A Recovery Crediting System that Supports Conservation Banking for an Endangered Floodplain Minnow in the Willamette Valley, Oregon

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Abstract. — Conservation banking is a new tool for resource managers that has the potential to provide both ecologically and economically sound alternatives while providing mitigation for impacts to listed species and their habitats. We developed a recovery crediting system to assess conservation credits and debits for the endangered Oregon chub (*Oregonichthys crameri*) that can be used in conservation banking. Our concept, which can nest within mitigation banking or stand alone, is based on prior studies assessing relationships between population abundance and habitat parameters for the species. Habitat parameters included habitat type, water velocity, aquatic vegetation, maximum and minimum depths, water temperatures, and shoreline slope. The model also incorporates rankings for piscivory risk, chub population abundance at the site or at proximal locations, site location (proximity to existing populations), and the status of proximal populations. Our approach assigns more credits to functioning bank sites that support abundant, viable populations of Oregon chub and requires more credits when impacted sites negatively affect or have the potential to negatively affect viable populations. Our approach is simple to use and has a strong biological foundation; real world examples are used to show the credit value calculations for determining baseline conditions and for assessing impacts to species habitat. We feel that as the demand to develop prime fish and wildlife habitat continues, there will be associated demands for compensatory conservation and managers will benefit by developing similar species models to promote the adequate mitigation needed to ensure the long-term survival of imperiled species.

The U.S. Endangered Species Act (ESA) prohibits “taking”, harming or harassing of threatened and endangered species. When impacts to a species or its habitat are unavoidable, the U.S. Fish and Wildlife Service (USFWS) may permit activities which otherwise violate the “take” prohibition through the issuance of incidental permits that allow the taking of a specified number of individuals of a threatened or endangered species. In return for issuing a take permit, mitigation is required to ensure that species survival is not appreciably reduced. In July 2008, the Secretary of Interior gave notice of the availability of new guidelines designed to help conserve ESA species (Federal Register 2008). Resource managers will now be able to use a recovery crediting system to create “banks” of credits through beneficial conservation actions on non-federal lands. This is especially important in areas that are experiencing rapid urban growth or intensified resource development because ESA needs can lead to substantial demand for habitat mitigation to offset impacts.

Conservation banking is designed to facilitate this compensatory mitigation process (USFWS 2003). Conservation banking was replicated after mitigation banking, which is the restoration, creation, and enhancement of wetlands and/or other aquatic resources to provide compensatory mitigation in advance of authorized impacts to wetland or other aquatic resources (USFWS 1995). The difference between the two is, conservation banks are designed to improve habitat for one fish or wildlife species or to enhance a key environmental correlate like vernal pools that support several endangered invertebrates (Figure 1), while mitigation banks are developed to replace a habitat type like wetlands that has value for multiple species so there is no net loss of that habitat. A conservation bank may co-reside with or within a mitigation bank on the same site or each bank may stand alone at a site. Conservation banks are permanently protected privately or publicly owned lands that contain habitat elements critical to the protection and recovery of one or more federally listed species. A conservation bank is protected in perpetuity and managed to generate credits that can be sold or traded to offset unavoidable adverse effects to the same habitats and species outside the bank boundary, but within the historical range of the species (USFWS 2003). Ideally, conservation banks function to preserve existing habitat with long-term conservation value to mitigate for the loss of other isolated and fragmented habitat that has little long-term value to the species (Federal Register 1995). The first conservation bank was created in 1995 to provide coastal sage scrub habitat for the California gnatcatcher at the Carlsbad Highlands Bank in San Diego County, California (California Environmental Protection Agency 2005).

As mentioned, the goal of conservation banking is to improve the status of the target species through habitat management, and because a species may depend on different habitat types during different states of its life cycle, it may be the case that exchanges of different habitat types or habitats in substantially different locations make sense for the species (Ruhl et al. 2005). Banks that concentrate on larger land parcels can result in the protection or enhancement of substantially larger habitats and better habitat connectivity than traditional on-site or piecemeal mitigation. Further, these banks must ensure that appropriate management will continue in perpetuity. Conservation banks allow a private landowner to transform a former legal liability, the presence of a listed species, into a financial asset, conservation credits (Fox and Nino-Murcia 2005). The two primary financial reasons for establishing banks are to sell credits for profit or to use credits internally to reduce permitting costs. Benefits of banks over conventional mitigation include: 1) the preservation of larger existing habitats that have long-term conservation value versus the creation of smaller, isolated, and often fragmented habitats with little long-term conservation value (Federal Register 1995), and 2) creation of a streamlined permitting process that reduces costs, improves environmental compliance efforts, and creates ecologically sustainable projects. In a survey of bankers of existing conservation banks representing more than 27,000 acres, half of the respondents reported that if developing a conservation bank was not an option, they would have developed their land for other uses (Fox and Nino-Murcia 2005). Because approximately 80% of endangered species occur on private lands and 50% of these rely exclusively on privately owned habitat for survival (Wilcove et al. 1998), conservation banking has the potential to substantially improve the recovery status of threatened and endangered species on private lands. There are multiple benefits of conservation banking. Private property owners are provided with an economically viable land management alternative, the USFWS is able to secure the conservation of contiguous, high quality habitat, and those in need of mitigation are provided with additional mitigation options. For some lands, use as a conservation bank may have a higher monetary value than for development.

