FEATURE:
FISH HABITAT

A Species Crediting Methodology that Supports Conservation Banking for an Endangered Floodplain Minnow

ABSTRACT: Conservation banks are permanently protected lands that contain habitat elements which may be critical to the protection and recovery of federally-listed species under the Endangered Species Act. These banks are managed in perpetuity and used to mitigate impacts occurring elsewhere to the species' habitat. We developed a species crediting methodology to assess conservation credits and debits for the endangered Oregon chub (*Oregonichthys crameri*) to support conservation banking. Our methodology is based on prior studies assessing relationships between population abundance and habitat parameters for the species. The methodology also incorporates ratings for piscivory risk, site location, and the abundance and status of existing and proximal populations. Our approach assigns more credits to functioning bank sites that support abundant, stable populations and requires more credits when impacted sites negatively affect these populations. Examples show the credit value calculations for determining baseline conditions and for assessing impacts to species habitat. Additional examples illustrate the incentives for creating habitats that support abundant, stable populations and the incentives for reducing the severity and duration of impacts to habitats. As the demand for economic development of prime fish habitat increases and as more conservation banks are developed, managers may benefit by developing similar crediting methodologies to promote adequate compensatory conservation for imperiled species.

Metodología de acreditación de especies para apoyar la creación de bancos de conservación para un ciprínido amenazado

RESUMEN: Los bancos de conservación son tierras permanentemente protegidas que contienen elementos de un hábitat que pueden ser críticos para la protección y recuperación de especies enlistadas dentro del Acta Federal de Especies Amenazadas. Estos bancos son administrados a perpetuidad y utilizados para mitigar los impactos que ocurren en otras partes del hábitat de las especies. En el presente trabajo se desarrolló una metodología de acreditación para evaluar los créditos y débitos de conservación del chub de Oregon (*Oregonichthys crameri*) y que apoyan la conservación a través de este instrumento. Nuestra metodología se basa en estudios previos que evalúan las relaciones entre la abundancia poblacional y los parámetros que definen el hábitat de la especie. La metodología también incorpora una clasificación de riesgo por piscivoría, ubicación del sitio, la abundancia y estado de las poblaciones existentes y proximales. Nuestro enfoque le asigna más créditos a aquellos bancos funcionales que sostienen poblaciones abundantes y estables y demanda de más créditos cuando los sitios impactados afectan negativamente estas poblaciones. Los ejemplos muestran el valor calculado de los créditos para determinar las condiciones de línea-base y evaluar los impactos de las especies en el hábitat. A medida que se incrementen las demandas de desarrollo económico para los principales hábitats de peces y mientras más bancos se establezcan, los manejadores pueden beneficiarse si desarrollasen metodologías crediticias similares que promuevan una adecuada conservación compensatoria para especies amenazadas.

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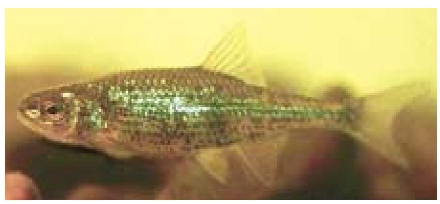
The U. S. Endangered Species Act (ESA) prohibits "taking," harming, or harassing of threatened and endangered species. When impacts to a species or its habitat are unavoidable, the U. S. Fish and Wildlife Service (USFWS) may permit activities which otherwise violate the "take" prohibition through the issuance of incidental take 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.

Conservation banking is designed to facilitate this compensatory mitigation process (USFWS 2003). In this context, conservation banks are properties that contain natural resource values that are conserved and managed in perpetuity to provide permanent conservation benefits to listed species to compensate for adverse impacts to those species at other locations. These banks have dedicated long-term stewardship funding and management plans, and are often managed through a conservation easement held by an entity, typically a land



trust, responsible for enforcing the terms of the easement (USFWS 2003). The conservation values accruing to the species within the bank habitat area are translated by the regulatory authority into qualified "credits," and assigned in proportion to their conservation accomplishments (USFWS 2003). Subsequently, adverse impacts to the species resulting from a development project are quantified through the permitting process into mitigation needs or "debits" (Ruhl et al. 2005).

