

Northwest Wetlands General Information

969. **Amphibian occurrence and aquatic invaders in a changing landscape: Implications for wetland mitigation in the Willamette Valley, Oregon, USA.**

Pearl, Christopher A.; Adams, Michael J.; Leuthold, Niels; and Bury, R. Bruce

Wetlands 25(1): 76-88. (2005)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetland mitigation/ breeding occurrence/ landscape characteristics

Abstract: Despite concern about the conservation status of amphibians in western North America, few field studies have documented occurrence patterns of amphibians relative to potential stressors. We surveyed wetland fauna in Oregon's Willamette Valley and used an information theoretic approach (AIC) to rank the associations between native amphibian breeding occurrence and wetland characteristics, non-native aquatic predators, and landscape characteristics in a mixed urban-agricultural landscape. Best predictors varied among the five native amphibians and were generally consistent with life history differences. Pacific tree frog (*Pseudacris regilla*) and long-toed salamander (*Ambystoma macrodactylum*) occurrence was best predicted by the absence of non-native fish. Northern red-legged frog (*Rana a. aurora*) and northwestern salamander (*Ambystoma gracile*) were most strongly related to wetland vegetative characteristics. The occurrence of rough-skinned newts (*Taricha granulosa*), a migratory species that makes extensive use of terrestrial habitats, was best predicted by greater forest cover within 1 km. The absence of non-native fish was a strong predictor of occurrence for four of the five native species. In contrast, amphibians were not strongly related to native fish presence. We found little evidence supporting negative effects of the presence of breeding populations of bullfrog (*Rana catesbeiana*) on any native species. Only the two *Ambystoma* salamanders were associated with wetland permanence. Northwestern salamanders (which usually have a multi-year larval stage) were associated with permanent waters, while long-toed salamanders were associated with temporary wetlands. Although all the species make some use of upland habitats, only one (rough-skinned newt) was strongly associated with surrounding landscape conditions. Instead, our analysis suggests that within-wetland characteristics best predict amphibian occurrence in this region. We recommend that wetland preservation and mitigation efforts concentrate on sites lacking non-native fish for the conservation of native amphibians in the Willamette Valley and other western lowlands.

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970. **Amphibian occurrence and wetland characteristics in the Puget Sound Basin.**

Richter, Klaus O. and Azous, Amanda L.

Wetlands 15(3): 305-312. (1995)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: breeding habitat/ hydrology/ land use/ predation/ vegetation class

Abstract: We studied the pattern of amphibian distributions within 19 wetlands of the Puget Sound Basin in King County, Washington State from 1988 through 1991.

Amphibian richness was compared to wetland size, vegetation classes, presence of bullfrog and fish predators, hydrologic characteristics of water flow, fluctuation, and permanence, and land use. Low velocity flow and low fluctuation were correlated with high species richness. Seasonal persistence of water was unrelated to species richness. Wetland size, distance to other wetlands favorable for breeding, fish and bullfrog predators, and the number of vegetation classes found at a wetland were unrelated to total number of species. Increasing mean water-level fluctuation and percent watershed urbanization were correlated with low species richness. Small and structurally simple wetlands often have high value amphibian habitat, and traditional reliance on wetland size and broad vegetation classes without site-specific studies should be avoided when assessing habitat value for amphibians.

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971. **Application of the synoptic approach to wetland designation: A case study in Washington.**

Abbruzzese, B.; Leibowitz, S. G.; and Sumner, R., EPA/600/3-90/072, 1990.

Notes: NTIS Order No.: PB90-270604/GAR

Descriptors: wetlands/ nature conservation/ environmental protection/ resource management/ classification systems/ USA, Washington/ conservation, wildlife management and recreation

Abstract: The synoptic approach is a rapid assessment method designed to provide a context for evaluating landscape sensitivity to cumulative wetland loss and to complement site specific information used in reviewing permit applications to alter wetlands. The objectives of the study were to: (1) test the utility of the synoptic approach in prioritizing wetland 'functional uses' (including State surface water designated uses) within the State of Washington; (2) demonstrate and improve this method's ability to identify wetland resources that are ecologically important or sensitive to change; (3) investigate the applicability of the synoptic approach in the landscape assessment of a relatively small watershed; and (4) implement the transfer of the research products to State wetland managers. Readily available data were compiled for Washington into a set of map overlays. The overlays were synthesized to produce indices of landscape input and wetland capacity for hydrologic, water quality, and life support functions, cumulative impacts and future wetland losses for watersheds within the State. The synoptic approach identifies wetland functions not included in Washington's designated uses of surface waters. The approach is appropriate for a state with a generalized set of water quality standards such as Washington's, i.e., one that has no specific designated uses relative to wetland hydrologic and water quality improvement functions. The products of this assessment will be useful in regional planning and in the development of State wetland conservation plans. Contract EPA-68-C8-0006 Sponsored by Corvallis Environmental Research Lab., OR (DBO).
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972. Characterization of wetland hydrology using hydrogeomorphic classification.

Shaffer, P. W.; Kentula, M. E.; and Gwin, S. E. *Wetlands* 19(3): 490-504. (1999)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ hydrology/ geomorphology/ classification/ decision making/ land management/ water management/ water level/ drainage/ classification systems/ water levels/ decision theory/ land/ USA, Oregon, Portland/ hydrogeomorphic classification

Abstract: Hydrologic data are essential for understanding relationships between wetland morphology and function and for characterizing landscape-scale patterns of wetland occurrence. We monitored water levels in 45 wetlands for three years to characterize the hydrology of wetlands in the vicinity of Portland, Oregon, USA and classified wetlands by hydrogeomorphic (HGM) class to determine whether hydrologic regimes differed in wetlands in different HGM classes. We also compared hydrologic regimes in naturally occurring wetlands (NOWs) and mitigation wetlands (MWs) and in wetlands with/without a human-made water-retention structure to determine whether and how human modifications are changing the hydrology of wetlands. We found no relationship between hydrologic attributes and land use, soil association, or wetland area. We did find significant differences related to presence of a water-retention structure and to wetland type (NOW or MW). Water levels were higher and had less temporal variability and more extensive inundation (as % wetland area) in MWs and in wetlands modified to include a retention structure. HGM class was very effective for characterizing wetland hydrology, with significant differences among HGM classes for water level and for extent and duration of inundation. For three regional classes, we found the lowest water levels and lowest extent/duration of inundation in slope wetlands, intermediate conditions in riverine wetlands, and the highest water levels and greatest extent and duration of inundation in depressions. In "atypical" classes, average water level and extent of inundation were similar to conditions in depressions, but the within-site variability in water levels in depressions-in-slope-setting and in-stream-depressions was significantly smaller than in the regional classes (p less than or equal to 0.001). Results highlight the importance of both geomorphic setting and wetland structure in defining wetland hydrology and support the use of HGM for wetland classification. Because hydrology is an important determinant of many wetland functions, resource managers using restoration and mitigation to offset wetland losses should strive for project design and siting that re-establish the hydrogeomorphology of natural wetlands to improve the likelihood of replacing wetland functions.

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973. Classification and management of aquatic, riparian, and wetland sites on the national forests of Eastern Washington: Series description.

Kovalchik, B. L. and Clausnitzer, R. R.; 593, 2004. 354 USDA Forest Service General Technical Report PNW.

NAL Call #: aSD11.A46 no. 593

<http://www.fs.fed.us/pnw/publications/gtr593/>

Descriptors: aquatic/ Eastern Washington/ plant association/ plant community/ riparian/ riparian ecosystems/ riparian vegetation/ series description/ vegetation classification/ wetland

Abstract: This is a classification of aquatic, wetland, and riparian series and plant associations found within the Colville, Okanogan, and Wenatchee National Forests. It is based on the potential vegetation occurring on lake and pond margins, wetland fens and bogs, and fluvial surfaces along streams and rivers within Forest Service lands. Data used in the classification were collected from 1,650 field plots sampled across the three forests. This classification identifies 32 series separated into four physiognomic classes: coniferous forests, deciduous forests, shrubs, and herbaceous vegetation. In addition, keys to the identification of 163 plant associations or community types are presented. The report includes detailed descriptions of the physical environment, geomorphology, ecosystem function, and management of each series. This classification supplements and expands information presented in upland forest plant association classifications previously completed for the three eastern Washington forests. It is a comprehensive summary of the aquatic, riparian, and wetland series and contributes to the understanding of ecosystems and their management in eastern Washington.

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974. Classification of aquatic and semiaquatic wetland natural areas in Idaho and western Montana.

Rabe, F. W. and Chadde, S. W.

Natural Areas Journal 14(3): 175-187. (1994)

NAL Call #: QH76.N37; ISSN: 0885-8608

Descriptors: wetlands/ classification systems/ hydrology/ water analysis/ nature conservation/ classification/ aquatic environment/ geochemistry/ natural areas/ geochemistry/ classification systems/ nature conservation

Abstract: A hierarchical classification of aquatic and semiaquatic zones associated with lentic (standing water) systems in Idaho and western Montana is proposed. This classification is structured like Cowardin et al. (1979), but is modified to apply to conditions in the Northern Rocky Mountains. Aquatic or open water sites are defined as having a depth greater than 0.5 m. Sites less than 0.5 m deep are considered semiaquatic. At the subsystem level our classification differs by separating size and depth of the aquatic area, making it possible to have both shallow and deep lakes and ponds. At the class and subclass levels only minor changes to the aquatic and semiaquatic descriptors used by the Cowardin system are proposed. We utilize water chemistry and hydrology as modifiers, similar to Cowardin, but do not employ water regime or soil as modifiers. We add geomorphic forms and special aquatic features not recognized by Cowardin. Wetland types found in Idaho and Montana such as peatlands, marshes, potholes, swamps, and vernal pools are described and classified. Photographs of selected study sites illustrate the classification process.

