1198. **Avian use of revegetated riparian zones.**
Anderson, Bertin W. and Ohmart, Robert D.
In: California Riparian Systems: Ecology, Conservation, and Productive Management/ Warner, Richard E. and Hendrix, Kathleen M.
Berkeley: University of California Press, 1984; pp. 626-631
NAL Call #: QH105.C2C36
Descriptors: birds/ communities/ ecosystems/ riparian habitat

1199. **Effects of stressors on invasive and halophytic plants of New England salt marshes: A framework for predicting response to tidal restoration.**
Konisky, R. A. and Burdick, D. M.
Wetlands 24(2): 434-447. (June 2004)
NAL Call #: QH75.A1W47; *ISSN:* 0277-5212
Descriptors: wetlands/ plant communities/ salt marshes/ environmental restoration/ flooding/ competition/ Halophytes/ hydrology/ interspecific relationships/ tidal models/ habitat improvement/ dispersion/ transplants/ environmental impact/ aquatic plants/ salinity effects/ marshes/ salinity tolerance/ plant growth/ biological production/ introduced species/ restoration/ plant populations/ stress/ Spartina/ salinity/ tolerance/ floods/ biomass/ habitats/ hydrological regime/ tides/ survival/ cattails/ field tests/ strength/ Juncus/ Phragmites australis/ Spartina patens/ Typha angustifolia/ Lythrum salicaria/ Spartina alterniflora/ Juncus gerardii/ USA, New England/ habitat community studies/ TSD distribution, water masses and circulation/ ecology/ community studies/ conservation, wildlife management and recreation/ estuaries
Abstract: Salt marsh restoration practices based on the reintroduction of tides to hydrologically-altered wetlands may be hindered by a lack of specific knowledge regarding plant community response to environmental change. Since saltmarsh plant communities are controlled by physical stress tolerance and competition, we conducted a field experiment that measured effects of saltwater flooding and competitive interactions on plants as a guide for predicting habitat response to tidal restoration. Six plant species of New England salt marshes were studied: halophytes Spartina alterniflora, Spartina patens, and Juncus gerardii and brackish invasive species Phragmites australis, Typha angustifolia, and Lythrum salicaria. Plant shoots were transplanted across a gradient of three flooding and three salinity regimes and arranged into pair-wise competitive combinations. After one growing season, saltwater flooding was found to decrease transplant survival, biomass production, and/or relative growth for all species. Reduction in halophyte growth was largely due to increased flood duration; brackish species were most reduced by increased salinity. Interspecific competition also influenced species growth, although the short duration of the study may have weakened these effects. Transplants paired with S. alterniflora had reduced growth, but combinations with Juncus produced increased growth. Standardized factors of stress tolerance and relative competitive strength were derived for the six study species as a framework for understanding community-level changes in marshes. As an aid to resource managers, experimental results can be used to predict plant community response to existing and potential alterations in saltmarsh tidal hydrology.

1200. **An evaluation of vernal pool creation projects in New England: Project documentation from 1991-2000.**
Lichko, L. E. and Calhoun, A. J.
Environmental Management 32(1): 141-151. (2003)
NAL Call #: HC79.E5E5; *ISSN:* 0364-152X
Descriptors: conservation/ freshwater ecology/ protected species/ vernal-pool-dependent species/ New England, USA/ vernal pool creation/ compensatory mitigation/ conjecture/ federal regulatory action/ key vernal pool functions/ long term landscape functions/ pool design specifications/ project monitoring: inconsistencies, reliability gaps/ record-keeping inadequacies/ reference wetlands/ standardization/ vernal pool creation projects/ vernal pools: forestry practice impacts, loss to development, size
Abstract: Vernal pools are vulnerable to loss through development and agricultural and forestry practices owing to their isolation from open water bodies and their small size. Some vernal pool-dependent species are already listed in New England as Endangered, Threatened, or Species of Special Concern. Vernal pool creation is becoming more common in compensatory mitigation as open water ponds, in general, may be easier to create than wooded wetlands. However, research on vernal pool creation is limited, A recent National Research Council study (2001) cites vernal pools as "challenging to recreate." We reviewed documentation on 15 vernal pool creation projects in New England that were required by federal regulatory action. Our purpose was to determine whether vernal pool creation for compensatory mitigation in New England replaced key vernal pool functions by assessing project goals and documentation (including mitigation plans, pool design criteria, monitoring protocols, and performance standards). Our results indicate that creation attempts often fail to replicate lost pool functions. Pool design specifications are often based on conjecture rather than on reference wetlands or created pools that function successfully. Project monitoring lacks consistency and reliability, and record keeping by regulatory agencies is inadequate. Strengthening of protection of isolated wetlands in general, and standardization across all aspects of vernal pool creation, is needed to ensure success and to promote conservation of the long-term landscape functions of vernal pools.