Conservation banking for ESA-listed species was patterned, in part, after wetlands mitigation banking (Federal Register 1995). The difference between the two is that conservation banks are designed to improve the status of one or more listed fish or wildlife species through habitat management, while wetland mitigation banks are developed to replace a specific wetland habitat type, with an emphasis on, and preference for, the exchange of like-kind wetlands located within the bank's service area, so that there is no net loss of that habitat. Conservation banking focuses on improving the status of an imperiled species, 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). The first such 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).

The two primary financial reasons for establishing conservation banks are to sell credits for profit or to use credits internally to reduce permitting costs. Benefits of banks over conventional mitigation can include: (1) the preservation or enhancement of substantially larger habitats with better habitat connectivity and long-term conservation value than the creation of smaller, isolated, and often fragmented habitats with little long-term conservation value (Federal Register 1995), and (2) the creation of a streamlined permitting process that reduces costs, improves environmental compliance efforts, and creates ecologically sustainable projects.

Conservation banks may allow a private landowner to transform a situation they perceived to be a legal liability, the presence of a listed species, into a financial asset through conservation credits (USFWS 2003; Fox and Nino-Murcia 2005). Landowners are offered economic incentives to protect natural resources, developers save time and money using pre-approved compensation banks, and the species is provided long-term protection on certain private lands (Bonnie 1999). Because the number of credits a bank earns is a function of how successfully species or habitats are restored, conservation 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. 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).

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 the 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.

The currency of a conservation bank represents the units of measure according to which the number of credits: (1) quantifies the natural resource (species or habitat) values conserved at a bank site into credits, and (2) quantifies the adverse impacts of activities into debits that developers must purchase as credits from a bank (Bauer et al. 2004). A number of biological criteria 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. Many early methods used "best professional judgment" as the basis of habitat assessment for mitigation banking, where species habitat experts ranked habitat quality and assigned compensation ratios. In the absence of suitable data, this approach may have been the best achievable method to assign compensation ratios. However, this methodology is subjective and can lack repeatability (Searcy and Shaffer 2008). Recent approaches for measuring habitat quality and function include assessments based on species composition or habitat suitability for specific indicator species, the use of biotic indices, and landscape-level assessments using geographic information systems (GIS). Searcy and Shaffer (2008) assigned conservation 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.

In this article, we describe a debit and credit accounting methodology for an endangered floodplain minnow, Oregon chub (*Oregonichthys crameri*), with a goal of ensuring that compensatory mitigation and conservation actions adequately address impacts to the species, habitat, and ecosystem function in the Willamette Valley, Oregon. To our knowledge, our methodology represents the first published approach to assigning conservation credits for an imperiled freshwater fish. This accounting system was developed in response to an anticipated demand for credits resulting from a major bridge replacement program in Oregon. We believe this methodology may be useful as a template for developing similar accounting methodologies to support conservation banking for other imperiled fishes. We start by describing the species and its habitat preferences, followed by descriptions of the conservation bank and habitat assessment methodology, descriptions of the model parameters (including rating and weighing), examples of credit and debit calculations, examples of incentives for creating functional banks and for minimizing development impacts, and a discussion of the merits and drawbacks of conservation banking for the recovery of imperiled species.

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 substrates, 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. Oregon chub spawning occurs in shallow vegetated areas of ponds and sloughs beginning in May and continuing through early August at temperatures ranging from 15° to 21°C (Pearsons 1989; Scheerer and McDonald 2003). Peak spawning typically 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°C), no spawning occurs and the gonads do not mature (Scheerer and McDonald 2000).

The reduction of suitable habitat, the threat of predation from nonnative fishes, and the restricted distribution of the Oregon chub resulted in its listing as endangered throughout its range under the federal ESA (Markle and Pearsons 1990; Federal Register 1993). This species was formerly distributed throughout the Willamette Valley floodplain in a dynamic of off-channel habitats (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; Li et al. 1987; Benner and Sedell 1997). In addition, nonnative 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). 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 nonnative fish occurrence (Scheerer 2002). Sites with low connectivity typically support larger populations of Oregon chub and contain fewer species of nonnative fish than sites with high connectivity (Scheerer 2002).

