

Chapter 19

Calapooia Watershed, Oregon: National Institute of Food and Agriculture–Conservation Effects Assessment Project

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The overall goals of the Oregon National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP), *Assessing Trade-offs Between Crop Production and Ecological Services*, were to quantify linkages between conservation practices and biophysical responses, including water quality and biological indicators, and to develop a model to assess tradeoffs between agricultural practices that maximize economic benefits and conservation actions that sustain or improve ecosystem services.

These goals were addressed through a set of specific research objectives that in aggregate served to examine whether the extent and distribution of tillage practices and riparian and in-channel vegetation were associated with an optimum balance of economic value and ecological services at the watershed scale. Specific objectives included the following:

1. Describe the extent, timing, and placement of conservation practices in the study watershed
2. Assess the effects of those conservation practices, their locations, and their interactions on water quality and quantity
3. Evaluate the effects of conservation practices on key biological indicators that respond to cumulative alterations in land cover and the resulting water quality and quantity
4. Develop an objective-optimization model based on the information derived from addressing the first three objectives to assist farmers, USDA Natural Resources Conservation Service (NRCS) staff, and local conservation districts in identifying cost-effective conservation practice strategies
5. Disseminate the findings of this research to specific target audiences through outreach activities and extension products

Watershed Information

The Willamette River is a major tributary of the Lower Columbia River, draining a total area of 29,728 km² (11,478 mi²) in western Oregon. Its mainstem is 301 km (187 mi) long. Flowing northward towards its confluence with the Columbia River, the Willamette River has an average discharge of 900 m³ s⁻¹ (32,000 ft³ sec⁻¹). Its basin is bounded by the mountains of the Oregon

Coast Range on the west and the Cascade Range on the east and is characterized by a broad valley with deep fertile soils.

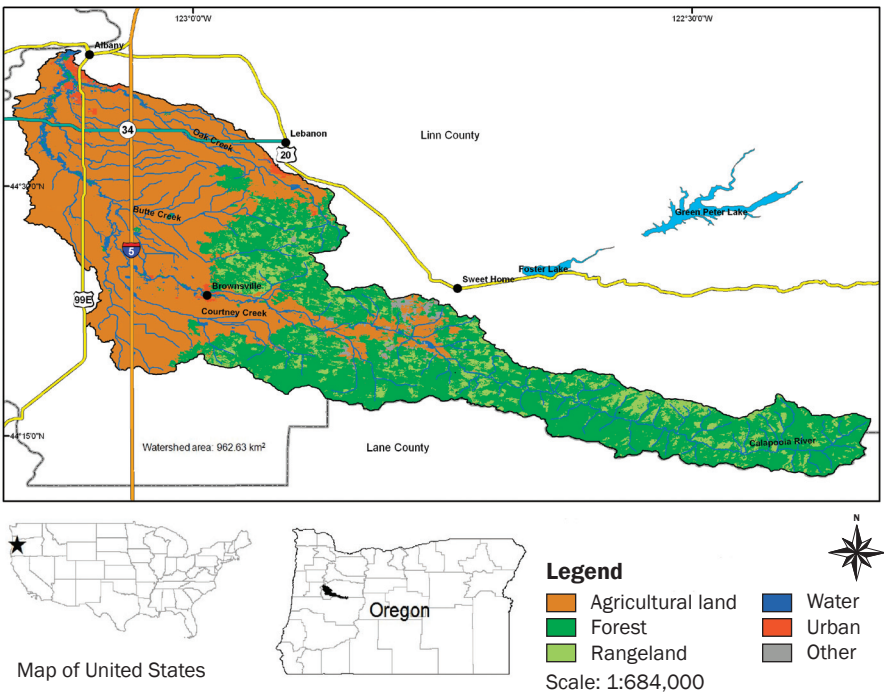
The Willamette Valley is inhabited by two-thirds of Oregon's population and includes the cities of Eugene toward its southernmost end, the state capital Salem in a relatively central location, and the state's largest city Portland at the confluence with the Columbia River. The valley has a modified Marine climate that resembles the warmer and drier Mediterranean type, and its precipitation regime varies considerably from place to place. However, on average, annual precipitation totals range from less than 1,000 mm (39 in) at low elevations to more than 2,000 mm (79 in) in the foothills of the Cascade and Coast Mountain Ranges. Most (70%) of this precipitation occurs in late fall and winter (November through March), and less than 5% occurs during the three months of summer. Because of the precipitation regime, there is more runoff per hectare of land than in any other large American river. Flooding occurs throughout the valley, and seasonal wetlands and ponds are abundant, but as with many of the valley streams and agricultural field ditches, they are wet for only six to nine months of the year and are dry during late summer and early fall. Mean annual temperatures in the Willamette Valley range from 8°C to 14°C (47°F to 57°F), and the growing season extends over 140 to 240 days, depending on the crop. The combination of climatic characteristics and soil conditions makes the Willamette Valley ideal for seed production of temperate grass varieties and other crops (e.g., clover, meadowfoam [*Limnanthes douglasii*]).

The fertile valley soils have resulted from a series of massive ice age floods derived from Glacial Lake Missoula, in Montana, which scoured across eastern Washington and into the northwestern part of Oregon. Those events have left behind glacial deposits consisting of silt and clay loam textures. Most of the soils are categorized as Mollisols, which means that the surface layer (A horizon) is deep with high organic matter content. The fertile floodplain soils are well-drained to excessively well-drained Mollisols with coarse texture and have thick, dark, base-rich surface horizons. In areas away from the floodplain, the soils often have a silt texture with clay-enriched subsoils, thus causing these soils to be poorly drained. As a consequence of the slow internal drainage of the poorly drained soils, agricultural lands are often artificially drained.