1201. **The hydrology of Alaskan wetlands, USA: A review.**
Ford, J. and Bedford, B. L.
Arctic and Alpine Research 19(3): 209-229. (1987)
NAL Call #: GB395.A73; *ISSN:* 0004-0851
Descriptors: wetlands/ hydrology/ water budget/ stream flow rate/ literature reviews/ extreme values/ USA, Alaska/ nearshore dynamics

Abstract: Alaska's wetland resources are vast and the literature dealing directly with any given aspect of Alaskan wetland hydrology is sparse. This review focuses on hydrological function and pays particular attention to (1) hydrologic inputs to and outputs from wetlands, and (2) the influence of wetlands on peak flow regulation. The influence of several characteristic high-latitude phenomena (permafrost, glaciers, and seasonal stream icings) on the overall water balance and the volume, areal distribution, rate, and timing of water release are discussed.

1202. **Importance of small wetlands for the persistence of local populations of wetland-associated animals.**
Gibbs, James P.
Wetlands 13(1): 25-31. (1993)
NAL Call #: QH75.A1W47; *ISSN:* 0277-5212
Descriptors: conservation/ isolation/ metapopulation/ population dynamics
Abstract: I simulated loss of small, legally unprotected freshwater wetlands in a 600 km-2 area of Maine, USA to examine how loss of small wetlands altered the geometry of the wetland mosaic and thereby might affect the dynamics of metapopulations of wetland-associated organisms. Loss of small wetlands resulted in total wetland area declining by 19% (from 2032 to 1655 ha), total wetland number declining by 62% (from 354 to 136 wetlands), and average inter-wetland distance increasing by 67% (from 0.6 to 1.0 km). Also, average upland-wetland proximity decreased by 50% (0.5 to 1.0 km), such that just 54% of the landscape was within the maximum migration distance (1000 m) of terrestrial-dwelling and aquatic-breeding amphibians after loss of small wetlands, versus 90% before loss. A spatially-structured demographic model revealed that local populations of turtles, small birds, and small mammals, stable under conditions of no wetland loss, faced a significant risk of extinction (P gt 5%) after loss of small wetlands. No change in metapopulation extinction risk was evident for salamanders or frogs, largely because high rates of population increase buffered these taxa against local extinction. These results suggest that small wetlands play a greater role in the metapopulation dynamics of certain tax or wetland animals than the most area comprised by small wetlands might imply.

1203. **Macroinvertebrate response to marsh management strategies in Utah.**
Huener, J. D. and Kadlec, J. A.
Wetlands 12(2): 72-78. (1992)
NAL Call #: QH75.A1W47; *ISSN:* 0277-5212
Descriptors: wildlife management/ marshes/ water levels/ macrofauna/ ecosystem management/ population density/ Invertebrata/ USA, Utah/ wildlife management/ macrofauna
Abstract: The authors examined the response of aquatic macroinvertebrates to three marsh management strategies. The three management practices compared were conventional full pool management, full pool management with carp (Cyprinus carpio) control, and contour furrowing (also with carp control). Significant differences in standing crops (both numbers and biomass) of invertebrates were observed among the three management strategies. The contour furrowed area had the highest standing crops of water column invertebrates, followed by the carp-controlled full pool area, while the conventionally managed area had the lowest standing crops. In the benthos, the two full pool areas (with and without carp) had higher standing crops than the contour furrowed area. Significant differences were noted in seasonal abundance, with all management practices having lowest densities of invertebrates in April and May. Implications for management include indications of the negative impacts of carp and winter drawdowns on invertebrates in managed marshes.

1204. **Relationship of breeding bird density and diversity to habitat variables in forested wetlands.**
Swift, B. L.; Larson, J. S.; and DeGraaf, R. M.
Wilson Bulletin 96(1): 48-59. (1984)
NAL Call #: 413.8; *ISSN:* 0043-5643
Descriptors: Aves/ community structure/ breeding/ forest wetland habitat relationships/ semiaquatic habitat/ forested wetland/ forest/ wetland/ breeding community structure relationships/ Massachusetts/ Connecticut Valley/ breeding community structure relative to forest wetland variables