THE CONSERVATION BANK AND HABITAT ASSESSMENT METHODOLOGY

In 2004, the Oregon Department of Transportation (ODOT), along with several partnering agencies, developed a statewide conservation banking program to fundamentally improve ODOT's approach to addressing habitat mitigation, habitat conservation, and species recovery (Warncke 2006). A 25-acre multi-species conservation bank is being developed in Lane County, Oregon, to address the protection and recovery of the Oregon chub. Formation of this bank was necessitated by the replacement of a series of aging bridges, with anticipated impacts to Oregon chub habitats and a need for species credits. To support the banking program, we developed a debit and credit accounting methodology with a goal of ensuring that compensatory mitigation and conservation actions adequately address impacts to Oregon chub, their habitats, and the functions of those habitats (ODOT 2005).

A habitat assessment methodology was patterned after the species and habitat associations described in "Wildlife-Habitat Relationships in Oregon and Washington" (Johnson and O'Neill 2001). The Oregon chub accounting methodology was developed 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 methodology, thereby allowing a straightforward assessment and exchange of debits and credits. Based on measured 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 methodology can be used to determine the credit value resulting from habitat restoration, creation, enhancement, and preservation.

The Oregon chub accounting methodology 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, presence of nonnative predatory fish, and water quality concerns. In addition, the model incorporates population 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 existing or proximal Oregon chub populations.

DESCRIPTION OF MODEL PARAMETERS

The debit-credit calculations integrate five primary factors: habitat area, habitat suitability, 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:

$$S_M = A_M \times F_S \times F_U \times F_I \times F_D \times 100,$$

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 piscivory risk; F_U is the habitat utility rating of the site and is based on chub presence, proximity to other chub populations, and abundance and 5-year trend of existing and/or proximal chub populations; F_I is the habitat integrity rating of the site and is based on the 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. To avoid working exclusively with fractions of credits, we multiply the product of these parameters by 100.

We normalized all parameters prior to running the model (Table 1). All parameters, with the exception of impact duration,

Table 1. Model parameter ratings and ranges of normalized values used in the Oregon chub accounting methodology.

Model parameter	Ratings	Range of normalized values
Habitat suitability		
Habitat type	0.5, 0.75, 1.0	0.5 – 1.0
Habitat quality		0.2 – 1.0
Water velocity	1, 3, 5	
Aquatic vegetation	1, 3, 5	
Water depth	1, 3, 5	
Shoreline	1, 3, 5	
Water temperatures	1, 3, 5	
Piscivory risk		0.2 – 1.0
Site connectivity	1, 3, 5	
Nonnative fishes	1, 3, 5	
Habitat utility		0.13 – 1.0
Oregon chub presence	1, 3, 5	
Oregon chub abundance	1, 3, 5	
Population status	0, 1, 5	
Habitat integrity	0.5, 0.75, 1.0	0.5 – 1.0
Impact duration	1, 2, 3	1.0 – 3.0

are weighted equally in the model. Impact duration was weighted more heavily to provide a strong incentive to minimize the longevity of impacts and to minimize the probability of a net loss of suitable habitat when credits are exchanged. Debit value calculations for impacts to Oregon chub habitat are the difference between the baseline or pre-impact calculation and the post-impact calculation (based on post-impact measurements).

Habitat area (A_M)

This is a measure of the acreage of wetted surface area of a site at ordinary high water. Site boundaries are mapped in the field using a global positioning system (GPS) and area is obtained using geographic information systems (GIS).

Habitat suitability (F_S)

The suitability ranking of a habitat includes three variables: habitat type, habitat quality, and piscivory risk. Each of these variables is quantified using field data collected during late-summer (August-September). The normalized values for each parameter are multiplied together to calculate the habitat suitability rating for each habitat unit.

Habitat 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 (Scheerer 2002). If multiple habitat types occur at a location, the habitat quality rating 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, and seeps or springs. These habitats are assigned a rating of 0.75. Ephemeral habitats may be utilized as migratory corridors or as seasonal spawning or rearing areas. These habitats are assigned a rating of 0.5.

