Improving Inferences from Fisheries Capture-Recapture Studies through Remote Detection of PIT Tags

The Challenges of Tracking Habitat Restoration at Various Spatial Scales
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NMT’s new Adult Fish Counter is available at an introductory price of $14,900 USD.
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COVER: A box housing PIT tag readers and associated equipment is mounted on a platform amidst spawning Lost River suckers (Deltistes luxatus) at Sucker Spring, Upper Klamath Lake.

This is the season when many of us engage in the time-honored activities associated with working on landscapes, large and small, deciding just how our relationships with the earth will be expressed this year. Within the constraints of space, climate, social order (e.g., laws, regulations, ordinances, covenants), and our willingness to remain engaged with our investment, we make choices. The fundamental choice is: “Do I garden or do I not?” If our choice is to garden, we till, fertilize, trim, plant, weed, move things around, and in general tidy up our domains to fit our unique suite of values and our long-term goals. Some of us garden for aesthetics; some garden for consumptive purposes. Some garden for both. Some garden for economic purposes. Some gently nudge nature. Some force nature to assume very specific vectors. We ask ourselves the questions: “What do I plant? How will the things I plant interact with one another? With what intensity do I intend to cultivate? Will I leave, maintain, or protect some ‘scruffy’ places for wild things and processes to prevail?”

One thing is for sure, if we don’t garden, somebody else will have to do it for us because contemporary human civilization must garden in order to meet tangible as well as intangible needs. And, interestingly, in most societies, we can tell one another how to garden. We can collectively dictate (through markets, regulations, and other social pressures) frameworks for production and quality control. We can require sensitivity to “scruffy” places. We can force the “gardeners” to consider scales beyond their individual domains. Just as interestingly, if we personally decide to be disengaged, we can be forced into engagement. If you are a member of a community (and most of us are), try going a full year without mowing your yard, ignoring water restrictions, or failing to clean up solid or chemical waste on property where you have vested responsibility.

Gardening certainly is not restricted to terrestrial environments. Aquaculture is intensive “gardening.” A capture fishery can, in every sense of the word, be considered as extensive “gardening.” Choices are made for our “gardens” and we proceed accordingly. We can and do have our “scruffy” places in fisheries where we allow the wild to prevail (to an extent). We also have aquatic environments that have been created or are highly modified by human activity. What do we plant in them? How do we till, fertilize, weed, cultivate, and harvest? What do we do with the pests that invariably rear their ugly heads, those unanticipated byproducts of naïveté or accident—and with situations where the best intentions went awry? How do we, how should we, as professionals, address these “gardens?” Let’s consider an example.

During the twentieth century’s era of dam building, smallmouth bass and smallmouth bass fishing in the Ozark Highlands region of the central United States took their licks. Hypolimnetic discharges from dams typically pushed temperature regimes in the receiving tailwaters below thermal tolerances for smallmouth bass (and other fishes) and for many of the aquatic invertebrates in these systems. Mitigation revolved around establishment and maintenance of salmonid fisheries, primarily for rainbow trout, and cold-tolerant invertebrate fauna.

The dams comprehensively changed the geographic and socioeconomic landscapes of the region. The dams brought electricity, some degree of flood management, productive new trout fisheries, and new opportunity for entrepreneurship (primarily through recreation and tourism) to an economically-depressed region. However, many things were lost, including free-flowing coolwater streams, gorgeous limestone bluffs and canyons, world-renowned smallmouth bass fisheries and, as the region was discovered by tourists, a degree of cultural innocence.

Fisheries professionals are not the sort of people who mope around lamenting what once was. We are action-oriented persons with an ingrained sense of responsibility to take what we have and make what is needed. We understand clearly that we are charged with the responsibility of engendering good relationships between humanity and living aquatic resources. Oftentimes this means that we have to figure out how to fix broken things.

In the case of the lost stream fisheries for smallmouth bass in the Ozarks, the “fix” was and continues to be the introduction of exotic fishes. Elsewhere in North America, where dams have impacted traditional fisheries, one of the “fixes” has been to remove the dams in order to help restore the original fisheries. But quite often the “fixes,” for broken (or created) inland systems at least, have been to introduce fishes with hopes that they will establish new and hopefully appropriately-founded fisheries. Sometimes it works. Sometimes it doesn’t. We’ve been known to poison native fish fauna (think twentieth century “rough fish removals”) in order to establish stocks of “more desirable” fishes and then, as value systems (and perhaps scientific understanding) evolved, to poison the previously stocked fish in order to “bring back the natives.”

As stewards of a modified landscape (N = 1: good old planet Earth) we truly are, in every sense of the word, “gardeners.” We plant what we think will bear fruit: wheat, rice, potatoes, tomatoes, strawberries, apples, longleaf pine, eucalyptus, roses, tulips, cattle, poultry, swine, sheep, ring-neck pheasant (and other Asian

Continued on page 246
Vision Unveiled for “Mosaic of Habitats” in the New York/New Jersey Estuary

The U.S. Army Corps of Engineers unveiled an innovative, comprehensive, restoration plan that was created in collaboration with the New York-New Jersey Harbor Estuary Program and more than 60 partnering organizations, including federal, state, and local agencies; non-governmental organizations; and regional stakeholders. The plan involves many partners because the New York-New Jersey Harbor Estuary spans 1,600 square miles across New York and New Jersey. Restoring the estuary will not only create a healthier environment for fish and wildlife, but it will also provide the public cleaner waters, healthier fisheries, increased flood protection, recreational opportunities, and a boost to the region’s economy.

“The primary goal of the New York-New Jersey Harbor Estuary Comprehensive Restoration Plan is to develop a mosaic of habitats that provides maximum ecological and societal benefits to the region,” said Lisa Baron, project manager and marine biologist with the U.S. Army Corps of Engineers New York District.

Baron, along with a diverse group of technical experts and consultants with the Corps New York District, developed the plan as part of the Hudson Raritan Estuary Ecosystem Restoration Study with the Port Authority of New York and New Jersey, the project’s local sponsor. The New York-New Jersey Harbor Estuary includes not only the harbor, but also rivers, wetlands, coastlines, and open waters, and is located within a complex ecological system inside a metropolitan region with a population of 20 million people. The plan’s boundary covers a large region of the estuary, which is a 25-mile radius around the Statue of Liberty National Monument.

“To perform restoration work in the estuary, the plan divides the estuary into eight regional areas associated with specific watersheds,” said Peter Weppler, chief of the Army Corps New York District Coastal Ecosystem Section.

The plan includes 11 priority targets for ecosystem restoration. Habitat restoration

With the skyline of Manhattan in the background, Col. John R. Boule II, Commander of the Army Corps’ New York District, addresses a group of waterfront leaders aboard the Army Corps’ vessel Hayward in the harbor. (Photo: Keegan O’Connell-Lilly, USACE).
islands for waterbirds, coastal and maritime forests, and eelgrass beds.

Coastal Wetlands—Coastal wetlands are the regional areas that connect the estuary's open waters to dry land.

“Due to industrialization, nearly 80% of the wetlands have been lost and most of what remains is degraded. Wetlands provide such an incredible benefit to the region, on so many levels. Their vegetation provides a critical habitat for wildlife, fish, and migratory birds. We live in an urban environment where there are lots of hardened surfaces and surface water runoff. Surface water runoff is water, from rain, snow-melt, or other sources that flows from the land surface into water ways, which can bring with it contaminants from the land. Wetlands filter and detoxify our water by catching contaminated sediments in the water,” said Baron.

“Wetlands are also nature’s sponges and act as shoreline barriers and stabilizers. They diminish wave impact, reduce erosion, and provide a buffer from flooding for our coastal areas and the communities living there,” said Jodi McDonald, chief of the Army Corps New York District Ecosystem Restoration and Flood Risk Management Section. The plan has identified over 26,000 acres of wetlands throughout the estuary that is suitable for coastal wetlands creation and restoration.

Shellfish Reefs—One of the plan’s priorities is to restore and create shellfish reefs including oysters, the keystone species for the estuary, mussels, and clams, as well as other shellfish. These reefs are intricate underwater structures made up of live shellfish and layers of empty shells. Oyster reefs have been almost eliminated due to poor water quality conditions, disease, and over-harvesting. In fact, the estuary supported a thriving oyster industry up until the late 1800s, covering approximately 200,000 acres.

These reefs provide nooks and crannies and potential nursery grounds for other species because they provide hiding places, feeding grounds, and egg attachment sites for many species. Shellfish also improve water quality by filtering sediment from the water and improve water clarity.

Islands for Waterbirds—The plan will restore island habitats for birds whose numbers have declined considerably in the estuary due to hunting, pollution, and habitat loss. The estuary supports 300 species of birds that provide a vital role in the health of the estuary’s environment and help regulate the population of other species by consuming them for food.

Coastal and Maritime Forests—Coastal and maritime forests are found on the fringe of seacoast habitats behind the dunes or a wetland and provide critical upland habitat. Maritime forests have trees that are often stunted by salt spray and high winds and they may grow in unusual, gnarled shapes. These hardy forests are needed by many species because they provide a home, food, and a nesting place for migratory birds. They also contribute to shore stabilization and flood control, as well as moderate global climate change.

Eelgrass Beds—Eelgrass used to be plentiful. The plant’s long shoots provide habitat and food for fish nurseries and estuary wildlife, and improves water quality through the production of oxygen in the water. Eelgrass also reduces shore erosion and improves water clarity and quality by acting as a sediment trap and filtering contaminants from the water.
**Journal Highlights:**

Fisheries Management

- **Fisheries**
  - A. Peter Klimley, Arnold Ammann, and Bruce MacFarlane, pages 142-156.
    - Estimating survival and migration route probabilities of juvenile chinook salmon in the Sacramento–San Joaquin river delta.
  - Russell W. Perry, John R. Skalski, Patricia L. Brandes, Philip T. Sandstrom, A. Peter Klimley, Arnold Ammann, and Bruce MacFarlane, pages 142-156.

- **Management Brief**
  - Comparison of green and white mesh trammel nets and gill nets to assess the fish community in a large river. Greg A. Wanner, Robert A. Klumb, Dana A. Shuman, Kirk Steffensen, Sam Stukel, and Nicholas J. Utrup, pages 12-25.

- **Management Brief**
  - Effect of radio-tagging on escape reactions of adult blueback herring to ultrasound. Dennis J. Dunning and Quentin E. Ross, pages 26-32.

- **Movement and Microhabitat Associations of Guadalupe Bass in Two Texas Rivers.** Joshua S. Perkin, Zachary R. Shattuck, Preston T. Bean, Timothy H. Bonner, Ekaterina Saraeva, and Thomas B. Hardy, pages 33-46.


- **Population Composition, Migration Timing, and Harvest of Columbia river Chinook Salmon in Late Summer and Fall.** M. A. Jepson, M. L. Keefer, G. P. Naughton, C. A. Peery, and B. J. Burke, pages 72-88.

- **Management Brief**


- **Associations between Watershed Characteristics and Angling Success for Sport Fishes in Mississippi Wadeable Streams.** J. Brian Alford and Donald C. Jackson, pages 112-120.

- **Management Brief**

- **Historical and Current Population Characteristics and Subsistence Harvest of Arctic Char from the Sylvia Grinnell River, Nunavut, Canada.** Colin P. Gallagher and Terry A. Dick, pages 126-141.


- **Habitat Selection and Spawning Success of Walleyes in a Tributary to Owasco Lake, New York.** Marc A. Chalupnicki, James H. Johnson, James E. McKenna Jr., and Dawn E. Dittman, pages 170-178.


- **Performance of Three Alternative Estimators of Stream Residence Time Based on Live and Dead Counts of Salmonids.** John R. Skalski, Shiqun Liao, and Rebecca A. Buchanan, pages 191-208.

- **Mandatory Catch and Release and Maximum Length Limits for Largemouth Bass in Minnesota: Is Exploitation Still a Relevant Concern?** Andrew J. Carlson and Daniel A. Isermann, pages 209-220.

- **Creel Survey Methods to Assess Catch, Loss, and Capture Frequency of White Sturgeon in the Snake River, Idaho.** Joseph R. Kozfkay and Jeff C. Dillon, pages 221-229.


- **A Six-Decade Portrait of Florida Marine Fisheries via Landings-Based Trophodynamic Indicators.** Joseph Munyandorero and Cameron B. Guenther, pages 259-280.


- **Mandatory catch and release and maximum length limits for muskellunge.** Jerry A. Younk, Brian R. Herwig, and Bruce J. Pittman, pages 281-288.


- **Comparison of Channel Catfish Age Estimates and Resulting Population Demographics Using Two Common Structures.** Robert E. Colombo, Quinton E. Phelps, Candice M. Miller, James E. Garvey, Roy C. Heidinger, and Nathaniel S. Richards, pages 305-308.

- **Fishing Technologies and Catch Levels among Small-Scale Fishers in Lagos State, Nigeria.** K. A. Akanni, pages 309-315.

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New Northeast Groundfish Management Measures
NOAA Fisheries Service has announced new measures that will establish new catch limits and major changes in how the Northeast groundfish fishery (which includes cod and flounder) will be managed. The new measures are intended to end the overfishing of Northeast groundfish and to continue the rebuilding of the fishery.

The new measures include a first time cap on the amount of all groundfish of any species that are permitted to be caught. In addition, there will be measures to mitigate if the catch limits are exceeded. In addition to the new caps, the measures include fundamental changes to the way that the fishery is managed. One of these changes includes allowing fishing vessels to fish in “sectors.” Sectors are voluntary groups for fishing vessels, that can formed each year and are given a portion of the total available groundfish catch based on the combined fishing history of their member vessels. Member vessels are exempt from many area and gear restrictions, but must agree to stop fishing once the sector catches its allotment of fish. Solo fishermen will still be allowed to fish, but must comply with strict limits on the number of fishing days, trip limits for some species, and seasonal and area closures. All vessels can also increase that allotment by leasing and trading shares of catch or fishing days. The new measures for Northeast groundfish will be effective 1 May 2010.

Shrimp bans hit Mexico on both sides of border
Mexico’s National Commission for Aquaculture and Fisheries instituted a ban on shrimp fishing in March that is designed to contribute to the renewal of stocks and to protecting the reproductive process to ensure future harvests. The temporary ban on shrimp fishing includes all marine waters under federal jurisdiction in the Pacific Ocean, including the Gulf of California, Lagoon estuarine marshes, and bays of the states of Baja California Sur, Sonora, Sinaloa, and Nayarit.

The ban imposed by Mexico’s National Commission for Aquaculture and Fisheries is coupled with Mexico’s loss of its certification in April to export its wild-harvest shrimp to the United States. The certification was withdrawn after the U.S. National Marine Fisheries Service determined that Mexico’s turtle excluder devices no longer meet U.S. standards. U.S. rules require that exporters use excluders comparable to those used by U.S. shrimpers. Mexico’s National Fisheries Council is working with U.S. experts to recertify its shrimp fleets following new inspections in August and September.