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975. Distribution of soil organic matter in freshwater emergent/open water wetlands in the Portland, Oregon metropolitan area.

Shaffer, P. W. and Ernst, T. L.

Wetlands 19(3): 505-516. (1999)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ hydrology/ geomorphology/ land management/ water management/ decision making/ resources management/ land use/ soil organic matter/ land/

decision theory/ resources/ organic matter/ USA, Oregon, Portland/ standing water

Abstract: We measured soil organic matter (SOM) concentrations in a large sample (n = 95) of freshwater emergent and open water wetlands in the Portland, Oregon, USA, area as part of a study of the ecological development of mitigation wetlands. Mean SOM concentrations were higher in naturally occurring wetlands (NOWs) than in mitigation wetlands (MWs) at 0-5 cm (SOM = 9.75 and 5.83%, respectively, p = 0.0001) and at 15-20 cm (SOM = 6.85, 4.68%, p = 0.0551). If temporal accumulation of SOM is occurring, it is slow; we found no significant relationship between SOM and wetland age (p = 0.6003) and no significant change in SOM concentration in soils in MWs sampled in 1987 and 1993. Concentrations of SOM were not significantly related to land use but were related to soil series, texture class, and association, and to hydrogeomorphic class. For a subset of wetlands monitored for hydrology, we also found a significant negative relationship between SOM and the extent of inundation by standing water. Mitigation may be leading to direct loss of SOM, probably resulting from soil management practices during project construction. We also show that hydrologic regime significantly affects SOM. Because most projects in our study were built in pre-existing wetlands and have extensive areas of open water, our results suggest that low concentrations of SOM are likely to persist. For SOM and probably for SOM-supported wetland functions, fundamental goals of mitigation and wetland management (in-kind wetland replacement, no-net-loss of structure and function) are not being achieved, at least in the short term. The success of mitigation, in terms of SOM, could be improved by better project design and better management of soils during project construction.

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976. Environmental gradients in Northwest USA freshwater wetlands.

Sanville W. D.; Eilers H. P.; Boss T. R.; and Pflieger T. G. *Environmental Management* 10(1): 125-134. (1986)

NAL Call #: HC79.E5E5; ISSN: 0364-152X

Descriptors: vegetation/ moisture/ model/ seasonality

Abstract: Wetland environmental characteristics are examined to determine their spatial and temporal relationships. Two very different Oregon freshwater wetlands provided a range of wetland types. Results are evaluated to determine the possible use of environmental characteristics in defining wetlands and their boundaries. Representative physical, hydrological, and edaphic properties were periodically measured in microplots along upland/wetland transects. A multivariate approach is stressed in the data analysis; correlation, cluster analysis, and principal components analyses were used. The results indicate the environmental characteristics change in a quantifiable manner both spatially and temporally. The controlling mechanism is moisture, spatially in terms of the upland/wetland transect and temporally with respect to seasonal response. These changes do not correlate well with vegetation. Several hypotheses are offered as an explanation. Correlation within environmental characteristics is variable but definite patterns are discernible. These data suggest both single and combinations of environmental characteristics that could

serve as "keys" in wetland identification and boundary determination. However, before extensive use is made of this information additional long-term monitoring of wetland environmental characteristics will be required.

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977. Forms and accumulation of soil P in natural and recently restored peatlands--Upper Klamath Lake, Oregon, USA.

Graham, S. A.; Craft, C. B.; McCormick, P. V.; and Aldous, A.

Wetlands 25(3): 594-606. (2005)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ marshes/ phosphorus/ peatlands/ drainage/ lakes/ storage/ soil

Abstract: Forms, amounts, and accumulation of soil phosphorus (P) were measured in natural and recently restored marshes surrounding Upper Klamath Lake located in south-central Oregon, USA to determine rates of P accumulation in natural marshes and to assess changes in P pools caused by long-term drainage in recently restored marshes. Soil cores were collected from three natural marshes and radiometrically dated to determine recent (super(137)Cs-based) and long-term (super(210)Pb-based) rates of peat accretion and P accumulation. A second set of soil cores collected from the three natural marshes and from three recently restored marshes was analyzed using a modification of the Hedley procedure to determine the forms and amounts of soil P. Total P in the recently restored marshes (222 to 311 $\mu\text{g cm}^{-1}$) was 2-3 times greater than in the natural marshes (103 to 117 $\mu\text{g cm}^{-1}$), primarily due to greater bulk density caused by soil subsidence, a consequence of long-term marsh drainage. Occluded Fe- and Al-bound P sub(i), calcium-bound P sub(i) and residual P were 4 times, 22 times, and 5 times greater, respectively, in the recently restored marshes. More than 67% of the P pool in both the natural and recently restored marshes was present in recalcitrant forms (humic-acid P sub(o) and residual P) that provide long-term P storage in peat. Phosphorus accumulation in the natural marshes averaged 0.45 $\text{g m}^{-2} \text{yr}^{-1}$ (super(137)Cs) and 0.40 $\text{g m}^{-2} \text{yr}^{-1}$ (super(210)Pb), providing a benchmark for optimizing P sequestration in the recently restored marshes. Effective P sequestration in the recently restored marshes, however, will depend on re-establishing equilibrium between the P-enriched soils and the P concentration of floodwaters and a hydrologic regime similar to the natural marshes.

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978. Historical wetlands in Oregon's Willamette Valley: Implications for restoration of winter waterbird habitat.

Taft, O. W. and Haig, S. M.

Wetlands 23(1): 51-64. (2003)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ environmental restoration/ overwintering/ historical ecology/ valleys/ habitats/ waterfowl/ agriculture/ river basins/ habitat improvement/ ecosystem management/ restoration/ anthropogenic factors/ biological surveys/ river valleys/ aquatic birds/ habitat/ Aves/ Cygnus buccinator/ Chen caerulescens/ Grus canadensis/ Numenius americanus/ USA, Oregon, Willamette Valley/ birds/ trumpeter swan/ snow goose/ sandhill crane/ long-billed curlew/ Anser caerulescens/ Olor buccinator

Abstract: Before agricultural expansion in the 19th century, river valleys of North America supported expanses of wetland habitat. In restoring these landscapes, it is important to understand their historical condition and biological function. Synthesizing historical primary accounts (from explorers, travelers, settlers, and farmers) with contemporary knowledge of these wetland systems, we developed a profile of the wetlands and their use by nonbreeding waterbirds (e.g., waterfowl, wading birds, and shorebirds) within the Willamette Valley, Oregon, ca. 1840. We found evidence for three types of wetlands used by non-breeding waterbirds in fall, winter, and spring: emergent wetlands, riverine wetlands, and wetland prairie. The most extensive wetland type was wetland prairie, which functioned as fall/winter habitat for waterbirds, but only while native Kalapuyans managed the region with fire. Since the mid-1800s, four species, in particular, have decreased their use of the Willamette Valley: trumpeter swan (*Cygnus buccinator*), snow goose (*Chen caerulescens*), sandhill crane (*Grus canadensis*), and long-billed curlew (*Numenius americanus*). Information suggests that ca. 1840, waterbirds and their habitats were more abundant in the Willamette Valley than today. Restoration of the Willamette Valley landscape is warranted, and today's agricultural wetlands-former wetland prairie-hold highest restoration potential.

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979. Hydric soils in a southeastern Oregon vernal pool.

Clausnitzer, David; Huddleston, J. Herbert; Horn, Edward; Keller, Mark; and Leet, Curtis

Soil Science Society of America Journal 67(3): 951-960. (2003)

NAL Call #: 56.9 So3; ISSN: 0361-5995

Descriptors: hydric soils/ ponding/ vernal pool/ wetlands soil

Abstract: Vernal pools on the High Lava Plain of the northern Great Basin become ponded in most years, but their soils exhibit weak redoximorphic features indicative of hydric conditions. We studied the hydrology, temperature, redox potentials, soil chemistry, and soil morphology of a vernal pool to determine if the soils are hydric, and to evaluate hydric soil field indicators. We collected data for 3 yr from piezometers, Pt electrodes, and thermocouples. Soil and water samples were analyzed for pH, organic C, and extractable Fe and Mn. Soils were ponded from January through April or May, but subsurface saturation was never detected. Soil temperatures 50 cm below the surface rose above 5°C by March. Clayey Bt horizons perched water and limited saturation to the upper 10 cm. Redox potentials at a 5-cm depth were often between 200 and 300 mV, indicating anaerobic conditions, but producing soluble Fe²⁺ concentrations <1 mg L⁻¹. Extractable soil Fe contents indicated Fe depletion from pool surface horizons and accumulation at or near the upper Bt1 horizon. Depletions and concentrations did not satisfy the criteria of any current hydric soil indicators. We recommend development of new indicators based on acceptance of fewer, less distinct redox concentrations for recognition of a depleted A horizon, and on presence of a thin zone containing redox concentrations located in the upper part of the near-surface perching horizon.

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980. Managing Oregon's estuarine resource lands.

Jackson, P. L.