A major challenge in conservation and mitigation banking has been the assessment of credits and determination of a compensation ratio that reflects the existing and/or potential functional condition in a bank (Stein et al. 2000). Normally conservation bank managers use the area of the habitat protected to assign mitigation credits to their land (Fox and Nino-Murcia 2005). However when using only the habitat area to determine the number of credits, it does not take into account the potential habitat functions of a site. Certain habitats are of higher quality than others and are more important to the survival of a species. Typically, compensation ratios are applied when determining the number of credits awarded to the bank and the number of credits required to mitigate for impacts and often do not account for differences in habitat quality, distance from and/or connectivity to other protected areas, or importance of a land parcel to regional conservation goals (Bauer et al. 2004). Impacted habitats with higher conservation value should receive greater conservation compensation than habitats with lower conservation values.

Credits are the quantification of a species' or habitat's conservation values within a bank. There are a number of biological criteria that govern the currency for issuance of bank credits including the species covered, habitat quality and quantity, property location and configuration, site connectivity, potential conservation benefits, and available or prospective resource values (Federal Register 1995; Ruhl et al. 2005). The process of quantifying habitat quality has taken many forms. Measures of habitat function can include biotic indices, assessment based on species composition or habitat suitability for specific indicator species, surveys of habitat characteristics, or landscape level assessments using Geographic Information Systems (GIS). Many early methods used "best professional judgment" as the basis of habitat assessment, where a species habitat expert ranks habitat quality and assigns compensation ratio. This method is both subjective and lacks repeatability. Stein et al. (2000) developed a model based on a framework that evaluates credits and debits for spatial and structural diversity, contiguity of habitats, invasive vegetation, hydrology, topographic complexity, characteristics of flood-prone areas, and biogeochemical processes. Searcy and Shaffer (2008) assigned credits based on the reproductive value of individuals inhabiting a site, where the habitat parameter was the distance from the breeding site for California tiger salamanders (*Ambystoma californiense*). Calculation of conservation credits for a bank for the California red-legged frog (*Rana aurora draytonii)* included habitat connectivity, habitat shape, and habitat location criteria (USFWS 2001). Bruggeman et al. (2005) proposed a landscape-scale approach as an accounting system to calculate conservation banking credits based on integrating metapopulation genetic theory with demographic observations. These methods may require extensive measurements of habitat parameters.

Ideally, the method of assigning mitigation credits should be accurate, repeatable, and objective. Thus, the goal of a credit-debit model is to develop a structured and systematic way to apply data and professional judgment to a decision-making process. The approach should have an ecologically defensible basis, an ease of use such that the level of expertise and time required to employ the method is not a deterrent to its application, and should provide a semi-quantitative measure of the condition of aquatic resources that can be translated to a mitigation ratio, if needed (Stein et al. 2000).

In this paper, we will describe a debit and credit accounting system for an endangered floodplain minnow, Oregon chub (*Oregonichthys crameri*), to ensure that compensatory mitigation and conservation actions adequately address impacts to the species, habitat, and functions and would eventually lead to recovery in the Willamette Valley, Oregon. This accounting system was developed in response to an anticipated demand for credits resulting from a major bridge replacement program by the Oregon Department of Transportation.

Species and Habitat Descriptions

Oregon chub are small minnows that are endemic to the Willamette Valley of western Oregon. Oregon chub prefer off-channel habitats such as beaver ponds, oxbows, side-channels, stable backwater sloughs, low gradient tributaries, and flooded marshes (Markle et al. 1991; Scheerer 2002). These habitats have little or no water flow, silty and organic substrate, and abundant aquatic vegetation and cover for hiding and spawning (Pearsons 1989; Scheerer and McDonald 2000). Oregon chub are poor swimmers (Pearsons 1989) and are not found in swift waters. Adult Oregon chub seek dense vegetation for cover and are frequently located along the margins of aquatic macrophyte beds. Oregon chub spawning occurs in shallow vegetated areas of ponds and sloughs beginning in late-May and continuing through early-August at temperatures ranging from 15^{o} to 21^{o}C (Pearsons 1989; Scheerer and McDonald 2003). Peak spawning occurs in July (Scheerer and McDonald 2003). Adult maturation is size- dependent and occurs when Oregon chub reach approximately 40 mm TL (age 2) (Pearsons 1989; Scheerer and McDonald 2003). When Oregon chub are exposed to prolonged cold temperatures (less than 15 ^{o}C), no spawning occurs and the gonads do not mature (Scheerer and McDonald 2000).

Loss of habitat combined with the introduction of non-native fishes have been implicated in the decline in Oregon chub abundance (Markle and Pearsons 1990; Federal Register 1993). The reduction of suitable habitat and the restricted distribution of the Oregon chub resulted in a listing as endangered throughout its range under the federal ESA (Federal Register 1993). This species was formerly distributed throughout the Willamette Valley floodplain in a dynamic of off-channel habitats such as beaver ponds, oxbows, stable backwater sloughs, and flooded marshes (Snyder 1908). In the past 150 years, suitable habitat has been lost as the channel length of the Willamette River drainage was drastically reduced by the construction of 13 major flood control dams, large-scale removal of large wood for navigation, channelization, revetments, and the drainage of wetlands to increase the land available for bottomland agriculture (Sedell and Froggatt 1984; Benner and Sedell 1997). In addition, non-native fishes are widely distributed in the Willamette Valley and are a major threat to Oregon chub populations. Many of the remaining off-channel habitats preferred by Oregon chub in the Willamette River drainage have been invaded by non-native fish predators and competitors. Non-native fishes have caused the extirpation of Oregon chub at numerous locations where they existed historically and appear to limit the abundance of Oregon chub at those sites where they co-occur (Markle et al. 1991; Scheerer 2002). Currently, the fish assemblages inhabiting off-channel habitats in the Willamette drainage are, in part, determined by the connectivity of the habitat to adjacent water bodies. Off-channel habitats with high connectivity have a higher likelihood of non-native fish occurrence (Scheerer 2002). Sites with low connectivity typically support larger Oregon chub populations and contain fewer species of non-native fish than sites with high connectivity (Scheerer 2002).