European Union subsidies linked to overfishing
An EU Financial Instrument for Fisheries Guidance March 2010 study links EU fisheries subsidies and the overfishing of valuable fish stocks. The study was carried out in 10 European countries including Britain, Denmark, France, and Spain. The examined countries account for almost all of the 4.9 billion euros of fishing subsidies handed out by Brussels from 2000–2006. The report states that 29% of the EU handouts went to measures which contributed to overfishing, while just 17% were dedicated to measures to support healthy fisheries. The report also indicated that Spain, France, Portugal, and Germany in particular have benefited from subsidies for “negative measures” as far as sustainable fisheries are concerned. The findings of the report state that among the key European fish stocks where overfishing has been enabled are southern hake, monkfish, sharks, and prawns.
ABSTRACT: Models for capture-recapture data are commonly used in analyses of the dynamics of fish and wildlife populations, especially for estimating vital parameters such as survival. Capture-recapture methods provide more reliable inferences than other methods commonly used in fisheries studies. However, for rare or elusive fish species, parameter estimation is often hampered by small probabilities of re-encountering tagged fish when encounters are obtained through traditional sampling methods. We present a case study that demonstrates how remote antennas for passive integrated transponder (PIT) tags can increase encounter probabilities and the precision of survival estimates from capture-recapture models. Between 1999 and 2007, trammel nets were used to capture and tag over 8,400 endangered adult Lost River suckers (Deltistes luxatus) during the spawning season in Upper Klamath Lake, Oregon. Despite intensive sampling at relatively discrete spawning areas, encounter probabilities from Cormack-Jolly-Seber models were consistently low (< 0.2) and the precision of apparent annual survival estimates was poor. Beginning in 2005, remote PIT tag antennas were deployed at known spawning locations to increase the probability of re-encountering tagged fish. We compare results based only on physical recaptures with results based on both physical recaptures and remote detections to demonstrate the substantial improvement in estimates of encounter probabilities (approaching 100%) and apparent annual survival provided by the remote detections. The richer encounter histories provided robust inferences about the dynamics of annual survival and have made it possible to explore more realistic models and hypotheses about factors affecting the conservation and recovery of this endangered species. Recent advances in technology related to PIT tags have paved the way for creative implementation of large-scale tagging studies in systems where they were previously considered impracticable.
INTRODUCTION

Management and conservation of animal populations depend on an understanding of key life history parameters and their roles in regulating population dynamics. For example, populations of fish species with low natural survival rates are often more productive and can support more intense exploitation than species with higher natural survival rates (Adams 1980). Such populations are said to be evolutionarily adapted to low survival and compensate through rapid growth or high fecundity. For long-lived species with high natural survival rates, populations can be rapidly depleted by harvest and other sources of anthropogenic mortality (Fujiiwara and Caswell 2001), and population growth rates are sensitive to variability in survival (Pfister 1998; Doherty et al. 2004; Schmutz 2009). In some situations, populations of imperiled species may require intervention to increase or stabilize survival and reduce the risk of extinction.

Accurate and precise estimates of survival are needed to evaluate hypotheses about factors that influence population dynamics and to develop effective management strategies. Capture-recapture (CR) or tagging studies are arguably the most reliable methods for generating such estimates, and development of theory and methods for analysis of CR data has been exceptionally rapid in the past few decades (Seber and Schwarz 2002; Senar et al. 2004; Thomson et al. 2009). Researchers are now able to use CR data to directly evaluate factors affecting not only survival (Burnham et al. 1987; Lebreton et al. 1992; Nichols 2005), but also recruitment and population growth rate (Pradel 1996; Nichols et al. 2000; Nichols and Hines 2002), movement or migration (Schwarz and Arnason 1990; Schwarz et al. 1993; Schwarz 2009), and reproductive success (Nichols et al. 1994; Rotella 2009).

Most recent developments can be viewed as special cases of a flexible class of models that treat individual animals as occupying one of a number of states, broadly defined, in any given time period (Lebreton and Pradel 2002; White et al. 2006; Bailey et al. 2009; Kendall 2009).

Borrowing theory and methods from generalized linear models, CR models can incorporate and evaluate the effects of variables (covariates) on model parameters, permitting evaluation of interesting biological hypotheses (Lebreton et al. 1992; Franklin 2001; Bonner and Schwarz 2004; Nichols 2005; Cam 2009; Conroy 2009). Models can be fit by maximum likelihood with free software, and competing models that represent various hypotheses can be compared in a model selection framework (White and Burnham 1999; Choquet et al. 2004). Importantly, a model selection framework avoids inappropriate interpretations of classical statistical tests as strength of evidence (Royall 1997), leads to a parsimonious interpretation of the data as represented by models, and provides a means to account for model selection uncertainty in estimates of model parameters and their variances (see Chatfield 1995 and Buckland et al. 1997; part of multimodel inference sensu Burnham and Anderson 2002 and Anderson 2008).

Capture-recapture data have been and remain integral to studies of fish stocks in marine and coastal ecosystems, most often in the form of tag returns from fishermen that are used in stock assessment analyses. Despite all of the advantages of CR, freshwater fisheries researchers have been slow to include CR studies and modern methods of analysis in their toolbox for estimating survival and other demographic parameters (Pine et al. 2003). Perhaps the primary reason for the tepid response is that fisheries capture-recapture studies are often difficult to implement. Three concerns are commonly expressed:

1. Cost and effort associated with tagging and recapture sampling is prohibitive;
2. Statistical model assumptions about tag retention and the effects of tagging on behavior and survival are hard to meet; and
3. Capturing and tagging a subset of fish that can be considered representative of the population as a whole is difficult.

We suggest that the first two concerns about costs and model assumptions can usually be overcome by careful planning and design, and that the benefits to inference about population dynamics from CR studies outweigh the costs. Tag retention and effects of tagging can be assessed with pilot or complementary studies, although a reliable tagging method with minimal adverse effects remains a prerequisite for robust inference. Fortunately, a large body of literature is available on tag types and tagging techniques for fishes (Parker et al. 1990; Nielsen 1992; Guy et al. 1996), as well as design and analysis of CR studies (Burnham et al. 1987; Pollock et al. 1990; Williams et al. 2002).

Concerns about the representativeness of the tagged subset of fish are important, but they should not prohibit important inferences from being made in most cases. Representative sampling is important for inferences based on CR, as it is for any statistical analysis of sample data. However, most fisheries studies require CR models that are applicable to open populations; that is, those that undergo change due to births, deaths, or migration during the study period. Inferences about dynamics in open populations can be restricted to the tagged subset of fish using models of the Cormack-Jolly-Seber (CJS) type (Lebreton et al. 1992). The CJS models are conditioned only on the encounter histories of tagged fish; as a result, CJS models avoid the numerous pitfalls associated with estimating population size (reviewed in Cormack 1968 and Williams et al. 2002, which contrast with Hayes et al. 2007). Because formal statistical inference is restricted to the tagged fish, generalization of inferences from CJS models to the population as a whole must be based on the adequacy of the study design. Provided that tagged fish are reasonably similar to the rest of the population, results should be useful in quantifying dynamics and evaluating hypotheses. Scientific inference is a process, and sampling and modeling can always be adapted to address important sources of variation that are expected or discovered in the population, such as those that might affect the representativeness of the tagged subset of fish.

A lingering and critical limitation for CR studies of fish populations is the need for relatively high probabilities of re-encountering tagged fish. High encounter probabilities are essential for estimating parameters of interest with satisfactory precision and, of equal or greater importance, for evaluating model assumptions (Cormack 1968; Burnham et al. 1987; Lebreton et al. 1992). Unfortunately, recapture probabilities
for tagged fish are often low in large water bodies, including many lakes and rivers and most estuarine and marine systems, and enormous sample sizes are needed to make inferences in such situations (e.g., Jiang et al. 2007). Low recapture probabilities are particularly common when the population is diffuse or the species is otherwise difficult to capture with traditional gears. The trade-off between encounter probabilities and sample size in study design has led to what is known as the “big law” of CR—increase encounter probabilities by any means possible (Figure 1). As a general guideline, encounter probabilities should be 0.2 or higher for modeling and inference to be fruitful without unreasonable sample sizes.

In this article, we describe the development of a capture-recapture monitoring program for endangered Lost River suckers (Deltistes luxatus) in which we had to overcome the problem of low encounter probabilities. Intensive sampling with traditional gears was unable to provide sufficient recaptures of fish tagged with passive integrated transponder (PIT) tags, but creative use of remote antennas increased encounter probabilities to nearly 100% and provided more robust model-based inferences about population dynamics. We suggest that recent advances in technology for PIT tags and antennas have made it possible to overcome the problem of low encounter probabilities in many systems, thus allowing for the implementation of capture-recapture studies in situations where they were previously considered impracticable.

**STUDY SPECIES AND SYSTEM**

Lost River suckers are long-lived catostomids endemic to the Upper Klamath River Basin in Oregon and California (Miller and Smith 1981; Scoppettone and Vinyard 1991). Individuals have been aged to over 40 years and the largest adult females can grow to 800 mm fork length (FL; Scoppettone 1988; Scoppettone and Vinyard 1991; Janney et al. 2008). Lost River suckers were listed as endangered under the U.S. Endangered Species Act in 1988 because of range contractions, declines in abundance, and a lack of evidence of recent recruitment to adult populations (USFWS 1988). Direct mortality from subsistence and recreational fisheries for spawning suckers may have contributed to population declines, but fishing for the suckers was banned in 1987 (USFWS 1993). Numerous other threats common to imperiled fishes in the western United States were identified as potentially contributing to the declines (e.g., habitat alteration and degradation, nonnative species), but the relative influence of the various causes is uncertain (NRC 2004).

The most intensively studied remaining population of Lost River suckers occurs in Upper Klamath Lake, Oregon (UKL). Two apparently distinct spawning subpopulations of Lost River suckers coexist in UKL (Janney et al. 2008). One subpopulation exhibits a reproductive strategy similar to other western lakesuckers (genus Chasmistes) and migrates relatively short distances up tributaries to spawn in the spring. Although spawning may have occurred in other tributaries in the past, nearly all riverine spawning activity for the suckers is now restricted to the lower Williamson River and the Sprague River (Figure 2). The other subpopulation spawns at upwelling springs along the eastern shore of the lake below Modoc Rim. The majority of spawning activity for both subpopulations occurs in March and April.

Impaired water quality conditions in Upper Klamath Lake have been implicated in reduced survival of adult suckers and are a concern for recovery efforts. Upper Klamath Lake is the largest lake in Oregon (280 km²), but is relatively shallow (average depth ca. 2 m). The combination of this bathymetry

![Figure 1.](image-url) An example of the “big law” of capture-recapture studies—increase encounter probabilities by any means possible. The example is based on a simple treatment-control experiment to estimate the effect of dam turbine passage on survival, and is based on the equation in Burnham et al. (1987:315). The effect size (E) is the ratio of survival for the treatment group to survival for the control group, and is set to 0.8, representing a 20% reduction in survival due to passing through the turbine. The study is a true experiment and the two groups of fish are assumed to be identical except for their probability of survival. The total required number of tagged and released fish, divided equally among treatment and control groups, is plotted against the probability of recapturing a released fish for three target values of the coefficient of variation (CV) for the estimated effect size: 2.5%, 5%, and 10%

\[
CV(E) = \frac{se(E)}{E} \times 100
\]

Increasing the probability of recapturing a tagged and released fish yields strongly disproportionate reductions in the required number of fish that need to be tagged to achieve a given level of precision on the effect size.
shortnose suckers (*Chasmistes brevirostris*). However, for simplicity of presentation we only describe sampling and analysis methods for the subpopulation of Lost River suckers that spawns at the shoreline springs, and we only include fish tagged in 1999 and later. Fish encountered at the springs are rarely encountered elsewhere in our sampling, so focusing on the spring spawning subpopulation greatly simplifies description. More details of life history, sampling, and analysis for both species are given in Scoppettone and Vinyard (1991), NRC (2004), and Janney et al. (2008).

From 1999 to 2008 we captured Lost River suckers for tagging by setting trammel nets at five known spring spawning areas between February and May, beginning soon after ice-out (Figure 2). Nets were set twice per week at each spring, allowing three or four days between sampling events at a given spring. Sampling for the season was continued until only a few fish were captured in a given week. Trammel nets (30 m x 1.8 m; 29 cm bar outer mesh, 3.5 cm bar inner mesh) were deployed from shore by wading in a semicircle around the perimeter of the area of concentrated spawning. Spawning areas are relatively small; size varies among springs, but is typically 500 m$^2$ or less. Nets were deployed for four hours around sunset and checked at least once per hour for newly captured fish. Captured fish were retained in floating net pens for processing and were released when sampling was completed for the night. None of the fish died as a result of handling or retention in the net pens, so we consider short-term mortality associated with sampling to be negligible.

Captured fish were scanned for the presence of a PIT tag and untagged fish were injected with a tag using a hypodermic syringe with a 12-gauge needle. The PIT tags were injected into the abdominal musculature anterior to the pelvic girdle. All fish tagged prior to 2005 were given 12 or 14 mm 125.0 kHz full-duplex tags, and all fish tagged in 2005 and thereafter were given 12 mm 134.2 kHz full-duplex tags.

Physical recaptures of tagged fish were obtained from the trammel net sampling from 2000 to 2008, but the number of fish recaptured by this method was con-
In the spring of 2005, as an experimental approach to increase the probability of re-encountering tagged fish, we opportunistically deployed a single remote flat plate PIT tag antenna at Cinder Flat spring (Biomark, 30.5 x 66 cm; Figure 3). The antenna was deployed for parts of 10 days late in the spawning season, between 21 April and 6 May, yielding a total sampling time of approximately 135 hours. Beginning in 2006, we deployed flat plate antennas for the entire spawning season at four springs: Cinder Flat, Ouxy, Silver Building, and Sucker (Figure 2). Two or three antennas were used at each spring, and each antenna was connected to its own Biomark FS2001F-ISO reader by a 6-m cable. Readers were stored in metal boxes on fixed platforms near the middle of the spawning areas and antennas were distributed around the platforms (Figure 3).

Analysis and modeling

Inferences about adult Lost River sucker survival have benefited greatly from the encounters provided by the remote PIT tag antennas, and we illustrate the benefits by comparing results from two sets of Cormack-Jolly-Seber models. Comprehensive reviews of CJS models were provided by Seber (1982), Pollock et al. (1990), Lebreton et al. (1992), Williams et al. (2002), and Nichols (2005). The fundamental input to CJS models are the encounter histories (series of zeros and ones where the ones indicate an encounter on a given sampling occasion; e.g., 100010111), and the parameters of interest are apparent survival probabilities (Φ) and encounter probabilities (p). Apparent survival includes true survival as well as permanent emigration from the study area, but in our case Φ closely approximates true survival because very few adult Lost River suckers leave Upper Klamath Lake (Banish et al. 2009).

Our first model set was developed for encounter histories that included only physical recaptures from trammel net sampling, and the second was developed for encounter histories that included both physical recaptures and remote encounters. Survival and encounter probabilities were estimated over annual time intervals, so multiple encounters of the same fish in the same sampling season (February-May) were treated as a single encounter. Model sets were developed by considering the effects of sex and time (year) on Φ and p, and then including models with and without those factors. We modeled Φ as a function of time because we expected that greater reproductive investment by females would lead to lower survival compared to males. Most importantly, we modeled Φ as a function of time because we hoped to detect changes in annual survival and relate those changes to factors such as

<table>
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<th>Year</th>
<th>Number released</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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<td>744</td>
<td>51</td>
<td>52</td>
<td>34</td>
<td>44</td>
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<td>2000</td>
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<td>91</td>
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<td>70</td>
<td>46</td>
<td>49</td>
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<td>17</td>
<td>308</td>
<td>1</td>
</tr>
<tr>
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<td>68</td>
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<td>422</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
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<td>57</td>
<td>51</td>
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<td>13</td>
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<td>6</td>
<td>10</td>
<td>0</td>
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<td>57</td>
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<td>753</td>
<td>4</td>
<td>26</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>2004</td>
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<td>82</td>
<td>30</td>
<td>17</td>
<td>665</td>
<td>3</td>
<td>38</td>
<td>1</td>
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<td>843</td>
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<td>17</td>
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<td>38</td>
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<td>7</td>
<td>843</td>
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<td>82</td>
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<tr>
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<td>5</td>
<td>346</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8,451</td>
<td>51</td>
<td>143</td>
<td>191</td>
<td>287</td>
<td>294</td>
<td>354</td>
<td>125</td>
<td>120</td>
<td>3,618</td>
</tr>
</tbody>
</table>
water quality conditions. For \( p \), we expected sex to be important because of differences in reproductive behavior (e.g., males stay at spawning areas longer than females, potentially increasing their probability of being encountered), and we expected time to be important because of annual differences in sampling intensity and environmental effects on the condition of the spawning habitat. Past analyses showed that models with some combination of both sex and time effects on \( p \) were overwhelmingly supported in model selection, so we only considered models with some combination of both effects (Janney et al. 2008). We included models with both additive and interactive effects for \( \Phi \) and \( p \). Additive models constrained effects to be the same between groups across time (e.g., the difference between male and female survival is the same in each year), whereas interactive models included more parameters and allowed effects to vary through time (e.g., separate estimates of survival for each sex in each year). Note that the last estimates of \( \Phi \) and \( p \) are confounded in the likelihood and cannot be separately estimated; this is a general characteristic of CJS models. As such, we do not report or discuss estimates of \( \Phi \) for 2007 or \( p \) for 2008.

