter water depth or flow	
				6.2	Diking	An embankment of earth and/or rock intended to change the direction of a course of water or confining water	Levees
				6.3	Dredging	Habitat degradation associated with dredging, including but not limited to habitat loss, hypoxia and turbidity	
				6.4	Channel Straightening	Habitat degradation associated with channel straightening, including but not limited to reduced instream habitat complexity, loss of LWD, unfavorable pool/riffle/run ratios and reduced sediment quality	Channelization
7	Floodplain Conditions	Loss and degradation of relatively flat peripheral habitat of streams and rivers that is periodically inundated during high flows. Includes associated sloughs, side-channels, and freshwater wetlands important for rearing. Includes factors that contribute to multiple limiting factors		7.1	Loss of Habitat Connectivity	Difficulties accessing side channel habitat	Access to Side-Channels, Dikes, Flapgates, Levees
				7.2	Degraded Side-Channel Habitat	Degradation or loss of side-channel habitat	
				7.3	Degraded or loss of Wetlands	Degradation or loss of wetlands	
8	Instream Habitat	Decline of the instream habitat quality. Based on the degree of habitat complexity and variety, includes the quantity and variability of stream depth and pools of varying size and depth.	Habitat, Stream Complexity, High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat, Channel Conditions, Instream Roughness	8.1	Instream LWD	(Loss of) Large wood pieces and trees that remain stable in the stream over some period of time and the associated loss of habitat complexity	
				8.2	Pool Habitat	(Loss of) Number and variety (size and depth) of pools and associated habitat function	Depth, Cover, Key Habitat

TABLE 1. (continued)

ID	Ecological Concern	Definition	Included Categories	ID	Ecological Concern-Subcategory	Definition	Included Categories
				8.3	Mass Wasting	Habitat disruption associated with the dislodgement and downslope transport of loose rock and soil material, often mediated by a fluid such as water	Landslides, Debris Flows, Debris Torrent
				8.4	Beaver Ponds	Loss of beaver created habitat and associated habitat function	
9	Artificial Structures	Instream and Nearshore structures that may interfere with water circulation, decrease essential habitat through shading and provide predator habitat		9.1	Overwater Structures	Overwater structures that may interfere with water circulation, decrease essential habitat through shading and provide predator habitat	Ramps, Pilings, sunlight input, Piers, Marinas
				9.2	Screening Mortality	Mortality due to unscreened or improperly screened water diversions, withdrawals or dam spillage	Entrainment
				9.3	Tidal Gates	Loss of estuarine habitat due to the presence of tidal gates, includes associated loss of access	
				9.4	Shoreline Armoring	Nearshore structures that induces changes to the habitat, including water circulation and sedimentation	Breakwaters, Jetties, Groins, Boat Launch, Sea Walls, Rip Rap
				9.5	Non-Permanent Dams	Temporary structures that divert water by raising the river level	Push Up Dam, Inflatable Dam, Flashboard Dam, Stop Log Dam, Splash Dam
10	Riparian Conditions	Degradation of the habitat adjacent to streams, rivers, lakes and nearshore environments. Impairment of the near-bank environment to support plants including grasses, forbs, shrubs and large trees that help stabilize stream banks, provide fish habitat, provide shade, add primary production to the aquatic ecosystem and includes the supply of mature trees into streams as LWD.	Impaired Riparian Function/Condition, microclimate	10.1	LWD Recruitment	Loss of mature streamside trees that may become instream structures and associated decline in habitat complexity	LWD supply
				10.2	Riparian Condition	Disturbance to streamside ecological relationships, including but not limited to, loss of flora, erosion and increased light and temperatures	Bank Degradation, Cover, Inability to supply organic matter and filter sediments, Insufficient buffers, Light, Loss of Natural Shade
11	Water Quality	Deviation from water quality standards as pertains to salmon.		11.1	Temp.	Deviation beyond the thermal tolerance limits of salmonids either in intensity or duration	Winter Cover Inadequate, Low Winter Water Temperatures
				11.2	O2	Deviations in oxygen concentration outside the tolerance limits of salmon	
				11.3	Nutrients	Elevated nutrient inputs to a water body and subsequent ecological consequences	
				11.4	Turbidity	Suspended sediments at concentrations harmful to salmon	Suspended sediments
				11.5	Salinity	Salinity at concentrations harmful to salmon	Refuge from salinity regimes