1205. **Relationships among wetland and indicators in Hawaiian rain forest.**
Wakeley, James S.; Sprecher, Steven W.; and Lichvar, Robert W.
Wetlands 16(2): 173-184. (1996)
NAL Call #: QH75.A1W47; *ISSN:* 0277-5212
Descriptors: ecology: environmental sciences/ methods and techniques/ soil science/ field method/ habitat/ hydric soil/ hydrophytic vegetation/ rain forest/ terrestrial ecology/ undulating flow pattern/ wetland/ wetland identification/ wetland indicators
Abstract: We applied established methods for wetland identification in lowland and montane wet forests (rain forests) on the island of Hawaii to determine whether rain forests exhibited wetland indicators specified in delineation manuals and to examine relationships among indicators of hydrophytic vegetation, hydric soils, and wetland hydrology. Morphological characteristics and ferrous iron tests indicated pockets of hydric organic soils within areas mapped as Folists. Hydrophytic vegetation decisions based on prevalence values agreed with hydric soil determinations more often than did decisions based on dominant plant species. None of the rain forest types we studied exhibited wetland indicators throughout, but some sites contained scattered small wetlands occupying microtopographic lows created by cracks, folds, and undulating flow patterns in the lava bedrock. Further work is needed to identify reliable wetland indicators that can be used during drier portions of the year and to distinguish hydric from nonhydric organic rain forest soils.

1206. **A review of vertebrate community composition in seasonal forest pools of the northeastern United States.**
Paton, Peter W. C.
Wetlands Ecology and Management 13(3): 235-246. (2005)
NAL Call #: QH541.5.M3 W472; *ISSN:* 0923-4861
Descriptors: terrestrial ecology: ecology, environmental sciences/ community composition/ breeding habitat/ seasonally flooded wetland/ seasonal forest pool
Abstract: Seasonally-flooded wetlands occur throughout the world and provide important foraging, resting, and

breeding habitat for a broad array of organisms. This review summarizes our current understanding of vertebrate community composition at seasonal forest pools in the northeastern United States. These wetlands typically have hydroperiods that range from temporarily flooded to intermittently exposed, which reduces densities of many potential predators (e.g., fish). Current research has shown that pool hydroperiod, canopy closure, vegetation structure within pools, presence of potential predators, and landscape structure surrounding pools are the key factors determining vertebrate diversity at seasonal forest pools. Of 25 species of amphibians in the region, frogs (10 of 12 species) are more likely to breed in seasonal forest pools than salamanders (6 of 13 species). Seven of 10 amphibian species that breed in seasonal forest pools are state-listed as threatened or endangered. Among 27 species of reptiles, 3 of 15 species of snakes, and 6 of 12 species of turtles utilize seasonal pools during at least one stage of their annual cycle. Seasonal forest pools are important foraging and basking habitat for three species of. turtles listed as threatened or endangered. Compared to other vertebrate taxa, most species of mammals are habitat generalists, with 50 of 63 mammal species potentially foraging at seasonal pools during part of their annual cycle. Chiroptera (bats; all 9 species) arc believed to actively forage at seasonal pools and some Insectivora, particularly Sorex palustris Richardson and S. fumeus (Miller) and Condylura cristata (L.), are detected regularly at seasonal pools. Breeding birds are less likely to utilize seasonal pools than other vertebrate taxa, although 92 of 233 species might forage or breed near seasonal pools. Several species of Anatidae, Rallidae, and some Passeriformes use seasonally flooded pools. All vertebrates that use seasonal forest pools use other habitats during some stage in their life cycle; thus gaining a clear understanding of their habitat requirements is critical to their long-term persistence.

1207. **Stream/aquifer interactions at Great Sand Dunes National Monument, Colorado: Influences on interdunal wetland disappearance.**
Wurster, Frederic C.; Cooper, David J.; and Sanford, William E.
Journal of Hydrology (Amsterdam) 271(1-4): 77-100. (2003)
NAL Call #: 292.8 J82; *ISSN:* 0022-1694
Descriptors: climatology: environmental sciences/ freshwater ecology: ecology, environmental sciences/ groundwater ecology: ecology, environmental sciences/ ground water level measurement/ ground water modeling/ mathematical and computer techniques/ natural stable isotope analysis/ applied and field techniques/ sand creek channel incision/ buried seed banks/ climatic fluctuations/ dune movement/ ground water pumping: agriculture related, regional water table lowering/ hydrologic data/ intermittent sand creek flows/ local hydrologic process changes/ long term wet dry cycles/ pressure waves: ground water level influence/ regional stream flow records/ seepage/ severe drought/ soil stratigraphy/ stream/ stream/ aquifer interactions: interdunal wetland disappearance influence/ sub creek ground water mound: seasonal development, seasonal dispersion/ unconfined aquifer/ wetland area
Abstract: Between 1937 and 1995 a complex of more than 100 interdunal wetlands disappeared from Great Sand Dunes National Monument, Colorado. We investigated three hypotheses that could explain wetland disappearance: (1) dune movement during a severe drought in the 1950s buried the wetlands, (2) agriculture related ground water pumping lowered the regional water table, and (3) changes in local hydrologic processes led to wetland loss. We used regional stream flow records, ground water level measurements, natural stable isotope analyses, soil stratigraphy, buried seed banks, and ground water modeling to address these hypotheses. Hydrologic data and stable isotope analyses illustrated the interaction between Sand Creek, a nearby stream, and the unconfined aquifer in the area where wetlands occurred. When the intermittent Sand Creek flows, seepage through its bed creates a large ground water mound under the creek. The seasonal development and dispersion of this mound propagates pressure waves through the aquifer that influence ground water levels up to 2 km from Sand Creek. Our data suggest the primary factors contributing to wetland disappearance were recent climatic fluctuations and incision of the Sand Creek channel. Below average stream flow between 1950 and 1980 reduced the duration of Sand Creek flow across the dune complex, minimizing ground water mound development. Consequently, the water table in the unconfined aquifer dropped apprx 1.0 m and interdunal wetlands dried up. Twentieth Century incision of Sand Creek's channel reduced ground water mound height apprx 2.5 m, decreasing seasonal water table fluctuations at interdunal wetlands and contributing to the overall water table decline. Long-term wet and dry cycles affect the water table elevation more than channel incision, leading us to conclude that many interdunal wetlands are ephemeral features. Wetland area is maximized during consecutive years of above average Sand Creek discharge and minimized as the water table drops during dry periods.