The two model sets were the same with one important exception: the model set for the encounter histories that included remote detections incorporated models with an effect of PIT tag type (125.0 vs. 134.2 kHz) on encounter probability in 2006–2008. The 134.2 kHz tags were first used in 2005 and first re-encountered in our 2006 sampling. The higher frequency tags have a greater read range and are more likely to be detected on the remote antennas than lower frequency tags. In our application, the distance from the antennas at which the 134.2 kHz tags can be read is 15–20 cm, compared with 5 cm for the 125.0 kHz tags. We included models that constrained the effect of tag type to be the same in 2006, 2007, and 2008, as well as models that allowed the effect of tag type to vary by year.

We used program MARK to fit the models using maximum likelihood (White and Burnham 1999). Models were specified and passed to MARK using the RMark package (Laake 2009; Laake and Rexstad 2009) within the R software environment (R Development Core Team 2009). All model likelihoods were constructed using a logit link function and optimized using the default Newton-Raphson algorithm.

Models within a set were compared using an information-theoretic model selection framework and Akaike’s Information Criterion corrected for small sample size and overdispersion (\( \text{QAIC}_c \); Burnham and Anderson 2002). For each model in a set, we follow Anderson et al. (2001) and report five quantities:

**Figure 3.** Clockwise from top left: a remote flat plate PIT tag antenna on the substrate; a box for housing the PIT tag readers and associated equipment, mounted on a platform amidst spawning suckers at Sucker Spring; an underwater photograph of spawning Lost River suckers.
1. The number of estimated parameters (k),
2. QAICc,
3. The difference in QAICc between a given model and the Kullback-Leibler (K–L) best model in the set (ΔQAICc),
4. The probability that the model is the best K–L model in the set (model probability, or Akaiake weight, \( w_c \)), and
5. The value of the maximized log-likelihood function (-2log_L).

Evidence ratios are used to compare pairs of models and are simply the ratio of model probabilities. Where possible, we account for model selection uncertainty in parameter estimates by calculating estimates and estimated variances as weighted averages from all models in the set, using the model probabilities as weighting factors.

**Assumptions of the Cormack-Jolly-Seber model**

The CJS model makes the following assumptions:

1. Tags are not lost, or missed when individuals are re-encountered;
2. Sampling periods are “instantaneous” relative to the interval between samples; and
3. There is no unmodeled individual variability (heterogeneity) in survival or encounter probabilities among the tagged animals.

Assumptions 1 and 2 must be addressed primarily through study design. For Lost River suckers, double-tagging experiments with Floy and PIT tags showed that PIT tag loss rates were less than 1% over three or more years (U.S. Geological Survey, unpublished data). For physical recaptures, we ensured that tags were not missed when present by scanning a test tag prior to scanning each fish, and also scanning a test tag after each fish that was found to be untagged. Regarding Assumption 2, sampling in our study occurs over a 3 to 3.5 month spawning period and is not instantaneous. However, the vast majority of captures and remote encounters occur over a much shorter time period, and individuals are fairly consistent from year to year in the relative times at which they join the spawning aggregation. Thus, on an individual basis, sampling can be considered nearly instantaneous relative to an annual interval used for parameter estimation. In addition, spawning fish almost always appear to be in excellent condition and water quality is good during the spring. Thus, we expect that little mortality occurs during the sampling period and does not bias survival estimates.

Assumption 3 regarding heterogeneity is complex and has received considerable attention in the capture-recapture literature (reviewed in Pollock et al. 1990; Williams et al. 2002; Pollock and Alpizar-Jara 2005). This assumption includes the important and well-recognized requirement for negligible effects of tagging on survival. Our observations of Lost River suckers after tagging suggest that mortality related to handling and tagging is negligible, but future analyses will investigate this further. Other aspects of Assumption 3 are often not fully addressed or are completely ignored in fisheries studies (Pine et al. 2003). One of the primary advantages of CJS models is that estimates of apparent survival are robust to heterogeneity in encounter probabilities (Carothers 1973; Gilbert 1973; Carothers 1979). Nonetheless, unmodeled heterogeneity in encounter probabilities will likely remain of concern in most large-scale fisheries capture-recapture studies, and we return to this issue in the Discussion. Heterogeneity can be addressed to some extent through goodness-of-fit testing and correction for overdispersion (Lebreton et al. 1992; Burnham and Anderson 2002). We performed goodness-of-fit tests for the most general model in each model set and neither showed any consistent departure from expectations under the CJS model (see also Janney et al. 2008). However, a small amount of overdispersion was evident, presumably caused by a lack of independence in the fates of tagged fish, and we corrected model selection statistics and inflated parameter variances to account for the overdispersion using a variance inflation factor (\( \hat{\varepsilon} \)). We estimated \( \hat{\varepsilon} \) with the median \( \hat{\varepsilon} \) procedure in program MARK.

**RESULTS**

**Summary of capture, tagging, and encounters**

Between 1999 and 2007, 8,451 adult Lost River suckers were captured and tagged at the spring spawning areas (Table 1). We recaptured 2,005 of those individuals (24%) in subsequent trammel net sampling through 2008. However, recaptures of tagged fish in a given year were low considering the intensity of our sampling and the discrete distribution of spawning activity. Trammel net recaptures never exceeded 500 individuals in a given year.

In contrast, by including the detections of fish on remote PIT tag antennas in 2005–2008, we re-encountered 6,401 of the tagged individuals (76%) and total annual re-encounters increased dramatically (Table 1). In the absence of detections from the remote antennas, 4,396 tagged fish were available in the population but would not have contributed to our inferences about survival. In 2005 alone, when a single antenna was deployed for a short period late in the spawning season at one spawning area, we detected 157 individuals that had been tagged prior to 2005, which compares with 500 individuals recaptured in trammel nets over five spawning areas throughout the 3-month spawning season. Of the 157 fish detected remotely, 125 had not been previously recaptured in trammel nets despite being at large for as many as 6 years (Table 1). In 2006, the first year of full remote antenna implementation, we detected 4,787 individuals over the course of the spawning season, compared to 182 individuals recaptured in trammel nets. Of the remotely detected fish, 3,618 had never been re-encountered before by either method. Even in 2008, after two years of full remote antenna coverage and eight years of trammel net sampling, four individuals that had been tagged in 1999 were re-encountered for the first time only on the remote antennas.

**Analysis including only physical recaptures**

Model selection results and parameter estimates indicated that the data set that included only physical recaptures could support rather limited inferences about annual survival of PIT-tagged Lost River suckers. The top model, which had a...
The 0.935 probability of being the Kullback-Leibler best model in the set, included additive effects of sex and time on $\Phi$ and the same additive structure for $p$ (Table 2). The second best model included the same additive structure for $p$ but separate estimates of $\Phi$ for each sex in each year; this model had much less support ($\Delta\text{QAIC}c = 5.8$, model probability = 0.051). The only difference between this model and the top model was the structure on $\Phi$, so the evidence ratio between the two models, 18.3, is direct and fairly strong evidence in support of additive structure on $\Phi$. All other models, including the global model [model 9; $\Phi$(sex*time), $p$(sex*time)], had essentially no support ($\Delta\text{QAIC}c > 10$, evidence ratios compared to the top model > 150).

Estimates of $\Phi$ from the top model were imprecise, particularly for males, and the point estimates for both sexes in 2000 and 2001 were on a boundary (1.0; Figure 4). The boundary estimates indicate that the data provided insufficient information to the likelihood in those years. In the second best model with full structure on $\Phi$, the 2000 and 2001 point estimates for males were on a boundary and five of the eight estimable parameters for females were on a boundary. Combined with much wider confidence intervals for the female estimates, the bottom line is that few of the $\Phi$ estimates from this model were usable, despite it being the second best model in the set. Estimation problems aside, point estimates of survival probabilities from the top model appeared to be relatively high for both sexes in all years, consistent with expectations based on life history (Figure 4).

Ultimately, limitations to inference about survival from the data set with only physical recaptures could be traced back to the “big law” (Figure 1). Recaptures were sparse and estimated encounter probabilities were consistently very low, never increasing to more than 0.2 (Figure 5). Consistent with our expectations, encounter probabilities for male suckers were more than double the encounter probabilities for female suckers; female encounter probabilities never exceeded 0.05. Strong decreases in encounter probabilities for both sexes in 2006 were a result of temporarily reduced sampling effort.

### Table 2. Model selection results for the set of 10 Cormack-Jolly-Seber models fit to the data set including only physical recaptures of PIT-tagged Lost River suckers. The number of parameters estimated in each model is indicated by $k$, and the estimate of the overdispersion parameter ($c$) used in calculating adjusted model selection criteria ($\text{QAIC}c$) was 1.17.

<table>
<thead>
<tr>
<th>Model number</th>
<th>Model</th>
<th>$k$</th>
<th>$\text{QAIC}c$</th>
<th>$\Delta\text{QAIC}c$</th>
<th>Model probability ($w$)</th>
<th>$-2\log L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\Phi$(sex+time),$p$(sex+time)</td>
<td>19</td>
<td>16,571.3</td>
<td>0.0</td>
<td>0.935</td>
<td>19,327.3</td>
</tr>
<tr>
<td>2</td>
<td>$\Phi$(sex*time),$p$(sex+time)</td>
<td>27</td>
<td>16,577.1</td>
<td>5.8</td>
<td>0.051</td>
<td>19,315.3</td>
</tr>
<tr>
<td>3</td>
<td>$\Phi$(sex),$p$(sex*time)</td>
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<td>16,581.8</td>
<td>10.5</td>
<td>0.005</td>
<td>19,337.3</td>
</tr>
<tr>
<td>4</td>
<td>$\Phi$(sex+time),$p$(sex*time)</td>
<td>27</td>
<td>16,582.1</td>
<td>10.8</td>
<td>0.004</td>
<td>19,321.1</td>
</tr>
<tr>
<td>5</td>
<td>$\Phi$(sex),$p$(sex*time)</td>
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<td>16,582.6</td>
<td>11.3</td>
<td>0.003</td>
<td>19,340.5</td>
</tr>
<tr>
<td>6</td>
<td>$\Phi$(time),$p$(sex*time)</td>
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<td>15.4</td>
<td>0.000</td>
<td>19,328.9</td>
</tr>
<tr>
<td>7</td>
<td>$\Phi$(time),$p$(sex+time)</td>
<td>18</td>
<td>16,587.6</td>
<td>16.3</td>
<td>0.000</td>
<td>19,348.7</td>
</tr>
<tr>
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<td>16.4</td>
<td>0.000</td>
<td>19,362.9</td>
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<td>$\Phi$(sex+time),$p$(sex+time)</td>
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<td>0.000</td>
<td>19,312.2</td>
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<td>28.7</td>
<td>0.000</td>
<td>19,379.6</td>
</tr>
</tbody>
</table>

### Figure 4. Estimates of survival probability (± 95% confidence intervals) from the top model [$\Phi$(sex*time),$p$(sex+time)] in the set of models fit to the data set including only physical recaptures of PIT-tagged Lost River suckers. Estimates for both sexes in 2000 and 2001 are not shown because they were on a boundary (1.0), indicating estimability problems. Estimates were not model-averaged because of problems with boundary estimates, particularly in the second best model, but the top model received nearly all of the support (model probability = 0.935).

### Figure 5. Model-averaged estimates of encounter probability (± 95% confidence intervals) from the set of models fit to the data set including only physical recaptures of PIT-tagged Lost River suckers. The estimate of the overdispersion parameter ($c$) used in calculating adjusted standard errors was 1.17.
Analysis including all encounters

Model selection results and parameter estimates for the data set that included both physical recaptures and remote detections supported much stronger inferences about the dynamics of annual survival of PIT-tagged Lost River suckers. Similar to the model selection results for the data set that included only physical recaptures, the top two models in the set included additive effects of sex and time on \( \Phi \) (Table 3). However, evidence ratios comparing models with additive versus full structure on \( \Phi \) with the same structure on \( p \) were much more supportive of the full structure on \( \Phi \) (model 1 vs. model 3 = 7.0; model 2 vs. model 4 = 2.5). As expected based on the increases in re-encounters provided by the remote antennas during 2006–2008, model selection strongly favored the inclusion of many effects on \( p \). The top six models all included separate estimates of \( p \) for each sex in each year and at least one effect for tag type in 2006–2008. None of the models without some form of tag type effect had any support.

The additional encounters from the remote antennas provided substantial improvements in precision for the estimates of survival probabilities. Model-averaged estimates of \( \Phi \) were highly precise for the expanded data set (Figure 6), with coefficients of variation never more than 4%. Estimates were so precise in the most recent years that survival probabilities were essentially known for the tagged set of fish. In contrast to the data set including only physical recaptures, survival probabilities for both sexes in 2000 were estimable, and both point estimates were near 1.0. However, point estimates for

Table 3. Model selection results for the top 10 Cormack-Jolly-Seber models fit to the data set including both physical recaptures and remote detections of PIT-tagged Lost River suckers. Twenty-five other reduced models were considered, but all had \( \Delta QAI/Cc > 33 \) and are not shown. The “tagtype” effect on \( p \) in the model names refers to the difference between 125.0 kHz and 134.2 kHz tags, which is only included for the years 2006, 2007, and 2008 (see text). The tagtype effect is either constrained to be the same across years (“tagtype” alone) or allowed to vary by year (“tagtype *time”). Both structures were combined additively (+ precedes tagtype) and interactively (* precedes tagtype) with the other effects in the models. The number of parameters estimated in each model is indicated by \( k \), and the estimate of the overdispersion parameter (\( \hat{\sigma} \)) used in calculating adjusted model selection criteria (\( QAI/Cc \)) was 1.35.

<table>
<thead>
<tr>
<th>Model number</th>
<th>Model</th>
<th>( k )</th>
<th>( QAI/Cc )</th>
<th>( \Delta QAI/Cc )</th>
<th>Model probability (( w ))</th>
<th>(-2\log L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( \Phi(sex<em>time), p(sex</em>time+[tagtype*time]) )</td>
<td>30</td>
<td>22,695.4</td>
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<td>0.606</td>
<td>30,557.7</td>
</tr>
<tr>
<td>2</td>
<td>( \Phi(sex<em>time), p(sex</em>time+tagtype) )</td>
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<td>22,697.8</td>
<td>2.4</td>
<td>0.179</td>
<td>30,566.4</td>
</tr>
<tr>
<td>3</td>
<td>( \Phi(sex<em>time), p(sex</em>time+[tagtype*time]) )</td>
<td>37</td>
<td>22,699.3</td>
<td>3.9</td>
<td>0.088</td>
<td>30,543.9</td>
</tr>
<tr>
<td>4</td>
<td>( \Phi(sex<em>time), p(sex</em>time+tagtype) )</td>
<td>35</td>
<td>22,699.6</td>
<td>4.2</td>
<td>0.076</td>
<td>30,549.7</td>
</tr>
<tr>
<td>5</td>
<td>( \Phi(sex<em>time), p(sex</em>time+tagtype) )</td>
<td>33</td>
<td>22,700.6</td>
<td>5.2</td>
<td>0.044</td>
<td>30,556.6</td>
</tr>
<tr>
<td>6</td>
<td>( \Phi(sex<em>time), p(sex</em>time+tagtype) )</td>
<td>40</td>
<td>22,704.6</td>
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<td>0.006</td>
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<tr>
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<td>( \Phi(sex<em>time), p(sex</em>time+[tagtype*time]) )</td>
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<td>22,709.0</td>
<td>13.6</td>
<td>0.001</td>
<td>30,597.6</td>
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<tr>
<td>8</td>
<td>( \Phi(sex<em>time), p(sex</em>time+tagtype) )</td>
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<td>22,709.8</td>
<td>14.4</td>
<td>0.000</td>
<td>30,604.2</td>
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<td>0.000</td>
<td>30,583.5</td>
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<tr>
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<td>22,715.4</td>
<td>20.0</td>
<td>0.000</td>
<td>30,590.1</td>
</tr>
</tbody>
</table>

Figure 6. Model-averaged estimates of survival probability (± 95% confidence intervals) from the set of models fit to the data set including both physical recaptures and remote detections of PIT-tagged Lost River suckers. Estimates for both sexes in 2001 are not shown because they were on a boundary (1.0), indicating estimability problems. The estimate of the overdispersion parameter (\( \hat{\sigma} \)) used in calculating adjusted standard errors was 1.35.