TABLE 1. (continued)

ID	Ecological Concern	Definition	Included Categories	ID	Ecological Concern-Subcategory	Definition	Included Categories
12	Altered Hydrography	Detrimental effects of deviations to the background (natural) amount and timing of water quantity instream, including lowered water quality, changes to sediment movement and barriers to access	Changes in Flow Regime, Spring Freshets, piped outfalls of surface and ground water, Dewatering of Redds	12.1	High Flow	Habitat disturbance associated with abnormally (compared to background) high water flow including loss of river substrate and the flushing of young fish downstream	Flooding
				12.2	Flow Timing	Detrimental effects of deviations to the background (natural) timing of water quantity instream	
				12.3	Low Flows	Habitat disturbance associated with reduced (compared to background) water flow, including but not limited to increased temperature, loss of sediment, nutrients, barriers to passage and critical habitat. Encompasses all low flow causes, as water withdrawals enhance the effects of natural low flows and cannot always be discriminated	Dewatering, Water Withdrawals, Surface Impoundments, Diversions, Irrigation Diversions
13	Access	Obstruction that deny access to good quality habitat-includes permanent barriers and transitory natural barriers which may be due to habitat alterations	Obstructions, Barriers, Passage Issues, Blocked,	13.1	Natural Barriers	Lasting natural barriers to stream access. May represent the end of good quality habitat	Steep Gradient, Waterfall

between broad-scale processes (threats or stressors) and the habitat changes they produce.

DATA DICTIONARY APPLICATION

The data dictionary was evaluated by populating a database with ecological concerns for the six subbasins within the Columbia-Cascade ecological province using habitat assessments created by two different sources,

The Columbia-Cascade is part of the Columbia River drainage basin, located in Washington State and a portion of British Columbia, Canada, east of the Cascade Range, including the Columbia River from Wanapum Dam to the limit of anadromous fish passage at Chief Joseph Dam. It is comprised of six subbasins (Entiat, Methow, Lake Chelan, Okanogan, Upper Middle Columbia, and Wenatchee, as defined by the Northwest Power and Conservation Subbasin Plans 2005) and smaller watersheds that drain directly to the Columbia River (Figure 1).

I found two sets of data for the Columbia-Cascade: the Northwest Power and Conservation subbasin plans and the Washington Conservation Commission's limiting factor analysis (WCC LFA). The Northwest Power and Conservation Council is part of the Bonneville Power Administration, a United States federal agency, whose mission "develops and maintains a regional power plan and a fish and wildlife program to balance the Northwest's environment and energy needs" (Available at http://www.nwcouncil.org/about/). In 2005 the council concluded one of the largest watershed planning efforts of its kind in the United States. Each subbasin planning effort was locally led in collaboration with state and federal fish and wildlife agencies, Indian tribes, local planning groups, fish recovery boards, and Canadian entities where the plans address transboundary rivers. These documents are publicly available from the Northwest Power and Conservation Council's web site.

Each subbasin plan included a habitat assessment and/or a limiting factors analysis. These were divided into smaller spatial units called "assessment units" (Figure 2). The assessment unit boundaries clearly followed watershed outlines but were not simply fifth or sixth field U.S. Geological Survey (USGS) hydrologic cataloging units (HUCs) but instead a mix of the two (e.g., two fifth field HUCs and a sixth field and a fifth field together). The habitat assessments synthesize field data, expert opinion, older documents, and spatial data. They are meant to be an integrated temporal assessment of habitat condition including the effects of past and present activities.

With the varying authorship and data sources, the data categories, methods, and habitat rating standards were largely unique to each subbasin plan. (The ecological concerns noted therefore reflect the author's opinions of the habitat priorities.)