1208. **Weather-related effects on woodland vernal pool hydrology and hydroperiod.**
Brooks, Robert T.
Wetlands 24(1): 104-114. (2004)
NAL Call #: QH75.A1W47; *ISSN:* 0277-5212
http://www.treesearch.fs.fed.us/pubs/6982
Descriptors: hydrology/ hydroperiod/ potential evapotranspiration/ precipitation/ vernal pools/ woodland vernal pools
Abstract: Woodland vernal pools occur commonly throughout northeastern North America. These pools provide preferred breeding habitat for mole salamanders (Ambystoma spp.) and wood frogs (Rana sylvatica) and support an abundant and diverse macroinvertebrate fauna. Vernal pool hydrology, and especially hydro-period or duration of the wet phase, affects the composition and productivity of pool fauna. The hydrology of ephemeral wetlands is dominated by local weather conditions. In this paper, I report a ten-year record of the relationships between precipitation and evapotranspiration and water-level change and hydroperiod in four typical southern New England vernal pools. Long-term average precipitation is evenly distributed throughout the year in the Northeast; potential evapotranspiration peaks in the summer months and exceeds precipitation from mid-June through mid-September. This period of water deficit causes the period of maximum vernal pool drying. Vernal pool hydroperiods were shorter and pools dried earlier in those years with

larger cumulative water deficits, especially when early spring ground-water resources were below long-term means and late winter snowpack was reduced or absent. Weekly water-level change in vernal pools was significantly related to precipitation and potential evapotranspiration, with precipitation having 2-5 times greater effect than evapotranspiration. Under climate-change predictions of more episodic precipitation and increased evapotranspiration, vernal pools would dry earlier in the year and remain dry longer. These changes would adversely affect the successful reproduction of pool-breeding amphibians and isolate the remaining productive pools.
This citation is from Treesearch.

1209. **Wetland features that influence occupancy by endangered Hawaiian duck on the island of Hawaii.**
Uyehara, Kimberly J.
Annandale-on-Hudson, New York: Bard College, 2005.
Descriptors: wetlands/ ducks/ wildlife habitat/ ecology