The Calapooia River subbasin is located in the upper Willamette Valley and has a total area of 96,263 ha (237,871 ac) (see figure 19.1). The Calapooia River mainstem is 115 km (71 mi) long and is a major tributary to the Willamette River. The 69,367 ha (171,410 ac) area downstream of a historic US Geological Survey river gage at Holley, Oregon, is commonly referred to as the Lower Calapooia Basin. This project has focused on the lower part of this subbasin, but the USDA Agricultural Research Service (ARS) cooperators (located in Corvallis, Oregon) have worked on the entire Calapooia Watershed since 1996.

The Calapooia Watershed includes both agricultural and forest landscapes. In the Lower Calapooia Watershed, where grass seed crops predominate, the geomorphology is dominated by somewhat poorly drained soils in a mostly flat landscape and, as a result, approximately 35% of the agricultural land has modified drainage intended to move water off the land quickly. During the six to nine month wet season, many intermittent streams and wetlands form in the fields due to this slow drainage, but during the summer months, many of these streams and wetlands dry out. Organic matter content in these soils ranges from 4% to 6%. There is sufficient mineralization of organic matter such that nitrogen (N) leaching losses on tilled fields, with no applied fertilizer, may be greater than 112 kg N ha⁻¹ (110 lb N ac⁻¹). Leaching losses from established grass seed fields are very low or negligible compared to other cropping systems, and research

Figure 19.1
Calapooia Watershed, Oregon, land use and stream networks.



has demonstrated that grass seed crops, with their deep fibrous root systems, are very efficient at using soil N. From previous work in this subbasin, the researchers in this project had estimates of in-field erosion as a component of total sediment loading to streams, soil carbon (C) and N, biogeochemical cycling of C and N, and other soil property parameters (including compaction, infiltration, soil organic matter) from selected sites throughout the system.

The Willamette Valley is a very diverse agricultural region with both dryland and irrigated agriculture and over 80 major crop and livestock commodities. The major crops in the Lower Calapooia Watershed are cool season grass seed crops, primarily annual ryegrass (*Lolium multiflorum* L.), tall fescue (*Schedonorus phoenix* [Scop.] Holub), and perennial ryegrass (*Lolium perenne* L.). Diversification of seed crop production has occurred over the past five years and includes wheat, legume seed, and oil seed crops. Production fields average 24 to 32 ha (60 to 80 ac) in size. In addition to crop production, 14,000 to 20,000 sheep are grazed on 10% of the total crop acreage of the watershed during the winter. Most of the grazing occurs on grass seed and white clover fields; annual ryegrass is the crop species grazed most often. The sheep owners lease fields from the seed producers during the grazing period and later move the sheep to other locations to allow the seed crops to develop. Only 0.03% of the watershed is believed to include confined animal feeding operations, but no information on livestock species or numbers is available.

Water Quality Information

Water Chemistry

The Calapooia River is on Oregon's Section 303(d) of the Clean Water Act (USEPA 2011) list of impaired streams for temperature, *E. coli*, and several other pollutants. In addition, the Oregon Department of Environmental Quality also reported high concentrations of nitrate-nitrogen ($\text{NO}_3\text{-N}$), ammonium, total nitrogen (TN), total phosphorus, total suspended solids (TSS), and biochemical oxygen demand. These are seasonal (fall, winter, and spring) concerns during the period of greater rainfall and streamflow. Nitrate-nitrogen concentrations in the Calapooia River (1.25 mg L^{-1}) are four times greater than in the Willamette River (0.35 mg L^{-1}).

Under the USDA NRCS Environmental Quality Incentives Program (EQIP) program, resource concerns for the Calapooia Watershed were ranked as follows:

- Streambank erosion
- Nutrients and organic waste
- Aquatic habitat suitability
- Concentrated-flow erosion
- Sheet and rill erosion
- Wildlife habitat

Aquatic habitat quality is a growing concern as the watershed supports several species that are listed either as endangered or as threatened: western pond turtle (*Emmys marmorata marmorata*), red-legged frog (*Rana aurora*), steelhead trout (*Oncorhynchus mykiss*), Oregon chub (*Oregonichthys crameri*), and fall Chinook salmon (*Oncorhynchus tshawytscha*).

Water quality data are available from 1998 to 2006 from 40 subbasins (57% of the land area) of the Calapooia Watershed. Subbasin areas ranged from 313 to 16,710 ha (774 to 41,293 ac). Thirty-nine of the subbasins were in the Lower Calapooia Watershed, and one was near the headwaters of the Calapooia River in the Cascade Mountains. Some subbasins were nested within others. Prior to this National Institute of Food and Agriculture–Conservation Effects Assessment Project (NIFA–CEAP) study, the US Geological Survey monitored groundwater and surface water quality at selected sites from 1991 through 1995 and conducted a study from 1996 to 1998 to characterize groundwater and surface water hydrology (Hinkle 1997; Wentz et al. 1998).

Water quality for the forty subbasins of the Calapooia Watershed was monitored by collecting synoptic grab samples at least monthly or more frequently from October 2003 to September 2006, with one additional sample taken in January of 2007. There were a number of conditions that precluded collection of water quality samples. To ensure safety of personnel, samples were not collected during very high flows that occurred with large rainfall events. When small, ephemeral streams became dry (usually in early summer to midfall) samples could not be collected until the streams began flowing again. In order to meet quality assurance guidelines, laboratory blanks were used as were duplicate samples (10% collection rate). Although single-day sampling was the norm for sample collection, on occasion it took two or three days. Grab samples were taken at over 100 locations watershed wide. A digitized stream layer based on aerial photography and a digital elevation model were used to confirm geographic locations of sample collection sites, including associated stream reaches and subbasin watershed polygons. Monitored water quality variables included pH, turbidity, conductivity, dissolved organic matter, ammonium, $\text{NO}_3\text{-N}$, dissolved inor-

ganic nitrogen, TSS, TN, total phosphorus, and orthophosphate. However, only TSS and TN were compared to land use (e.g., soil disturbance, tillage).