The Conservation Bank and Habitat Assessment Method

In 2004, the Oregon Department of Transportation (ODOT), along with several partnering agencies, developed a statewide Banking Program to fundamentally improve ODOT's approach to address habitat mitigation, habitat conservation, and species recovery (Warncke 2006). As part of the banking program, we developed a debit and credit accounting system to ensure that compensatory mitigation and conservation actions adequately addressed impacts to Oregon chub, their habitats, and the functions of those habitats (Oregon Department of Transportation 2005). A conservation bank in the Willamette Valley is being designed and permitted to address the protection and recovery of the Oregon chub. This bank was deemed a necessity by the replacement of a series of aging bridges, anticipated impacts to Oregon chub habitats, and a need for species credits.

A habitat assessment method was patterned after the species and habitat associations described in "Wildlife-Habitat Relationships in Oregon and Washington" (Johnson and O'Neil 2001). The Oregon chub accounting method was developed as a species-specific accounting method to address the extent and quality of habitat for Oregon chub and to incorporate additional information relating to species specific habitat suitability.

This approach focuses on changes in the ecological function of the site and provides an opportunity to evaluate where systems may be most vulnerable to impacts and where management activities should be focused to protect or enhance Oregon chub habitat integrity. Both impact and bank sites are evaluated with this method, thereby allowing a straightforward assessment and exchange of debits and credits. Based on anticipated post-project conditions, a post-project habitat value is calculated and subtracted from the baseline habitat value in order to determine the debit or credit amount. The accounting method can be used to determine the credit value resulting from habitat restoration, creation, enhancement, and preservation.

The Oregon chub accounting method describes those habitat features that are considered to have the greatest impact on the abundance and persistence of Oregon chub populations (Scheerer 2002). Habitat features include wetted surface area, area of aquatic vegetation, maximum depth during late-summer, water velocity, site connectivity, the presence of non-native predatory fish, the presence of Oregon chub, and water quality concerns.

In addition, the model includes population / subpopulation parameters including the presence of Oregon chub, the proximity of the bank or impact site to existing Oregon chub populations, and the status (abundance and 5-year trends) of proximal Oregon chub populations.

Description of Model Parameters

The debit-credit calculations integrate six primary factors: habitat area, habitat suitability, piscivory risk, habitat utility, habitat integrity, and impact duration (impact sites only). Calculations are computed separately for each habitat type present at a bank, or impacted site and then summed. The following equation is used to calculate Oregon chub values:

$$S_M = A_M \times F_S \times F_U \times F_I \times F_D,$$

where S_M is the specific Oregon chub value of a given habitat unit, A_M is the area of a given habitat unit in acres, F_S is the habitat suitability rating of the given habitat unit and is based on water body type, habitat quality rating, and water quality rating, F_U is the habitat utility rating of the site and is based on chub abundance, proximity to other chub populations, and abundance and 5-year trend of proximal chub populations, F_I is the habitat integrity rating of the site and is based on risks of delivery of excess sediments or toxic chemicals to the site, and F_D is the impact duration rating of the activity (impact sites only) and is based on the amount of time that the habitat is impacted by the land-use activity.

The parameters are normalized prior to running the model as follows: habitat type (range 0.8 to 1.0; normalized range 0.8 to 1.0), habitat quality (range 0 to 16; normalized range 0 to 10); water temperatures (range 0.25 to 1; normalized range 0.25 to 1), piscivory risk (range 1 to 10.0; normalized range 0.1 to 1.0), habitat utility (range 2 to 9; normalized range 0.22 to 1), habitat integrity (range 0.8 to 1.0; normalized range 0.8-1.0), and impact duration (range 0.25 to 1.0; normalized range 0.25 to 1.0). Debit value calculations for long-term or permanent impacts to Oregon chub habitat are the difference between the baseline calculation and the post-impact calculation.

Site descriptors

The following descriptive information is collected for each site: 1) site name, 2) geographic coordinates (Universal Transverse Mercator), 3) the name of the subbasin (4^{th} Field Hydrologic

Unit Code name and number), and the 4) Oregon chub recovery area from the Oregon Chub Recovery Plan (USFWS 1998).

Habitat area

This is a measure of the acreage of wetted surface area of a site at ordinary high water. Site boundaries can be mapped in the field using a Global Positioning System (GPS) and area can be obtained using GIS.

Habitat suitability

The suitability of a habitat incorporates four variables: habitat type, habitat quality, water quality, and piscivory risk. Each of these variables is quantified using field data collected during late-summer (August-September) and pre-determined mathematical relationships. The values for each parameter are multiplied together to determine the habitat suitability rating for each habitat unit.