Effects of Agricultural Conservation Practices on Wetlands

1210. **Contaminant loading in drainage and fresh water used for wetland management at Stillwater National Wildlife Refuge.**
Kilbride, K. M.; Paveglio, F. L.; Altstatt, A. L.; Henry, W. G.; and Janik, C. A.
Archives of Environmental Contamination and Toxicology 35(2): 236-248. (Aug. 1998)
NAL Call #: TD172.A7; *ISSN:* 0090-4341
Descriptors: wetlands/ agricultural pollution/ drainage water/ ecosystem management/ arid environments/ agricultural runoff/ heavy metals/ detritus/ dissolved chemicals/ pesticides/ USA, West/ drains/ water pollution/ pollution load/ contamination/ water management/ land management/ freshwater pollution/ drainage/ trace elements/ aquatic organisms/ biota/ irrigation/ national parks/ USA, Nevada, Stillwater National Wildlife Refuge/ USA, Nevada, Stillwater Natl. Wildl. Refuge/ characteristics, behavior and fate/ sources and fate of pollution/ freshwater pollution
Abstract: Throughout the western United States, studies have identified various detrimental effects of contaminants to aquatic biota from the use of agricultural drainage water for management of arid wetlands. However, little is known about the relative contributions of contaminant loading from pollutants dissolved in water compared with those carried by drifting material (e.g., detritus) associated with drainage water. Consequently, we determined loading rates for contaminants dissolved in water and those incorporated by drifting material for drainage (Diagonal Drain) as well as fresh (S-Line Canal) water used for wetland management at Stillwater National Wildlife Refuge (SNWR), Nevada during the early, middle, and late periods of the irrigation season (June through mid-November) in 1993. We found loading rates for trace elements throughout the irrigation season were almost entirely (> 98%) associated with contaminants dissolved in the water rather than incorporated by drift. Although drift contributed little to the total loading for trace elements to SNWR wetlands, contaminant concentrations were much greater in drift compared with those dissolved in water. Loading rates for dissolved As, B, Hg, and total dissolved solids (TDS) differed among periods for the Diagonal Drain. Along the Diagonal Drain, loading rates for dissolved As, B, Hg, Mo, unionized ammonia (NH sub(3)-N), TDS, and Zn differed among its three sampling sites. B was the only trace element with differences in loading rates for drift among periods from the Diagonal Drain. In contrast, loading rates for As, B, Cr, Cu, Hg, Se, and Zn in drift differed among periods for the S-Line Canal. Along Diagonal Drain, loading rates in drift for B (middle and late periods), Cr, Cu, and Zn differed among sites. Hg (x greater than or equal to 12.0 ng/L) and NH sub(3)-N (x greater than or equal to 0.985 mg/L) dissolved in water as well as B (x greater than or equal to 97.4 mu g/g DW) and Hg (x greater than or equal to 0.461 mu g/g DW) in drift from the Diagonal Drain and S-Line Canal exceeded screening levels (SLs) for protection of aquatic biota throughout the irrigation season. Dissolved As (x greater than or equal to 0.0426 mg/L) in water from the Diagonal Drain during all periods exceeded the SL for protection of aquatic biota. Dissolved B (x = 1.03 mg/L) in water from the Diagonal Drain during the early period exceeded the SL for protection of aquatic biota.

1211. **Detailed study of irrigation drainage in and near wildlife management areas, west-central Nevada, 1987-90.**
Hoffman, R. J.
Denver, Colo.: U.S. Geol. Survey, Earth Science Information Center, 1994. USGS Water-Resources Investigations Report.
NAL Call #: GB701.W375 no.92-4024C
Descriptors: wetlands/ wildlife habitats/ water quality/ irrigation effects/ public health/ contamination/ toxicity/ heavy metals/ agricultural hydrology/ aquatic life/ bioaccumulation/ water pollution effects/ USA, Nevada/ Stillwater Wildlife Management Area
Abstract: This report presents a summary of the detailed scientific study of Stillwater Wildlife Management Area and other nearby wetlands in west-central Nevada during 1987-90. The work was funded by the National Irrigation Water Quality Program of the U.S. Department of the Interior with the overall objectives of determining (1) the extent, magnitude, and effects of selected water-quality constituents associated with irrigation drainage on fish, wildlife, and human health, and (2) the sources and exposure pathways that cause contamination where adverse effects are documented. Much of the information in this report was summarized from two previously published interpretive reports that were completed to fulfill study objectives. Where applicable, data for the study area from other published sources also were utilized. The results of these studies indicate that the aquatic biota in natural wetlands of the Carson Desert are adversely affected by hydrological and geochemical sources and processes in the Newlands Irrigation Project area. Reactions between water and naturally occurring minerals in the shallow alluvial aquifer increase concentrations of potentially toxic constituents in ground water that eventually enters the wetlands. Once in the wetlands, these constituents are