Biological Indicators

Prior to the beginning of this project, fish and amphibians had been sampled in several sub-basins of the Upper Willamette Valley, including the Calapooia. The sampling effort focused on the intermittent streams and ditches, the waterways, and seasonal ponds of the Lower Calapooia Watershed. Approximately every two weeks from November to May, fish and amphibians were caught at 22 sites in 17 drainages in 2002 to 2003, 12 sites in 9 drainages in 2005 to 2006, and 21 sites in 19 drainages in 2006 to 2007.

Fry and juvenile fish smaller than 150 mm (5.9 in) were caught using minnow traps and seine nets, whereas individuals larger than 150 mm (5.9 in) were caught using backpack electrofishers or hoop-traps (i.e., oversized minnow traps). Captured fish were anesthetized with Tricaine Methanesulfonate (MS-222), identified to species, measured, and weighed to determine body condition. They were also examined for signs of skin and fin lesions, ectoparasites, and gill abrasion as indicators of general health. They were subsequently released at their sites of capture. Concurrent with fish sampling, additional water quality grab samples were collected.

Benthic macroinvertebrates were also sampled in intermittent waterways in the springs of 2003, 2006, and 2008. The reason for sampling in 2006 was to compare macroinvertebrate density and taxa richness at paired sites within drainages that had vegetated and unvegetated channel substrates. In 2008, least-disturbed sites, which were underrepresented in earlier years, were sampled and compared to highly agricultural sites with respect to invertebrate density, taxa richness, and community composition.

Macroinvertebrates were also collected in intermittent wetlands during the final phase of the project. Ten wetlands were sampled in annual grass seed fields, ten in perennial grass seed fields, and ten in remnant native wet prairie sites during the spring of 2009. In spring of 2010, 8 wetlands were sampled in annual grass seed fields, 10 in perennial grass seed fields, and 10 in remnant native wet prairie. Metrics included vegetative cover, conductivity, turbidity, density, biomass, and taxa richness. Potential differences in invertebrate community composition in the various wetland types were examined. Invertebrate data were compared with the geographic information system (GIS) land-use database.

Amphibian populations were surveyed in 15 streams and 10 ponds from the fall of 2006 to the spring of 2008. Amphibian identification was based on visual and auditory detection. Land-use and land-cover data were overlaid with amphibian data to determine the extent to which conservation practices affect their populations. Amphibian species richness was assessed as a function of land use (i.e., conservation practices, such as woody riparian buffers and conservation tillage). Land use was quantified across multiple spatial scales, including independent hydrological units (i.e., subbasin) and a series of buffers radiating out from each pond and stream channel that was sampled. These buffers ranged from 500 to 1,500 m (1,640 to 4,922 ft) around each water body.

Summer bird species were identified at 32 sites in 2007 and 2008. A moving-window sampling design was used to stratify the sample. Four visits were made during May through June to three location types (i.e., riparian buffers, grassed waterways, and conservation tillage). Researchers spent 10 minutes at each site between 5 a.m. and 10 a.m. and recorded each bird call (by species and location). A similar survey was conducted in 2004 and 2005 with winter birds (24 sites).

Data on stream networks and subbasins were stored as ArcGIS feature classes, while water quality, wetland invertebrate, and bird data were stored in Microsoft Excel spreadsheets, and fish and stream invertebrate data were stored in Microsoft Access databases. These data were linked by sample location.

Land Treatment

As a retrospective study that used prior conservation practice implementation, there were no quantitative objectives for treatment of agricultural pollutants, nor any selection of critical areas within the watershed for practice implementation. Land treatment focused on conservation tillage and riparian buffers because most of the agriculture in the Calapooia Basin involves cool-season grass-seed production, which is mostly comprised of perennials; some fields have been untilled for over 30 years. Prior to a burning ban ordinance, many producers had burned stover residue, and now many landowners have successfully shifted from burning crop residue to conservation tillage for those fields where annual rye grass seed is produced or farmers are shifting crops.

Land treatment was tracked by using existing information from the USDA NRCS, Oregon State University Extension, and the USDA ARS, along with farmer interviews and aerial photographs followed by site visits. From 2004 to 2010, a technician cataloged agricultural practices on 4,800 fields annually. These data were collected to document crop species grown, tillage practices, and residue left on 100% of the farmed land in the watershed (Steiner et al. 2006). The cataloged practices were then distributed into 56 classes relative to vegetative cover and time, and all data were georeferenced and entered into a GIS database. The verified land-use and land-cover information was related to remote sensing information. Of the 40 subbasins surveyed, the least-disturbed basins had 80% perennial land cover; the most-disturbed basins had 20% perennial vegetation. Annual crop yield data were collected on over 4,040 ha (9,984 ac), starting in 2000 through the use of yield monitors. All data were georeferenced.

There was some linkage between water quality and land cover but only generally when comparing water quality data between agricultural subbasins to forested subbasins. Most of the study was focused on the relationship between organism populations and land use.