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 (water velocity, aquatic vegetation, water depth, shoreline rearing habitat, and water temperature) 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 25, which results in a normalized rating scale that ranges from 0.2 to 1.0.

(1) *Water velocity*—Oregon chub prefer low velocity habitats (typically less than ~30 cm/s). If a habitat has less than 250 m^2 of surface area (or less than 25% of surface area at an impact site) with low velocities, we assign a rating of 1. If a habitat has 250 to 500 m^2 of surface area (or 25 to 50% of surface area at an impact site) with low velocities, we assign a rating of 3. If a habitat has greater than 500 m^2 of surface area (or greater than 50% 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 m^2 of the surface area (or less than 25% of surface area at an impact site) that is vegetated, we assign a rating of 1. If a habitat has 250 to 500 m^2 of habitat (or 25 to 50% of surface area at an impact site) that is vegetated, we assign a rating of 3. If a habitat has more than 500 m^2 of habitat (or greater than 50% 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 m^2 of the surface area (or less than 25% of surface area at an impact site) that is greater than 0.5 m deep, we assign a rating of 1. If a habitat has at least 250 m^2 of the surface area (or greater than 25% of surface area at an impact site) that is greater than 0.5 m deep and has less than 50% of the surface area that is less than 2 m deep, we assign a rating of 3. If a habitat has at least 250 m^2 of the surface area (or greater than 25% of surface area at an impact site) that is greater than 0.5 m deep and has at least 50% of the surface area that is less than 2 m deep, we assign a rating of 5.

(4) *Shoreline rearing habitat*—Shallow shorelines are important rearing habitat for larval and juvenile chub. If less than 25% of the shoreline of the habitat (defined as a 3 m band around the edges or perimeter of the site) is less than 0.5 m deep and/or has shallow side slopes (less than 10:1) then we assign the habitat a rating of 1. If between 25% and 50% of the shoreline is less than 0.5 m deep and/or has shallow side slopes (less than 10:1) then we assign the habitat a rating of 3. If greater than 50% of the shoreline is less than 0.5 m deep and/or has shallow side slopes (less than 10:1) then we assign the habitat a rating of 5.

(5) *Water Temperatures*—Water temperatures have the potential to exert strong influence on the viability of Oregon chub populations by affecting the success of chub spawning and survival of larval chub. Water temperature is monitored using a continuous temperature logger. If the maximum daily temperatures exceed the chub spawning threshold of 16°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 1. If the maximum daily temperatures exceed 16°C for 25% to 50% of the days during the spawning period, then we assign the habitat a rating of 3. If the maximum daily temperatures exceed 16°C for more than 50% of the days during the spawning period, then we assign the habitat a rating of 5. If this variable is not measured at an impact site, then we assign a default value of 5.

Piscivory risk—Predation by nonnative fishes is a major threat to Oregon chub (USFWS 1998; Scheerer 2002). Piscivory risk is assessed using two parameters: the presence/absence of nonnative 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 both of these variables and dividing by 10, resulting in a normalized rating scale that ranges from 0.2 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 nonnative predatory fish. If a site has high connectivity, i.e., sites that are perennially connected with water courses containing nonnative fishes, then we assign the habitat a rating of 1. If a site is intermittently connected with water courses containing nonnative 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 nonnative fishes over multiple years (recurrence interval greater than 10 years), 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) *Nonnative fishes*—If nonnative fishes are common or abundant at a site, then we assign the habitat a rating of 1. If nonnative 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 nonnative fishes are absent, 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.

Habitat Utility (F_U)

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 presence of Oregon chub at or in close proximity to a bank or impact site, the abundance of existing or proximal chub population(s), and the status (5-year abundance trend) of existing or proximal chub population(s) are important for assessing the value of a bank site or the effects of an impact site on the recovery status of populations within each Oregon chub recovery area. Abundance and status categories were based on downlisting and delisting criteria in the Oregon Chub Recovery Plan (USFWS 1998). The habitat utility rating is calculated for each habitat unit by summing the rating for each of these variables and dividing by 15, resulting in a normalized rating scale that ranges from 0.13 to 1.