Habitat (water body) type

This parameter ranks the type(s) of habitat present at the bank site or at the location that will be impacted by the proposed activity. Habitat units are delineated on the basis of three variables: water body type, water depth, and bathymetric characteristics of the submerged/benthic zone. The variables must be relatively homogeneous within each habitat unit (i.e., a single habitat unit cannot contain multiple categories for any of the three variables). Delineation of habitat units should reflect "late summer" conditions. This timing is based on the need to verify that the habitat unit is perennially inundated and to accurately describe important habitat characteristics. These ratings are used to account for intangible habitat elements that have been observed to be important for Oregon chub. If multiple habitat types occur at a location, the habitat quality rating (see below) is calculated for each habitat unit separately, and then summed for all habitat types present. Oregon chub prefer beaver ponds, oxbows, backwater pools, sloughs, open water ponds, riverine wetlands, and dammed pools (Scheerer 2002). These habitats are assigned a rating of 1.0. Less preferred habitats used by chub include secondary channel pools, lateral scour pools, stream or river corridors, ditches, seeps or springs, and ephemeral habitats. These habitats are assigned a rating of 0.8.

Habitat quality

The quality of physical habitat for Oregon chub is assessed during the late-summer (August-September) by rating the abundance and/or character of individual habitat elements that are particularly important for the species. The habitat quality rating is calculated for each habitat unit by summing the rating for each individual habitat element and dividing by 1.6, resulting in a normalized rating scale that ranges from 0 to 10. We chose ten versus one for the maximum normalized rating for habitat quality to avoid assigning only fractions of credits and debits at typical bank and impact sites.

1) *Water velocity*- Oregon chub prefer low velocity habitats (less than 30 cm sec^{-1}). If a habitat has less than 250 sq m of surface area (less than 25 percent of surface area at an impact site) with low velocities, we assign a rating of 0. If a habitat has 250 to 500 sq m of surface area (25 to 50 percent of surface area at an impact site) with low velocities, we assign a rating of 3. If a habitat has greater than 500 sq m of surface area (greater than 50 percent of surface area at an impact site) with low velocities, we assign a rating of 5.

2) *Aquatic vegetation (submergent and emergent)*- Oregon chub require aquatic vegetation for cover and spawning. If a habitat has less than 250 sq m of the surface area (less than 25 percent of surface area at an impact site) that is vegetated, we assign a rating of 0. If a habitat has 250 to 500 sq m (25 to 50 percent of surface area at an impact site) that is vegetated, we assign a rating of 3. If a habitat has more than 500 sq m (greater than 50 percent of surface area at an impact site) that is vegetated, we assign a rating of 5.

3) *Water depth*- Water depth is an important feature of Oregon chub habitats as it provides a measure of the risk of habitat desiccation (too shallow) and an indirect measure of the potential of a habitat to support emergent and submergent vegetation. Sites with maximum depths less than 0.5 meters are prone to desiccation during drought conditions. Ideal habitats range between 0.5 m and 2 m. If a habitat has less than 250 sq m of the surface area (less than 25 percent of surface area at an impact site) that is greater than 0.5 m deep, we assign a rating of 0. If a habitat has at least 250 sq m of the surface area (greater than 25 percent of surface area at an impact site) that is greater than 0.5 m deep and has less than 25 percent of the surface area that is less than 2 m deep, we assign a rating of 1. If a habitat has at least 250 sq m of the surface area (greater than 25 percent of surface area at an impact site) that is greater than 0.5 m deep and has 25 to 50 percent of the surface area that is less than 2 m deep, we assign a rating of 2. If a habitat has at least 250 sq m of the surface area (greater than 25 percent of surface area at an impact site) that is greater than 0.5 m deep and has greater than 50 percent of the surface area that is less than 2 m deep, we assign a rating of 3.

4) *Shoreline slope*- Shallow shorelines are important rearing habitat for larval and juvenile chub. If the majority of the shoreline of the habitat (defined as a 3 m band around the edges or perimeter of the site) is greater than 0.5 m deep or has steep side slopes that exceed 15:1 then we assign the

habitat a rating of 0. If the majority of the shoreline is less than 0.5 m deep and/or has shallow side slopes (less than 15:1) then we assign the habitat a rating of 3.

Water Temperatures

Water temperatures have the potential to exert strong influence on the viability of Oregon chub populations. Water temperature regimes can affect the success of chub spawning and high temperatures could be lethal for Oregon chub. If there is a high likelihood the maximum water temperature would exceed the upper lethal temperature for Oregon chub survival (29^{o}C) (Scheerer and McDonald 2003) then the habitat is assigned a rating of 0. If the maximum daily temperatures exceed the chub spawning threshold of 16^{o}C for fewer than 25% of the days during the spawning period (May 1 and August 31) then we assign the habitat a rating of 0.5. If the maximum daily temperatures exceed 16^{o}C for more than 25% of the days during the spawning period then we assign the habitat a rating of 1.0. If this variable is not measured at an impact site, then we assign a default value of 1.0.

Piscivory Risk

Predation by non-native fishes is a major threat to Oregon chub. Piscivory risk is assessed using two parameters: the presence/absence of non-native fish and the degree of habitat isolation (site connectivity). The piscivory risk rating is determined for each habitat using field data, maps, agency records and reports, communication with knowledgeable agency staff, and best professional judgment to assign the predation risk parameters. The piscivory risk rating is calculated for each habitat unit by summing the rating for each of these variables and dividing by 10, resulting in a normalized rating scale that ranges from 0.1 to 1.0.