Water Quality Response

Water Chemistry

The Calapooia Watershed remains on the Oregon Clean Water Act Section 303(d) list for temperature and *E. coli*. Neither of the two conservation practices used on small tributaries—small buffers near intermittent waterways or conservation tillage—would address these water quality impairments in the larger mainstem of the river (Wigington et al. 2003). Additionally, these waterways are dry during the late spring-summer period, when water quality impairments in the mainstem are the worst and, therefore, are easier to detect.

A comparison of TSS and TN loads from forested and agricultural subbasins showed higher sediment concentrations from forests than agricultural lands (150 versus 100 mg L⁻¹). Total N losses followed an opposite pattern, with the average TN concentration from agricultural subbasins (10 mg L⁻¹) being greater than those from forest (0.5 mg L⁻¹). Not surprisingly, the peak nitrogen levels for the agricultural system occur in the winter and spring due to the climatic conditions found in western Oregon.

Landuse varied, dependent on subbasin, from 100% agriculture to 96% forested. The topograph was flat (1%) slope to reasonably steep (19%). Measured water quality parameters showed significant ranges. Since $\text{NO}_3\text{-N}$ and TN results were similar, TN will be presented. Additionally, $\text{NO}_3\text{-N}$ was the predominant N form in agricultural streams due to the rapid nitrification from any ammonium fertilizers. Total N was measured from 0.5 mg L^{-1} in some sites to 43.0 mg L^{-1} , and TSS concentrations showed a 10-fold range (29 to 249 mg L^{-1}), although both constituents often were at or below detection limits. During the winter when the majority of $\text{NO}_3\text{-N}$ is delivered to the system through overland flow and the shallow groundwater, TN delivery increased when lands were cropped to nongrass seed summer annuals, established seed crops of perennial ryegrass, tall fescue, orchard grass (*Dactylis glomerata* L.), and clover, and newly planted stands of perennial ryegrass and clover. Not surprisingly, TN was lower when more land area was in trees or Italian (annual) ryegrass (*Lolium multiflorum*). With the use of Fourier analysis, TN delivery within subbasins was determined to be low ($<2 \text{ mg L}^{-1}$), Type I; medium (8 mg L^{-1}), Type II; or high (21 mg L^{-1}), type III with peak delivery in December. There was an additional subbasin type (Type IV) that had very high TN loss ($<43 \text{ mg L}^{-1}$) but no temporal signal.

Results from the Fourier transformations allowed further analysis of N fluxes from the managed and natural ecosystems of Western Oregon. When TN losses were low ($<0.5 \text{ mg L}^{-1}$) the land use was forested systems. Medium and high TN losses occurred in subbasins with additional N applications (managed ecosystems). Even though the magnitude of the N loss from the subbasins was different, N losses through overland flow and the shallow groundwater into the streams declined after late fall due to a slowing of mineralization and leaching.

Biological Indicators

Surveys of seasonal waterways from 2001 to 2002 and 2002 to 2003 showed that these drainages supported a diverse community of native aquatic vertebrates that included at least 14 species of fishes (four nonnative), five species of amphibians (one nonnative) and one species of reptile (see table 19.1).

Fish community composition and abundance were mainly influenced by broad-scale variables, such as distance to perennial water, upstream channel gradient, and percent land-cover type. The only local-scale habitat variable that affected both number of fish species present and total abundance was the proportion of channel substrate with rooted vegetation. Few exotic species of fish used these seasonal habitats, and they were only present in the spring when water temperature was above 16°C (61°F). Catch per unit effort was greater in the nonvegetated waterways relative to the vegetated ones. Species richness, however, was inversely related to catch per unit effort, and the vegetated waterways had higher numbers of species. Therefore, one cannot firmly conclude that rooted vegetation in these channels will positively affect fish populations, but it seemed to increase diversity of fish species present.

Previous research on macroinvertebrates in intermittent drainages had indicated that total invertebrate density was primarily related to channel-bottom vegetation (direct relationship) and site water velocity (inverse relationship). On the other hand, macroinvertebrate community composition was related to watershed agricultural land use. Follow-up research done under a NIFA–CEAP funding grant in 2006 confirmed that in highly agricultural watersheds, vegetated waterway substrate was an important determinant of macroinvertebrate density. However, in-channel vegetation did not affect invertebrate taxonomic richness. New sampling that included

Table 19.1
List of species of fish, amphibians, and reptiles captured by the research team in the Lower Calapooia Watershed from 2002 until 2008.

Fish	Amphibians	Reptiles
Threespine stickleback (<i>Gasterosteus aculeatus</i>)	Roughskin newt (<i>Taricha granulosa</i>)	Western pond turtle (<i>Emmys marmorata marmorata</i>)
Redside shiner (<i>Richardsonius balteatus</i>)	Long-toed salamander (<i>Ambystoma macrodactylum</i>)	
Reticulate sculpin (<i>Cottus perplexus</i>)	Pacific treefrog (<i>Hylla regilla</i>)	
Speckled dace (<i>Rhinichthys osculus</i>)	Red-legged frog (<i>Rana aurora</i>)	
Largescale sucker (<i>Catostomus macrocheilus</i>)	Bullfrog (<i>Rana catesbiana</i>)*	
Northern pikeminnow (<i>Ptychocheilus oregonensis</i>)		
Chinook salmon (juv.) (<i>Oncorhynchus tshawytscha</i>)		
Cutthroat trout (<i>Oncorhynchus clarki</i>)		
Riffle sculpin (<i>Cottus gulosus</i>)		
Oregon chub (<i>Oregonichthys crameri</i>)		
Mosquitofish (<i>Gambusia affinis</i>)*		
Goldfish (<i>Carassius auratus</i>)*		
Bluegill (<i>Lepomis macrochirus</i>)*		
Yellow bullhead (<i>Ameiurus natalis</i>)*		

* Denotes nonnative species.

more least-disturbed sites (2008) confirmed that the amount of watershed agriculture was related to invertebrate community composition. Sites with less watershed agriculture had more representatives in the sensitive aquatic insect orders (e.g., Ephemeroptera, Plecoptera, and Trichoptera—mayflies, stoneflies, and caddisflies, respectively) and higher overall taxonomic richness. Sites with highly agricultural watershed area had macroinvertebrate communities dominated by noninsects.