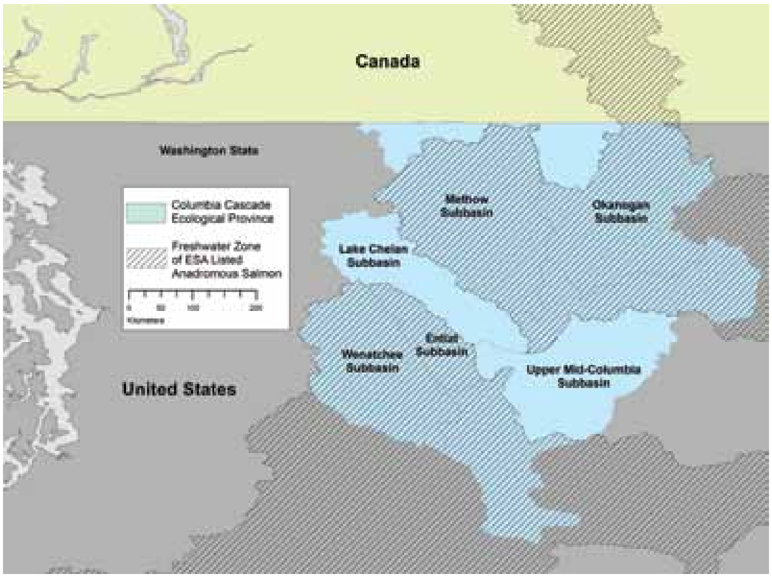

Figure 1. Columbia-Cascade province, with labeled subbasins, overlaid with the range of Endangered Species Act (ESA)-listed anadromous salmonids. (Endangered Species Act of 1973 (ESA; 7 U.S.C.))

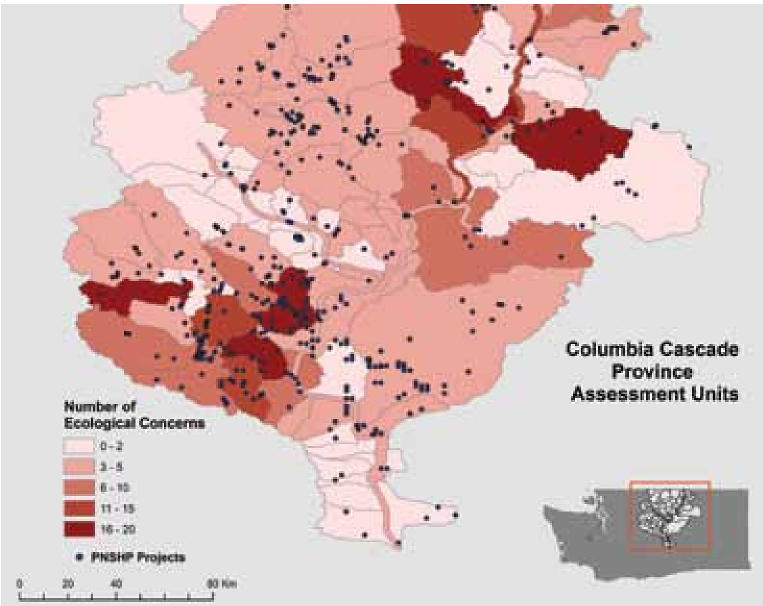

Figure 2. Number of ecological concerns per assessment unit and the location of restoration projects from the Pacific Northwest Salmon Habitat Project (PNSHP database in the Columbia-Cascade Province. (Pacific Northwest Habitat Project Database. Katz et al. 2007)

Each category of ecological concern mentioned within each assessment unit was entered into the database. The database fields consisted of subbasin, assessment unit, and ecological concern along with document reference and date. Due to difficulties in obtaining original geographical information system (GIS) files of the assessment units, each assessment unit was recreated based on maps and other information within the subbasin plans. The USGS National Hydrography Dataset (NHD) HUC 5 and 6 borders were used to delineate assessment unit boundaries. The GIS layer of assessment units was then incorporated into a map of the province. The habitat assessments within the subbasin plans were one of the two sources of habitat information for this study.