1) *Site connectivity*- The connectivity or isolation of a habitat is a major factor determining the current distribution of abundant populations of Oregon chub (Scheerer 2002). Sites with high connectivity are at risk, due to the increased possibility of invasion of the habitat by non-native predatory fish. If a site has high connectivity, i.e., sites that are perennially connected with water courses containing non-native fishes, then we assign the habitat a rating of 1. If a site is intermittently connected with water courses containing non-native fishes (recurrence interval 2 to 10 years), then we assign the habitat a rating of 3. If the site has perennial isolation from water courses containing non-native fishes over multiple years (recurrence interval >10 years), or if adjacent waterways contain no non-native predators, then we assign the habitat a rating of 5. If this variable is not determined for an impact site, then we assign a default value of 3.
2) *Non-native fishes*- If non-native fishes are common or abundant at a site, we assign the habitat a rating of 1. If non-native fishes are present but one of the least abundant species sampled (site dominated by native fishes), then we assign the habitat a rating of 3. If non-native fishes are absent, then we assign the habitat a rating of 5. If this variable is not obtained at an impact site, then we assign a default value of 5.

Habitat Utility

The habitat utility rating for Oregon chub reflects habitat use by resident populations. This rating is determined for the entire project site, as it is extremely unlikely that more than one population will be present at a given site. The status of the Oregon chub population presently occupying a habitat, the proximity of a bank or impact site to existing chub populations, and the status of proximal chub populations are assessed by rating the abundance of the Oregon chub population relative to downlisting and delisting criteria in the Oregon Chub Recovery Plan (U.S.

Fish and Wildlife 1998). These parameters are important for assessing the value of a bank site or the effects of an impact site on the recovery status of the subpopulation in the Oregon chub recovery area and on the minimum viable population size of a directly impacted chub population. The habitat utility rating is calculated for each habitat unit by summing the rating for each of these variables and dividing by 9, resulting in a normalized rating scale that ranges from 0.22 to 1.

1) *Oregon chub abundance*- If no chub are present and volitional chub immigration is unlikely; then we assign the habitat a rating of 0. If no chub are present but there is a potential for volitional chub immigration, or the site is a candidate for reintroducing Oregon chub, then we assign the habitat a rating of 1. If chub are present and the population abundance is less than 50 fish, then we assign the habitat a rating of 2. If chub are present and the population abundance is between 50 and 500 fish, then we assign the habitat a rating of 3. If chub are present and the population abundance is greater than 500 fish, then we assign the habitat a rating of 4. If chub are present and the population abundance is greater than 500 fish and has a stable or increasing abundance trend for five years (Oregon Chub Recovery Plan criteria), then we assign the habitat a rating of 5. If this variable is not determined for an impact site, then we assign a default value of 5.
2) *Proximity to Oregon chub populations*- The potential beneficial effects of a bank site and conversely the potential detrimental effects of an impact site on the overall health of the subpopulation (metapopulation) are greater if the site is in close proximity to existing chub populations. If a site is greater than one kilometer from an existing chub population, then we assign the habitat a rating of 1. If a site is less than or equal to one kilometer from an existing chub population, then we assign a default rating of 2.

3) *Abundance and status of proximal chub population(s)* - If any proximal chub population (located within one kilometer) is abundant (500 or more adults) and has a stable or increasing 5-year trend, then we assign the habitat a rating of 2. If no proximal chub population exists, no proximal population is abundant (less than 500 adults), or the proximal population(s) has a declining 5-year trend, then we assign the habitat a rating of 1.

Habitat Integrity (Off-site risks of delivery of excessive sediments and/or toxic chemicals)

The habitat integrity rating for Oregon chub reflects the type and importance of off-site influences that affect the suitability and long-term viability of individual habitat units. The two factors used to assess habitat integrity, risk of excessive sediment delivery and risk of toxic chemical delivery, were determined from a review of threats in the Oregon Chub Recovery Plan (USFWS 1998) and through discussions with ODFW and USFWS species experts. If there are no off-site influences related to sedimentation and toxic chemicals, then we assign a rating of 1.0. If there is a risk of either excessive sediments or toxic chemical delivery, then we assign a rating of 0.9. If there was a risk of both factors, then we assign a rating of 0.8.

Duration of Project Impacts (Impact sites only)

Impacts of proposed activities on Oregon chub and their habitats differ according to the duration or longevity of the impact. Activities that reduce the quantity or quality of the habitat include, but are not limited to, reduction of the habitat area, reduction of the aquatic vegetation, reduction of the minimum water depth, alteration of the flow patterns at a site that would increase water velocity or channelization, increased piscivory risk, and decreased water quality, and impacts to bank or channel structure. Impact duration is measured from the start of the project. If impacts extend beyond two years (considered permanent), then we assign a rating of 1.0. If the impact duration is at least one year and less than two years, then we assign a rating of.0.75. If the duration of impacts is at least six months and less than one year, then we assign a rating of 0.5. If the duration of impacts is less than six months, then we assign a rating of 0.25.