Early project macroinvertebrate studies showed that the majority of organisms in samples from seasonal waterways were noninsects (worms, snails, crustaceans, etc.). These were organisms that had specialized life-history characteristics to allow them to survive and/or recolonize after channels dried up during summers. Sites with less watershed agriculture had greater relative abundances of aquatic insects and generally had several representatives of the insect orders that are most sensitive to disturbance (i.e., mayflies, stoneflies, and caddisflies). Sites had widely varying macroinvertebrate densities. Higher densities were found at sites with highly vegetated channel substrates and slow current velocities.

Two years of seasonal wetland invertebrate sampling demonstrated specific responses of macroinvertebrate assemblages to land use. Wetland macroinvertebrate metrics were compared using a one-way analysis of variance, as well as pair-wise comparisons. Native wet prairie had the greatest taxa richness despite the fact that there was no difference in density of macroinver-

tebrates due to habitat. In 2009, invertebrate biomass was greater for wetlands in perennial grass fields compared to that in native wetlands or annual grass fields. In 2010, wetlands in perennial fields and native wetlands had similar biomass measures, and both had significantly greater biomass than the annual field wetlands. Vegetation was lowest for annual field wetlands and was greatest for native wet prairie. Conductivity was the similar for sites in annual and perennial field wetlands, but wetlands in both of these types of farmed fields had significantly higher conductivity than native wetland sites.

Wetland macroinvertebrate results showed that wetland type affected diversity of invertebrate species and families. Annual grass seed wetlands had the lowest biomass and density, while perennial grass wetlands had the greatest. Although aquatic invertebrate communities were less diverse, most agricultural seasonal wetlands were fairly complex. Perennial grass seed wetland communities were characterized by some groups of organisms closely related to native wetland species. These invertebrates provide food resources for both terrestrial and aquatic wildlife.

Amphibians were sampled at ponds and streams, and amphibian type and number of amphibians were related to conservation practices: no-tillage, straw left on the fields, nonannual harvesting, and year-round vegetation. Numbers of amphibians identified included 1,199 amphibians in ponds and 775 in streams, of which there were four native and one invasive species (table 19.1). By using the land-use and land-cover database, it was demonstrated that perennial cover greatly increased salamander habitat and that canopy density and cover increased frog habitat.

Amphibian species diversity showed a strong positive relationship with percent conservation. Conservation efforts, such as reduced tillage practices and leaving crop residue on fields after harvest, were shown to have a positive impact on amphibian species diversity. This relationship, however, was only observed at the subbasin or landscape scale. Analysis of conservation tillage and buffer size at the local scale, around each water body, showed no direct impact on amphibian diversity. This is likely a function of the need for connectivity between aquatic breeding sites and upland over-wintering sites. Landscape-scale conservation allows migration between these terrestrial and aquatic habitats. In addition, the project measured habitat associations and found that the relationships between habitats and species were site specific.

Winter bird species results demonstrated greater bird species richness in areas with higher tree and shrub cover, but conservation practices had no effect on bird richness. Breeding bird numbers increased slightly when tree and shrub buffer cover went from almost none to just a little. Some bird species actually decreased with increasing tree and shrub cover. In-field conservation practices are only slightly associated with bird species. Although riparian areas had a greater number of bird species than did the in-field conservation practices (conservation tillage or grassed waterways), there was no difference in bird species richness. Species counts increased in the agricultural fields relative to the buffers, depending on species. These results show the importance of habitat on species, and conservation practices would need to be targeted based on the bird species in need of preservation.

Model Application

The goal of modeling was to develop a modeling tool that will allow landowners and conservation planners to determine the best return on resources spent on buffers and conservation

tillage vis-à-vis protection of aquatic habitat. The tool was to determine tradeoffs associated with the implementation of conservation tillage and buffers.

The Soil and Water Assessment Tool (SWAT), SWAT2000, was selected as the water quality model because it has been calibrated and used in the Calapooia mainstem by the USDA ARS prior to the NIFA–CEAP. As part of the NIFA–CEAP, SWAT2000 was used to estimate flows from each of the tributaries using the newly established gaging stations and was then expected to be used within a hybrid genetic algorithm for multiobjective problem solving.

Socioeconomic Analysis

The economic team was charged with the development of a method that integrated an economic model of agricultural production with a biophysical model. The model had to account for multiple objectives because there was more than one environmental objective.

The economic team thus built a large, complex, computationally expensive model to evaluate alternative conservation practices at the watershed level. The goal was to use an activity analysis model to develop four-dimensional Pareto efficiency frontiers for farm-level profit, environmental quality, program efficiency, and location within the watershed. A multiobjective optimization method called data envelope analysis and a genetic algorithm were used to estimate the model. In an early paper, the economic team developed a frontier showing profit and N tax rate on the vertical axes on the left and right side of a graph, respectively, and N runoff on the horizontal axis (Whittaker et al. 2009). The curves showed profits starting at about US\$2,000 ha⁻¹ (US\$809 ac⁻¹) with approximately 55 kg N ha⁻¹ (49 lb N ac⁻¹) and leveling off at US\$6,100 ha⁻¹ (US\$2,470 ac⁻¹) for approximately 120 kg N ha⁻¹ (107 lb N ac⁻¹).