Journal of Soil and Water Conservation 46(1): 23-26. (1991)

NAL Call #: 56.8 J822; ISSN: 0022-4561

Abstract: Reviews one of the first attempts at mitigation banking to balance development with maintenance of fragile ecosystems. Estuarine mitigation has become an important phase in the planning and management of Oregon's coastal wetlands. As a part of a coordinated program of local comprehensive planning, land use regulation, and waterway alteration laws, mitigation banking is used to maintain the integrity of estuarine ecosystems by restoring or enhancing substitute habitat where planned development would otherwise result in the loss of resource lands. Oregon had adopted mitigation banking as the bank concept presents an alternative to applicants for state permits for material removal or fill in development estuaries. The article describes Oregon's first mitigation bank, the Astoria mitigation bank, established in 1987 at Young's Bay in the Columbia River Estuary. This project's objective was to restore a 33.8 acre diked pasture to its former condition as tidal marsh and swamp habitat. Another example of a large-scale habitat restoration is studied - the Salmon River Estuary project. Although this project was not a mitigation bank, it provides excellent evidence that diked pastureland along the Oregon coast can be returned to functioning salt-marsh habitat by restoration actions. The article finally assesses the prospects for estuarine mitigation. -from Author

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981. Nesting ecology of waterbirds at Grays Lake, Idaho.

Austin, J. E. and Pyle, W. H.

Western North American Naturalist 64(3): 277-292. (2004)

NAL Call #: QH1 .G7; ISSN: 1527-0904

Descriptors: wetlands/ nesting behavior/ lakes/ montane environments/ aquatic birds/ mountains/ nesting/ breeding success/ reproductive behaviour/ Aves/ *Fulica americana*/ *Aythya americana*/ *Gallinago delicata*/ *Phalaropus tricolor*/ *Podiceps nigricollis*/ *Recurvirostra americana*/ *Anas platyrhynchos*/ *Oxyura jamaicensis*/ *Rallus limicola*/ *Branta canadensis*/ *Circus cyaneus*/ *Asio flammeus*/ *Grus canadensis tabida*/ *Numenius americanus*/ *Anas strepera*/ USA, Idaho, Grays L./ birds/ gadwall

Abstract: Montane wetlands provide valuable habitat for nesting waterfowl and other waterbirds in the western United States, but relatively little information is available about the nesting ecology of their waterbird communities. We describe the general nesting ecology of breeding waterbirds at a large, shallow, montane wetland in southeastern Idaho during 1997-2000. Habitats include upland grasslands and intermittently to semipermanently flooded wetland habitats. We located a total of 1207 nests of 23 bird species: Eared Grebe (*Podiceps nigricollis*), Canada Goose (*Branta canadensis*), Mallard (*Anas platyrhynchos*), Gadwall (*A. strepera*), American Wigeon (*A. americana*), Green-winged Teal (*A. crecca*), Blue-winged Teal (*A. discors*), Cinnamon Teal (*A. cyanoptera*), Northern Shoveler (*A. clypeata*), Northern Pintail (*A. acuta*), Redhead (*Aythya americana*), Canvasback (*A. valisineria*), Lesser Scaup (*A. affinis*), Ruddy Duck (*Oxyura jamaicensis*), Northern Harrier (*Circus cyaneus*), American Coot (*Fulica americana*), Virginia Rail (*Rallus limicola*),

Greater Sandhill Crane (*Grus canadensis tabida*), American Avocet (*Recurvirostra americana*), Long-billed Curlew (*Numenius americanus*), Wilson's Snipe (*Gallinago delicata*), Wilson's Phalarope (*Phalaropus tricolor*), and Short-eared Owl (*Asio flammeus*). Most nests were initiated in May-early June and were terminated (hatched or destroyed) by the 3rd week of June. Mean daily survival rate (DSR) for Canada Goose nests was 0.954 plus or minus 0.005 (s sub(x); n = 127 nests), equivalent to Mayfield nest success of 21%. Mean DSR for dabbling duck nests over all 4 years was 0.938 plus or minus 0.006 (n = 41), equivalent to Mayfield nest success of 11%. For all other species where we found >10 nests each year (Eared Grebe, Redhead, Canvasback, Coot, Sandhill Crane, American Avocet, and Wilson's Snipe), >50% of nests found hatched at least 1 young. Success rates for geese, cranes, and ducks were lower than reported for Grays Lake during 1949-1951 and lower than most other wetlands in the region.

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982. *Quercus garryana* communities in the Puget Trough, Washington.

Thysell, David R. and Carey, Andrew B.
Northwest Science 75(3): 219-235. (2001)
NAL Call #: 470 N81; ISSN: 0029-344X

Descriptors: biodiversity/ terrestrial ecology: ecology, environmental sciences/ vashon glaciation/ community composition/ exogenous disturbances/ forest types/ plant cover/ prairies: habitat/ species diversity/ species richness/ tree diameter/ tree height/ tree regeneration/ wetlands: habitat

Abstract: Among the legacies of the Vashon Glaciation are Oregon white oak (*Quercus garryana*), prairie, wetland, and Douglas-fir (*Pseudotsuga menziesii*) communities arrayed in a mosaic in the Puget Sound Area (PSA). Much of this mosaic has been destroyed. The largest remaining portion is on Fort Lewis Military Reservation. We examined oak communities on Fort Lewis to assess encroachment by exotic plants and by Douglas-fir, to determine amounts of regeneration of oak and other tree species, and to compare oak community diversity with that of nearby Douglas-fir forests and glacial till prairies. For the 22 largest communities, we determined densities of trees, distributions of tree diameters and heights, amounts of regeneration for each tree species, evidence of exogenous disturbances, and covers of vascular understory species. For study sites, we calculated basal areas of tree species, richness and diversity of vascular plants, and percentages of species that were exotic. We constructed species accumulation curves for oak communities, Douglas-fir forests, and prairies. We performed Bray-Curtis and weighted averaging ordinations for 176 sampling plots from the 22 sites. Oak communities were typically more diverse than either Douglas-fir forests or prairies and were transitional in species composition between them. However, oak communities contained numerous exotics, particularly Scot's broom (*Cytisus scoparius*) and colonial bentgrass (*Agrostis capillaris*). Most oak communities contained large-diameter Douglas-firs and other tree species and appeared to be transforming to conifer or conifer/mixed hardwood forests. With succession, exotic species become less prevalent, but the extent and abundance of oaks is diminished. Maintenance of oak communities, and the PSA natural mosaic, may require

tree-density management in oak stands, removal of Douglas-fir, development of replacement oak sites, prescribed burning, and mechanical suppression of exotics before burning.

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983. Recent wetlands trends (1981/82-1994) in the Willamette Valley, Oregon, USA.

Bernert, J. A.; Eilers, J. M.; Eilers, B. J.; Blok, E.; Daggett, S. G.; and Bierly, K. E.

Wetlands 19(3): 545-559. (1999)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ land use/ runoff/ land management/ farms/ classification/ resources management/ agriculture/ tile drains/ irrigation/ ecosystem disturbance/ mapping/ land/ farms and farming/ resources/ drains/ irrigation
Abstract: A two-stage, stratified, systematic sample design was implemented in the Willamette Valley, Oregon, USA, to quantify wetland and land-use changes from the 1980s to the 1990s. The Stage I sample (n = 711) was drawn from public land survey sections and was stratified by land use and runoff potential. The Stage II sample (n = 114) re-sampled the Stage I sample stratified by the amount of hydric soils identified in the Stage I sample. Wetland and upland classes were delineated on large-scale aerial photographs, digitized into ARC/Info coverages, and compared to quantify land-cover changes. Total loss of wetlands to uplands during the study period was about 3,800 ha, representing a 2.1 percent wetland loss from the 1980s. The net loss after adjusting for wetland gains was about 2,750 ha. During the study period, 70 percent of the wetland loss was associated with agriculture, six percent was lost to urbanization, and 24 percent was lost to other changes. The loss of wetlands to agriculture and the conversion of wetland types was consistent with a pronounced climatic component related to below-normal precipitation from 1985 to 1994, although continued installation of tile drains and expansion of irrigated agriculture also may have contributed to the changes. The loss of wetlands to agriculture raised questions regarding the effectiveness of current agricultural wetland policy, which appears ill-prepared to protect small wetlands or to deal with loss of wetlands from intensified use of existing farmland. This study identified a larger number and area of wetlands compared with national wetland surveys because of the larger scale data used in this study, the nature of the strata used in the statistical design, and the inclusion of palustrine farmed wetlands in the land-use classification.

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984. Restoration of degraded riverine/riparian habitat in the Great Basin and Snake River regions.

Platts, W. S. and Jensen, S. E.

In: *Wetland Creation and Restoration: The Status of the Science.*

Covelo, Calif.: Island Press, 1990; pp. 367-404.