further concentrated by evaporation and transpiration. Water from some agricultural drains that enter Stillwater WMA was acutely toxic to aquatic organisms. The drains in the agricultural areas, which eventually discharge to the wetlands, were also implicated as sites of uptake of selenium and mercury by aquatic organisms.
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1212. **Detailed study of irrigation drainage in and near wildlife management areas, west-central Nevada, 1987-90 - Part B: Effect on biota in Stillwater and Fernley wildlife management areas, and other nearby wetlands.**
Hallock, R. J. and Hallock, L. L.
Denver, Colo.: U.S. Geological Survey; Water Resources Investigation Report: 92-4024B, 1993.
Descriptors: wetlands/ water pollution effects/ toxicity/ selenium/ dissolved solids/ water quality/ waterfowl/ water control/ wildlife/ irrigation/ drainage/ pollution effects/ USA, Nevada, Stillwater/ irrigation drainage/ pollution effects/ water pollution effects/ dissolved solids/ waterfowl/ water control
Abstract: A water-quality reconnaissance study during 1986-87 found high concentrations of several potentially toxic elements in water, bottom sediment, and biota in and near Stillwater Wildlife Management Area (WMA). This study prompted the U.S. Department of the Interior to initiate a more detailed study to determine the hydrogeochemical processes that control water quality in the Stillwater WMA, and other nearby wetlands, and the resulting effects on biota, especially migratory birds. Present wetland size is about 10% of historical size; the dissolved-solids load in the water in these now-isolated wetlands has increased only moderately, but the dissolved-solids concentration has increased more than seven-fold. Wetland vegetation has diminished and species composition in flow water has shifted to predominant salt-tolerant species in many areas. Decreased vegetative cover for nesting is implicated in declining waterfowl production. Decreases in numbers or virtual absence of several wildlife species are attributed to degraded water quality. Results of toxicity tests indicate that water in some drains and wetland areas is acutely toxic to some fish and invertebrates. Toxicity is attributed to the combined presence of arsenic, boron, lithium, and molybdenum. Biological pathways are involved in the transport of mercury and selenium from agricultural drains to wetlands. Hatch success of both artificially incubated and field-reared duck eggs was greater than/= 90 percent; no teratogenesis was observed. Mercury in muscle tissue of waterfowl harvested from Carson Lake in October 1987 exceeded the human health criterion six-fold.
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1213. **Detailed study of selenium and selected elements in water, bottom sediment, and biota associated with irrigation drainage in the middle Green River basin, Utah, 1988-90.**
Stephens, D. W.; Waddell, B.; Peltz, A.; and Miller, J. B.
Denver, Colo.: U.S. Geological Survey; Water-Resources Investigations Report 92-4084, 1992. 164 p.
Descriptors: wetlands/ bioaccumulation/ drainage water/ selenium/ water pollution effects/ water pollution sources/ ducks/ irrigation/ water birds/ waterfowl/ wildlife habitats
Abstract: Studies completed at Stewart Lake Waterfowl Management Area, lower Ashley Creek, Ouray National Wildlife Refuge, and Pariette Wetlands, Utah identified several areas where selenium was adversely affecting water quality and creating a hazard to wildlife. The source of contamination at Stewart Lake is drainwater and shallow groundwater from soils derived from Mancos Shale. Median concentrations of selenium in all drainwater discharged to Stewart Lake exceeded the State standard of 5 microg/L established for wildlife protection. Selenium concentrations i all biological tissues sampled at Stewart Lake Waterfowl Management Area were large compared to concentrations in biota from most other sites in the middle Green River basin. Selenium concentrations in Ashley Creek upstream of the City of Vernal generally were less than 1 microg/L but 12 miles downstream averaged 73 microg/L. The source of the contamination was believed to be from inflows of shallow groundwater and surface water originating as seepage from a sewage-lagoon system that flows through Mancos Shale and mobilizes selenium. Waterfowl from the area contained selenium concentrations as large as 27.2 microg/g in muscle tissue, and an eared grebe egg contained 71 microg/g. Selenium contamination of ponds at Ouray National Wildlife Refuge was limited to a small area on the western part of the refuge and was apparently due to seepage of shallow groundwater into waterfowl ponds. Geometric mean concentrations of selenium in plants, invertebrates, bird eggs, and fish from the North and South Roadside Ponds were larger than concentrations known to cause reproductive failure in mallards. (USGS)
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1214. **Effects of agricultural runoff on vegetation composition of a priority conservation wetland, Vermont, USA.**
Gustafson, S. and Wang, D.
Journal of Environmental Quality 31(1): 350-357. (2002)
Descriptors: wetlands/ agriculture/ composition/ conservation/ runoff/ vegetation/ watersheds/ subwatersheds/ environmental engineering/ water pollution/ conservation of natural resources/ ecosystem/ eutrophication/ plants
Abstract: This study examined the effects of agricultural runoff on the vegetation structure of Franklin Bog, a priority conservation area located in a rapidly developing region of northwestern Vermont. Forested and agricultural runoff from the mixed land use watershed created differential vegetation patterns in the wetland, including weedy species introductions. Concentrations of nitrogen and phosphorus were measured in the stream runoff from four forested subwatersheds and two agricultural subwatersheds. Nutrient concentrations were significantly higher for agricultural vs. forested runoff for all measured parameters. Nitrate and total phosphorus concentrations in agricultural runoff ranged from 0.62 to 1.35 mg L-1 and 0.07 to 0.37 mg L-1, respectively. Forested runoff values were less than 0.37 mg L-1 nitrate and 0.09 mg L-1 total phosphorus. Significantly higher proportions of weedy species occurred at impacted vs. reference sites (46 ± 5% vs. 23 ± 4%). Furthermore, significantly higher total percent vegetated cover occurred at impacted vs. reference sites (116 ± 11% vs. 77 ± 9%) suggesting nutrient induced plant growth. Of the nine frequently occurring species categorized as bog species, only one was found within impacted sites while all nine were found at the reference sites. This suggests that the wetland's distinctive native flora is being replaced by widespread, vigorous species enhanced by agricultural

nonpoint pollution in the watershed of Franklin Bog. Protection of wetlands requires attention to conservation measures throughout the entire watershed.