Oregon chub presence—The potential beneficial effects of a bank site and conversely the potential detrimental effects of an impact site on the overall status of the populations in a recovery area are greater if Oregon chub are present at the site or if the site is in close proximity to existing chub populations. Because Oregon chub are poor swimmers and most migratory corridors in the Willamette Valley have abundant populations of nonnative predators, we feel that migration distances greater than 1 kilometer are rare. Therefore, we chose 1 km as a cut-off when assigning our ratings. If no chub are present and volitional chub immigration is unlikely, then we assign the habitat a rating of 1. If no chub are present, but there is a potential for volitional chub immigration and the nearest proximal chub population is greater than 1 km, then we assign the habitat a rating of 3. If chub are present or there is a potential for volitional chub immigration and a proximal chub population exists within 1 km of the site, then we assign the habitat a rating of 5.

Oregon chub population abundance—If Oregon chub are present at the site or at a proximal location (less than 1 km) and the population abundance is less than 50 fish, then we assign the habitat a rating of 1. 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 5. Population abundance is obtained using single-sample mark-recapture protocols (Ricker 1975). If this variable is not determined for an impact site, then we assign a default value of 5.

Status of existing or proximal chub population(s)—If no chub are present and no proximal chub population exists, then we assign the habitat a rating of 0. For impact sites, if an existing or proximal chub population (located within 1 km) has a stable or increasing 5-year trend, then we assign the habitat a rating of 1. For impact sites, if an existing or proximal chub population (located within 1 km) has a declining 5-year trend, then we assign the habitat a rating of 5 (i.e., more credits are needed if an activity negatively affects a declining population). For bank sites, if an existing or proximal chub population (located within 1 km) has a declining 5-year trend, then we assign the habitat a rating of 1. For bank sites, if an existing or proximal chub population (located within 1 km) has a stable or increasing 5-year trend, then we assign the habitat a rating of 5 (i.e., more credits are awarded if a bank site supports a stable or increasing population).

Habitat Integrity (F_I)

The habitat integrity rating for Oregon chub reflects the off-site risks of delivery of excessive sediments or toxic chemicals that affect the suitability and long-term viability of individual habitat units. These factors 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 0.75. If there is a risk of both factors, then we assign a rating of 0.5.

Duration of Project Impacts (F_D)

Impacts of proposed activities on Oregon chub and their habitats differ according to the duration or longevity of the impact at the site. 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, decreased water quality, and impacts to bank or channel structure. Impact duration is measured from the start of the project until the end of impacts. The longer the habitat is impacted, the more credits that are needed. To determine the impact duration, the site is visited at six-month intervals for the first two years. If impacts extend beyond two years, they are considered permanent and assigned a rating of 3. If the impact duration is at least six months and less than two years, we assign a rating of 2. If the duration of impacts is less than six months, we assign a rating of 1.

ASSIGNMENT OF RATINGS AND PARAMETER WEIGHTING

The ratings that we assigned to the parameters included in the model were based on an evaluation of their relative effects on the total calculated species values (credits or debits) using a sensitivity analysis (Table 2). We started by assigning three ratings (1, 3, and 5) to each additive component variable comprising the habitat quality, piscivory risk, and habitat utility parameters and by assigning three ratings (0.5, 0.75, and 1.0) to the habitat type and habitat integrity parameters (multiplicative parameters). When these parameters were normalized, each parameter had a maximum normalized value of 1.0. Finally, we assigned three ratings (1, 2, and 3) to the impact duration parameter. We chose a minimum rating (and normalized value) of 1 for impact duration, so that this parameter would not result in a reduction in the number of credits needed for short-term impacts and would result in higher ratings for longer-term impacts as an incentive to encourage developers to minimize impact duration. We then evaluated the proportional change in credits that resulted when the rating for each parameter was changed from the maximum value to each lesser rating to assess the magnitude of the influence of each model parameter. Each time we made a major modification to the model, we presented the model and the sensitivity analysis to the agencies involved (ODFW, ODOT, and USFWS) to seek feedback and consensus agreement regarding the relative influence of the rating and weighting of the model parameters on the calculated species values.