Example of Credit Value Calculations

To illustrate the crediting system, we chose a proposed conservation bank site on the Middle Fork Willamette River to demonstrate the credit value calculations for evaluating baseline conditions and credit value uplift from habitat creation. As a review, credits for activities that create, restore, or enhance Oregon chub habitat and baseline habitat values for bank and impact sites are calculated by multiplying the normalized ratings for habitat area by the habitat suitability (which includes habitat type, habitat quality, and water quality) by the piscivory risk by the habitat utility by the habitat integrity.

Site descriptors

The site name is East Fork Minnow Creek Pond. The geographic coordinates (UTM) are zone 10T, easting 0521411, and northing 4859624. The subbasin name is the Middle Fork Willamette River (HUC 17090001). The Oregon chub recovery area is the Middle Fork Willamette River.

Habitat area (A_M)

We mapped the site and determined that there were 0.53 acres of chub habitat during the period of ordinary high water.

Habitat suitability (F_S)

The habitat type is a beaver pond (rating 1.0). The habitat quality rating is based on water velocity, aquatic vegetation, maximum depth, and shoreline slopes. More than 500 sq m of pond area has low velocities (rating 5). More than 500 sq m of pond area has submergent and/or emergent aquatic vegetation (rating 5). More than 250 sq m of pond area exceeds 0.5 m deep in depth and more than 50% of the pond area is less than 2 m deep (rating 3). The majority of shoreline is less than 0.5 m deep and has shallow side slopes (rating 3). The water temperature rating was based on data from field measurements (recording thermographs). The maximum daily temperatures exceeded 16^{o}C for more than 25% of days during spawning period (rating 1.0). The piscivory risk is based on site connectivity and presence of nonnative fishes. The site has perennial isolation from water courses containing non-native fishes over multiple years (rating 5) and non-native fishes are absent (rating 5). The habitat suitability rating is calculated as:

$$F_S = 1.0 \text{ x } ((5 + 5 + 3 + 3) / 1.6) \text{ x } 1.0 \text{ x } (10 / 10) = 10$$

Habitat utility (F_U)

The habitat utility is based on Oregon chub abundance at the site, the proximity of the site to existing Oregon chub populations, and the abundance and status of proximal Oregon chub populations. Oregon chub are present at the site, the population abundance exceeds 500 fish, and the 5-year abundance trend has been declining (rating 4). The site is less than one kilometer from an existing chub population (rating 2) and the proximal chub population has a declining 5-year trend (rating 1). The habitat utility rating is calculated as:

$$F_U = (4 + 2 + 1) / 9 = 0.78$$

Habitat integrity (F_I)

There is a risk of off-site sedimentation from logging and a major highway is situation immediately upslope of the site (rating 0.8).

Duration of project impacts (F_D): not applicable (default rating 1).

Baseline Recovery Credit Calculations (S_M)

$$S_M = A_M \text{ x } F_S \text{ x } F_U \text{ x } F_I \text{ x } F_P$$

$$S_M = 0.53 \text{ x } 10 \text{ x } 0.78 \text{ x } 0.8 = 3.30$$

A restoration project was completed at this site to increase the area of suitable habitat for Oregon chub. A total of 0.31 acres of habitat was excavated and connected to the existing habitat in the summer of 2008. Excavated materials were placed upslope from the pond creating a berm that acts to minimize potential runoff or spills from the adjacent highway. The habitat integrity rating for the newly created habitat was 0.9. Likewise, the habitat integrity rating for the baseline habitat improved to 0.9. The habitat quality rating for the aquatic vegetation subcomponent was 5.0, despite lack of vegetation, because a sufficient amount of suitable vegetation exists in the pre-existing habitat and the created habitat was connected to pre-existing habitat. All other ratings were the same for the existing and the created habitat. The subsequent post-construction credit calculations were calculated separately for the existing and newly created habitats.

Future Recovery Credit Calculations (S_M)

$$S_M = (0.53 \times 10 \times 0.78 \times 0.9) + (0.31 \times 10 \times 0.78 \times 0.9)$$

$$S_M = 3.71 + 2.17 = 5.88$$

Example of Debit Value Calculations

To further illustrate the crediting system, we used data from a bridge replacement project (impact site) on the Row River to demonstrate the debit value calculations. In this example, the removal of a bridge abutment resulted in loss of a small backwater slough that formed behind the channel obstruction (abutment).

Site descriptors

The site name is Row River Interstate Bridge. The geographic coordinates (UTM) are zone 10T, easting 0497059, and northing 4851280. The subbasin name is the Coast Fork Willamette River (HUC 17090002). The Oregon chub recovery area is the Coast Fork Willamette River.

Habitat area (A_M)

The area of chub habitat impacted at the site is 293 sq m (0.07 acres).