Notes: ISBN: 1559630450

NAL Call #: QH541.5.M3W462

Descriptors: habitat restoration/ riparian land/ stream restoration/ water resources management/ wetland restoration/ environmental impact/ planting management/ riparian waters/ soil-water-plant relationships/ water resources development/ watershed management/ wildlife habitats

Abstract: Riverine/riparian habitat (RRH) includes interdependent aquatic (riverine) and streamside (riparian) resources that are valuable for fish and wildlife habitat, flood storage and desynchronization, nutrient cycling and water quality, recreation, and heritage values. RRH includes resources both wetter and drier than stipulated for wetlands. Whereas the 'natural or achievable state' of a riparian habitat may be wetland, the 'existing state' may be non-wetland because of natural or anthropogenically-induced changes in the hydrologic character of RRH. There are many different types of RRH, each with distinctive structure, function, and values. Restoration commonly requires: planning to identify preliminary goals and a general approach; baseline assessments and inventories; designs from which the feasibility of accomplishing goals can be assessed; evaluation to assure compliance with designs; and monitoring of variables important to goals and objectives. The goals, approach, and design of restoration projects must be tailored to each type of RRH. Some general elements important to restoration of degraded RRH are: establishment of hydrologic conditions compatible with project goals; efficient handling of soil and substrates in construction; selection and propagation of plants suited to the site and project goals; evaluation of features to enhance habitat for target species; maintenance and control of impacts; and scheduling construction to reflect site constraints and goals.

(Author's abstract)

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985. Saturation, reduction, and the formation of iron-manganese concretions in the Jackson-Frazier Wetland, Oregon.

D'Amore, David V.; Stewart, Scott R.; and Huddleston, J. Herbert

Soil Science Society of America Journal 68(3): 1012-1022. (2004)

NAL Call #: 56.9 So3; ISSN: 0361-5995

Descriptors: redoximorphic features: hydric soils, wetting drying cycles

Abstract: The Jackson-Frazier wetland is a rare, relatively undisturbed wetland in the Willamette Valley of Oregon that experiences repetitive annual flooding and drying cycles. Redoximorphic features formed by these wetting and drying cycles have not been calibrated with saturation and reduction. Long-term measurements of soil saturation and soil redox potential (EH) were combined with measurements of Fe and Mn concentrations to understand the formation of these redoximorphic features in the wetland soils. The Jackson-Frazier wetland is underlain by three stratigraphic units that control its hydrology: Holocene alluvium (A and Bss horizons), Malpass clay (2Bt horizon), and Irish Bend silts (3BC horizon). All three units are saturated for up to 9 mo each year, leading to EH values that fall below the Fe reduction threshold. Extractable Fe and Mn in nodules, concretions, and soft masses document substantial depletions from the matrix soil in all three units. In the 3BC, diffuse halos of Fe accumulation and matrix chromas from two to four indicate a source of Fe that can be reduced, translocated, and concentrated in nodular form. In the Bss and 3BC horizons, soft masses surrounding concentrations and higher ratios of oxalate to dithionite-citrate-bicarbonate Fe (Fe_{ox}/Fe_{DCB}) in the larger concentrations suggest that nodules and concretions are currently forming by accretion of Fe. In the 2Bt, virtually all

of the Fe and Mn is gone from the matrix, and concretion boundaries are sharp. These are not relict features, as the current conditions would favor continued formation had the supply of Fe and Mn not been exhausted.

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986. Sensitive wetlands delineation using multitemporal satellite imagery: A comparative study in the intermountain western U.S.

Cheney, B.; Jackson, M.; and Hardin, P.

In: *Proceedings of SPIE - The International Society for Optical Engineering*; Vol. 4171.; pp. 340-350; 2001.

Descriptors: Kauth-Thomas transformation/ multitemporal image analysis/ wetland delineation

Abstract: This paper details an effort to develop an operational methodology to distinguish lacustrine, palustrine and riverine wetlands from irrigated agriculture in a continental area using archived multi-temporal/multi-spectral Landsat Tm data. Archival Landsat Tm data were acquired over the Little Wood River Valley of Idaho in April, August and September of 1985. All dates of imagery were subjected to a Kauth-Thomas transformation and then stacked into a single 9-band image and submitted to a supervised classification. Dem data was used to remove spectral confusion with mountain vegetative systems with similar temporal signatures to the wetlands of interest. Field checks and comparison to National Wetland Inventory (nwi) maps completed in 1984 revealed a 98.3% agreement in classification of non-wetland areas. 54% of the areas classified as wetland on the Nwi were classified as wetland using our method. This is attributed to practice of generalization of the Nwi maps in which several small wetlands are circumscribed into a single large area. The digital method correctly identified the wetland patches and classified the interstices as dry land. Confusion with irrigated agriculture was almost completely absent. © 2006 Elsevier B.V. All rights reserved.

987. Tidal wetlands of the Puget Sound region Washington USA.

Boule M. E.

Wetlands 1: 47-60. (1981)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: spruce/ alder/ pine/ inundation/ salinity/ climate/ zonation/ plant evolution/ topography/ tide/ river/ freshwater/ marine/ marsh/ swamp

Abstract: Wetland plant associations in the Puget Sound region are controlled by the same physical factors identified in wetlands throughout the world: frequency and/or duration of inundation, and salinity. Physiographic and climatic features and plant evolutionary responses to them have resulted in an unusual diversity and zonation of tidal wetlands. Substantial freshwater runoff and fjord-like topography results in diminished baseline ("marine") salinity conditions within Puget Sound. The steep topography/bathymetry also means there is little suitable wetland habitat in Puget Sound waterways. Tide ranges of up to 4m at river mouths may result in tidal fluctuations 40 km or more upstream, while high river flows often limit measurable surface salinities to less than 2km upstream. As a consequence, Puget Sound wetlands are found predominantly in tidal, freshwater rivers. Plant communities vary from low salt marsh associations at river mouths with

brackish marshes immediately above them to fresh marshes and shrub swamps upriver. In undeveloped locations, forested swamps of spruce, alder, or occasionally pine, may be found in upstream tidal areas.

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988. Tracking changes in wetlands with urbanization: Sixteen years of experience in Portland, Oregon, USA.

Kentula, Mary E.; Gwin, Stephanie E.; and Pierson, Suzanne M.

Wetlands 24(4): 734-743. (2004)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: hydrologic modifications/ geographic information system: GIS, applied and field techniques/ field survey: applied and field techniques/ national wetlands inventory/ human manipulation/ rainfall/ residential use/ wetland urbanization

Abstract: Long-term studies are essential to understanding the effects of urbanization on wetlands and the effectiveness of management actions. Using data from the National Wetlands Inventory (NWI) in combination with GIS analyses and field surveys, we tracked changes over 16 years (1982-1998) in small (ltoreq2 ha), palustrine emergent/open water wetlands (PEM/POW) in Portland, Oregon, USA. Wetlands identified on NWI maps and that had not been converted to other land uses at the time of the 1992 survey were surveyed in 1998. Data were collected on 164 of the 171 wetlands in the target population. Despite development pressure throughout the 1990s, loss of small PEM/POW wetlands slowed between 1992 and 1998, with only 6% of the sites being destroyed as compared to 40% between 1982 and 1992. Of 11 sites that were not identifiable due to drought in 1992, eight had recovered with the return of typical rainfall; three had been destroyed. Most of the wetlands existing in 1998 were in hydrogeomorphic (HGM) classes atypical to the region due to human manipulation. Hydrologic modifications were observed on 60% of the sites, but on-site disturbances like mowing, dumping, and trail building had decreased since the 1992 survey. Over the time period studied, land uses adjacent to the study sites shifted from undeveloped and agricultural to urban and residential use. Reflecting the common occurrence of on- and off-site stressors and modifications, we rated the condition of only 11 % of the

sites as good, with 46% fair and 43 % poor. Our results demonstrate the utility of combining field surveys with GIS analyses to track the status of wetland resources over time. The next challenge is to use such data to develop strategies to manage urban wetlands in ways that maintain and ultimately improve the condition of the resource.

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989. Wetland determination of a southeast Oregon vernal pool and management implications.

Clausnitzer, D. and Huddleston, J. H.

Wetlands 22(4): 677-685. (2002)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ steppes/ classification/ on-site investigations/ hydrology/ soil properties/ vegetation/ water holes/ livestock/ ecological effects/ ecosystem management/ soil/ sediment properties/ temporary ponds/ classification systems/ biota/ plant populations/ nature conservation

Abstract: Numerous landscape depressions on the High Lava Plain of southeast Oregon, USA are ponded in most years, but their wetland status has not been examined closely. We applied the standard wetland criteria (hydrology, soils, and vegetation) to one such pool to evaluate whether the pool meets federal criteria as a jurisdictional wetland. Wetland hydrology was determined to be present based on data from piezometer and ponding observations. Soils were determined to be hydric based on hydrology, soil temperature, and redox potentials. Vegetation met wetland criteria according to the 50/20 rule. Vegetation was similar to that of California Northern Basalt Flow vernal pools. Oregon pools are locally called 'upland playas,' but they fit the definition of vernal pools. Many southeast Oregon vernal pools are dug out as waterholes for livestock, increasing ponding depth and duration. Increased water availability can alter biological communities within pools and on surrounding semi-arid uplands. Effects due to grazing and excrement inputs have not yet been investigated. Vernal pools constitute distinct habitat sites within semi-arid landscapes and, therefore, probably play an important, and so far poorly understood, ecological role on the southeast Oregon steppe.

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Effects of Agricultural Conservation Practices on Wetlands

990. Controls on selenium distribution in wetland sediment, Benton Lake, Montana.

Zhang, Yiqiang and Moore, J. N.

Water, Air, and Soil Pollution 97(3-4): 323-340. (1997)

NAL Call #: TD172 .W36; ISSN: 0049-6979

Descriptors: wetlands/ selenium/ sediment pollution/ water management/ carbon/ agricultural runoff/ distribution/ pumping plants/ water supply/ drainage/ land management/ pollution monitoring/ USA, Montana, Benton L.