The final project model used proprietary tax information from approximately 80 farms to develop cost estimates for best management practices. The data were at the farm level and scarce, so a bootstrapping technique was used to make final cost estimates. The model was planned to rely on SWAT for biophysical information. However, at the project end, the model had only been run for proxies adapted from the environmental indice data. The final implementation has not been completed at this time and will likely encounter compatibility issues for the environmental data collected relative to the types of data normally used with SWAT.

Outreach

Direct stakeholders in the NIFA–CEAP included 22 grass seed growers, who granted project personnel access to their fields to sample water, invertebrates, fish, amphibians, and birds in and around waterways and ponds. The research team kept in regular contact with several of them, and these farmers were kept informed of the findings annually at the Oregon Ryegrass Growers Association meeting, which is attended by approximately 300 landowners every year. Results were also reported to the Calapooia and the Long Tom Watershed councils on an annual basis. In addition, slide presentations of project results were given to other watershed councils (e.g., Mary's River, Lukiamute River, Muddy Creek) and to Soil and Water Conservation Districts. Findings were also annually published in the form of articles in Oregon State University's Grass Seed Agriculture Extension Reports, which reach all grass seed producers in the valley.

Those farmers who worked directly with the project began adopting conservation practices more willingly than other producers. Over time, as more people became aware of the diverse

array of species that use the agricultural ecosystems and it was determined that the conservation practices reduced operation costs, farmers were more willing to implement some of the conservation practices, such as conservation tillage.

Another intended outreach product was to be an easy-to-use CD that would allow landowners and regulators to determine tradeoffs between water quality and land treatment (see Model Application and Socioeconomic Analysis sections in this chapter). The tradeoff tool, however, that has been developed is a research tool. Because the tool cannot be developed as an outreach product, project personnel produced a video of agency personnel and producers discussing the benefits of conservation practices, which will be distributed on DVD format to 300 members of the Oregon Ryegrass Growers Association, the Oregon Seed Growers League, and the local watershed councils. Also, Oregon Public Broadcasting made a short documentary of the project during which several of the research team members and farmers were interviewed about the project and its key findings. This video will be aired in winter of 2012 during the program entitled “Oregon Field Guide.”

Conservation practice outreach, not associated with this project, is currently being done through the local Soil and Water Conservation District and the Calapooia Watershed Council. The district is primarily focused on changing furrow irrigation to pivot irrigation because the belief held in the district is that the grass-seed practices are already sustainable. In the past, the district has worked with Oregon State University (extension agents and a specialist) to implement conservation tillage, wetlands, and the Conservation Reserve Enhancement Program (CREP).

The Calapooia Watershed Council conducted a water quality assessment in 2004 in which temperature was identified as the major water quality problem in waterways with permanent water flow (which are not the intermittent streams and ditches that were the focus of the NIFA–CEAP). Since then, implementation resources have been focused on developing riparian buffers. Watershed councils in Oregon are public-private partnerships; some councils only conduct outreach and education, some only implement conservation practices, and some do both. Councils receive approval from their counties and get funding from state lottery revenues that are administered through the Oregon Watershed Enhancement Board. The Calapooia Watershed Council only implements conservation practices and has a diverse board: two livestock producers, three grass-seed farmers, two forestry representatives, and three citizens.

Calapooia Watershed National Institute of Food and Agriculture–Conservation Effects Assessment Project Publications

This project’s results have been published in numerous journal articles, abstracts, and other publications. The list of these publications is provided below.

Publications

Colvin, R., G.R. Giannico, J. Li, K.L. Boyer, and W.J. Gerth. 2009. Fish use of intermittent watercourses draining agricultural lands in the Upper Willamette River Valley, Oregon. *Transactions of the American Fisheries Society* 138:1302-1313.

- Confessor, R.B., Jr., and G.W. Whittaker. 2007. Automatic calibration of hydrologic models with multi-objective evolutionary algorithm and parent optimization. *Journal of the American Water Resources Association* 43:1-9.
- Davis, J.H., S.M. Griffith, W.R. Horwath, J.J. Steiner, and D.D. Myrold. 2007. Mitigation of shallow groundwater nitrate in a poorly drained riparian area and adjacent cropland. *Journal of Environmental Quality* 36:628-637.
- Davis, J.H., S.M. Griffith, W.R. Horwath, J.J. Steiner, and D.D. Myrold. 2008. Denitrification and nitrate consumption in an herbaceous riparian area and perennial ryegrass seed cropping system. *Soil Science Society of America Journal* 72:1299-1310.
- Davis, J.H., S.M. Griffith, and P.J. Wigington, Jr. 2010. Surface water and groundwater nitrogen dynamics in a well drained riparian forest within a poorly drained agricultural landscape. *Journal of Environmental Quality* 40:505-516.
- Floyd, W.C., S.H. Schoenholtz, S.M. Griffith, P.J. Wigington, Jr., and J.J. Steiner. 2009. Nitrate-nitrogen, land use/land cover, and soil drainage associations at multiple spatial scales. *Journal of Environmental Quality* 38:1473-1482.
- Griffith, S.M., G.M. Banowetz, R.P. Dick, G.W. Mueller-Warrant, and G.W. Whittaker. 2011. Western Oregon grass seed crop rotation and straw residue effects on soil quality. *Agronomy Journal* 103:1124-1131.
- Mueller-Warrant, G.W., S.M. Griffith, G.W. Whittaker, G.M. Banowetz, W.F. Pfender, T.S. Garcia, and G.R. Giannico. 2012. Impact of landuse patterns and agricultural practices on water quality in the Calapooia River Basin of western Oregon. *Journal of Soil and Water Conservation* 67(3):183-201, doi:10.2489/jswc.67.3.183.
- Mueller-Warrant, G.W., G. Whittaker, S.M. Griffith, G. Banowetz, B. Dugger, T. Garcia, G. Giannico, K. Boyer, and B. McComb. 2011. Remote sensing classification of grass seed cropping practices in western Oregon. *International Journal of Remote Sensing* 32(9):2451-2480, doi:10.1080/01431161003698351.
- Steiner, J.J., W.E. Gavin, G.W. Mueller-Warrant, S.M. Griffith, G.W. Whittaker, and G.M. Banowetz. 2007. Conservation practices in western Oregon perennial grass seed systems. III: Impacts on gray-tailed vole activity. *Agronomy Journal* 99:537-542.
- Steiner, J.J., G.W. Mueller-Warrant, S.M. Griffith, G.W. Banowetz, and G.W. Whittaker. 2007. Conservation practices in western Oregon perennial grass seed systems. II: Meadowfoam rotation crop management. *Agronomy Journal* 98:1501-1509.
- Whittaker, G., R. Confessor, Jr., M. DiLuzio, and J.G. Arnold. 2010. Detection of overparametrization and overfitting in an automatic calibration of SWAT. *American Society of Agricultural and Biological Engineers* 53:1487-1499.
- Whittaker, G., R. Confessor, Jr., S.M. Griffith, R. Fare, Shawna Grosskopf, J.J. Steiner, G.W. Mueller-Warrant, and G.M. Banowetz. 2009. A hybrid genetic algorithm for multi-objective problems with activity analysis-based local search. *European Journal of Operational Research* 193:195-203.