Figure 7. Model-averaged estimates of encounter probability (± 95% confidence intervals) from the set of models fit to the data set including both physical recaptures and remote detections of PIT-tagged Lost River suckers. The estimate of the overdispersion parameter (\( \hat{\sigma} \)) used in calculating adjusted standard errors was 1.35. In 2006 and 2007, confidence intervals are only plotted for females with 125.0 kHz tags; for other estimates the confidence intervals are too narrow to distinguish them from the estimates [\( \hat{\sigma} \) ≤ 0.006]. Note change in y-axis scale compared to Figure 5.
both sexes were again on a boundary (1.0) in 2001. Survival of PIT-tagged Lost River suckers in 2001 was either very nearly 100% or there was simply not enough information in the data about individuals at large during 2001; either explanation is plausible.

Compared to the estimates from the data set including only physical recaptures (Figure 4), point estimates of \( \Phi \) based on the expanded data set changed by nontrivial amounts extending all the way back to 1999. Except for 2003, estimates for males increased by 1–11% when estimated with the expanded data set. Of particular note are the estimates for the three most recent years, which were all apparently underestimated by more than 7% using the data set with only physical recaptures. In contrast, \( \Phi \) estimates for females decreased in each year by 1–9%, and the data set including only physical recaptures produced the largest apparent overestimations in 2002 and 2003. Estimates from both model sets indicated that female survival was greater than male survival in each year, in contrast to our expectations based on reproductive studies. Remote detections and the “big law” of capture-recapture

Janney et al. (2008) showed that annual survival of adult suckers in Upper Klamath Lake was reduced in years when conspicuous fish die-offs occurred, but was also low in years without conspicuous fish die-offs. Those results add to ongoing concerns about the chronic effects of poor water quality and other sources of mortality on the recovery of endangered sucker populations (NRC 2004). The data provided by the remote detection systems has made it possible for us to pursue modeling that investigates hypotheses about the effects of various factors on survival. Results of such analyses are of pressing concern to management agencies tasked with conserving and recovering these species.

Remote detections and the “big law” of capture-recapture

Miranda and Bettoli (2007:251) noted that “tagging is not extensively used to assess mortality of fish populations, mostly due to cost and practical difficulties.” Results from our PIT-tagging program have shown that it is possible to overcome one critical difficulty represented by the “big law”—low encounter probabilities—by use of remote detection systems. Capture probabilities are often very low for traditional fisheries gears, so the problem of low encounter probabilities will remain a hindrance to fishery-independent capture-recapture studies that rely on traditional gears. Capture probabilities can be increased by more intensive sampling or alternative sampling strategies, but costs can become prohibitive and some active gears may not be permissible for some species (e.g., electrofishing).

In an important sense, the encounter probability “problem” is also an advantage for fisheries CR studies, in that it requires investigators to confront the realities of sampling in the system. Capture-recapture studies will only provide robust inferences when the data provide substantial information about the animals under study, and low encounter probabilities and imprecise estimates make it clear that much remains unknown. Although this issue is raised most commonly for CR studies, it applies equally to any method that depends on capture data. Inferences based on samples that represent only a small percentage of the individuals in the population cannot be considered strong inferences.

Our results with remote detection systems for PIT tags should be encouraging to fisheries scientists considering CR methods and wrestling with the difficulties of low encounter probabilities. Although CR methods are often considered to be too expensive and too difficult to implement in fisheries studies, remote detection systems can shift the balance...
in their favor. Advances in technology have made it possible to construct antennas or arrays of antennas that can span entire rivers, up to 50 meters wide or wider. Antenna systems are now primarily restricted only by flow conditions in the study system (high flows or debris can damage antennas), and antennas often require only infrequent maintenance. In addition, the range at which tags can be read by the antennas continues to increase. Finally, data can be acquired and transmitted in a fully electronic and remote process, reducing or eliminating some sources of error.

The initial investment in establishing a capture-recapture program based on PIT tags and remote detections may be high, but costs decline substantially in subsequent years. The total equipment costs for full remote antenna implementation at our sites in 2006 was around $54,000 USD, but maintenance and supplemental costs in subsequent years have typically been less than $1,000. Under budget constraints, PIT-tagging efforts and remote detection systems can be developed incrementally by adding antennas and readers as funding allows. Encounter probabilities are estimated as part of the analysis, so these changes in sampling design can be accommodated in models and the precision of survival estimates will progressively improve. In most cases, once remote detection systems are in place and encounter probabilities increase, the number of fish that need to be tagged and released each year can be reduced, potentially reducing costs associated with field efforts. In addition, some equipment, including antennas, can be designed and assembled independently to save costs in comparison to purchasing proprietary equipment from commercial manufacturers.

**Capture-recapture as an essential tool in fisheries**

Freshwater fisheries scientists have been slow to appreciate the utility and advantages of capture-recapture methods for estimating survival and other demographic parameters, and also to adopt modern methods for analyzing CR data. On this count, we reiterate the advice of Pine et al. (2003) that CR methods have much to offer fisheries research and management. In turn, we concur with the recent synthesis concerning mortality estimation by Miranda and Bettoli (2007) that freshwater fisheries scientists should incorporate into their toolbox numerous methods that appear to be largely restricted to marine and coastal fisheries. We believe that modern CR methods are one such tool. The use of tagging studies and tag return data is increasing in analyses of marine and coastal fisheries. The challenges of implementing tagging studies in these large and open systems are greater than those for most freshwater systems (with the possible exception of some commercially exploited stocks), so the groundwork has been laid for implementing modern CR methods in freshwater fisheries.

Capture-recapture methods offer a number of advantages over traditional methods for estimating survival based on fishery-dependent catch and effort data or fisheries-independent survey data (e.g., catch curves, change-in-ratio methods, and length- or age-based methods; Ricker 1975; Hilborn and Walters 1992; Quinn and Deriso 1999). Most traditional methods provide estimates of survival that are notoriously imprecise and require strong assumptions that are difficult to meet or assess in order to avoid biased estimates (e.g., constancy of recruitment, survival, catchability, or growth). Indeed, many of the assumptions are known to be violated a priori, but are commonly ignored. Improvements to traditional methods, such as year-class curves (Cotter et al. 2007) and nonequilibrium length-based estimators (Gedamke and Hoenig 2006), can improve the accuracy and precision of survival estimates, but still require strong assumptions that are difficult to meet or assess. Furthermore, because studies of population dynamics are concerned with understanding variation in survival and the factors that influence it, the utility of many of the traditional methods is limited because they assume that survival is constant during the study.

In general, CR methods are designed to estimate many of the parameters that are “assumed away” in the traditional methods. For example, rather than make strong and untestable assumptions about the time-invariance of survival and encounter (recapture) probabilities to estimate a single survival rate, CR methods are designed to jointly estimate both parameters, and assumptions and temporal dynamics can be evaluated. As noted by D. G. Chapman (quoted in Cormack 1968:456):

> If far reaching assumptions are made, then strong conclusions are reached. But if these assumptions are not accepted then the whole structure built upon sand collapses.

Modern methods of CR analysis have been developed to accommodate the realities of fisheries and wildlife field studies, including heterogeneity in capture probabilities and failures of the closure assumption (Pollock 1982, 1991; Kendall et al. 1995; Williams et al. 2002; Pledger et al. 2003; Cowen and Schwarz 2006). These methods should be integrated into the standard toolbox of freshwater fisheries scientists.

**Remaining hurdles**

The advantages of remote detection systems to inference and estimation are numerous, but there are also limitations. Two of the thorniest issues in capture-recapture analyses are goodness-of-fit assessment and heterogeneity in encounter probabilities. Although the primary parameters of interest in CJS and related models (e.g., survival probabilities) are robust to heterogeneity in encounter probabilities (Carothers 1979; Pollock et al. 1990), model selection and inferential procedures become suspect when too much heterogeneity exists in the data. Such heterogeneity must be accounted for either by inflating variance estimates using a correction factor (\( \hat{C} \)) or by adding additional justifiable structure to the model. Given the nonrandom patterns of association among individual fish in many populations, heterogeneity in encounter probabilities is likely to be worse than in many wildlife studies (Pollock 1991; Seber and Schwarz 2002). No hard and fast rules exist, but \( \hat{C} \) estimates above about 3.0 are suspicious and probably indicate that model structure is inappropriate (Choquet et al. 2009).

In our study, heterogeneity in encounter probabilities for Lost River suckers increased after the remote detection systems were put in place, and even more so after the change in the type of PIT tag (from 125.0 kHz to 134.2 kHz). Ironically,
because encounter probabilities were so high, goodness-of-fit tests were very sensitive to small deviations from expected values. To address heterogeneity, we had to adjust model structures to account for the two different tag types and still had to account for overdispersion because some heterogeneity remained (\( \hat{\theta} \) for data set with all encounters = 1.35).

Encounter probabilities are typically not of primary interest (“nuisance” parameters), so effort should be directed at reducing heterogeneity to avoid using information in the data to estimate additional encounter probabilities.

An additional concern with remote detection systems is that they only detect the marked portion of the population. Information on the unmarked portion of the population is needed to estimate population size, recruitment, and population growth rate. Also, for models addressing hypotheses about individual covariates (e.g., length, weight, condition), individual fish must be captured for the covariate to be measured. Although modeling strategies are available to accommodate remote detections in some situations (e.g., Al-Chokhachy and Budy 2008), careful attention must be paid to study design and substantial effort will need to be directed at capture sampling when these additional parameters are of primary interest. In addition, new modeling strategies will be needed to accommodate some study situations.

**Future possibilities**

The technology of PIT tags has made it possible for researchers to routinely pursue biological questions that were nearly impossible to answer prior to the 1980s (Gibbons and Andrews 2004). Technological advances have continued to reduce the limitations of PIT tags for biological studies, and remote detection systems have further enhanced their utility (Prentice et al. 1990; Zydlewski et al. 2006). The data provided by remote detection systems open up numerous possibilities for modeling and inference, allowing researchers to ask questions that address more complex hypotheses. For example, data from studies that previously were aimed at simply trying to obtain one estimate of survival can now be used to address hypotheses about factors affecting the dynamics of survival. The development of models to pursue such hypotheses has been the focus of much of the theoretical work in capture-recapture over the last decade (e.g., Thomson et al. 2009). Analyses will be more complex and challenging, but also more interesting from a biological standpoint.

Encounter data from remote detection systems should also allow capture-recapture methods to be used in systems where they were previously considered impracticable, from studies of rare or elusive species in small streams to assessments of fish populations in large systems. For rare or elusive fishes in small streams, physically recapturing tagged individuals with some reasonable probability may be impossible. However, a combination of surveys with portable detection systems (e.g., wands) and stationary antenna arrays operating continuously can be sufficient (Berger and Gresswell 2009). In large systems, such as Upper Klamath Lake, remote detection systems will need to target areas where individuals aggregate, such as spawning areas or constriction points in migration routes. For example, millions of fish are PIT-tagged in the Columbia River Basin each year and monitored with dozens of remote detection systems located at constriction points in migration, such as dam bypasses (see the PIT Tag Information System [PTAGIS]; www.ptagis.org).

Tag return data from commercial fisheries can also be enhanced by using PIT tags and remote detection systems placed at bottlenecks during harvest and processing. By placing remote detection systems on selected vessels and combining PIT tags with conventional T-bar tags, researchers were able to precisely estimate tag reporting rates, exploitation rates, and natural mortality for southern rock lobsters (Jasus edwardsii) in Australia (Burch et al. 2009; Frusher et al. 2009). For fisheries with larger bottlenecks at processing facilities, antennas or arrays of antennas could be incorporated into the processing line. For example, antennas could be constructed to fit the trailers at processing facilities for Bristol Bay-Bering Sea crab fisheries to detect tagged crabs as they are offloaded from the boats. Bottlenecks in processing occur in many other fisheries, such as whitefish stocks in the Great Lakes and shrimp stocks in the Gulf of Mexico and the Pacific Ocean, and we suspect that remote detection systems could be integrated into these facilities. The benefits to inference and estimation should be worth the initial costs and public relations work that would be required.

Finally, encounter data from remote detection systems can benefit analyses that integrate multiple sources of information through a joint likelihood approach. For example, tag returns from fishermen can be combined with telemetry studies (Pollock et al. 2004) as well as various sources of fishery-dependent data (Coggins et al. 2006; Eveson et al. 2007, 2009; Conn et al. 2009). An integrated model that incorporates information from tag re-encounters can often disentangle parameters of interest that are otherwise not estimable, such as tag reporting rate. The future of assessments for large commercial fisheries appears to lie in such integrated modeling (Maunder 2003), but other population dynamics investigations can benefit from such an approach as well. Remote detection systems for PIT tags offer potential for dramatically increasing encounter probabilities and the density of data provided by tagged individuals, which would benefit a wide range of fisheries studies.

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FISH HABITAT

FEATURE:

Los retos de dar seguimiento a la restauración de hábitat en varias escalas espaciales

RESUMEN: La evaluación de la efectividad ecológica de los cientos de millones de dólares que se han invertido en la recuperación del salmón del Pacífico noroeste, tiene varios pre-requisitos –principalmente, un conocimiento detallado de las acciones de manejo. A falta de un monitoreo ecológico coordinado, los meta-datos (tipo, localización, tiempo, etc.) derivados de proyectos básicos de restauración, son la principal fuente de información para ordenar los planes de restauración y decisiones de manejo. Sorprendentemente existen muy pocas fuentes de información sobre restauración de hábitat en escalas que sean útiles para la recuperación del salmón; dichas escalas van desde las pequeñas sub-cuecas hasta unidades (multi-estado) evolutivas significativas. Se evaluó la consistencia de dos inventarios de restauración de la cuenca del Río Columbia, desarrollados de forma diferente pero con un objetivo común: informar sobre la asignación de proyectos futuros. Se comparó la base de datos del proyecto “Hábitat del Pacífico Noroeste”, compilada por investigadores del Servicio de Pesquerías de la NOAA, y los “Inventarios de Sub-cuenca”, compilados por las entidades locales dentro de cada una de las 62 sub-cuecas. Conjointando estos dos conjuntos de datos, se encontraron 11,805 proyectos en la cuenca del Río Columbia, con tan sólo 13% (1,549/11,805) en común. Los Inventarios a nivel de Sub-cuenca capturaron más proyectos con patrocinio local que los que capturaron las bases de datos de gran escala. Los atributos comunes de los proyectos entre ambos grupos de datos coincidieron en menos de la mitad de las ocasiones, lo que sugiere que aquellas organizaciones que trabajan en un mismo proyecto realizan sus reportes de manera independiente y diferente ya sea a la base de datos o a los inventarios. Se encontró que la falta de estándares en los datos comunes y de conocimiento acerca de fuentes de información accesibles son las principales dificultades en cuanto a la disponibilidad de los datos y la toma de decisiones.