Table 2. Sensitivity analysis for Oregon chub accounting model parameters. The values represent the percentage change in total credits as the rating for each parameter is reduced from the maximum rating to a lesser rating, and all other parameters remain unchanged.

Model parameter	Ratings	Percentage change from maximum rating		
Habitat suitability				
Habitat type	0.5, 0.75, 1.0	50%	25%	0%
Habitat quality				
Water velocity	1, 3, 5	16%	8%	0%
Aquatic vegetation	1, 3, 5	16%	8%	0%
Water depth	1, 3, 5	16%	8%	0%
Shoreline	1, 3, 5	16%	8%	0%
Water temperatures	1, 3, 5	16%	8%	0%
Piscivory risk				
Site connectivity	1, 3, 5	40%	20%	0%
Nonnative fishes	1, 3, 5	40%	20%	0%
Habitat utility				
Oregon chub presence	1, 3, 5	27%	13%	0%
Oregon chub abundance	1, 3, 5	27%	13%	0%
Population status	0, 1, 5	33%	27%	0%
Habitat integrity	0.5, 0.75, 1.0	50%	25%	0%
Impact duration	1, 2, 3	67%	33%	0%

EXAMPLE OF CREDIT VALUE CALCULATIONS

We will use the proposed East Fork Minnow Creek 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 restoration (Table 3). This site is within the Oregon chub recovery area on the Middle Fork Willamette River. The area of the bank site was 0.53 acres ($A_M = 0.53$) and 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. Most of the pond area (> 500 m^2) has low velocities (rating 5), submergent and/or emergent aquatic vegetation (rating 5), and exceeds 0.5 m deep in depth (rating 5). More than 50% of the pond area is less than 2 m deep (rating 5) and the majority of shoreline is less than 0.5 m deep and has shallow side slopes (rating 5). Maximum daily water temperatures exceeded 16ºC for more than 50% of days during spawning period (rating 5). The piscivory risk is based on site connectivity and presence of nonnative fishes. The site has perennial isolation from water courses containing nonnative fishes over multiple years (rating 5) and nonnative fishes are absent (rating 5). The calculation for habitat suitability (F_S) is thus:

$$F_S = 1.0 \text{ x } ((5 + 5 + 5 + 5 + 5) / 25) \text{ x } ((5 + 5) / 10) = 1.0$$

Habitat utility (F_U) is based on Oregon chub presence, abundance of existing or proximal Oregon chub populations, and the status of existing or proximal Oregon chub populations. Oregon chub are present at the site (rating 5), chub abundance is greater than 500 fish (rating 5), and the existing chub population has a declining 5-year trend (rating 3). The calculation for habitat utility is thus:

$$F_U = (5 + 5 + 3) / 15 = 0.87$$

There is a risk of off-site sedimentation from logging and a major highway is situated immediately upslope of the site. The habitat integrity (FI) rating is thus 0.5. The duration of project impacts parameter (F_D) does not apply to conservation bank sites.

Baseline Recovery Credit Calculations (S_M)

$$S_M = A_M \text{ x } F_S \text{ x } F_U \text{ x } F_I \text{ x } F_D \text{ x } 100$$

$$S_M = 0.53 \text{ x } 1.0 \text{ x } 0.87 \text{ x } 0.5 \text{ x } 100 = 23.1$$

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 0.75. Likewise, the habitat integrity rating for the baseline habitat improved to 0.75. 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 (Table 3). The subsequent post-construction credit calculations were calculated separately for the existing and newly created habitats and summed.

Future Recovery Credit Calculations (S_M)

$$S_M = (0.53 \text{ x } 1.0 \text{ x } 0.87 \text{ x } 0.75 \text{ x } 100) + (0.31 \text{ x } 1.0 \text{ x } 0.87 \text{ x } 0.75 \text{ x } 100)$$

$$S_M = 34.6 + 20.2 = 54.8$$

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 (Table 3). In this example,

Table 3. Site areas, habitat and population parameter ratings, and credit value calculations for an Oregon chub conservation bank, pre- and post-restoration, and a bridge impact site.