The second data set found for the Columbia-Cascade stems from the statewide habitat limiting factors summary produced by the WCC LFA (Smith 2005). In 1998, Engrossed Substitute House Bill 2496 (now 77RCW) directed the development of habitat-only limiting factors analysis for salmonids in Washington State watersheds. It is a publicly available Excel file of habitat ratings for stream reaches in Washington State (Salmon Habitat Limiting Factor Reports 2005). To create a comparable data set, the StreamNet GIS Data (StreamNet 2003) routed stream network (1:100k), a publicly available data storehouse of fisheries and aquatic data for the Columbia River Basin, was imported into ArcMap GIS. The stream reaches were then linked to the Excel table of limiting factors based on stream name. Streams that fell within each subbasin assessment unit were binned along with the habitat condition information and given the same name assessment unit name and verified using the Water Resrouce Inventory Area (WRIA) numbers included in the Excel table.

The spatial coverage of the two sets of assessments did not completely correspond. The Lake Chelan subbasin was not included in the WCC LFA. Of the remaining five subbasins, for three, the Methow, Wenatchee, and Entiat, there was information for all assessment units. In the remaining two subbasins, 8 of 18 assessment units in the Upper Mid-Columbia were assessed by both sources and 5 out of 20 in the Okanogan subbasin had information from both sources (Table 2).

All WCC LFA categories with ratings of "fair" to "poor," corresponding to ecological concerns, were marked as present. All data gaps were excluded. Information from both assessment sources were translated into the general type and subtype ecological concern categories. To compare the two assessment sources and create the graphs, a lowest common denominator approach was used, rolling up each set of assessments into the general data dictionary categories.

The WCC limiting factors categories were crosswalked to 10 general ecological concern categories while the subbasin plans had information for all 13 general categories. Due to the difference in the number of potential categories, the comparison between sources of assessed ecological concerns was done using all categories and only the shared categories. All comparisons were done using only shared spatial units. This process produced two parallel data sets consisting of a list of ecological concerns for a set of standardized spatial units ready for comparison. The matches and mismatches between the ecological concerns noted by the two data sets were compared using a 2 × 2 contingency table of presence/absence. Due to null cell values for one subbasin, Fisher's exact test was also performed to test concordance between assessment scoring (Table

TABLE 2. Comparison between the Northwest Power Council subbasin plans and the Washington Conservation Commission limiting factor analysis of assessments done and similarity between them.

Subbasin	Number of AUs in subbasin	Number of AUs assessed by both sources	Average number of ecological concern mismatches between assessments	Chi square test for heterogeneity: shared categories		Fisher Exact Probability Test: two-tailed
				Yates value	p	
Entiat	4	4	3.75	7.43	0.01	0
Methow	12	12	4.92	4.05	0.04	0.04
Wenatchee	12	12	4.08	8.21	0.28	0
Okanogan	20	5	7.4	NA	NA	0.18*
Upper Mid-Columbia	18	8	3.75	4.48	0.03	0.02

*Indicates a nonsignificant association between the two Okanogan assessments.

TABLE 3. Testing for similarity of ecological concern scoring with shared categories (10 of 13) between the subbasin plans and the WCC limiting factor analysis.

Wilcoxon Signed-Rank Test on Scoring of Shared Categories	Entiat	Methow	Wenatchee	Okanogan	Upper Mid-Columbia
W =	7	-16	-31	45	4
Ns/r =	7	9	9	9	8
p (2-tail) =			Critical W at .05 = 29	Critical W at .005 = 43	
One-Way ANOVA: Number of Mismatches					
N	4	12	12	5	8
Mean	2.5	4.08	3.58	6.4	3.62
Std. Dev.	2.08	1.24	1.88	1.34	1.19
	SS	F	p		
	41.06	4.3	0.01		
Tukey Test: HSD [.05]=2.42	**Entiat**	**Methow**	**Wenatchee**	**Okanogan**	**Upper Mid-Columbia**
Entiat		NS	NS	P<.01	NS
Methow			NS	NS	NS
Wenatchee				P<.05	NS
Okanogan					P<.05
Upper Mid-Columbia					

2).