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INTRODUCTION

The magnitude and scale of efforts to manage habitat and revive salmon runs in the Pacific Northwest are unprecedented in U.S. history and possibly world history (Lichatowitch 1999; Ruckelshaus et al. 2003). The freshwater range of the five Endangered Species Act (ESA) listed Pacific salmon species (Oncorhynchus tshawytscha, O. keta, O. kisutch, O. nerka, O. mykiss) span the majority of four states: Washington, Oregon, Idaho, and California, and historically parts of two others (Montana and Nevada). The Columbia River Basin, the major river basin in the Northwest and the second largest in the U.S., was once home to the most abundant salmon runs in the world, but now many of these runs require extensive protective measures for persistence (Groot and Margolis 1991; Lichatowitch 1999). The role of salmon as a cultural icon of the Pacific Northwest creates a broad range of stakeholders that includes local, state, federal, and tribal agencies; private groups; fishing interests; and private citizens; resulting in unprecedented support for habitat restoration.

Testing any hypothesis related to the effectiveness of this restoration on a
managed resource, in this case salmon, has two prerequisites: information about the resource and information about past and present restoration actions (Katz et al. 2007). However, despite hundreds of millions of dollars spent annually on Columbia River Basin management actions (GAO 2002), specific data on the implementation and monitoring of these actions—including habitat restoration, and the links between restoration and the benefits to salmon—remain largely undocumented (McDonald et al. 2007). As highlighted by a few recent studies (Paulsen and Fisher 2005; Roni 2008; Bernhardt et al. 2005), habitat restoration metadata (type, location, timing, etc.) are not readily available to inform restoration strategies, project placement, or monitoring plans for salmon recovery (Rumps et al. 2007).

There are historical reasons why until recently restoration data had not been compiled across the Columbia River basin's large scale. Principally, projects were conducted by local or state groups to improve local conditions—as many projects continue to be. However, listing of salmonids under the ESA occurred at a different geographic scale determined by the evolution and demography of the species called an evolutionarily significant unit (ESU; Waples 1991; McElhany et al. 2000). Salmon ESUs cover part of one or more states, with the migration corridors of these anadromous fishes crossing as many as three states. Consequently, restoration data likely intended only for local accounting purposes must now be assessed at an ESU and regional level.

The Pacific Northwest is unique in having two recently compiled large restoration datasets available to compare: the multi-state Pacific Northwest Salmon Habitat Project Tracking Database (PNW database) and the watershed-level Columbia River subbasin plans. Both databases were similar in goal to guide future project planning; however, they differ in the geographical scale of compilation. This allows for an evaluation of the role of scale in tracking restoration data, including lessons learned about reconciling data at different scales and recommendations for streamlining reporting.

The PNW database (Katz et al. 2007) is a spatially-explicit restoration database containing over 29,000 projects at over 46,000 locations across all of Washington, Oregon, Idaho, and Montana, the states that overlap the Columbia River Basin. It was created by researchers at NOAA Fisheries to inform future project placement and effectiveness monitoring. The PNW database confederated data from many sources (federal, state, watershed, and private), though the majority of the projects were federally or state funded. A potential weakness of the PNW database is that by targeting large data holders and funders (federal and state), it may under-represent county, municipality, and other locally-sponsored projects. Local-scale management is increasingly assumed to be intrinsically more knowledgeable and more effective than management conducted at larger scales (e.g., United Nations 1992; Tsing et al. 1999). This idea is parsimonious since scaling up of the norms and rules that govern environmental management are increasingly challenging as the management community becomes more diverse at larger scales (Ostrom et al. 1999).

Within the Columbia River Basin, a portion of the area covered by the PNW database, a parallel inventory of restoration project data was assembled at the subbasin level. Sixty-two subbasins were designated to manage the effects of hydropower dam operation on fish and wildlife (Pacific Northwest Electric Power Planning and Conservation Act 1980 [Northwest Power Act]). By 2005, all subbasins were required by the Northwest Power and Conservation Council (created by the Northwest Power Act), to complete a plan (NWPPC 2001). The plans consist of three parts: an inventory of existing programs, including restoration actions and management plans (SB inventories); an assessment of the potential for fish and wildlife improvement; and a management plan to guide the next 10-15 years of actions. Together these components were expected to be the foundation documents for management planning into the future. Importantly, by focusing on individual subbasins, these reports are inherently more local in origin and scale than the PNW database.

Here we compare the PNW database project information to the completed SB inventories. The comparison allows a number of assessments including:

1. Estimates of the total number of projects on the ground in the Columbia River Basin;
2. Estimates of project reporting consistency provided by cross checking multiply-reported projects;
3. Evaluation of how the scale at which data is collected leads to similar or different data compilations; and
4. Indications of what makes some subbasins more successful than others at compiling and recording project data.

Finally, we suggest ways to streamline reporting to benefit restoration and monitoring and evaluate the effectiveness of restoration actions.

METHODS

Data Acquisition

We found 40 plans available on the Columbia River subbasin planning website, www.subbasin.org/fw/subbasinplanning/Default.htm. Together, these plans cover 58 of the 62 Columbia River subbasins; some of the 40 plans cover more than one of the 58 subbasins. Plans were not available for the following subbasins: Bitterroot, Blackfoot, or Clark Fork (Montana), Sandy (Oregon). We found restoration inventories in 50 of the 58 subbasins with plans (Figure 1).
Figure 1. Subbasin plan and restoration inventory data availability for Columbia River subbasins. The majority of subbasins contained complete plans (light gray). However, eight subbasins lacked an inventory of restoration actions in their plan (medium gray), and five subbasins lacked a plan altogether.
Semantics:
Defining a project record and estimating project record abundance

We defined a restoration project as a completed action or set of actions that actively changed the physical characteristics of a site, thus management plans, assessments, monitoring activities, and land acquisitions, though sometimes included in the subbasin restoration inventories, were excluded from our analysis. There was no universal identifier or common data dictionary that allowed us to easily find projects in common to both the SB inventory and the PNW database (http://webapps.nwfc.noaa.gov/pnshp). Therefore, we established a series of criteria to determine if the SB inventory and PNW database overlapped in projects captured.

We first looked at co-location; subbasin inventories report location at the subbasin (or in some cases a watershed within the subbasin) level, while the PNW database maintains location as latitude and longitude. Thus we mapped the PNW database projects to a subbasin to allow comparison of all projects in one subbasin at a time. Projects in the PNW database with start dates after 2004 were excluded from this analysis as the SB inventories were completed in 2005. Next, projects presumably occurring in the same subbasin were compared on the basis of title, description, funding source, year, cost, and location details (e.g., stream name). Finally, projects having the same title and/or description and occurring over the same time frame were then considered to be the same project or “in common.”

In many cases we did not find a one-to-one relationship between projects captured by both datasets. For example, a single project in the PNW database consisting of multiple installations (e.g., riparian fencing and large woody debris addition along the same stream segment and on the same contract) may be reported as two projects in the SB inventory data. Project records in the PNW database that refer to multiple sites were maintained in the format received from the data provider, which rarely allowed mapping of restoration activity to a single specific location among several possibilities (Katz et al. 2007). We counted in-common projects as the number of projects in the PNW database that matched projects in the SB inventory. We calculated the total number of unique records from both databases to estimate a minimum “total” number of projects in the Columbia River Basin.

Comparing Metrics: Data Source

To evaluate the expectation that SB inventories better capture locally sponsored projects, we compared the percentage of federal and state projects in common to both datasets (see Katz et al. 2007 for more information on PNW database sources). We defined local projects as those not funded by or reported in federal or state databases. Not all subbasin inventories provided data source or funder, but all projects in the PNW database have a source, therefore dually reported projects were assigned to the source reported in the PNW database.

Further, we calculated the fraction of the combined total projects per subbasin in-common (C) and used this as one measure of overlap between the two datasets:

\[ O_{basin} = \left( \frac{C_{basin}}{Total_{basin}} \right) \]

We then evaluated predictive factors, or covariates, that might explain some of the variability in the number of in-common records for a subbasin. These include: (1) size of subbasin, (2) total records in the subbasin, (3) the contributions to the total from the SB inventory and PNW database, and (4) who compiled the SB inventory. We found five classes of inventory compilers: consultant, local, state, local and state, and local and consultant. Local authors included soil and water conservation districts, counties, Indian Nations, fish recovery boards, and local watershed groups/councils, among others. All inventories authored by a state agency (e.g., Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game [IDFG]) were considered “state.” Inventories compiled by multiple coauthors were given multiple categories. We further looked to see if the compiler influenced the number of projects collected in the SB inventory as a percent of the total, regardless of in-common projects.

Comparing Metrics: Project Attributes (Cost, Year, Location)

The in-common project records provided the opportunity to evaluate the consistency of reporting by various compilers. In-common projects were examined for cost (within $100 was considered the same), start year, and end year. Cost was compared only when cost for both records was available. Costs that differed but by less than $5,000 were recorded separately as a measure of similarly-reported projects (e.g., in-kind funds could be included in one cost and not another, rounding of costs could account for the differences, etc.).

Similar to cost, we compared project metadata for year and compiler. Dates that differed but by only one year, we categorized separately to accommodate possible differences in how parties defined when a project began (e.g., planning time vs. permitting, recording fiscal year rather than calendar year). We then compared the consistency of reporting by various compilers: consultant, local, state, local and state, and local and consultant. Local authors included soil and water conservation districts, counties, Indian Nations, fish recovery boards, and local watershed groups/councils, among others. All inventories authored by a state agency (e.g., Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Idaho Department of Fish and Game [IDFG]) were considered “state.” Inventories compiled by multiple coauthors were given multiple categories. We further looked to see if the compiler influenced the number of projects collected in the SB inventory as a percent of the total, regardless of in-common projects.

Data Analysis

Correlations between measures of data quality and predictive factors were performed with Kendall’s rank correlations.
RESULTS AND DISCUSSION

Project Overlap

The 50 Columbia River subbasins with restoration data reported a total of 4,249 projects while the PNW database reported 9,105 projects for these same subbasins. Fourteen out of the 50 SB inventories provided project descriptions for all projects while 15 subbasins provided descriptions for some projects (ranging from 25-95%). Twenty-one subbasins provided no project description. Using this project information (title, description, and subbasin) we found 1,549 projects reported in both the SB inventories and the PNW database (representing 17% of the PNW database and 36% of the subbasin inventories; Figure 2). Forty of the 50 subbasins with inventories had projects in common with the PNW database. The SB inventory contained 2,700 records of projects that the PNW database lacked. Thus, there are now 11,805 total known projects in the Columbia River Basin for the 50/62 subbasins with inventory data (the total increases to 16,301 when including projects from the PNW database for the 12 subbasins without SB inventories). Of the 11,805 projects, 64% came from the PNW database exclusively, 23% came from the SB inventories exclusively, and 13% were in common (Figure 2). The percent of the total contributed by a single SB inventory ranged from 0-80%, suggesting that collection methods, effort, and engagement in the subbasin planning process varied widely by subbasin (subbasins that contributed 0% completed a full inventory that reported projects of many types: wildlife management, riparian assessment, fisheries research, monitoring, etc. but none of the reported projects fit our definition of a restoration project).

The limited overlap between the PNW database and the SB inventories is notable. Only 13% of the total records were common to both inventories, suggesting that the SB inventories and PNW database focused on data sources with different spatial extents and report very different snapshots of what restoration actions are taking place in the subbasin. Further, SB inventories captured a median of 27% of the total records per subbasin, missing the majority of known projects. This lack of overlap also limits our ability to test the consistency of specific metrics by allowing comparison with only a small portion of either dataset.

Using the overlap metric equation, we evaluated factors that might explain some of the variability in the number of in-common records across subbasins. The fraction of total records contributed by a SB inventory correlated with the number of records in common to both data sources ($\tau = 0.43, P < 0.01$). The fraction of the total number of records in a subbasin in common to both data sources was also correlated with the size of the subbasin ($\tau = 0.23, P = 0.02$), but not to the total number of records in the subbasin ($\tau = 0.04, P = 0.67$). Thus, SB inventories captured a greater fraction of completed restoration in larger basins, but not necessarily in basins with more restoration data. In contrast, the relative performance of the PNW database in capturing records did not correlate with basin size or data abundance.
Project Source

Two-thirds of the PNW database (updated since the publication of Katz et al. 2007) came from three federal and three state sources: the Regional Ecosystem Office of the U.S. Forest Service, the Bureau of Land Management, the Columbia Basin Fish and Wildlife Authority, the Oregon Watershed Restoration Inventory (OWRI), the Washington Salmon Recovery Funding Board (WA SRFB), and the Idaho Department of Fish and Game. Of the 4,249 records contributed to the total by the SB inventories, 83% were from sources other than the six major federal and state datasets (Figure 2). Thus, the SB inventories did not rely on large federal and state data sources to compile their inventories. Since the PNW database targeted large data holders, including states, one might expect greater agreement between the PNW data and SB inventories compiled by state agencies. One would then expect less overlap with locally-sourced inventories which would potentially report different details on a local level project (e.g., when there are many contributors to a single project, local groups may only report their contribution as the project attributes). Bernhardt et al. found that on average a single river restoration project has more than three funding sources and seven to eight different entities or partners (Bernhardt et al. 2007). Project partners or funders reporting results of a project separately or differently may explain some of why we found limited overlap between the PNW database and SB inventories.

Subbasin restoration inventories were compiled by five different entity types: consultant, local, state, local and state, and local and consultant. Different areas used different entities that were spatially clustered in the Columbia River basin (Figure 3). For example, most inventories in Idaho were compiled solely by state agencies and all inventories in Oregon were compiled by local or state entities. Local entities were responsible for collecting close to half (20) of the inventories basinwide followed by consultants (14; Figure 4). Inventories compiled jointly by state and local, or only by state representatives, most thoroughly captured restoration projects; however, both of these categories also had the largest variance. The variability in the overlap metric, the fraction of the total number of records in a subbasin in common to both data sources, is in some cases limited by the available data in the subbasin. Coefficients of variation in the overlap metric by compiler indicated a difference (0.71-0.85) across subbasins. Inventories compiled solely by local groups included the least coverage of state-sponsored restoration project data. This may be due to some combination of causes including limited funding to support the subbasin process and the level of awareness of large-scale data availability on the part of inventory compliers (e.g., not looking beyond local sources). Further, inventories compiled by both local and state representatives found a greater percentage of project data than local groups working alone. State representatives may have contributed knowledge about state-level restoration datasets or have access to additional resources that local groups alone lacked.

Figure 3. Spatial distribution of restoration inventory compiler by subbasin.
Inventories compiled by the state in Idaho (7) reported a median of 96% of the state-sponsored (IDFG) projects in the PNW database while SB inventories compiled by consultants (7) in all states found only 25% of state (IDFG, WA SRFB, OWRI) projects. Surprisingly, Idaho Department of Fish and Game was also the only data source in the PNW database for which the SB inventories found more than half of the known projects. This may result from a combination of factors, including state recording practices that include more complete metrics allowing for easier matching, facilitated data sharing agreements, and significant awareness of state-sponsored projects among state staff.

Interviews with compilers would be required to identify the reasons for the oversight of regional data sources. SB inventories are expected to guide the next 10–15 years of management actions; overlooking regional data sources severely limits the restoration data available to influence what types of future projects are conducted in the subbasin. Including regional data sources could change both the project density and project type composition of the subbasin, thus changing priorities for future project placement. While access and knowledge of data appear to be the major limitations to using data, subbasin inventory compiler alone was not a good predictor of the amount of in-common projects ($\tau = 0.10, P = 0.31$).

**Project Attributes:**
Cost, Year, Compiler, Location

To evaluate the relative data quality in the different reporting systems, we compared the attributes of the 1,549 projects reported in both the SB inventories and PNW database. Our expectation was that records for the same project, no matter who reported it, would have the same attributes. Ten of the 40 subbasins with in-common records reported none of the three metrics, so only 1,449 projects could be compared.