Habitat suitability (F_S)

The habitat type is a backwater (rating 1.0). The habitat quality rating is based on water velocity, aquatic vegetation, maximum depth, and shoreline slopes. More than 50% of the site area has low velocities (rating 5). More than 50% of site area has submergent and/or emergent aquatic vegetation (rating 5). More than 25% of the wetted area exceeds 0.5 m deep in depth and less than 50% of the site area is less than 2 m deep (rating 3). The majority of shoreline is less than 0.5 m deep and has shallow side slopes (rating 3). Water temperatures data was not available (default rating 1.0). The piscivory risk is based on site connectivity and presence of nonnative fishes. The site has perennial connectivity to the mainstem of the river which contains non-native fishes over multiple years (rating 0); non-native fishes are not present at the site (rating 5). The habitat suitability rating is calculated as:

$$F_S = 1.0 \text{ x } ((5 + 5 + 3 + 3) / 1.6) \text{ x } 1.0 \text{ x } (5 / 10) = 5$$

Habitat utility (F_U)

The habitat utility is based on Oregon chub abundance at the site, the proximity of the site to existing Oregon chub populations, and the abundance and status of proximal Oregon chub populations. Oregon chub are not present at the site, but there is a potential for volitional immigration (rating 1). The site is more than one kilometer from an existing chub population (rating 1) and the proximal chub population is not abundant (rating 1). The habitat utility rating is calculated as:

$$F_U = (1 + 1 + 1) / 9 = 0.33$$

Habitat integrity (F_I)

There is no risk of off-site sedimentation. There is a risk of spills from the highway (rating 0.9).

Duration of project impacts (F_D):

Duration of impacts was more than 6 months and less than 1 year (rating 0.5).

Baseline Recovery Credit Calculations (S_M)

$$S_M = A_M \times F_S \times F_U \times F_I \times F_D$$

$$S_M = 0.07 \times 5 \times 0.33 \times 0.9 \times 0.5 = 0.05$$

Discussion

Jelks et al. (2008) identified habitat destruction and degradation as the most widespread threat to imperiled fishes, affecting ninety-two percent of the species. Most species on the endangered species list have the majority of their habitat on private lands and species that occur exclusively on non-federal lands (primarily private lands) are faring worse than species that occur primarily on federal lands (Wilcove et al. 1996). The long-term survival of most endangered species depends not only on our ability to prevent further losses, but also on our ability to increase their populations by restoring degraded habitats, often on private lands (Wilcove and Lee 2004).

Conservation banking is a relatively new tool that provides managers with the ability to enhance the status of threatened and endangered species on private lands (U.S. Fish and Wildlife Service 2003). A conservation bank is a parcel of private property that is conserved and managed in perpetuity under a conservation easement for the benefit of rare species. The party that holds the easement is granted credits by a federal or state agency for the land's species and habitat value. A bank owner may use or sell the credits within a pre-designated service area to address mitigation required by state of federal law (USFWS 2003). While banking may not increase the quantity of suitable habitat for a species, it may result in the conservation of higher quality habitat for a species (Fox and Nino-Murcia 2005).

Conservation banking provides an ecologically effective and economically efficient alternative to traditional site-specific mitigation as a means to fulfill compensatory mitigation requirements. Site-specific mitigation is often not biologically advantageous because small, isolated patches of habitat often do not provide viable habitat for listed species. By exchanging habitats that are isolated and/or have a low probability of long-term viability for suitable habitat that is strategically located relative to other endangered species populations, banking offers an opportunity not only to compensate for habitat losses but also to enhance the prospect for long-term survival of listed species (Bonnie et al. 1999). One of the conservation banking's greatest assets is the long-term management requirement, which provides stability both from an ecological and economic standpoint (Federal Register 1999). In addition, because the number of credits that a bank earns is a function of the how successful species or habitats are restored, bankers are given a strong economic incentive to do the best restoration job possible. Conversely, developers are given a strong economic incentive to minimize impacts and/or avoid areas with the highest resource values. The economic incentives of conservation banking often compete with other commercial development and provide a business argument for conserving land (Bonnie 1999). In addition, the preservation of species habitats often does not preclude other beneficial uses such as grazing, timber harvest, hunting, tourism, and low density housing (Ruhl et al. 2005).

Failure of many past mitigation projects to replace in-kind habitats is well documented (Ambrose 2000; Ambrose et al. 2006; DeWeese 1994; Spieles 2005) and can have deleterious impacts on imperiled species. To remedy this situation, there has been much recent effort to develop biologically defensible criteria based on habitat functionality to determine mitigation ratios (Bonds and Pompé 2003; Bruggeman et al. 2005; Searcy and Shaffer 2008; Stein et al. 2000).

We developed a simple, biologically based approach to determine species credits and debits for the endangered Oregon chub in the Willamette Valley of western Oregon based on assessing changes in the structural, functional, and population characteristics of both impact and mitigation sites. These characteristics were used as indicators of ecologic condition of the aquatic resource and change was assessed by evaluating conditions before and after alterations to the site. Accounting parameters were identified through prior research focused on the habitat and life history requirements of the species, including data from successful restoration projects and species reintroductions (Pearsons 1989; Markle et al. 1991; U.S. Fish and Wildlife Service 1998; Scheerer 2002; Scheerer and McDonald 2003; Scheerer 2007a; 2007b; Scheerer et al. 2007). By placing more emphasis (weighing) on the population response (population abundance and 5-year trends), our credit-debit system encourages recovery through the protection, restoration, and/or creation of functional banks that support genetically viable populations. Our credit-debit system also discourages major impacts to, or impacts in close proximity to, abundant viable populations by increasing the amount of mitigation required. This represents a spatial component that has been encouraged by many authors (Stein et al. 2000; Bonds and Pompé 2003; Ruhl et al. 2005; Bruggeman et al. 2005; Searcy and Shaffer 2008) and also addresses the concept of minimal viable population size.