1215. **Physical, chemical, and biological data for detailed study of irrigation drainage in the middle Green River basin, Utah, 1988-89, with selected data for 1982-87.**
Peltz, L. A. and Waddell, B.
Denver, Colo.: U.S. Geological Survey; Open-File Report 91-530, 1991. 213 p.
Descriptors: wetlands/ water quality/ water pollution sources/ nonpoint pollution sources/ Utah/ selenium/ irrigation/ drainage water/ sediments/ plants/ waterfowl/ fish/ invertebrates/ water measurement/ data collections/ irrigation
Abstract: Physical, chemical, and biological data were collected in the middle Green River basin, eastern Utah, between 1988 and 1989, as part of a detailed study of the effects of irrigation drainage on wetlands areas. Data-collection efforts were concentrated in the Stewart Lake Waterfowl Management Area near Jensen, and Ouray National Wildlife Refuge near Ouray. Data also were collected from Ashley Creek near Vernal, Pelican Lake near Ouray, and in Pariette Wetlands near Myton. A limited quantity of data collected during earlier studies (1982-87), funded by the U.S. Fish and Wildlife Service, also is included. This report contains data needed to assess the effects of selenium and other potentially toxic contaminants on streams and wetlands. Data consist of concentrations of trace elements and common elements in samples of water, sediments, plants, waterfowl, birds, fish, and invertebrates. Other data presented in the report are groundwater levels, surface water discharges, radiochemical constituents in water, analyses of organochlorine compounds in biota, and morphometric measurements of biota. (USGS)

1216. **Protection of habitat for rare wetland fauna during timber harvesting in Massachusetts (USA).**
Kittredge, D. B.
Natural Areas Journal 16(4): 310-317. (1996)
Descriptors: wetlands/ conservation/ rare species/ environmental protection/ trees/ harvesting/ nature conservation/ aquatic organisms/ ecosystem disturbance/ environmental impact/ forestry/ environmental effects/ forest industry/ USA, Massachusetts/ harvesting/ forest industry/ trees/ forestry/ rare species/ nature conservation/ aquatic organisms/ ecosystem disturbance/ environmental impact/ environmental effects
Abstract: The practice of harvesting timber is commonly thought of as conflicting with the protection of rare species habitat. In Massachusetts, over 5 years and more than 3,300 harvesting operations, rare wetland faunal habitat was involved 5.3% of the time (175 occurrences). The Massachusetts Natural Heritage and Endangered Species Program reviewed all proposed harvesting that involved habitat for rare wetland species and determined that operations would cause "no impact" in 58.9% of the cases, "possible impact" in 40% of the cases, and "definite impact" in 1.1% of the cases. Rare fauna whose habitat was most frequently involved were wood turtle (Clemmys insculpta), spotted turtle (Clemmys guttata), and spring salamander (Gyrinophilus porphyriticus). The Natural Heritage and Endangered Species Program recommended mitigating measures such as timing of the harvest, buffers around water bodies, improved stream crossing techniques, and other practices. In most circumstances, these were incorporated into the forest cutting plan and were made a requirement of the operation. When they were not required, the regulating agency had determined that the recommendations did not apply to the specific circumstances on the ground. In general, habitat of rare wetland faunal species is not impacted by timber harvesting in Massachusetts, and likewise, harvesting is not seriously impacted by habitat protection. Regulation of harvesting, an atlas of rare species habitats, and good communication result in protection of habitat that is compatible with harvesting.