**Cost**

Only 6 of the 40 SB inventories with in-common records reported cost. Further, because not every record in the PNW database includes cost (Katz et al. 2007), only 104/214 records had cost reported by both sources, allowing a direct comparison. When cost information was available, 71 (33%) of the dually-reported projects had the same cost, and 33 (15%) had different costs (Figure 5). The median and average cost per project for the six SB inventories were $35,000 and $139,000 respectively ($n = 355$), while the median and average cost per project in the PNW database for these same six subbasins were $16,000 and $116,000, respectively, $n = 874$ (for all 62 subbasins $14,000$ median, and $158,000$ average, $n = 10,501$).

Thus, the SB inventories had both a higher median and average cost than the PNW database. This is surprising given our expectation that the SB inventories collected smaller-scale, more local restoration project data. More importantly, this suggests that there are large, expensive local projects taking place in addition to what is reported in state and federal databases.
Almost twice as many subbasin inventories reported start and end year than reported costs (29/40 start year, 30/40 end year). About half of the in-common projects reported the same start and end years. However, 15% of what appear to be in-common records (based on title and description) had different start or end years, half of which differed only by 1 year (Figure 5). This suggests that in many cases, different organizations involved in the same restoration projects are reporting the project independently and differently to either the PNW database or the SB inventory sources. For example, a local watershed group collaborates with a state fish and wildlife agency, and both groups reported the project; however, the attributes reported were not identical. With the available data, it is impossible to tell if projects with vastly differing start and end years may or may not actually be in-common projects. This illustrates the inadequacy of using only a title or description as a project identifier and the need for standardized project reporting metrics to allow in-common projects to be easily identified.

**Compiler**

We further examined the data to see if inventories by different compilers had different levels of metric reporting consistency. State-compiled inventories provided start/end year matches; however, no state compiled inventories reported cost (Figure 6 a,b,c). Any compiler that included local (local/state, local/consultant, local) had close matches (± 1 year) for the majority of non-identical start and end years, suggesting minor differences in reporting of the same project. Only projects in SB inventories compiled by consultants or local groups reported costs. Of these, consultant cost metrics were more often the same as the records in the PNW database. Data agreement aside, among the potential in-common records, half had insufficient documentation of cost to allow a comparison.

**Location**

Five subbasin plans included project data for more than one subbasin, allowing us to look at the consistency of reporting project records at a larger, multi-subbasin scale. For example, in the Lower Columbia (10 subbasins) we found 22 additional in-common records (18% increase) by comparing the 10 inventories as a group to the PNW database than we did matching subbasin by subbasin. Similarly in the Upper Snake SB inventory we found 11% (6) more matches when comparing the inventory for all three subbasins as a group than individually (54). However, the Boise, Payette, Weiser Plan and the PNW database were in agreement on all project assignments to subbasins but one.

In the Lower and Upper Middle Snake Inventory, subbasin was not specified for all projects, however most had either a U.S. Geological Service Hydrologic Unit Code (watershed) or county specified. From the location information available, we were able to assign each project to a subbasin and found no discrepancies between datasets. However, in the process of dividing the inventory into Lower Middle and Upper Middle Snake, we found 29 projects that were located outside of both the Upper and Lower Middle Snake subbasin (compared to 29 total projects positively identified as Upper and 14 as Lower). Out of all five multi-subbasin plans covering a combined 24 subbasins (or over one-third of all Columbia River subbasins), only the Intermountain Plan (Columbia Upper, Couer d’Alene, Pend Oreille, Sanpoil, Spokane) assigned all in-common projects to the same subbasin as the PNW database.
For the remaining 16 subbasin inventories that reported individually (i.e., not part of a multi-basin inventory), we were not able to identify additional in-common projects where assignment to subbasin differed. As the fundamental spatial framework of the SB inventories was the subbasin, we compared projects subbasin-by-subbasin and did not have a reasoned basis for cross-referencing project records from other basins. Consequently, we did not estimate a correction for matching projects assigned to different subbasins in making an estimate of the total number of restoration actions across the entire Columbia River Basin.

**Lessons Learned and the Need for Common Data Standards**

Our findings demonstrate the variation in two attempts to compile restoration data across a large geographical area. This reveals important opportunities to improve the reporting of management actions and the accountability for the resources applied to those actions. Methods, effort, and engagement varied widely by SB inventory as demonstrated by the diversity of compilers and variation in percentage of in-common projects. In general, we found that SB inventory data was focused less on state and federal data sources and thus assume it was focused more on locally-sponsored projects. The comparison with the SB inventories revealed that the PNW database is missing as much as one-fifth of the available restoration data and the missing data is likely for local projects. These missing local projects were not necessarily inexpensive, implying they are larger and more significant restoration efforts that are lacking in the PNW database. Subbasin-scale inventories appear to capture locally-sponsored projects better than the large-scale data inventories (such as the PNW database), but it is still not clear whether they have better knowledge of projects taking place in their local watershed. Three data sets publicly available on the web, the Regional Ecosystem Office Interagency Restoration Database, the Oregon Watershed Restoration Inventory, and the Washington Salmon Recovery Funding Board, were not well utilized in the subbasin inventories. Yet, small local datasets included in the SB inventory were not locatable by the PNW database. This suggests that knowledge of a data source’s existence may be a better predictor of inclusion in a database than the ability to access the data.

Though we observed that the total records for the Columbia River Basin include thousands of projects not reported in SB inventories and concluded that SB inventory compilers knew how to locate more local sources of data—despite missing a lot of large-scale, accessible information about their local areas—there is an alternative hypothesis. Local entities may know both their local data and local areas better, and the large amount of additional data available represents an over-reporting of management investments in habitat improvement by state and federal agencies. The quality of restoration action data is an accumulated consequence of the actual amount of projects in the field, the quality of the data reporting and record keeping, and the quality of our investigative work in discovering data. However, eliminating the hypothesis that large numbers of these records do not correspond to work done on the ground requires visits to the sites and evaluation of the quality of the data reporting. We are currently evaluating this and will report those results in a subsequent publication.

Compiling the PNW database provides numerous lessons on what contributes to a good inventory, but this comparison with the SB inventories elucidates other reporting challenges. In the Pacific Northwest, projects are being implemented and reported separately by entities ranging in scale from single Boy Scout troops to large federal agencies. Furthermore, reporting standards and requirements vary drastically across the region depending on the project sponsor and funding source. This lack of a single data repository or at least common standards in distributed databases creates further inconsistencies as the project sponsor, contributing agencies/organizations, and project funder all may report the same project and with slightly different attributes. This can result in apparent bias, such as in the total effort expended and other characteristics (Bernhardt et al. 2007) as we discovered when comparing the cost, year, and location of projects.

As characterized in this study, failure to resolve multiply-reported projects on the basis of project attribute not only may result in over-reporting inefficiencies, but results in increased regional cost inefficiencies in the time spent resolving the data. A standardized definition of a project and basic project metrics (identifier, date, description, etc.) that are consistently reported would go a long way to solving this problem. Perhaps the most crucial reporting metric is spatial location. Absent consistent and specific location information (latitude, longitude), many projects were misassigned to subbasin, creating a significant hurdle to correlating projects across reporting systems. In some cases, the location of the agency or organization doing the work may have been used rather than the subbasin the work was actually located in.

Beyond data verification, spatially explicit project data can be used in a geographic information system (GIS) and combined with data such as salmon habitat utilization or water temperature to evaluate treatment-response effectiveness. The added value of spatial data also comes with added complexity and data management difficulties since a project often has multiple restoration sites (Katz et al. 2007). Having some consistent spatial references for projects also allows association with more diverse, and in some cases familiar and useful spatial attributes (e.g., county, state, stream, etc.) that makes spatial data usable to groups working outside of GIS (e.g., query for the number of projects on a given stream or in a county). Creating the full set of spatial data requires time and data management capabilities as well as adequate support resources, beyond what is required to store only tabular data. Absent this approach to spatial information, restoration data can only be handled as it was in the SB inventories with presence/absence at a subbasin or even larger geographic scale, which ultimately limits its usefulness.

Significant resources were required to compile the PNW database in part as a consequence of the lack of standardized reporting or a centralized reporting system (Katz et al. 2007). This resulted in numerous partially complete records and a long latency between project initiation and reporting of the project (Katz et al. 2007). It is very likely that the SB inventories lacked information from some of the larger, regional data sources (e.g., REO, OWEB etc) because they lacked the resources to reconcile the diverse data formats. The lack of consistent sources to find all restoration data is a larger regional problem, if not a national restoration problem (Bernhardt et al.
A national inventory in 2005 found 37,000 projects, of which 62% (23,000) were from the PNW database (Bernhardt et al. 2005). Though the PNW may have a greater density of restoration effort than many parts of the country, four states accounting for 62% of all national projects is not our expectation. It suggests that there may be similar data management issues at work in the rest of the country and this disparity reflects data accessibility limitations rather than the actual distribution of on-the-ground projects. More money and effort are spent on restoration in the Columbia River Basin than anywhere else in the United States, yet basic expectations for what data should be available (standardized fields, location, monitoring) are still not met. Even with the number of papers and groups providing guidelines for capturing restoration data (Palmer et al. 2005), we found in both the PNW database compilation effort and the SB inventories that only the most basic project implementation data is available.

Here we examined the products of two attempts at compiling restoration data to inform future project planning and analysis. To assess the impact of restoration on habitat quality for salmonids requires more specific information on specific habitat project-level metrics (e.g., number of culverts removed, species and amount (acres) of planting etc.), the level of habitat alteration from natural conditions, and the distribution of salmonid population limiting factors. Compiling restoration data into a database is not an answer to the question of “what kind of response are we getting for all the restoration effort?” Yet, it does inform our understanding of what information people have available to them to make decisions about restoration. In the absence of targeted monitoring of habitat response to restoration, however, project data is one of the only tools managers have to use in making the best tactical decisions about future restoration activities.

ACKNOWLEDGEMENTS

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REFERENCES


COLUMN:
GUEST DIRECTOR’S LINE

Certification—
Promoting the Importance of Fisheries Professionals

Gail Goldberg
Goldberg is the AFS units coordinator and may be contacted at ggoldberg@fisheries.org.

Certification enhances the professional image and formalizes accomplishment levels. AFS began the Certification Program at the 93rd Annual Meeting in 1963, when attendees approved standards developed by the Professional Standards Committee. Certified Fisheries Professionals are recognized as those who achieved specific standards of professional competence.

We are approaching the 50th anniversary of the AFS Certification Program, so we conducted a survey of Certified Fisheries Professionals to assess the program’s efficacy. About 680 certified individuals were asked to provide feedback on the program and over 250 responses were received—a respectable 36% response rate. Here is some of what we learned.

We first measured the level of satisfaction with the application process, including the application form, web site information, and online submission. In each of these areas, the majority of replies were “very satisfied” (50–75%). Second, we asked how rigorous were the requirements to obtain Certified Fisheries Professional status. Eighty-six percent thought the requirements were about right. Respondents were then asked about the renewal process and how they would rate the requirements to maintain certification and apply for renewal. Again, most (79%) said these requirements were about right.

The survey also asked what benefits were derived from certification as a Fisheries Professional. Seventy-eight percent of respondents selected “achievement of a career goal” and “personal satisfaction” as the main benefits. After that, 42% cited “recognition by peers.” There was an opportunity to provide further comments regarding perceived benefits. Here most responses were positive and supported the concept of enhanced credentials. However, a frequent negative comment was about the lack of any financial benefit.

Finally, our survey asked for “general comments on the Professional Certification Program.” Many of the positive comments reinforced the notion of personal satisfaction, with comments such as:

* Very worthwhile program, I always encourage my students to set this as one of their career goals.
* Of greatest value early in my career.
* Considered important in the environmental consulting industry.
* Fine program with the right mix of academic education and professional experience while fostering AFS involvement.
* AFS needs to push hard for participation in a rigorous program for the sake of the profession.
* As I apply for increasingly advanced positions within my agency I have appreciated the certification opportunity provided by AFS because it gives me a chance to document a broad range of education and experience that I believe are important for modern scientists working on fisheries issues.

Negative comments focused on the renewal program. Many, citing a consequence of the general economic downturn, did not agree with paying a fee to renew their certification every five years; one respondent said it was “too expensive to renew with the furlough salary reductions in California.” Moreover, there were comments from state employees noting the difficulty of renewing certification with less or even no funding available to support travel to meetings and continuing education.

Other negative comments also cited the absence of financial benefits.

While I value my certification, my employer does not. I work for a state agency and there is no incentive for promotion, merit pay, or any other consideration for obtaining certification. A Certified Fisheries Professional is not recognized in the same way as a Professional Engineer (PE) and that is unfortunate for our profession….Sadly, CFP has not been considered in the hiring decisions of staff internally or externally. This is probably because rarely is someone in a hiring position also a CFP. AFS and the profession need to find a way to make certification more recognizable, accepted and a minimum condition for employment. Those of us in my agency who are certified have done so because we believe in a higher standard, but that is not the norm apparently in our profession.

We appreciated the many thoughtful suggestions that were received. An often repeated recommendation was to get state and federal agencies to endorse or provide compensation based on professional certification.
I wish more (all) state agencies recognized the importance of the Certified Fisheries Professional status and would use it for hiring and adjusting salaries.

We need to make certification more meaningful….for example getting more employers to compensate for certification.

AFS and the profession need to find a way to make certification more recognizable, accepted, and a minimum condition for employment.

A movement in that direction actually can be detected, with state agencies in Alabama and Kentucky using or requiring professional certification in the employment process.

Another commenter suggested that AFS leaders demonstrate their support of the professional certification program by becoming certified themselves.

When it becomes important to AFS, then it will start to become important to our members…. Leaders lead, and in this case become certified. That demonstrates to the general membership that they should take the time to complete the form.

We as a Society should do MUCH MORE to promote the importance of certification. Geologists did this about 20 years ago and now being a PG is important in that field.

We need to promote our profession and increase the rigor of certification so it means something. Consider recognizing certified professionals at annual meetings? Perhaps a note on their name badge and/or footnote on abstracts they author.

It must be noted that some AFS Units are taking the lead in that regard. In particular, the effort of the Atlantic International Chapter (AIC) to encourage professional certification is especially worthy of mention. AIC has 15 active members that are certified and current AIC President Scott Craig has just announced an initiative to double that number before the Annual Meeting in Pittsburgh. To support this effort, the Chapter will offer financial assistance.

In December 2009, Aaron Jubar, with the AFS Texas Chapter, surveyed state fisheries agencies. His findings echo what we learned here from certified individuals. In his conclusions, Jubar stated,

Although very few state agencies require new hires to either meet the requirements of or possess AFS certification, applicants who have these credentials are looked favorably upon….Most states do not offer incentives in the form of promotions or wage increases for current employees that obtain their certification. However, a few respondents indicated they were encouraged by supervisors to seek certification. In some cases, agencies will support employees who are actively seeking certification by allowing them work time to complete application materials, and possibly reimburse expenses incurred such as the application fee or fees associated with training or coursework required for certification.

More information on AFS certification, including guidelines, frequently asked questions, application materials, and a list of certified professionals, is available at the AFS website at www.fisheries.org/afs/certification.html.

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Dakota Chapter
Meets in Spearfish, South Dakota
The Dakota Chapter’s annual meeting was held in Spearfish, South Dakota, in the heart of the Black Hills on February 22 through 24. The theme was “New Fisheries Solutions for a New Decade.” With over 125 participants and 50 presentations, the meeting was well attended and full of information. The meeting started with a fish disease continuing education course taught by Rick Cordes. A special retiree social was held, during which former member Dennis Unkenholz was recognized for his induction into the Fisheries Management Hall of Excellence. Also, in keeping with the positive spirit of engagement stressed by the Chapter leadership, angler groups, such as the Black Hills Fly Fishers and the Rapid City and Sioux Empire chapters of Walleyes Unlimited, were involved both financially and in the technical sessions. The meeting closed with the awards ceremony and banquet.