Abstracts

- Colvin, R., K. Boyer, G. Giannico, J. Li, and S.M. Griffith. 2007. Fish and amphibian use of vegetated and non-vegetated intermittent channels in the Upper Willamette Basin. Annual meeting of the Oregon Chapter of the American Fisheries Society, Eugene, OR, February 28-March 2, 2007.
- Gerth, W., J. Li, and G. Giannico. 2009. Summer-dry stream invertebrates in a western Oregon lowland landscape. Abstract #274. Annual meeting of the North American Benthological Society. Grand Rapids, MI, May 17-22, 2009.
- Mueller-Warrant, G., G. Banowetz, G. Whittaker, S. Griffith, G. Giannico, T. Garcia, A. Herlihy, and B. McComb. 2007. Multi-year GIS of western Oregon cropping systems. Abstract. Madison, WI: American Society of Agronomy, Crop Science Society of America, and the Soil Science Society of America.

Presentations

- Gerth, W., R. Colvin, A. Herlihy, G. Giannico, R. Confessor, G. Whittaker, and S. Griffith. 2009. Developing biological indices for water quality in intermittent agricultural streams in western Oregon. Cooperative State Research, Education, and Extension Service. National Water Conference. St. Louis, MO, February 8-12, 2009.
- Gerth, W.J., Li, J., and V. Driesche, and R. Limnephilid. 2008. Caddisflies of summer-dry streams in a western Oregon agricultural landscape. Abstract #275. Annual meeting of the North American Benthological Society, Salt Lake City, UT, May 25-28, 2008.
- Giannico, G., K. Boyer, R. Colvin, R. Confessor, B. Dugger, R. Fare, T. Garcia, W. Gerth, S. Griffith, S. Grosskopf, A. Herlihy, J. Li, B. McComb, G. Mueller-Warrant, and G. Whittaker. 2008. Assessing trade-offs between crop production and ecological services: The Calapooia Basin. USDA Cooperative State Research, Education, and Extension Service. National Water Conference: Research, Extension, and Education for Water Quality and Quantity. Sparks, NV, February 3-7, 2008.
- Griffith, S. 2009. Value of grass to the environment. Oregon Grass Seed Bargaining Association Meeting, Salem, OR, February 17, 2009.
- Herlihy, A., G.W. Whittaker, G.W. Mueller-Warrant, S.M. Griffith, W. Gerth, J. Li, G. Giannico, K. Boyer, T.S. Garcia, B. McComb, B. Dugger, S. Grosskopf, and R. Fare. 2010. Assessing trade-offs between crop production and ecological services in the Willamette Valley, Oregon - The Calapooia CEAP study. Abstract 31321809. SWCS Managing Ag Landscapes II. Achieving More Effective Conservation. Denver, CO, April 28-30, 2010.

Theses

- Baker, N. 2009. Agricultural Impacts on Amphibian Survival, Growth and Distributions. Master's thesis. Department of Fisheries and Wildlife, Oregon State University.
- Wyss, L. 2011. Effects of Grass Seed Agriculture on Aquatic Invertebrate Communities in Seasonal Wetlands of the Southern Willamette Valley, Oregon. Master's thesis. Department of Fisheries and Wildlife, Oregon State University.