Abstract: The distribution of selenium in sediment in Benton Lake is mainly controlled by the location of the dissolved selenium inputs. Selenium concentrations in sediment decrease along flow paths downgradient within the wetland system. Construction in 1961 of a pump station to increase water supply and dikes to facilitate water management, along with current water management, has

increased the rate of selenium accumulation in sediments as compared to the pre-1961 natural lake. Agricultural practices (alternate crop/fallow rotation) in the non-irrigated farm land of the seleniferous Benton Lake basin also have increased selenium loading to Benton Lake. Carbon content is an important factor affecting selenium distribution in sediment but this relationship is greatly affected by dissolved selenium inputs. Amelioration of selenium contamination in Benton Lake will require a combination of land and water management modifications. Within the wetland system, minimizing the duration of inlet-perennial ponds would minimize selenium accumulation and increase the life of the refuge.

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991. Effects of RodeoReg. and GarlonReg. 3A on nontarget wetland species in central Washington.

Gardner, S. C. and Grue, C. E.

Environmental Toxicology and Chemistry 15(4): 441-451. (1996)

NAL Call #: QH545.A1E58; ISSN: 0730-7268

Descriptors: wetlands/ herbicides/ toxicity/ effects/ weeds/ weed control/ aquatic organisms/ aquatic weeds/ control/ chemical control/ glyphosate/ triclopyr/ nontarget effects/ aquatic invertebrates/ *Lythrum salicaria*/ *Daphnia*/ rainbow trout/ *Lemna*

Abstract: Purple loosestrife, *Lythrum salicaria*, is an invasive wetland perennial that became established in northeastern North America in the early 1800s. Despite its designation as a noxious weed, its distribution has continued to expand. Treatment with herbicides is the most widely used means of controlling purple loosestrife. This study examined the nontarget effects of two herbicides, Rodeo [glyphosate] and Garlon 3A [triclopyr amine], currently used or being considered for use in controlling purple loosestrife in Washington State, resp. Growth and/or survival of duckweed [*Lemna* spp.], *Daphnia*, and rainbow trout were monitored for at least 24 h following an application of each herbicide. Free-living water column and benthic invertebrates were monitored 24 h and 7 d post-spray using activity traps and sediment cores. Neither chemical was associated with significant decreases in survival or growth of the bioassay organisms, with the exception that growth of duckweed was reduced 48 h after exposure to Rodeo. Nor were significant decreases in the abundance of free-living aquatic invertebrates detected following the herbicide applications. Results suggest that neither herbicide, at the application rates used, poses a hazard to aquatic invertebrates in wetlands in central Washington. However, Rodeo, because it is a broad-spectrum herbicide, may pose a greater hazard to nontarget aquatic vegetation.

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992. Home ranges, movements, and habitat selection of Oregon spotted frogs (*Rana pretiosa*).

Watson, James W.; McAllister, Kelly R.; and Pierce, D. John

Journal of Herpetology 37(2): 292-300. (June 2003)

NAL Call #: QL640.J6; ISSN: 0022-1511

Descriptors: *Rana pretiosa* (Ranidae)/ home range/ home range use/ distribution within habitat/ movement patterns/ habitat selection and home range use relationships/ habitat utilization/ range use/ habitat preference/ semiaquatic habitat/ wetland upland pasture mosaic/ grassland/ Washington/ Thurston County/ Dempsey Creek/ habitat selection/ home range use and movement patterns/ upland pasture wetland mosaic

Abstract: From 1997-1999 we studied one of four known populations of Oregon Spotted Frogs (*Rana pretiosa*) in Washington State to investigate patterns of range use, movements, and habitat selection. Sixty telemetered frogs occupied a range that was a mosaic of wetlands (15.6 ha) and upland pasture (13.2 ha) grazed by dairy cows. Mean (. [plus or minus] SE) home-range size for four frogs was 2.2 [plus or minus] 1.0 ha. Patterns of spatial use, determined from 654 telemetry locations, were closely related to season and changing surface water conditions. During the breeding season (February to May), frogs occupied >=50% of the area they used the entire year, and oviposited in

shallow pools (depth = 16.9 [plus or minus] 0.6 cm) on the margins of an ephemeral creek. In the dry season (June to August), frogs moved down stream to deeper, permanent pools (depth = 23.6 [plus or minus] 1.0 cm), significantly reduced their movements, and occupied the smallest ranges of any season. During the wet season (September to January), frogs moved back up stream and reoccupied the breeding range. During the coldest weather, frogs buried themselves at the base of dense vegetation in shallow water under ice (depth = 17.4 [plus or minus] 0.8 cm). Frogs avoided dry uplands. Frogs selected sedge (*Carex obnupta*, and *Carex utriculata*)/rush (*Juncus effusus*) habitat during breeding and hardhack (*Spiraea douglasii*) cover during the dry season that shaded and maintained remnant pools. Frogs preferred microhabitats with 50-75% water surface exposure based on comparisons between telemetry locations and nearby locations that were randomly selected. Aquatic requirements necessary to complete the life cycle of Oregon Spotted Frogs in this population include (1) stable, shallow water areas for egg and tadpole survival in the breeding season, (2) deep, moderately vegetated pools for adult and juvenile survival in the dry season, and (3) shallow water levels over emergent vegetation for protecting all age classes during cold weather in the wet season.

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993. The importance of flood irrigation in water supply to wetlands in the Laramie Basin, Wyoming, USA.

Peck, D. E. and Lovvorn, J. R.

Wetlands 21(3): 370-378. (Sept. 2001)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ flood irrigation/ irrigation effects/ irrigation efficiency/ environmental effects/ hydrology/ percolation/ ecosystems/ salinity/ conductivity/ irrigation water/ agriculture/ water supply/ nature conservation/ canals/ water policy/ water management/ irrigation/ flooding/ water supplies/ USA, Wyoming, Laramie Basin/ groundwater management/ mechanical and natural changes/ freshwater pollution

Abstract: As in many areas of western North America, flood irrigation for hay production has created many wetlands in the Laramie Basin, Wyoming. Since the early 1900s, water from mountain snowmelt has reached wetlands via ditches and as interflow and ground water percolating from flooded fields and unlined ditches. Such systems are viewed as inefficient for irrigation and other human uses because they reduce the volume and increase the salinity of downstream flows. Increasing irrigation efficiency by lining ditches or installing sprinklers would decrease wetland habitat, but such effects are seldom considered. To assess potential impacts of increased irrigation efficiency, we determined how flood irrigation affects the hydrology and types of wetlands in the Laramie Basin. For 74 wetlands with 80 total inflows, just 14% of inflows were as surface flow from natural stream channels. In contrast, 65% of inflows were directly from irrigation: 30% as surface flow from ditches and 35% as interflow percolating from ditches and irrigated fields. Fifteen percent of inflows were as surface flow from other wetlands, and 6% of inflows were from ground water with unknown recharge source (probably either natural streams or irrigation). In this year of high water availability (1999), wetlands receiving surface water generally were fresh or

oligosaline regardless of whether that flow was from natural streams, other wetlands, or ditches (mean plus or minus 1 SD = 3.28 plus or minus 5.07 mS/cm, median = 1.60, range 0.07-22.10). In contrast, wetlands receiving water as interflow percolating from ditches or irrigated fields, or as ground water with unknown recharge source, were more likely to have conductivities of mesosaline or higher (mean plus or minus 1 SD = 22.45 plus or minus 32.71 mS/cm, median = 9.08, range 0.60-112.00). Conductivity of surface water in the 74 wetlands (mS/cm) ranged from fresh (0.07) to hypersaline (112.00), with a mean of 10.89 plus or minus 22.80 (SD) and median of 2.60; this range of salinity corresponds to substantial variation in wetland community structure. In the Laramie Basin and similar areas, flood irrigation is critical to the existence, hydrology, and community types of most wetlands, and these effects should be considered in plans to increase irrigation efficiency.

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994. Nitrogen and phosphorus loading from drained wetlands adjacent to Upper Klamath and Agency Lakes, Oregon.

Snyder, Daniel T. and Morace, Jennifer L.
Portland, Ore.: U.S. Dept. of the Interior, U.S. Geological Survey 67 p. Water-resources investigations report.
NAL Call #: GB701.W375 no.97-4059
http://or.water.usgs.gov/pubs_dir/Pdf/97-4059.pdf
Descriptors: nutrient pollution of water---Oregon/ lakes---fertilization---Oregon/ eutrophication---Oregon/ water quality biological assessment---Oregon
This citation is from AGRICOLA.

Wetlands as Agricultural Conservation Practices

995. Constructed wetland systems in the arid and semi-arid west to treat irrigation wastewater.

Hoag, J. C.
In: Wetlands and Remediation: An International Conference. (Held 16 Nov 1999-17 Nov 1999 at Salt Lake City, UT .) Means, J. L. and Hinchee, R. E. (eds.); pp. 295-300; 1999.