Because the WCC LFA categories matched only a subset of ecological concern categories, all tests were done with both all and shared categories. The number of concerns recorded by each assessment source was compared by subbasin and collectively. The Wilcoxon signed-rank test was used to compare the paired samples due to the small sample sizes and lack of assumptions about the distribution underlying the differences between the two assessments. Because the scoring data were categorical and discontinuous, the Wilcoxon signed-rank test was also used to compare scoring similarity (Table 3a) for each subbasin and collectively. A one-way analysis of variance (ANOVA) was done using each subbasin and shared categories and with the number of mismatches as the independent factor (Table 3a). The significance of each Subbasin × Subbasin comparison was determined by a post hoc test (Table 3b).

The map layer of assessment units was also used to select the restoration projects implemented within each assessment unit as an additional source of data for analysis (Figure 2). Restoration project types and locations were obtained from the Pacific Northwest Salmon Habitat Project (PNSHP) database, a publicly accessible database created and maintained by the Northwest Fisheries Science Center (NOAA) for research purposes. The scatter plot (Figure 3) shows the relationship between the number of ecological concerns (based on subbasin plans) and restoration projects per assessment unit.

RESULTS

When combining or comparing data sets, it is only possible with the lowest common denominator between them and a concomitant loss of precision that is biased toward increasing correspondence. For instance, if comparing two different subtypes (decreased sediment and increased sediment) within the same general category (sediment problems), they become equivalent if rolled up to the next level in the hierarchy. The two different methods of assessing the habitat, a predefined set of limiting factor categories for the WCC LFA and the narrative assessments of the subbasin plans, produced challenges for standardization. The WCC LFA includes very broad categories that were each converted to multiple ecological concerns. The narrative assessment increases the subjectivity of translation on the part of the reader. Both data sets were rolled up into the general categories of ecological concerns for comparison.

After compiling and standardizing the subbasin plan habitat assessments, counts of ecological concerns for each assessment unit can be displayed to provide a visual indication of habitat condition across a large region (Figure 2). This method also provides the means to visually contrast different assessments; for example, a comparison of ecological concern counts per assessment unit for the Wenatchee subbasin (Figure 4).

A predefined set of categories to evaluate habitat constrains an assessment in ways that a narrative assessment does not. Written habitat assessments from the subbasin plans were often translated to every category of ecological concern in the data dictionary. Although the WCC LFA assessment had a smaller number of potential categories than the subbasin plans and a small difference between the mean number of concerns was noted when comparing all categories (6.00 for subbasin assessments and 5.17 for the WCC LFA), I found no significant difference between the number of ecological concerns noted for an assessment unit whether comparing all or shared categories (Wilcoxon matched-pairs rank test, $W = 145$, $P \leq 0.26$, $W = -7$, $P \leq 0.95$, respectively). In other words, there was no significant difference between the number of specific ecological concerns noted by the two sources.

To test how different the actual scoring was between the two assessments, a chi-square contingency test was done comparing the matches to nonmatches for each ecological concern category for each assessment unit. The correlation in scoring was significant for the Entiat, Methow and Upper Mid-Columbia subbasins. It was nonsignificant for the Wenatchee subbasin ($P = 0.28$) and not applicable due to null cell values for the Okanogan subbasin. For this reason and due to small expected cell values for some comparisons, I used Fisher's exact probability test with the contingency table. I found that all assessments from the two different sources were highly correlated, with the noteworthy exception of the Okanogan (Table 2). In order to better understand whether the two assessments really differed after translation, the similarity of ecological concern scoring between the two assessment sources was also examined using the Wilcoxon signed-rank test. Though there was no significant difference between the two assessment sources for the whole region, when testing each subbasin independently I found significant divergence in the ecological