Site name	Minnow Pond (pre-)	Minnow Pond (post-)	Row River Slough
Habitat area (acres)	(A_m = 0.53)	(A_m = 0.84)	(A_m = 0.07)
Habitat suitability	(F_S = 1.0)	(F_S = 1.0)	(F_S = 0.8)
Habitat type	1.0	1.0	1.0
Habitat quality			
Velocity	5	5	5
Vegetation	5	5	5
Depth	5	5	5
Shoreline	5	5	5
Temperatures	5	5	5
Piscivory risk			
Isolation	5	5	1
Nonnatives	5	5	5
Habitat utility	(F_U = 0.87)	(F_U = 0.87)	(F_U = 0.27)
Chub presence	5	5	3
Chub abundance	5	5	1
Chub status	3	3	0
Habitat integrity	(F_I = 0.5)	(F_I = 0.75)	(F_I = 0.75)
Impact duration	n/a	n/a	(F_D = 3)
Credit value	23.1	54.8	4.5

the removal of a bridge abutment may result in loss of a small backwater slough that formed behind the channel obstruction (abutment). The Oregon chub recovery area is the Coast Fork Willamette River (note that the conservation bank service area includes both the Middle Fork and Coast Fork Willamette River). The habitat area (A_M) of chub habitat impacted was 0.07 acres and the habitat type is a backwater pool (rating 1.0). More than 50% of the site area has low velocities (rating 5) and submergent and emergent aquatic vegetation (rating 5). More than 25% of the wetted area exceeds 0.5 m deep in depth and more than 50% of the site area is less than 2 m deep (rating 5). The majority of shoreline is less than 0.5 m deep and has shallow side slopes (rating 5). Water temperature data were not available (default rating 1.0). The piscivory risk is based on site connectivity and presence of nonnative fishes. The site has intermittent connectivity to the mainstem of the river which contains nonnative fishes over multiple years (rating 3); nonnative fishes are not present at the site (rating 5). The calculation for habitat suitability (F_S) is thus:

$$F_S = 1.0 \text{ x } ((5 + 5 + 5 + 5 + 5) / 25) \text{ x } ((3 + 5) / 10) = 0.8$$

Oregon chub are not present at the site but there is a potential for volitional immigration (rating 3). Chub abundance is 0 fish (rating 1). Because no chub are present, there is no 5-year trend (rating 0). The calculation for habitat utility (F_U) is thus:

$$F_U = (3 + 1 + 0) / 15 = 0.27$$

There are no risks of off-site sedimentation or delivery of toxic chemicals. The habitat integrity (F_I) rating is 1.0. Duration of impacts is anticipated to be more than 2 years (F_D = 3.0).

Debit Calculations (SM)

$$S_M = 0.07 \text{ x } 0.8 \text{ x } 0.27 \text{ x } 1.0 \text{ x } 3 \text{ x } 100 = 4.5$$

DISCUSSION

These examples illustrate simple species value (S_M) calculations that are possible using the accounting methodology. For the East Fork Minnow Creek bank site, the initial species value was 23.1 credits and the uplift from restoration activities was 31.7 credits (total post-restoration value of 54.8 credits). For the Row River impact site, ODOT will need to use 4.5 of these credits. Thus, the Minnow Creek bank site will cover ODOT's mitigation obligations for approximately 12 similar bridge impact sites. Also, the total habitat area of 12 impact sites of similar quality and size to the one described in our example (12 times 0.07 acres) is equal to the area of the conservation bank site (0.84 acres), so there would be no net loss of chub habitat area under this scenario. This accounting methodology provided ODOT with a substantial incentive to conduct the restoration activities at the conservation bank site (137% increase in total credits available) and if the

restoration results in a reversal in the declining abundance trend, then ODOT will gain an additional 8.2 credits (15% increase). In the Row River impact example, ODOT has a strong incentive to attempt to reduce the impact duration. If successful, they can reduce the number of credits needed by as much as 67% (Table 2).

In another scenario, if ODOT activities have impacts at a location where no chub population exists within 1 km, then they will need 67% fewer credits than if they have impacts at a location that is proximal to or supports a large, stable Oregon chub population, all other parameters being equal. Also, if ODOT activities impact a population with a declining abundance trend, then they will need 27% more credits than if their activities impact a population that is not in decline. Therefore, our methodology clearly provides incentives for minimizing impacts to populations that are important to species recovery.