Descriptors: wetlands/ irrigation water/ waste utilization/ pollution control/ water pollution treatment/ agricultural pollution/ water pollution control/ agriculture/ irrigation/ precipitation/ irrigation/ precipitation (atmospheric)/ wastewater treatment/ phosphorus removal/ nitrogen removal/ construction/ arid environments/ environmental engineering/ constructed wetlands/ USA, Idaho, Magic Valley/ protective measures and control/ wastewater treatment processes/ water treatment/ sewage & wastewater treatment

Abstract: Three Constructed Wetland Systems for water quality improvement of irrigation wastewater were built in the Magic Valley of Idaho in 1994, 1995, and 1996. The Nature Conservancy CWS is the oldest CWS. Preliminary data indicates that in it has a removal efficiency of 88% of Total Suspended Solids, 72.5% Total Phosphorous, 73.4% Ortho-phosphorous, and 65% nitrogen. Preliminary data indicates that the Cedar Draw CWS has a removal efficiency of 65.2% TSS, 43.2% TP, 16% OP, and 16% N (very limited sampling data). CSI CWS is the youngest wetland and little sampling has been completed on it. The plant communities have filled in significantly since planting with a few problems associated with water control.

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996. Created and restored marshes in the Lower Fraser River, British Columbia: Summary of their functioning as fish habitat.

Levings, C. D. and Nishimura, D. J. H.
Water Quality Research Journal of Canada 32(3): 599-618. (1997); ISSN: 1201-3080

Descriptors: Canada, British Columbia, Fraser R./ marshes/ aquatic habitats/ estuaries/ invertebrates/ smolt/ salmon/ aquatic plants/ artificial wetlands/ rehabilitation/

comparison studies/ environmental restoration/ Oncorhynchus

Abstract: Ecological comparisons of transplanted, natural (reference) and disrupted (unvegetated) marsh sites on the Fraser River estuary, British Columbia, were conducted between 1991 and 1994. The study examined vegetative biomass and cover, invertebrate abundance, fish abundance, fish residency, fish food, and submergence time for the three habitats. Standing crop biomass at three transplant sites was within the range of values for reference sites, but was much lower at an unstable site where sediment slumping had occurred. The percent cover of Lyngbyei's sedge (*Carex lyngbyei*) in eight transplant sites was <50% of that observed in adjacent reference sites when data were averaged over the study area; rushes (*Juncus* spp.) were more abundant in transplant sites. In all study reaches, abundance of invertebrates at transplant and reference sites was significantly higher than at disrupted sites. In several instances, invertebrate abundance at transplant sites was greater than at reference sites. No significant difference ($p > 0.05$) was observed among marsh sites when chum salmon (*Oncorhynchus keta*) and chinook salmon (*O. tshawytscha*) fry abundance were compared. However, chinook and sockeye smolt catches were significantly different ($p < 0.05$) among marsh sites and were usually higher at disrupted sites. In nine sites in the North Arm and Deas Slough area chum fry residency was examined. At one transplant site (DE1) marked chum fry were caught up to 48 h after release. No fry were caught 1 h after release at a transplant site (D11) and a disrupted site (DE4). At the remaining sites, fry were caught up to 1 and 3 h after release. At all sites, over 80% of the total number of food organisms examined in chum fry stomachs were harpacticoid copepods. Mean submergence time for reference marshes ranged from 33.2 to 50.7%, but for transplanted sites the value ranged from 26.4 to 60.1%. Our study shows that numerous factors need to be examined in determining if restored marshes will function as natural habitats. The development of a standardized set of reference criteria would assist in evaluating whether or not transplanted marshes are functioning as designed.

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997. Duwamish River Coastal America restoration and reference sites: Results from 1997 monitoring studies.

Cordell, J. R.; Tear, L. M.; Jensen, K.; and Higgins, H. A. Seattle, WA: Fisheries Research Institute; FRI-UW-9903, 1999.

Notes: Other numbers: Technical report. School of Aquatic and Fishery Science, Fisheries Research Institute, Washington University [Rep. Fish. Res. Inst. Wash. Univ.]. No. 9903

Descriptors: wetlands/ habitat improvement/ water resources/ riprap/ restoration/ brackishwater environment/ man-induced effects/ tidal currents/ riparian vegetation/ fishery sciences/ environmental protection/ coastal zone/ fishery management/ coastal inlets/ anthropogenic factors/ *Oncorhynchus*/ *Carex lyngbyei*/ *Scirpus maritima*/ USA, Washington, Seattle, Duwamish Waterway/ habitat community studies

Abstract: In this report, we present the results of 1997 biological monitoring at three wetland restoration sites in the Duwamish River estuary, Seattle, Washington. Restoration at these sites was originally facilitated by the federal Coastal America program and was carried out by a partnership of the City of Seattle, U.S. Fish & Wildlife Service, the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency. Two of these sites are in the middle portion of the Duwamish Waterway, in a region dominated by tidal influence and mixed fresh- and marine water. The first of these sites consists of the General Service Administration (GSA) site located adjacent to the Federal Center South, which is a long, narrow intertidal strip running parallel to the east bank of the Duwamish Waterway adjacent to the Seattle District Corps of Engineers. Restoration at this site included removal of rock riprap and a large overwater wharf structure to allow natural colonization by existing wetland plants, construction of a sediment "bench" at 0.0-m elevation to promote use by juvenile salmon (*Oncorhynchus* spp.), and planting of upland riparian vegetation. The second site is at Terminal 105 (T-105); this site originally consisted of a vacated street end and a large pipe that drained a small degraded wetland area. Restoration included removal of debris and replacement of the pipe with an estuarine channel that restored tidal flow to the area. The third Coastal America restoration site is at the upper Turning Basin at the head of the Duwamish Waterway. This site/comprises an upland riparian buffer planted with native vegetation and a small regraded upper intertidal basin planted with fringing native sedge, *Carex lyngbyei*, and rush, *Scirpus maritima*.

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of the effect of fire in wetland prairies, which are also threatened with encroachment of woody species. The present study investigated wetland species responses to experimental burning, hand-removal of woody species, and mowing with removal of cut material. The possible ecological mechanisms responsible for individualistic responses of species, including direct mortality, ability to resprout, and release from competition are considered. We also evaluated these treatments as tools for meeting restoration objectives of reducing the abundance of woody species, reducing or preventing spread of non-native pest species, and increasing or at least maintaining native species' abundance. After two years of treatments (1994 and 1996) three patterns emerged. 1) Woody species: Burning and hand-removal caused the greatest reductions in cover of woody species. Mowing with removal of cut material, however, did not reduce the cover of woody species compared to controls. As woody plant cover decreased, plant mortality increased, indicating that treatments influenced woody plant cover at least partially through mortality. 2) Native herbaceous species: Burning significantly decreased inflorescence production of *Deschampsia cespitosa*, the dominant wetland prairie grass. In contrast, burning, along with mowing, significantly increased flowering of *Juncus tenuis*. Flowering and cover of all native graminoids combined, however, showed no significant responses to treatments. Burning and hand-removal significantly promoted the cover of native forbs as a group, with *Lotus purshiana* and *Veronica scutellata* showing the greatest increases. 3) Non-native herbaceous species: Burning and hand-removal significantly reduced the cover of non-native forbs as a group and particularly reduced the cover of *Hypericum perforatum*. The number of inflorescences of non-native grasses (*Holcus lanatus* and *Anthoxanthum odoratum*) increased with hand-removal and mowing. Overall, no treatment was clearly superior in fulfilling the restoration objectives. Burning was effective in reducing woody cover and did not promote abundance of non-native herbaceous species. Burning, however, reduced the flowering of the key native grass, *Deschampsia cespitosa*. Hand-removal of woody species was also effective at reducing woody cover and promoted the abundance of some native species, but it sometimes increased the cover of non-native herbaceous species. Because mowing with removal of cut material was ineffective in reducing woody cover and tended to promote non-native herbaceous species, this treatment is not recommended as a management tool.

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998. Fire, mowing, and hand-removal of woody species in restoring a native wetland prairie in the Willamette Valley of Oregon.

Clark, D. L. and Wilson, M. V.

Wetlands 21(1): 135-144. (2001)

NAL Call #: QH75.A1W47; ISSN: 0277-5212

Descriptors: wetlands/ prairies/ fires/ mowing/ mortality/ indigenous species/ environmental restoration/ flowering/ plant communities/ freshwater environments/ land use/ land management/ environmental quality/ ecosystem management/ ecosystem disturbance/ introduced species/ vegetation cover/ fire

Abstract: The invasion of prairies by woody species is a worldwide conservation concern. Fire is frequently used to inhibit this invasion. However, there is little documentation

999. Hydrologic design considerations of constructed wetlands for urban stormwater runoff.

Koob, T.; Barber, M. E.; and Hathhorn, W. E.

Journal of the American Water Resources Association

35(2): 323-332. (Apr. 1999)

NAL Call #: GB651.W315; ISSN: 1093-474X

Descriptors: artificial wetlands/ hydrology/ urban runoff/ vegetation/ water stress/ drought/ tolerance/ design criteria/ storm runoff/ land reclamation/ stormwater runoff/ water budget/ droughts/ environmental engineering/ agricultural runoff/ runoff (urban)/ design data/ runoff/ USA, Washington, Spokane/ control of water on the surface/ protective measures and control/ environmental action/ water & wastewater treatment/ underground services and water use/ wastewater treatment processes

Abstract: The successful design of constructed wetlands requires a continuous supply of water or vegetation that can withstand drought conditions. Having a constant water source is the best alternative to insure species diversity throughout the season. Consequently, detention structure designs should be based on times between events as well as on hydrologic return periods, since between events is when most evaporation and infiltration losses are likely to occur. In arid or semi-arid environments, this is a difficult process because of long interevent times and seasonal changes in precipitation patterns. This discussion is predicated on the assumption that phytoplankton, epiphytic algae, and emergent vegetation require moist conditions to be effective at removing nutrients, metals and other pollutants. There are drought tolerant species of vegetation that can be used in constructed wetlands but it may take several days to re-establish the attached bacteria communities necessary for optimum pollutant removal. This paper examines a stochastic framework to examine the probability of extended dry periods based on historic rainfall data. The number of consecutive dry days is selected for a specified level of assurance. By multiplying this value by the sum of daily system losses, an overall pond volume can be determined that ensures a minimum depth of water. To illustrate the utility of the approach, the method is applied to a site in Spokane, Washington.