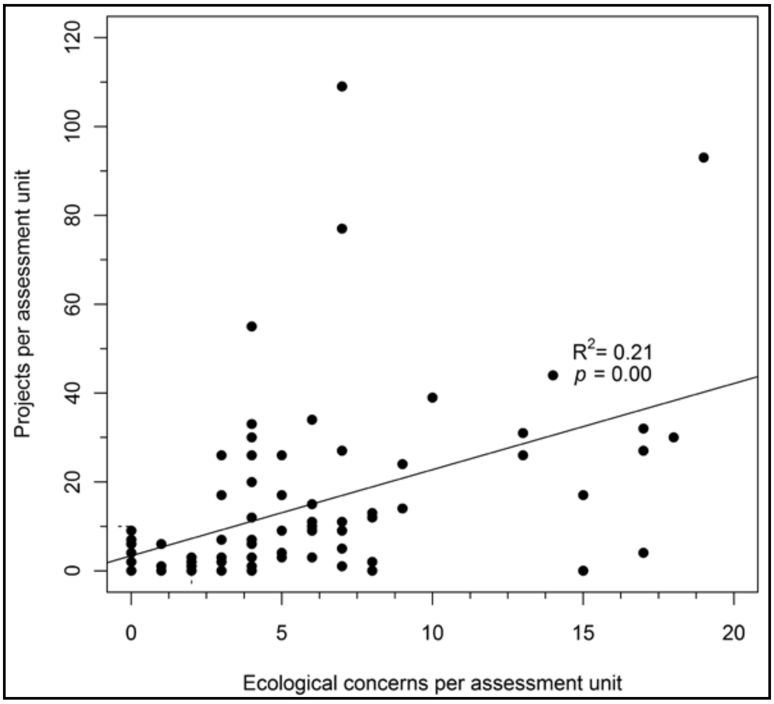

Figure 3. Correlation between the number of ecological concerns and the number of restoration projects per assessment unit.

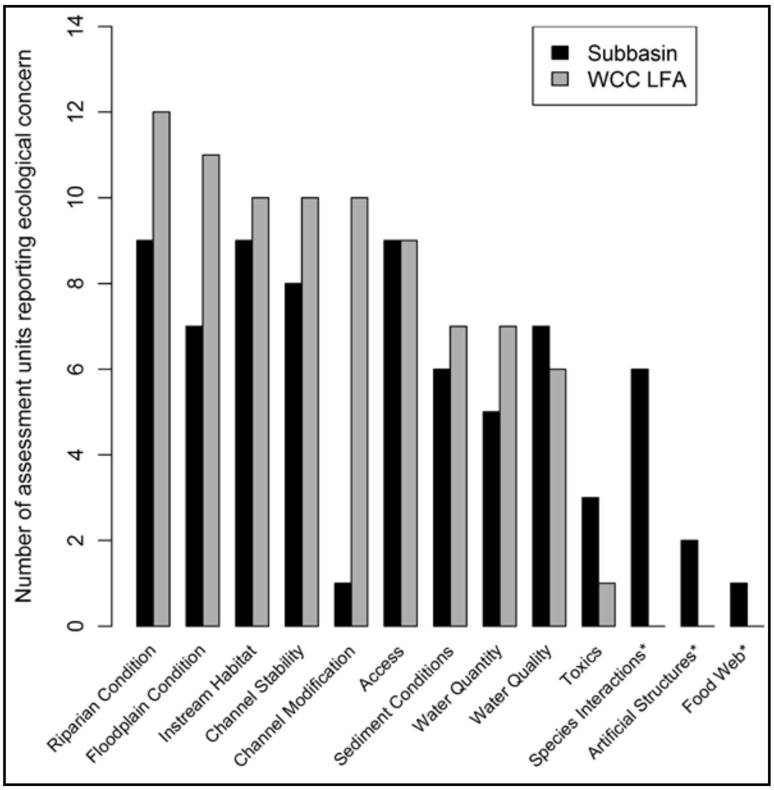

Figure 4. Number of assessment units where each category of ecological concern was found, as assessed by two different sources, the subbasin plan and the WCC limiting factor analysis for the Wenatchee subbasin. Ecological concerns marked with an asterisk are categories that were not part of the WCC limiting factor analysis.

concerns noted between assessments for two subbasins. The *W* score was significant for the Wenatchee subbasin at the 0.05 level, whereas the *W* score for the Okanogan assessments was significant below the 0.005 level. A visual assessment of the comparison for the Wenatchee subbasin (Figure 4) suggests that large differences in the frequency that categories like channel modification were noted may explain the difference between the assessment sources. As an additional attempt to characterize similarity between the assessments, I used an ANOVA on the number of mismatched scores for each subbasin and only found a significant difference between the Okanogan subbasin and the other subbasins (post hoc Tukey's test).