Interest in using economic and regulatory incentives, like conservation banking, to promote species conservation is increasing (Heinen 1995; Ferraro and Kiss 2002) and is driven by several factors (Wilcove and Lee 2004). First, habitat destruction is the leading cause of species endangerment (Wilcove et al. 1998) and is the most widespread threat to imperiled fishes (Jelks et al. 2008). Second, many endangered species have the majority of their habitat on private lands and species that occur exclusively on non-federal lands are faring worse than species that occur primarily on federal lands (Wilcove et al. 1996). Third, by the time species are listed under the ESA, their numbers are often perilously low (Wilcove et al. 1993). Thus, the long-term survival of many endangered species depends not only on our ability to prevent further declines, but also on our ability to increase population abundance by restoring degraded habitats on private lands (Wilcove and Lee 2004). Because private landowners are not obligated to restore habitat for imperiled species under the ESA, and fear of the ESA may prevent landowners from allowing access to conduct surveys on their lands or even result in proactive destruction of unoccupied habitats, incentive-based programs can be useful for engaging private landowners to improve habitats for imperiled species.

One of the criticisms of conservation banking is that credits can be earned solely from the preservation of existing habitats. This can result in a net loss in the amount of suitable habitat available for a species and may simply slow the rate of habitat loss, rather than promoting recovery. Ideally there would be an overall species benefit because the quantity and quality of permanently protected habitat increases. Using our methodology and under the scenario described above, there would be no net loss of Oregon chub habitat, the quality and functionality of the habitat placed into the conservation bank under permanent protection is better, and the habitat is less fragmented than the impacted habitats. Also, ODOT had the incentive of increased available credits to conduct restoration activities at the bank site. Because the existing unmanaged habitat was becoming unsuitable due to sedimentation and vegetative succession, the development of the conservation bank resulted in improved conditions that probably would not have occurred otherwise. Further, by consolidating and managing the conservation bank site as a reserve, there is a high probability that the overall status of the species will improve in this recovery area. Another unique component of our methodology is that the effects of nonnative species, the second leading cause of species endangerment, are also factored in to the calculations.

There has also been concern that mitigation banking reduces the pressure on developers to avoid harm to existing habitats, and that restored habitats fail to replace the same ecological functions as the impacted habitats (Roberts 1993). Our methodology, through increased compensation ratios for longer-term impacts, provides an incentive for developers to reduce the impacts to existing habitats.

There are other tools that managers can use to improve the status of imperiled species on private lands. Wilcove and Lee (2004) assessed three new incentive-based programs for restoring endangered species on private lands: safe harbor, landowner conservation assistance (LCAP), and conservation banking. By evaluating the number of participating landowners, the number of species targeted for assistance, and cumulative acreage of enrolled land, they found that both safe harbor and LCAP have been remarkably successful. Conservation banking proved more difficult to assess because few banks had been created at the time of publication. Of the three programs, conservation banking provides the greatest financial incentives to landowners for habitat restoration, with direct payments for credits sold.

Failure of many past mitigation projects to replace functional 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 assign mitigation credits and debits (Bonds and Pompé 2003; Bruggeman et al. 2005; Searcy and Shaffer 2008; Stein et al. 2000). Ideally, the methodology for 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, should have an ease of use such that the level of expertise and time required to employ the methodology is not a deterrent to its application, and should provide a sufficiently quantitative measure of the condition of aquatic resources that it can be translated to a mitigation ratio, if needed (Stein et al. 2000).

We developed a simple, biologically-based methodology 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; USFWS 1998; Scheerer 2002; Scheerer and McDonald 2003; Scheerer 2007a, b; Scheerer et al. 2007). By placing emphasis on the population response (population abundance and 5-year trends), our credit-debit system encourages recovery through the protection, restoration, or creation of functional conservation banks that support 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 indirectly 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 conservation 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 are available for the species in question. 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. We believe that our accounting methodology can serve as a template for fisheries scientists developing similar methodologies to support conservation banking for other imperiled fishes.

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