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1000. Hydrologic regime controls soil phosphorus fluxes in restoration and undisturbed wetlands.

Aldous, Allison; McCormick, Paul; Ferguson, Chad; Graham, Sean; and Craft, Chris

Restoration Ecology 13(2): 341-347. (June 2005)

NAL Call #: QH541.15.R45R515; ISSN: 1061-2971

Descriptors: wetlands/ soil/ flooding/ mineralization/ phosphorus/ environmental restoration/ lakes/ habitat improvement/ fertilizers/ hydrology/ ecosystem disturbance/ agriculture/ USA, Oregon, Upper Klamath L./ reclamation/ habitat community studies/ mechanical and natural changes

Abstract: Many wetland restoration projects occur on former agricultural soils that have a history of disturbance and fertilization, making them prone to phosphorus (P) release upon flooding. To study the relationship between P release and hydrologic regime, we collected soil cores from three restoration wetlands and three undisturbed wetlands around Upper Klamath Lake in southern Oregon, U.S.A. Soil cores were subjected to one of three hydrologic regimes-flooded, moist, and dry-for 7.5 weeks, and P fluxes were measured upon reflooding. Soils from restoration wetlands released P upon reflooding regardless of the hydrologic regime, with the greatest releases coming from soils that had been flooded or dried. Undisturbed wetland soils released P only after drying. Patterns in P release can be explained by a combination of physical and biological processes, including the release of iron-bound P due to anoxia in the flooded treatment and the mineralization of organic P under aerobic conditions in the dry treatment. Higher rates of soil P release from restoration wetland soils, particularly under flooded conditions, were associated with higher total P concentrations compared with undisturbed wetland soils. We conclude that maintaining moist soil is the means to minimize P release from recently flooded

wetland soils. Alternatively, prolonged flooding provides a means of liberating excess labile P from former agricultural soils while minimizing continued organic P mineralization and soil subsidence.

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1001. Integrated pest management to control reed canarygrass in seasonal wetlands of southwestern Washington.

Kilbride, K. M. and Paveglio, F. L.

Wildlife Society Bulletin 27(2): 292-297. (1999)

NAL Call #: SK357.A1W5; ISSN: 0091-7648

Descriptors: wetlands/ weed control/ control methods/ herbicides/ integrated control/ mowing/ spraying/ sprays/ disking/ weeds/ cultural control/ Phalaris/ Phalaris arundinacea

Abstract: Reed canarygrass (*Phalaris arundinacea*) is an exotic, invasive species that threatens to degrade wetlands throughout North America. Although efficacies of control methods for canarygrass have been studied in the Midwest, little information is available regarding efficacies for treatments in the Pacific Northwest. Here, integrated pest management techniques for the control of canarygrass in seasonal wetlands of southwestern Washington were investigated. Techniques used included mechanical (disking or mowing) and chemical (RodeoReg.) treatments, and combinations of disking and Rodeo together with water-level control for 3 growing seasons. Stem densities of canarygrass were reduced most by spraying and disking with a follow-up application of Rodeo during the next growing season. Disking with a follow-up application of Rodeo during the next growing season generally had similar canarygrass control as the most efficacious treatment. Canarygrass that germinated and grew from viable rhizomes following drawdown after the initial Rodeo application or disking made a follow-up treatment with herbicide imperative for effective control. To prevent canarygrass re-infestation, treatments should not be initiated until the ability to manage consistent water levels throughout the winter and early spring exists for a wetland.

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1002. Nutrients in salmon hatchery wastewater and its removal through the use of a wetland constructed to treat off-line settling pond effluent.

Michael, J. H.

Aquaculture 226(1-4): 213-225. (Oct. 2003)

NAL Call #: SH1 .A6; ISSN: 0044-8486

Descriptors: aquaculture effluents/ biodegradation/ water pollution treatment/ water quality control/ wastewater treatment/ phosphorus/ hatcheries/ solid impurities/ fish culture/ nutrients/ habitat/ fisheries/ settling basins/ artificial wetlands/ salmonidae/ USA, Washington/ salmonids/ effects of aquaculture on the environment/ effects of aquaculture on the environment/ sewage & wastewater treatment/ water & wastewater treatment

Abstract: The presence of nutrients in the wastewater of salmonid hatcheries is of growing concern to water quality managers. Presently, Washington State regulations require quiescent settling to remove settleable and suspended solids from the water but do not as yet address nutrient concerns. In order to evaluate the load of nutrients discharged by salmon hatcheries, the Washington Department of Fish and Wildlife (WDFW) initiated two studies. Water from the Issaquah Hatchery, located in a

watershed with identified excessive levels of anthropogenic phosphorus in the aquatic system, was monitored for total phosphorus for more than a year at the points of diversion from the creek, at the points of water return to the creek, and at the point of discharge from the off-line settling pond. Monitoring showed that the hatchery's contribution to watershed phosphorus levels was low and that the primary phosphorous input from the hatchery appeared to be the process water as opposed to water from the off-line settling system. In order to evaluate the efficacy of a constructed wetland in the removal of nutrients from a conventional offline settling system, WDFW installed a constructed wetland at the Dungeness Hatchery. Over the course of 4 years of monitoring, the wetland removed most of the solids, phosphorus, and nitrogenous compounds, which resulted in a reduction in biological oxygen demand (BOD) of the influent water. At times, the offline settling system actually increased the level of some of the nutrients, suggesting that treatment of hatchery effluent will need to include a combination of quiescent settling, constructed wetland, and some sort of process water treatment if anthropogenic solids and nutrients are to be more completely removed. The constructed wetland also provided habitat used by amphibians and birds for breeding and foraging. At facilities in locations with sufficient land base available to develop a constructed wetland, it should be possible to reduce the nutrient input to receiving waters and provide additional habitat for aquatic animals.
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1003. Prescribed fire and the response of woody species in Willamette Valley wetland prairies.

Pendergrass, K. L.; Miller, P. M.; and Kauffman, J. B. *Restoration Ecology* 6(3): 303-311. (1998)
NAL Call #: QH541.15.R45R515; ISSN: 1061-2971
Descriptors: fire management/ fire suppression/ fuel biomass/ fuel properties/ height growth/ prescribed burning/ wetland prairies/ woody species density
Abstract: A single fall-season prescribed burn and two consecutive fall-season prescribed burns were conducted in 1988 and 1989 to quantify the effects of fire intensity and frequency on woody species in two Willamette Valley wet prairies. Fuel biomass, fuel properties, fire behavior, biomass consumption, and changes in woody species density and height were documented before and after the burns. Before burning, *Rosa nutkana* (Nootka rose) was the most abundant woody species at both sites. In 1988, burns were significantly more intense, produced more heat per unit area at Fisher Butte than at Rose Prairie, and were fairly complete, with 37% and 35% woody biomass consumption, respectively. In 1989, burns were spotty; only 11% of woody biomass was consumed at Fisher Butte. The one-burn treatment did not affect *R. nutkana* density in 1 approx 15 m transects at either site; the two-burn treatment significantly increased its density in three of the five communities sampled. Burning significantly reduced height growth by eliminating taller individuals while stimulating sprouts from belowground tissues. Redistribution of *R. nutkana* and trees into shorter height classes indicates the possibility of reducing the visual dominance of woody species if periodic burns were conducted in native Willamette Valley prairie. The low-intensity burns in this study were sufficient to remove the woody shoots under 3 m tall but did not reduce their capacity to regenerate and did not reduce the density of woody species. After decades

of fire suppression, two burns were not sufficient to reestablish the desired balance between native herbaceous and woody species or to reduce the presence of introduced woody species. A long-term commitment to the reintroduction of fire as a management tool will be required to maintain native wetland prairies in the Willamette Valley.
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1004. Reduction potential of selenate in wetland sediment.

Zhang, Y. Q. and Moore, J. N. *Journal of Environmental Quality* 26(3): 910-916. (1997)
NAL Call #: QH540.J6; ISSN: 0047-2425
Abstract: Laboratory and field experiments were conducted to examine the reduction potential of dissolved selenate in wetland sediment at Benton Lake, Montana. Results showed that selenate reduction in wetland sediment was a microbially mediated process. This process proceeded rapidly and removed more than 50% of added selenate from solution to the sediment during the first day of the experiment. The reduction potential of selenate in sediment was positively correlated to Se concentrations in sediment, but not to sediment organic C content. This process occurred at the sediment surface because the depth of diffusion of selenate was limited, resulting in most Se accumulating in the top 2 cm of the sediment. The results from this study indicate that selenate reduction in sediment dominates selenate removal from water.
This citation is from AGRICOLA.

1005. Response of a terrestrial mollusc community to an autumn prescribed burn in a rare wetland prairie of western Oregon, USA.