The correlation of the number of ecological concerns and the number of projects implemented in each assessment unit was positive and significant ($r^2 = 0.21$, $P = 0.00$) despite the large amount of scatter (Figure 3).

DISCUSSION

Though the listing of salmonids has resulted in the collection of large amounts of habitat and restoration data, this data collection is being conducted by federal, state, and local entities, with the accompanying diversity of methods and protocols (Johnson et al. 2001; Collins 2003; Marmorek et al. 2004; Katz et al. 2007). Variation also exists between locations and individuals collecting data, leading to widely varying assessments results and conclusions (Al-Chokhachy and Roper 2010).

Recommendations for improved methods of freshwater habitat assessment and prioritization exist (Montgomery and Buffington 1997; Beechie et al. 2003), but these methods do not provide a guide for synthesizing existing documents. For instance, the proposed physical habitat classifications do not include biological and ecological information, such as predation, disease, and competition, which are commonly a part of existing habitat assessments and are addressed by some types of restoration projects. Similarly, existing standardized habitat descriptions such as the Interactive Biodiversity Information System (IBIS; Northwest Habitat Institute), Washington GAP Analysis Program (GAP), or the Nature Conservancy's Ecoregional Assessments for the Pacific Northwestare of habitat type or general landscape features and not specific aspects of habitat condition that may guide restoration. Hence, there is no way to relate other relevant and available data such as restoration projects. Similarly, preexisting threats definitions—for instance, the Unified Classifications of Direct Threats and Conservation Actions by the International Union for Conservation of Nature–Conservation Measures Partnership (IUCN-CMP)—are too general to compare against specific salmonid habitat restoration projects, for which there is considerable data available in the Pacific Northwest (Salafsky et al. 2008).

The value of a common language for conservation and management, around which data collection, analysis, and planning can be based, has been recognized, and there is ongoing debate as to the best way to structure this information (Salafsky et al. 2008, 2009; Balmford et al. 2009). However, these schemas are all intended to be universal, applicable for all terrestrial regions, any species, and all sources of threats. The resulting schemas are general and lack the sort of low-level complexity necessary to evaluate specific restoration activities, compare the consequences of a threat occurring in different regions, or take advantage of the enormous amount of data within the many assessments of salmonid freshwater habitat.

A data dictionary records the simple presence/absence of ecological concerns, uses an explicit definition to restrict the number of potential categories, and separates ecological concerns from their causes. This data dictionary can translate assessments from different sources for a single area into a standardized form so their degree of concordance can be measured. By surveying terms and categories already in use, starting with the assessments themselves, a balance can be maintained between retaining the most categories and degree of specificity while still enabling synthesis with other assessments. The resulting data dictionary is more fine grained, containing categories that are distinct but can be linked to larger scale processes and threats as well as the specific categories of restoration projects found in the PNSHP database of restoration projects. The categories of habitat degradation found within any of the top-down or universal schemes mentioned previously are not sufficiently detailed to evaluate specific restoration project types.