Fact Sheets

- Colvin, R.W., G.R. Giannico, A.T. Herlihy, W.J. Gerth, R.B. Confessor, R.G. Fare, T.S. Garcia, S.M. Griffith, S.P. Grosskopf, B.C. McComb, G.W. Whittaker, and G.W. Mueller-Warrant. 2008. Assessing trade-offs between crop production and ecological services: The Calapooia Basin. *In* 2007 Seed Production Research at Oregon State University, USDA ARS Cooperating, ed. W.C. Young III, 78-79. Department of Crop and Soil Science Ext/CrS 127, April. Corvallis, OR.
- Griffith, S.M., J.H. Davis, and G.M. Banowetz. 2010. Soil carbon budget for annual and perennial ryegrass grown for seed. *In* 2009 Seed Production Research at Oregon State University, USDA ARS Cooperating, ed. W.C. Young III, 31. Department of Crop and Soil Science Ext/CrS 129, April. Corvallis, OR.
- Griffith, S.M., J.H. Davis, R.P. Dick, G.M. Banowetz, and J.J. Steiner. 2010. Crop rotation and straw residue effects on soil carbon in three grass seed cropping systems of western Oregon. *In* 2009 Seed Production Research at Oregon State University, USDA ARS Cooperating, ed. W.C. Young III, 32-34. Department of Crop and Soil Science Ext/CrS 129, April. Corvallis, OR.
- Griffith, S.M., J.H. Davis, and P.J. Wigington, Jr. 2010. Riparian forest and adjacent grass seed production field in western Oregon: Nitrogen dynamics and water quality. *In* 2009 Seed Production Research at Oregon State University, USDA ARS Cooperating, ed. W.C. Young III, 16-17. Department of Crop and Soil Science Ext/CrS 129, April. Corvallis, OR.

- Griffith, S.M., and W.E. Gavin. 2007. Temporal changes in tall fescue straw residue degradation. *In* 2006 Seed Production Research at Oregon State University, USDA-ARS Cooperating, ed. W.C. Young III, 19-21. Department of Crop and Soil Science Ext/CrS 126, April. Corvallis, OR.
- Mueller-Warrant, G.W., S.M. Griffith, G.W. Whittaker, G.M. Banowetz, W.F. Pfender, T.S. Garcia, and G.R. Giannico. 2011. Making sense of nitrogen flux patterns in the Calapooia River Basin. *In* 2010 Seed Production Research at Oregon State University, USDA ARS Cooperating, ed. W.C. Young III, 40-44. Department of Crop and Soil Science Ext/CrS 130, April. Corvallis, OR.
- Wyss, L., A. Herlihy, B. Dugger, J. Li, B. Gerth, and G. Giannico. 2011. Grass seed agriculture and invertebrate communities of seasonal wetlands in the Southern Willamette Valley. *In* 2010 Seed Production Research at Oregon State University, USDA ARS Cooperating, ed. W.C. Young III, 45-48. Department of Crop and Soil Science Ext/CrS 130, April. Corvallis, OR.

Project Web Site

Assessing Trade-Offs Between Crop Production and Ecological Services: The Calapooia Basin. http://fwl.oregonstate.edu/Labs/giannico/html/fishery_ditches_calapooia.html#assessing.

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Project Personnel

This project involved expertise in multiple disciplines and included faculty from Oregon State University and several USDA Agricultural Research Service employees. At the start of the project, a hydrologist with a postdoctoral position, Remegio Confessor, linked the SWAT model with a GIS and field-collected data. This model was essential in the economics modeling work developed by three economists, who are still testing it with different variables and market scenarios. Guillermo Giannico (fish ecologist) was the project investigator. Bruce Dugger (wildlife ecologist), Rolf Fare (economist), Brenda McComb (wildlife ecologist), Tiffany Garcia (wildlife ecologist), William Gerth (aquatic entomologist), Shawna Grosskopf (economist), Alan Herlihy (aquatic ecologist), Judith Li (stream ecologist), and Mark Mellbye (agriculture extension specialist) were coproject investigators. Other participants from Oregon State University included Nick Baker (graduate student), Remegio Confesor (postdoctoral fellow), Randall Colvin (graduate student), Lance Wyss (graduate student) and USDA Agricultural Research Service participants included Stephen Griffith (research plant physiologist), George Mueller-Warrant (research agronomist), and Gerald Whittaker (research hydrologist). The USDA Natural Resources Conservation Services participant included Kathryn Boyer (fish biologist).

References

- Hinkle, S.R. 1997. Quality of shallow ground water in alluvial aquifers of the Willamette Basin, Oregon, 1993-95: U.S. Geological Survey Water-Resources Investigations Report 97-4082-B.
- Steiner, J.J., S.M. Griffith, G.W. Mueller-Warrant, G.W. Whittaker, G.M. Banowetz, and L.F. Elliott. 2006. Conservation Practices in Western Oregon Perennial Grass Seed Systems. I: Impacts of Direct Seeding and Maximal Residue Management on Production. *Agronomy Journal* 98:177-186.

- USEPA (United States Environmental Protection Agency). 2011. Clean Water Act Section 303. Water Quality Standards and Implementation Plans. <http://water.epa.gov/lawsregs/guidance/303.cfm>.
- Wentz, D.A., B.A. Bonn, K.D. Carpenter, S.R. Hinkle, M.L. Janet, F.A. Rinella, M.A. Urich, I.R. Waite, A. Laenen, and K.E. Bencala. 1998. Water Quality in the Willamette Basin, Oregon, 1991-95: U.S. Geological Survey Circular 1161. <http://pubs.usgs.gov/circ/circ1161>.
- Wigington, Jr., P.J., S.M. Griffith, J.A. Field, J.E. Baham, W.R. Horwath, J. Owen, J.H. Davis, S.C. Rain, and J.J. Steiner. 2003. Effectiveness of a riparian water quality buffer along a small agricultural stream in western Oregon. *Journal of Environmental Quality* 32:162-170.
- Whittaker, G., R. Confessor, Jr., S.M. Griffith, R. Fare, Shawna Grosskopf, J.J. Steiner, G.W. Mueller-Warrant, and G.M. Banowetz. 2009. A hybrid genetic algorithm for multi-objective problems with activity analysis-based local search. *European Journal of Operational Research* 193:195-203.