Severns, Paul M. *Journal of Molluscan Studies* 71(Part 2): 181-187. (2005)
NAL Call #: QL401; ISSN: 0260-1230
Descriptors: prescribed burning: applied and field techniques/ grasslands/ wetland prairie
Abstract: Conservation and management of grasslands may involve the use of prescribed fire to reinstate a historical disturbance regime recently suppressed by humans. I used traps to describe the terrestrial mollusc community in a rare wetland prairie ecosystem of western Oregon, USA over a 3-year period in an adjacent burned and unburned wetland prairie parcel beginning 1 year following an autumn prescribed fire. Species richness was lower throughout the burned area for the duration of the study period and mollusc abundance was lower in the first postburn year, but steadily increased over time, surpassing the adjacent burned area by the third postburn year. According to Multi-response Permutation Procedure, the mollusc community in the adjacent burned area differed significantly from the unburned prairie each year since the burn, suggesting that fire history may structure the wetland prairie mollusc community. Indicator species analysis identified that *Deroceras reticulatum* and *Monadenia fidelis* were indicator species for unburned wetland prairie, while *Catinella rhederi* and *Vertigo modesta* were indicator species for burned habitat at the study site. Since fire appears to decrease wetland prairie mollusc diversity and abundance, prescribed burns should be conducted in accordance with refuges, to provide a source population for colonizing molluscs and for other animals with unknown responses to fire.
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1006. Subsurface flow wetland treatment of dairy farm stormwater.

Bruce, I. D. and Puget Sound Action Team, Olympia WA USA.

In: 2003 Georgia Basin/Puget Sound Research Conference Proceedings. (Held 3 Mar 1931-3 Apr 2003 at Vancouver, BC (Canada).) Droscher, T. W. and Fraser, D. A. (eds.); 2004.

Descriptors: wetlands/ water quality/ nutrients (mineral)/ tributaries/ ponds/ suspended particulate matter/ habitat improvement/ airports/ water pollution/ agricultural pollution/ farms/ artificial wetlands/ coliforms/ nutrients/ streams/ fisheries/ sampling/ interception/ storm seepage/ suspended solids/ monitoring/ agriculture/ dairy wastes/ storm wastewater/ Canada, British Columbia, Vancouver I., Victoria/ Canada, British Columbia, North Saanich/ habitat community studies/ prevention and control/ industrial effluents/ water & wastewater treatment

Abstract: Non-point source pollution from agriculture can cause chronic water quality impacts in small streams and downstream marine waters. In North Saanich, B.C., water quality sampling of a tributary of TENTEN Creek in February 2000 indicated excessive levels of nutrients, suspended solids and faecal coliforms present in stormwater originating from an adjacent dairy farm. The tributary from the farm crosses into lands managed by the Victoria Airport Authority (VAA). The WSIKEM-TENTEN Stewardship Project, working in partnership with VAA, Pendray Farms, Tseycum First Nation and Fisheries & Oceans Canada, developed a stormwater interception and treatment complex beginning in August 2000. A 2.1 million-litre stormwater detention pond was constructed with two piped outlets, one that fed a 150 metre long, 3-metre wide sub-surface flow constructed wetland. Monitoring of treatment efficacy in the winter of 2000-01 indicated that up to 99% of source faecal coliforms were removed, while nutrient and TSS reductions ranged from 25-95%. Subsequently a second wetland was constructed in 2001 to treat additional stormwater, and we estimate that during the first three years of operation, over 300 million litres of stormwater were treated. This paper discusses how the project was developed, its successes and limitations, and the role of stewardship partnerships in habitat and water quality restoration. Data describing wetland efficacy in treating agricultural stormwater is presented in tabular and chart formats, along with discussion of several of the water quality parameters that were investigated.

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1007. Use of radar remote sensing (RADARSAT) to map winter wetland habitat for shorebirds in an agricultural landscape.

Taft, O. W.; Haig, S. M.; and Kiilsgaard, C.

Environmental Management 33(5): 750-763. (2004)

NAL Call #: HC79.E5E5; ISSN: 0364-152X

Descriptors: wetlands/ radar/ remote sensing/ habitat/ agriculture/ wildlife/ mapping/ aquatic birds/ agricultural ecosystems/ radarsat/ shorebirds/ plovers/ sandpipers

Abstract: Many of today's agricultural landscapes once held vast amounts of wetland habitat for waterbirds and other wildlife. Successful restoration of these landscapes relies on access to accurate maps of the wetlands that remain. We used C-band (5.6-cm-wavelength), HH-polarized radar remote sensing (RADARSAT) at a 38 degree incidence angle (8-m resolution) to map the

distribution of winter shorebird (Charadriiformes) habitat on agricultural lands in the Willamette Valley of western Oregon. We acquired imagery on three dates (10 December 1999, 27 January 2000, and 15 March 2000) and simultaneously collected ground reference data to classify radar signatures and evaluate map accuracy of four habitat classes: (1) wet with less than or equal to 50% vegetation (considered optimal shorebird habitat), (2) wet with > 50% vegetation, (3) dry with less than or equal to 50% vegetation, and (4) dry with > 50% vegetation. Overall accuracy varied from 45 to 60% among the three images, but the accuracy of focal class 1 was greater, ranging from 72 to 80%. Class 4 coverage was stable and dominated maps (40% of mapped study area) for all three dates, while coverage of class 3 decreased slightly throughout the study period. Among wet classes, class 1 was most abundant (about 30% coverage) in December and January, decreasing in March to approximately 15%. Conversely, class 2 increased dramatically from January to March, likely due to transition from class 1 as vegetation grew. This approach was successful in detecting optimal habitat for shorebirds on agricultural lands. For modest classification schemes, radar remote sensing is a valuable option for wetland mapping in areas where cloud cover is persistent.

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1008. The value of agricultural wetlands as invertebrate resources for wintering shorebirds.

Taft, O. W. and Haig, S. M.

Agriculture, Ecosystems & Environment 110(3-4): 249-256. (2005)

NAL Call #: S601 .A34; ISSN: 0167-8809

Abstract: Agricultural landscapes have received little recognition for the food resources they provide to wintering waterbirds. In the Willamette Valley of Oregon, modest yet significant populations of wintering shorebirds (Charadriiformes) regularly use hundreds of dispersed wetlands on agricultural lands. Benthic invertebrates are a critical resource for the survival of overwintering shorebirds, yet the abundance of invertebrate resources in agricultural wetlands such as these has not been quantified. To evaluate the importance of agricultural wetlands to a population of wintering shorebirds, the density, biomass, and general community composition of invertebrates available to birds were quantified at a sample of Willamette Valley sites during a wet (1999-2000) and a dry winter (2000-2001). Invertebrate densities ranged among wetlands from 173 to 1925 (mean +/- S.E.: 936 +/- 106) individuals/m² in the wet winter, and from 214 to 3484 (1028 +/- 155) individuals/m² in the dry winter. Total invertebrate estimated biomass among wetlands ranged from 35 to 652 (mean +/- S.E.: 364 +/- 35) mg/m² in the wet winter, and from 85 to 1405 (437 +/- 62) mg/m² in the dry winter. These estimates for food abundance were comparable to that observed in some other important freshwater wintering regions in North America. This citation is from AGRICOLA.

1009. Variability of treatment performance in constructed wetlands.

Kuehn, E. and Moore, J. A.

Water Science and Technology 32(3): 241-250. (1995)

NAL Call #: TD420.A1P7; ISSN: 0273-1223

Descriptors: wetlands/ wastewater treatment/ pollutants/ biochemical oxygen demand/ aquatic plants/ *Schoenoplectus acutus*/ *Typha latifolia*/ pulp and paper mill effluents/ constructed wetlands

This citation is from AGRICOLA.

1010. Why pest plant control and native plant establishment failed: A restoration autopsy.

Wilson, M. V.; Ingersoll, C. A.; Wilson, M. G.; and Clark, D. L.

Natural Areas Journal 24(1): 23-31. (Feb. 2004)

NAL Call #: QH76.N37; ISSN: 0885-8608

Descriptors: environmental restoration/ pest control/ prairies/ community composition/ seeds/ restoration/ introduced species/ vegetation cover/ plant populations/ plant control/ population density/ mortality/ competition/ ecosystem management/ ecosystem disturbance/ seedlings/ indigenous species/ fallowing/ burning/ maintenance/ USA, Oregon/ USA, Oregon, Willamette Valley/ native species/ wetland prairies/ reclamation/ conservation, wildlife management and recreation/ biodiversity

Abstract: Explaining restoration failure can be as important as touting success. We used a series of studies to understand the failure of techniques commonly used to restore wetland prairies in the Willamette Valley of western Oregon. Burning, fallowing, and solarization (covering tilled plots with plastic sheeting to heat the soil) had pronounced first-year effects on several individual species, but either did not reduce overall pest plant abundance or reduced the abundance of native species as well. The 34% overall plant cover in solarized plots was the only significant difference from the 60% cover present in control plots. All first-year responses essentially disappeared by the second year. These measures had little lasting effect on pest and other exotic plants because many survived treatment and resprouted. In addition, treatments had little effect on the number of seeds in the soil, leaving a pool of immediate and potential regeneration. Specific control measures of target plants, such as hand removal and repeat maintenance after initial treatments, should prove more successful. In a second study, three mixtures of native species sown into fallowing treatment plots had low emergence rates of 1%-7%, despite high seed viability, and produced only 0%-3% cover. Native species should be selected and sown at densities high enough to lead to significant numbers of surviving seedlings, especially in the face of competition from surviving pest plants.

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