South Dakota State University (SDSU) students dominated the best student presentation awards ceremony with Jessica Howell winning the Best Undergraduate Paper with her presentation “Diet Overlap Patterns Among Age-0 Common Carp and Four Native Fishes.” The Best Graduate Student Poster was awarded to Michael Weber, for his poster titled, “Effects of Morphology, Size and Location on Survival Growth, and Tag Retention Using Passive Integrated Transponders.” Best Graduate Student Paper went to Justin VanDeHey for his paper titled, “Effects of Simulated Cold-fronts on Hatch Success and Survival of Yellow Perch.” Greg Wanner of the U.S. Fish and Wildlife Service won the award for Best Professional Presentation, “Spatial and Temporal Patterns in the Niobrara River Fish Community.” Several scholarships were awarded, including the Schmulbach Scholarship presented to Bobbi Adams from SDSU. Two Alven Kreil Memorial Scholarships were presented to Nikki Lorenz and Jake Mertes. The Sauger Scholarships

Bobbi Adams receives the Schmulbach Scholarship from Will Sayler, Schmulbach Committee Chair.

Randy Hiltner presents the Best Graduate Student Poster Award to Michael Weber.

Randy Hiltner presents Best Graduate Student Paper to Justin VanDeHey.

Matt Wipf is recognized for his exemplary efforts as assistant editor of the Dakota Chapter Newsletter.

Jim Hawke, Hans Stephenson, and Ev Hoyt, representing the Black Hills Fly Fishers, present Dennis Unkenholz with a plaque in recognition of his years of service to fisheries conservation in South Dakota.

The Sauger Scholarships are presented to: Donna Abler, Jessica Howell, Bobbi Adams, and Nikki Hegna from SDSU by McLain Johnson (middle), president of the SDSU Student Subunit.
were presented to Donna Abler, Bobbi Adams, Jessica Howell, and Nikki Hegna from SDSU. Awards were presented for recognition of professional service and contributions toward improving the appreciation and use of aquatic resources in their communities. Bob Hanten and Greg Simpson won the Distinguished Professional Service Awards. A Special Recognition Award went to Norm Kopecky for his efforts in introducing recreational angling to special needs individuals. Aquatic Resource Conservation Awards were presented to the Rapid City Area Chapter of Walleyes Unlimited and Ken Edel. Will Sayler was presented with a “Parliamentarian Extraordinaire” award and

Matt Wipf from Black Hills State University was recognized for his work as associate editor of the Dakota Chapter newsletter. The Dakota Chapter also held a photography contest and accepted photographs from Chapter members, who had to be present to win. The categories and winners were:

Angling—Breanne VanDeHey; Kids and Fishing—Justin VanDeHey; Fisheries in Action—Michael Weber; Just Fish—Wes Bouska; Scenery—Joshua Peters; Humor—Luke Schultz; Wildlife—Will Schreck; Outdoor Activities—Matt Wipf; Miscellaneous—Tyler Berger; People’s Choice—Breanna VanDeHey; and Best in Show—Michael Weber.

New Chapter officers were elected at the meeting. Bill Haase (secretary/treasurer), Paul Bailey (vice president), and Chris Longhenry (president elect) join President Mike Barnes.

—Kasondra Brooke

Photography winners pose with Chapter member Michelle Bucholz, pictured in the left front.
game birds), mountain goat, whitetail deer, elk, black bear, wild turkey, striped bass, rainbow trout, brown trout, brook trout, smallmouth bass, largemouth bass, walleye, bluegill, channel catfish, tilapia, Nile perch, red drum, peacock bass, Pacific salmon… and the list goes on and on… because we have decided that we like these plants and animals and are willing to cultivate them, generally at the expense of other life forms. We have extirpated native species, assemblages, and entire communities, on terrestrial landscapes as well as in aquatic systems, and oftentimes have supplanted them with less complex (and thus in our minds more efficient) assemblages (often monoculture).

It is all a matter of value systems and what we see as our professional roles and responsibilities. We certainly make mistakes along the way. But is it a mistake to build a pond or a reservoir, stock it with fish that people like, and establish a fishery? Was it a mistake to create rainbow trout fisheries in cold tailwaters throughout the eastern United States (I’ll also leave it to you to determine if the dams that created the tailwaters were a mistake or not); largemouth bass fisheries in California, Japan, and Kenya; Pacific salmon fisheries in the Great Lakes and New Zealand; peacock bass fisheries in Gatun Lake (Panama); Nile perch fisheries in Lake Victoria (East Africa); landlocked coho salmon fisheries in central Alaska; brown trout fisheries in Patagonia; and tilapia and common carp fisheries everywhere? What about brook trout in Colorado, channel catfish and flathead catfish along the eastern seaboard, and striped bass along the California coast? When I review the above examples I will say “yes” to some and “no” to others. But my two lists very likely differ from yours.

Last month the American Fisheries Society (AFS) and The Wildlife Society (TWS) addressed the issue of “gardening” through a collaborative symposium on species introductions and reintroductions. Held on the campus of Mississippi State University, it was the first such joint venture of sister organizations from within the newly-established Consortium of Natural Resources Societies (AFS, TWS, the Society of American Foresters, and the Society of Range Management). This was also the first venture by AFS to conduct a topic-oriented meeting (TOM) which, by design and purpose, is a highly-focused event, rapidly-organized (<1 year from idea to event closure), and is conducted within the framework of a relatively small budget (<$20,000). During this meeting there were over 50 participants from throughout North America and beyond, 20 oral presentations, and a dozen posters. The plenary session included keynote addresses by Dan Simberloff (University of Tennessee-Knoxville), and Jeff Hill (University of Florida and president of the AFS Introduced Fish Section). For persons able to schedule attendance but unable to travel to the event, AFS and TWS provided live streaming of the symposium through their respective websites. Summary papers will be developed for Fisheries and for The Wildlife Professional. Abstracts from presentations, along with a webcast of the event, will be available on AFS and TWS websites so that members from both societies will have access to the information shared during this TOM, and be able to “attend” the meeting virtually and at their leisure.

The meeting allowed participants opportunities in both formal and informal settings (i.e., two offsite evening events and end-of-conference field trips) to discuss the topic at hand. Good science was presented and, as the conference evolved, trans-disciplinary common denominators were revealed. These common denominators revealed opportunities for new relationships, new synergism, and new collaborative ventures between and among participants who, prior to the meeting, were in many cases unknown to one another. There was incredible energy in the group during the conference and a “sparkle in their eyes” as they rode the crest of the wave at the end of the conference. I am firmly convinced that we can, in the future, expect increasingly good guidance from these and other “Master Gardeners” within our professional ranks.
AMERICAN FISHERIES SOCIETY
APPLICATION FOR COMMITTEE APPOINTMENT

As a small organization, AFS depends on volunteers for many tasks related to the science and the profession. Committees at all levels of the American Fisheries Society (AFS) provide many ideas that shape the future of the Society, and they are excellent avenues for members to begin or continue volunteer service to AFS. We encourage new members to contact their Chapter, Division, and Section officers to volunteer their services. We encourage experienced members, including students, to apply for AFS Committee appointments. (AFS committee terms are considered by the incoming AFS President for appointment starting in September). By volunteering at one or more of these levels, a member gains experience and leadership skills.

Please number, in order of priority, no more than two (2) Committees on which you would like to serve:

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(Please indicate level—Chapter, Division, Section, Society)

I HAVE HAD EXPERIENCE ON THE FOLLOWING COMMITTEE(S):
(Please indicate level—Chapter, Division, Section, Society)

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Please complete and return form for consideration to:
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e-mail: ggoldberg@fisheries.org
When I learned about the Janice Lee Fenske Excellence in Fisheries Management Fellowship, I jumped at the opportunity to apply. That's because the fellowship is not your average funding opportunity. The Fenske Fellowship provides Michigan State University Department of Fisheries and Wildlife graduate students from the under-served community with a year-long experience designed to assist the recipient in learning about the role and activities of fisheries management agencies. During the year, recipients interact with numerous fisheries professionals, work on a project of their design to inform management decisions, and learn from great mentors. Priority is given to female applicants with excellent academic and service records and an interest in fisheries management. The fellowship was created to honor the commitment, integrity, and memory of Jan Fenske (see inset), Michigan's first female fisheries biologist, who passed away in 2005.

As a Fenske Fellow I worked closely with mentors within the former Michigan Department of Natural Resources (DNR, now Michigan Department of Natural Resources and Environment), Gary Towns (fisheries supervisor, Lake Erie Management Unit), and Jim Breck (fisheries research biologist, Institute for Fisheries Research) as well as my major professor at Michigan State University, Mary Bremigan. My mentors led me through the Fenske Fellowship experience, guiding me through several meetings. I attended two Michigan DNR Fisheries Division Management Team Meetings where I observed the dynamics of communication and decision-making at the state level by witnessing discussions among representatives from management units, the research section, and the chief of the Michigan DNR Fisheries Division. I also participated in meetings between the Michigan DNR Fisheries Division and other agencies, such as the Huron-Erie Corridor Initiative Meeting at the Environmental Protection Agency offices in Detroit, Michigan. There fisheries professionals from multiple states and Canada interacted to work toward the common goal of managing the shared resource. I also had the opportunity to attend several other meetings, such as the AFS Michigan Chapter and society-level AFS meetings, Great Lakes Fishery Commission Lake Committee meetings, and the Michigan DNR Fishery Research/Biologist Meeting.
My diverse group of mentors also provided significant input in planning my fellowship research project, an assessment of a change in Michigan DNR fishing regulations allowing angling of black bass during the spring nesting season. My mentors guided me through the process of planning a large, collaborative project involving MSU students as well as members of the Michigan DNR from across the state. We worked together to plan black bass nest survey methods and coordinated electrofishing efforts across four different study lakes. From my mentors I learned more about conducting research, but equally invaluable is the example they set for me concerning the importance of communication and seeking input on the project from managers, biologists, and technicians, in addition to other researchers.

For me, the Fenske Fellowship was a challenge. Transitioning into graduate school can be difficult on its own, and the fellowship added another layer of commitment. It pushed me to develop myself professionally and to create connections between myself and members of the Michigan DNR Fisheries Division. The fellowship provided me with unique lessons and experiences I never would have without the fellowship, ones that have been extremely valuable in preparing me for a career in fisheries management. I also found inspiration in Jan Fenske’s story since she worked tirelessly for the protection and wise use of Michigan’s natural resources. Her numerous achievements led her to receive many awards from the Fisheries Division, Trout Unlimited, and from the American Fisheries Society. She was very proud of her association with the latter and particularly enjoyed participating in professional debates and discussions at Society meetings.

Fenske blazed a trail for women working in fisheries management in Michigan by entering the Fisheries Division, then considered a “man’s division.” She succeeded in her endeavors by facing the toughest of challenges with a steadfast resolve, and these experiences spurred her desire to be a mentor to others, especially women. It was in honor of her commitment, integrity, and memory that the Janice Lee Fenske Excellence in Fisheries Management Fellowship was created. For more information about Jan Fenske, visit the Michigan Chapter of the American Fisheries Society website at www.fisheries.org/units/miafs/fenske_award.html.
CONNECTING HABITATS

The plan not only includes ways to create and restore habitats, but also methods to connect the habitats so that they can benefit from one another. These methods include rebuilding shorelines and creating habitats for fish, crabs, and lobsters.

Over the years, the estuary's 1,000 miles of natural shorelines have been replaced with piers, docks, and bulkheads which have altered the naturally sloped shorelines which transition from shallow to deep water and are needed by fish and sea life to thrive. The plan suggests replacing abandoned piers with naturally sloped shorelines and creating new piers and other shore structures that will be designed in a way to have less of an impact on the natural shoreline and foster habitat complexity. Regional fish, crabs, and lobsters require many different habitats to breed and for their young to develop into full maturity.

HABITAT SUPPORT STRUCTURES

The plan also focuses on the physical landscape, balancing necessary urban infrastructure with environmental restoration to include opening up tributaries that may be obstructed by man-made barriers and improving the water quality of enclosed waterways. Networks of tributaries connect rivers and streams to the estuary. Each year, migratory fish navigate these connections, swimming many miles upstream to spawn. Man-made barriers such as dams can prevent fish from reaching egg-laying sites, threatening the future of these fish populations.

The plan recommends removing unnecessary barriers and reconstructing others to include fish passage such as fish ladders that can connect upstream habitats with the rest of the estuary. In some areas of the estuary, bodies of water are isolated or enclosed, such as dead-end canals. Often these areas collect pollution discharge and stormwater runoff, resulting in water that is polluted, stagnant, contains sparse vegetation, has low species diversity, and emits noxious odors.

HEALTH AND SOCIETAL VALUE

The plan includes ways that millions of people can safely enjoy access to the estuary. For centuries, the estuary has been an area for disposal of chemical and industrial wastes. These contaminated sediments are harmful to the estuary's wildlife, pose a public health risk, and reduce the port's commercial viability. The goal of the plan is to reduce contaminated sediments throughout the estuary by isolating or removing the contamination. Cleanup of contaminated sediments will reduce human health and ecological risks, improve fishery resources, remove fish consumption advisories, and provide the public economic benefits. Increasing and improving public access throughout the estuary is also a goal of the plan, with the hope of enabling everyone in the region to be able to reach the estuary in a 20-minute walk or by public transportation.

PROJECT GOALS

Just some of the plan's short and long-term goals include creating 1,200 acres of coastal wetlands by the year 2015 and 15,200 by 2050, enhancing four or more islands for waterbirds by 2015 and all islands by 2050, creating or restoring 250 acres of coastal and maritime forest by 2015 and 1,000 by 2050, and creating 500 acres of oyster reefs habitats by 2015 and 5,000 by 2050.

“"The team is already achieving the plan’s restoration goals,” said Weppeler. “Salt marshes are being created within some of the estuary’s regional areas. This is tangible evidence towards fulfilling our vision of a restored estuary.”
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The Continuing Education Committee has put together a diverse suite of courses for the 2010 Annual Meeting. The courses cover a variety of topics, ranging from the responsibilities of fisheries professionals in Endangered Species Act consultations, to building leadership skills in AFS, to complex modeling of instream habitat for river management. When you register for the meeting, please consider taking one or more of these courses or technology workshops. All of them will help increase your professionalism, perspective, and skill set when you return to your job.

**Introduction to Instream Habitat Modeling Using MesoHABSIM**

Piotr Paraiewicz and Josef N. Rogers, Rushing Rivers Institute; piotr@rushingrivers.org, joe@rushingrivers.org

Student $150; Member $250; Non-member $300

This two-day course will serve as an introduction to modeling instream habitat using the MesoHABSIM approach (and associated SimStream software) and how it can be applied to river restoration and management.

**Basic/Intermediate GIS for Fisheries Biologists**

Joanna Whittier, Kansas State University; whittier@ksu.edu

Student $125; Member $220; Non-member $250

This course will provide an overview of basic/intermediate GIS skills for fisheries biologists using ArcGIS, including use of existing data, creating your own data, and review of fundamental concepts for GIS.

**Advanced GIS for Fisheries Biologists**

Joanna Whittier, Kansas State University; whittier@ksu.edu

Student $150; Member $220; Non-member $270

Building on the “Basic/Intermediate GIS for Fisheries Biologists” course, this course will focus on geoprocessing, interpolation, and spatial analysis methods to aid in fisheries monitoring and research.

**Leadership at All Levels in AFS**

Dirk Miller, Wyoming Game and Fish Department; Dirk.miller@wgf.state.wy.us

FREE!

This course will focus on helping AFS leaders understand how to work effectively within the AFS governance structure at all levels: Chapter, Section, and Division.

**Instream Structures for Habitat Enhancement**

Wolfgang Wolter, AECON; Wolfgang.Wolter@aecom.com, and John Parish, PARISH Geomorphic Ltd; jparish@parishgeomorphic.com

Student $75; Member $125; Non-member $175

Topics include an introduction to stream restoration, benefits of stream restoration, adaptive environmental management, use of instream structures for habitat enhancement, and design and implementation of instream structures, including working examples. A case study will be presented that will examine the physical, biological, and technical aspects of channel and structure design with a focus on fish habitat. Material will be presented in lecture format with encouragement of participation from students.