Using the data dictionary to compare multiple assessments created under two different mandates, I found that high correlations among the suite of ecological concerns identified within each assessment. One set of comparisons, assessing the Okanogan subbasin, stands out as disagreeing significantly with one another. This served to focus attention on the area for closer examination of the method and context of the assessment creation. The Okanogan subbasin plan had a more complicated creation than the other assessments (Northwest Power and Conservation Council, Okanogan Subbasin Plan 2004). It was done jointly, with contributions from the Canadian and U.S technical advisory groups, including the use of the EDT software and a limiting factors analysis done for the Confederated Tribes of the Colville Reservation by private contractors and possibly left unfinished. This LFA was also supplied to the Washington Conservation Commission for use in its statewide analysis, meaning that there were not two independent assessments to compare. However, the Okanogan habitat ratings supplied in the WCC LFA database are an interpretation of the LFA, in conjunction with other information from the subbasin plan, and an attempt to verify the LFA habitat ratings with local experts was unsuccessful (Smith 2005). Given that this comparison is in part comparing a single document against its interpretation, it is surprising that they are the most different from one another, including very limited spatial overlap in the regions assessed. The lack of spatial overlap suggests information coming from different sources and highlights uncertainty in these documents creation. One strength of the data dictionary is that it does not standardize assessment to the point that it eliminates all differences. Documents retain sufficient information that the degree of differentiation between assessments of the same region done by different parties under different mandates can be measured. Assessments from the same areas largely agree with one another; however, significant conflict between two assessments serves to single out particular areas for greater scrutiny. Using the data dictionary provides a more objective basis from which to synthesize data or choose one assessment over another when compiling habitat information for a broader area.

Comparing the number of ecological concerns and projects found in each assessment unit, I found significant positive correlation between the number of ecological concerns (i.e., the diversity of ecological impairments) and the number of projects implemented. If this is the case, it appears that more severely degraded areas receive more restoration effort. This result is more reassuring than expected given that there has been little in the way of retrospective analysis of restoration, and existing studies have found evidence of significant problems with restoration prioritization and project design. This comparison, however, does not provide any information as to whether particular restoration action is appropriate.

In addition, the number of ecological concerns may be a useful proxy for a measure of habitat degradation. Due to the interconnected nature of ecosystem processes, as these processes break down, habitat degradation results from the cascade of effects. The resultant negative changes increase in variety as well as severity. So although there is no quantitative aspect to the data dictionary categories, an area with more ecological concerns is likely to be more degraded. A linkage between the number of ecological concerns and the state of the habitat is logical, and perhaps even obvious. However, a single metric for measuring and mapping habitat condition has not previously existed and is useful for comparing habitat condition against restoration effort, land use, and other drivers, causes, effects, and responses to habitat condition. Given that restoration projects have been designed, funded, and implemented independently by various parties, the trend between restoration effort and habitat condition implies some consensus over perceived need and restoration response.

THE DATA DICTIONARY'S FUTURE ROLE IN EFFECTIVENESS MONITORING AND RESTORATION PLANNING

A number of different methods have been proposed to better prioritize restoration, account for the effects of restoration, and use well-developed restoration plans as experiments to answer key uncertainties (Jones et al. 1996; Beechie et al. 2008). Though these methods appear highly useful, much restoration continues to be implemented without adequate and explicit expression of expected outcomes or appropriate effectiveness indicators and lacks sufficient monitoring to ensure success or learning from mistakes (Roni 2005).Given the current lack of coherence in restoration practice, data dictionaries can provide a framework for integrating existing and future information. The ability to integrate older assessments is necessary for detecting the effects of restoration actions through time. Because much restoration happens at the reach or watershed scale, synthesizing assessments allows a range-wide or whole Ecological Significant Unit (ESU) characterization of habitat status that better matches the scale of recovery planning (Williams et al. 2007).

Billions of U.S. federal dollars being spent on actions to improve freshwater salmon habitat (GAO 2002) and habitat restoration expenditures increase annually (Katz et al. 2007) despite the challenges of evaluating the effectiveness of either individual or aggregate restoration actions (Roni et al. 2008) and a limited understanding of restoration success (Christian-Smith and Merenlender 2010). Basic tools for accounting and evaluating restoration are needed to see that restoration is occurring in a manner that is reasonable and likely to produce the intended changes. The ecological concerns data dictionary presented here was designed to translate existing habitat assessments into a standardized language and set of categories. Standardized information then provides the basis for assembling larger, richer data sets; facilitates the analysis of habitat condition over larger spatial scales; and provides the basis for creating habitat data that specific restoration activities can be evaluated against.

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NOTE: An additional appendix containing the Ecological Concerns Data Dictionary Sources as a bibliography is available as Supplementary Data at http://www.tandfonline.com/UFSH.