To assure adequate compensatory mitigation, it is essential that fisheries scientists develop biologically accurate species accounting methods to determine debits and credits and to develop, monitor, and manage credits at banks where credits are awarded for conservation outcomes (i.e. habitat functionality and species response) (Bauer et al. 2004). The need to assess species credits will increase as more conservation banks are developed. The choice of parameters that will form the foundation for species accounting will be determined, in large part, by the quality and quantity of life history and species-habitat data that is known about the species. For well studied species, it may be possible to replace categorical functions with continuous distribution functions (Searcy and Shaffer 2008) to assign habitat values for a species. However, this approach requires substantial knowledge of habitat-species density relationships that may not be available for many rare species.

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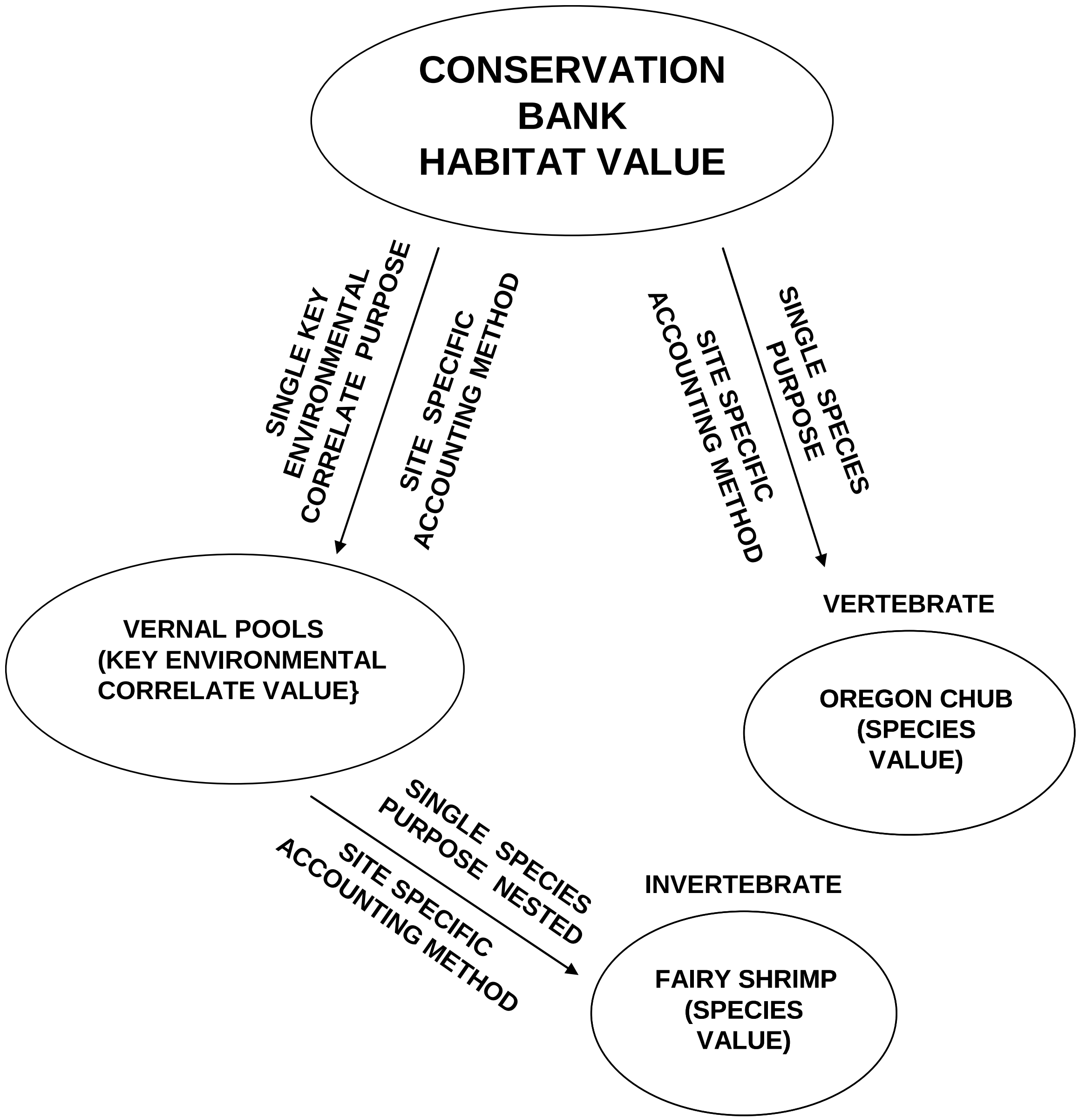
Figure 1. Conceptual approach showing conservation banking using the Recovery Crediting System that is driven by a site specific accounting method for either an individual vertebrate species value or a key environmental correlate value with a nested individual species value for invertebrates (modified from Johnson and O'Neil 2001).


CONSERVATION
BANK
HABITAT VALUE
SINGLE KEY
ENVIRONMENTAL
CORRELATE PURPOSE
SITE SPECIFIC
ACCOUNTING METHOD
SITE SPECIFIC
ACCOUNTING METHOD
SINGLE SPECIES
PURPOSE
VERNAL POOLS
(KEY ENVIRONMENTAL
CORRELATE VALUE}
VERTEBRATE
OREGON CHUB
(SPECIES
VALUE)
SINGLE SPECIES
PURPOSE NESTED
SITE SPECIFIC
ACCOUNTING METHOD
INVERTEBRATE
FAIRY SHRIMP
(SPECIES
VALUE)