**Introduction to Programming in R for Fisheries Scientists**

Matt Catalano and Cheryl Murphy, Michigan State University; mcatalano@msu.edu, camurphy@msu.edu

Student $100; Member $150; Non-member $200

This course will introduce the basics of Program R using a command-line interface and examples from fisheries research. Program R is a powerful open-source mathematical and statistical software program gaining popularity in the fisheries and ecological sciences.

**Mapping Habitat of Aquatics Systems Using Low-Cost Side-Scan Sonar**

Adam J. Kaeser and Thom Litts, Georgia Department of Natural Resources; Adam.kaeser@dnr.state.ga.us, Thom.litts@dnr.state.ga.us

Student $100; Member $150; Non-member $200
This course is an introduction to using the inexpensive Humminbird® Side Imaging system to map and quantify benthic habitats at the landscape scale. The course includes a practical session covering techniques for geoprocessing sonar imagery and map development within ArcGIS 9.x.

**NEW! SCIENCE, TOOLS AND INFORMATION RESOURCES FOR DOWNSTREAM FISH PASSAGE**

Doug Dixon, Bioengineering Section AFS; ddixon@epri.com
Student $75; Member $125; Non-member $175

This course will provide attendees with state-of-the-art knowledge of basic and applied fisheries bioengineering information associated with downstream passage for fish at dams, primarily those associated with hydropower power generation and navigation. The program will focus on the science of downstream passage including the reasons for providing passage, the physics of water flow, fish biology, fish way design and evaluation, and criteria and processes for fishway implementation—as required in both Canada and the United States.

**NEW! APPLYING FISHXING IN FISH PASSAGE ASSESSMENT AND DESIGN AT ROAD-STREAM CROSSINGS**

Margaret Lang and Mike Love, Bioengineering Section AFS; Margaret.Lang@humboldt.edu, mlove@h2odesigns.com
Student $60; Member $100; Non-member $150

This half-day course will present participants with an introduction to the FishXing software and an overview of how to use the software for assessment and design of fish and aquatic organism-friendly road crossings. This course will be of particular interest to engineers and biologists responsible for assessment, planning, or design of road crossings on natural waterways.

**NEW! BASIC FISH POPULATION MODELING USING EXCEL**

Mike Allen, University of Florida; msal@ufl.edu
Student $75; Member $125; Non-member $175

This course is intended to teach basic fish population modeling skills to students and professionals who are interested in quantitative analysis of fish populations. The program requires no experience in modeling, but a basic understanding of fish mortality and growth (e.g., von Bertalanffy growth model) would be helpful.

**NEW! RIVER MORPHOLOGY AND RESTORATION**

Jim Gracie, Brightwater, Inc; jgracie@brightwaterine.com
Student $150; Member $250; Non-member $300

This two-day course covers general principles of river morphology, classification systems, hydrology and hydraulics, stream stability, natural channel restoration approaches, and a description of stabilization devices, habitat improvement devices, and performance monitoring. The material is presented with real-life examples and includes extensive class participation and problem solving.

**NEW! ENDANGERED SPECIES ACT CONSULTATIONS AND THE ROLE OF FISHERIES PROFESSIONALS**

Margaret Murphy, Michael Schiewe and Paul Schlenker, ANCHOR QEA, LLC; mmurphy@anchorqea.com, MSchiewe@anchorqea.com, PSchlenker@anchorqea.com
Student $40; Member $70; Non-member $100

With the recent expansion of the ESA listing for the Gulf of Maine Atlantic salmon, the numerous listings of salmonids on the West Coast, and many freshwater listings, fisheries professionals have important roles in recovery planning. ESA Section 7 consultations, and Habitat Conservation Plan (HCP) development. This program will introduce participants to the ESA and explain the roles and responsibilities of fisheries professionals in supporting species recovery.

**NEW! AFS TECHNOLOGY WORKSHOPS: VEMCO ACOUSTIC TELEMETRY TECHNOLOGY WORKSHOP**

Nancy Edwards (VEMCO Division and AMIRIX Systems Inc.; nancy.edwards@amirix.com)

This course will discuss VR2 (VR3 & VR4) passive and active automated acoustic receiver technology, designed and produced by VEMCO, and its application to assess movement patterns, behavior, and site fidelity of fishes and invertebrates.
## CALENDAR: FISHERIES EVENTS

To submit upcoming events for inclusion on the AFS Web site Calendar, send event name, dates, city, state/province, web address, and contact information to cworth@fisheries.org.

(If space is available, events will also be printed in *Fisheries* magazine.)

More events listed at www.fisheries.org.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
<th>Location</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 23-26</td>
<td>Australasian Aquaculture International Conference and Trade Show</td>
<td>Hobart, Tasmania</td>
<td><a href="http://www.australian-aquacultureportal.com">www.australian-aquacultureportal.com</a></td>
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<tr>
<td>May 30-Jun 3</td>
<td>AFS Early Life History Section's 34th Annual Larval Fish Conference</td>
<td>Santa Fe, New Mexico</td>
<td><a href="http://www.larvalfishcon.org">www.larvalfishcon.org</a></td>
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<tr>
<td>Jun 16-18</td>
<td>Offshore Mariculture Conference</td>
<td>Dubrovnik, Croatia</td>
<td><a href="http://www.mercatormedia.com">www.mercatormedia.com</a></td>
</tr>
<tr>
<td>Jun 21-24</td>
<td>International Symposium on Genetic Biocontrol of Invasive Fish</td>
<td>Minneapolis, Minnesota</td>
<td><a href="http://www.seagrant.umn.edu/ais/biocontrol">www.seagrant.umn.edu/ais/biocontrol</a></td>
</tr>
<tr>
<td>Jul 7-12</td>
<td>Joint Meeting of Ichthyologists and Herpetologists</td>
<td>Providence, Rhode Island</td>
<td><a href="http://www.dce.ksu.edu/conf/jointmeeting">www.dce.ksu.edu/conf/jointmeeting</a></td>
</tr>
<tr>
<td>Jul 24-28</td>
<td>Second International Sclerochronology Conference</td>
<td>Mainz, Germany</td>
<td><a href="http://www.scleroconferences.de">www.scleroconferences.de</a></td>
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<tr>
<td>Aug 1-6</td>
<td>95th Annual Meeting of the Ecological Society of America</td>
<td>Pittsburgh, Pennsylvania</td>
<td><a href="http://www.esa.org/pittsburgh">www.esa.org/pittsburgh</a></td>
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<tr>
<td>Aug 31-Sep 2</td>
<td>Third Annual Conference of the North American Chapter of World Sturgeon Conservation Society</td>
<td>Chico Spring, Montana</td>
<td><a href="http://www.wsccs.info">www.wsccs.info</a></td>
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<tr>
<td>Sep 8-11</td>
<td>Fish Sampling with Active Methods Meeting</td>
<td>Ceske Budejovice, Czech Republic</td>
<td><a href="http://www.fsam2010.wz.cz">www.fsam2010.wz.cz</a></td>
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<tr>
<td>Sep 12-16</td>
<td>American Fisheries Society 140th Annual Meeting</td>
<td>Pittsburgh, Pennsylvania</td>
<td><a href="http://www.fisheries.org/afs10/">www.fisheries.org/afs10/</a></td>
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<tr>
<td>Sep 22</td>
<td>World Ocean Council: Sustainable Ocean Summit</td>
<td>Honolulu, Hawaii</td>
<td><a href="http://www.oceanconcurrency.org">www.oceanconcurrency.org</a></td>
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<tr>
<td>Sep 22-23</td>
<td>Electrofishing Class</td>
<td>Vancouver, Washington</td>
<td><a href="http://www.smith-root.com">www.smith-root.com</a></td>
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<tr>
<td>Sep 28-30</td>
<td>Wild Trout Symposium</td>
<td>West Yellowstone, Montana</td>
<td><a href="http://www.wildtroutsymposium.com">www.wildtroutsymposium.com</a></td>
</tr>
<tr>
<td>Oct 3-8</td>
<td>Aquatic Resources Education Association Biennial Conference</td>
<td>Omaha, Nebraska</td>
<td><a href="http://www.areanet.org">www.areanet.org</a></td>
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<tr>
<td>Dec 10-13</td>
<td>Fifth Shanghai International Fisheries and Seafood Exposition—The Best Opportunity to Explore Chinese Market</td>
<td>Shanghai, China</td>
<td><a href="http://www.sifse.com">www.sifse.com</a></td>
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</tbody>
</table>
M.S. Graduate Research Assistantship, Illinois Natural History Survey and the University of Illinois.

**Salary:** approximately $16,000 per year plus tuition and fee waiver.

**Closing:** 30 May or until filled.

**Responsibilities:** Participate in a multidisciplinary study to investigate the impacts of invasive Asian carp on Midwest river ecosystems. Projects will involve investigations of physiological parameters that influence the spread and abundance of invasive Asian carp, and interactions between invasive Asian carp and native fishes.

**Qualifications:** B.S. in fisheries, ecology, biology, or a related field and 3.0 GPA minimum 1100 V Q GRE. Previous experience with fish collection and fisheries field work is preferred but not essential.

Contact: Submit a letter of interest, resume, contact information for three references, copies of transcripts (unofficial are OK) and GRE scores (unofficial are OK) to Greg Sass, Director, Illinois River Biological Station, ggsass@illinois.edu; and Cory Suski, at Urbana—Champaign, Dept of Natural Resources and Environmental Sciences, W401-C Turner Hall, MC047, 1102 S. Goodwin Ave. Urbana, Illinois, 61801; 217/244-2237; fax: 217/244-3219 University of Illinois, suski@illinois.edu. See http://fishlab.nres.uiuc.edu.

M.S. or Ph.D. Graduate Assistantship, State University of New York, College of Environmental Science and Forestry, Department of Environmental and Forest Biology.

**Salary:** $18,000 per year, tuition waiver, housing available during field season.

**Closing:** 31 May 2010 or until filled.

**Responsibilities:** Perform independent research on coolwater fish habitat in the St. Lawrence River. Research will involve an intense field and analytical effort, reporting results in written reports, peer-reviewed publications, and oral presentations at professional meetings.

**Qualifications:** B.S. or M.S. in fisheries, aquatic sciences, or related discipline. Quantitative fisheries or related field and spatial database and survey skills are preferred. Highly qualified individuals with strong GPA and GRE and experience are encouraged to apply. Highly motivated with demonstrated ability to work well in a team environment.

Contact: Send application to John M. Farrell, Office of Instruction Graduate Studies, SUNY-ESF One Forestry Drive, 227 Bray Hall, Syracuse, NY 13210. See www.esf.edu/graduate/admission.htm.


**Salary:** Depends on experience.

**Closing:** 1 June 2010.

**Responsibilities:** Work independently and with project scientists to develop and manage project-specific databases, facilitate quality control/quality assurance of these data, and perform statistical and spatial analysis.

**Qualifications:** M.S. in applied statistics or biostatistics, with supporting formal training in ecology, fisheries, and aquatic ecology, or a M.S. in ecology, fisheries, aquatic ecology with supporting formal training in applied statistics.
and biostatistics, and a minimum of three years experience, preferably in quantitative ecology. Demonstrated knowledge of analysis software, including but not limited to SAS, MATLAB, GIS and the application of this software to describe patterns in biological and environmental data and test hypotheses concerning these data. 

Contact: Submit cover letter and resume to HR@normandeau.com, jmfarrell@esf.edu.

Closing: 1 June 2010.
Responsibilities: Support senior staff in population monitoring and impact assessments responsible for program implementation, quality control, data analysis and interpretation. Travel to, and participate in, field fisheries programs. Occasional overtime, weekend, or evening work may be required to meet deadlines.
Qualifications: M.S. in biology, zoology, fisheries, or related discipline with 1–3 years of experience and a broad background in freshwater or marine fish population ecology, with emphasis on quantitative field applications. Specific experience is desired in one or more of the following areas: sampling design statistics, population models, mark-recapture techniques, and SAS programming. Ability to work in U.S. without company sponsorship. Ability to design and conduct successful field fisheries programs. Excellent report writing and communication skills.
Contact: Submit cover letter and resume to HR@normandeau.com.

Zebrafish Research Technician—Fish Facility Maintenance, New York University, New York, New York.
Salary: $37,500 per year.
Closing: 1 June 2010.
Start date: 1 March to 1 June 2010.
Responsibilities: Two-year commitment. Maintain a zebrafish aquaculture facility of 3,500 tanks. Breed and rear zebrafish; maintain, and repair the water system; and assist with experiments investigating the genetic regulation of zebrafish development.
Qualifications: B.S. or M.S. in biology, fisheries, or related fields obtained in the last five years. Aquaculture experience. Excellent time management, leadership, verbal, and written communications skills. Plumbing and/or electrical hands on knowledge and/or research experience.
Contact: Send to holger.knaut@med.nyu.edu using the subject line: Zebrafish technician: Your name, include your name, address, degree date awarded, and GPA. Also include name, e-mail, and phone number of 3 references and state in which capacity these references know you. NYU School of Medicine offers an excellent salary and benefits package including four weeks paid vacation and tuition remission at NYU.

M.S. Graduate Assistantship in Fisheries and Aquatic Ecology, Oklahoma Department of Wildlife Conservation, University of Oklahoma.

Salary: $1,545 per month plus tuition waiver.

Closing: 31 July 2010.

Starting date: 1 January 2011.

Responsibilities: Participate in Oklahoma Biological Survey Monitoring and research on zebra mussels, *Dreissena polymorpha* on Lake Texoma, Oklahoma. Research topic will likely be directed toward local life history, expansion, and management of zebra mussels.

Qualifications: B.S. in zoology or biology with preference for emphasis on aquatic ecology or related discipline.

Contact: Send cover letter, resume, copies of transcripts (unofficial OK), GRE scores (mandatory) and three letters of reference to Greg Summers, Oklahoma Fishery Research Laboratory, 500 E. Constellation, Norman, Oklahoma; 73072; gsummers@odwc.state.ok.us; 405/325-7288. See www.ou.edu/cas/zoology/graduate_degrees.htm.

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Membership Type (includes print Fisheries and online Membership Directory)

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Developing countries II

Regular

Student (includes online journals)

Young professional (year graduated)

Retired (regular members upon retirement at age 65 or older)

Life (Fisheries and 1 journal)

Life (Fisheries only, 2 installments, payable over 2 years)

Life (Fisheries only, 2 installments, payable over 1 year)

North America/Dues

N/A

$22

$40

$40

$1,200

$1,000

$10

$35

$40

$1,737

$1,737

$1,200

$1,000

JOURNAL SUBSCRIPTIONS (optional)

Transactions of the American Fisheries Society

North American Journal of Fisheries Management

North American Journal of Aquaculture

Journal of Aquatic Animal Health

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All memberships are for a calendar year. New member applications received January 1 through August 31 are processed for full membership that calendar year (back issues are sent). Applications received September 1 or later are processed for full membership beginning January 1 of the following year.

FISHERIES, VOL. 35 NO. 5 MAY 2010

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Fisheries • VOL 35 NO 5 • MAY 2010 • WWW.FISHERIES.ORG
Balancing Fisheries Management and Water Uses for Impounded River Systems

Edited by Micheal S. Allen, Steve Sammons, and Michael Maceina

Professionals from a broad range of disciplines describe both historical and current-day issues associated with balancing fisheries management with other uses of water in impounded systems.

This work describes how water allocation issues can present economic and legal constraints to fisheries management and influence fishery quality. Reviews unique ways to approach reservoir management by considering the tools available in the watershed. Additional reservoir management topics addressed include conflict resolution and human dimension issues, new ways to evaluate fish species interactions, stocking programs, prey composition and abundance, and fish habitat.

697 pages
List price: $69.00
AFS Member price: $48.00
Item Number: 540.62P
Published January 2009

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