1217. **Role of wetlands and developed land use on dissolved organic nitrogen concentrations and DON/TDN in northeastern U.S. rivers and streams.**
Pellerin, B. A.; Wollheim, W. M.; Hopkinson, C. S.; Mcdowell, W. H.; Williams, M. R.; Voeroesmarty, C. J.; and Daley, M. L.
Limnology and Oceanography 49(4): 910-918. (2004)
NAL Call #: GC1 .L5; *ISSN:* 0024-3590
Descriptors: watersheds/ resource management/ dissolved organic nitrogen/ drainage water/ anthropogenic factors/ agriculture/ man-induced effects/ rivers/ streams/ organic matter/ nitrogen/ human factors/ drainage/ urban areas/ land use/ limnology/ dissolved organic matter in river water/ nitrogen in watersheds/ nitrogen in wetlands/ USA, Massachusetts
Abstract: Previous studies have shown that watersheds with significant human development (i.e., urban and agricultural land use) generally have higher concentrations and fluxes of dissolved inorganic nitrogen (DIN) in comparison to less-developed or forested watersheds. However, the impact of watershed development on dissolved organic nitrogen (DON) concentrations in drainage waters has received little attention. We present data from 39 watersheds in Massachusetts (Ipswich River watershed) encompassing a gradient of developed land use (0%-92% urban plus agriculture) and wetland abundance (0%-32%) to assess controls on mean annual DON concentrations and DON/total dissolved nitrogen (TDN) in drainage waters. In addition, we compiled published data from 119 northeastern U.S. watersheds to evaluate broader-scale relationships between DON, developed land use, and wetlands. The percentage of developed land is a poor predictor of DON concentrations in the Ipswich watersheds (r super(2) = 0.09) and the compiled dataset (r super(2) = 0.27). In contrast, wetland percentage explains 56% of the variability in DON concentrations in the Ipswich watersheds, and 60% when all literature data are included. Excluding watersheds with direct wastewater inputs to surface waters improves the regional relationship significantly (r super(2) = 0.79). The DON:TDN ratio is best explained by a multiple regression of wetland percentage and developed land use percentage for both the Ipswich watersheds (r super(2) = 0.73) and the compiled dataset (r super(2) = 0.50). Watersheds with abundant wetlands may therefore have high DON concentrations and DON:TDN ratios despite elevated anthropogenic nitrogen inputs associated with human development.

1218. **The transformation of Sonoran desert wetlands following the historic decrease of burning.**
Davis, O. K.; Minckley, T.; Moutoux, T.; Jull, T.; and Kalin, B.
Journal of Arid Environments 50(3): 393-412. (2002)
NAL Call #: QH541.5.D4J6; *ISSN:* 0140-1963
Descriptors: wetlands/ historical ecology/ fires/ sediments/ vegetation changes/ vegetation/ history/ deserts/ fungi/ plant populations/ USA, Arizona/ Mexico
Abstract: The analysis of sediments from six wetlands (cienegas) in the Sonoran Desert of Arizona, U.S.A., and Sonora, Mexico, document a marked expansion of wetland taxa--particularly woody plants--about 200 years ago at the beginning of the historic period, following a decrease in charcoal percentages and increased percentages of the dung fungus Sporormiella. The presence of charred seeds and fruits of wetland plants in prehistoric sediment establishes burning of the cienega itself. The charcoal decline ca. 250 years ago precedes the first occurrence of the pollen exotic plants at several sites, the change of cienega sediment from silt to peat, and the increase of percentages of the decay fungus Tetraploa. We conclude that prior to the historic period, burning was frequent enough to exclude most woody plants (Celtis, Cephalanthus, Populus, Fraxinus, Salix) from the wetlands and suppress the abundance of bulrush (Scirpus). The cienegas were probably burned seasonally as a management tool to harvest animals and promote agriculture. Prehistoric agricultural utilization of the cienegas is demonstrated by the presence of corn (Zea) and pre-Columbian weeds. This study also records post-settlement (ca. 200 years ago) change of upland vegetation; i.e. an increase in the abundance of Juniperus, Quercus, Larrea, and Prosopis pollen. Historic fire suppression may have permitted the expansion of these non-wetland woody species. Copyright 2002 Elsevier Science Ltd.

Wetlands as Agricultural Conservation Practices

1219. **Analysis of sediment retention in western riverine wetlands: The Yampa River watershed, Colorado, USA.**
Arp, Christopher D. and Cooper, David J.
Environmental Management 33(3): 318-330. (2004)
NAL Call #: HC79.E5E5; *ISSN:* 0364-152X
Descriptors: freshwater ecology: ecology, environmental sciences/ hydrogeomorphic approach/ applied and field techniques/ wetland resource management
Abstract: We quantified annual sediment deposition, bank erosion, and sediment budgets in nine riverine wetlands that represented a watershed continuum for 1 year in the unregulated Yampa River drainage basin in Colorado. One site was studied for 2 years to compare responses to peak flow variability. Annual mean sediment deposition ranged from 0.01 kg/m along a first-order subalpine stream to 21.8 kg/m at a sixth-order alluvial forest. Annual mean riverbank erosion ranged from 3 kg/m-of-bank at the first-order site to 1000 kg/m at the 6th-order site. Total sediment budgets were nearly balanced at six sites, while net export from bank erosion occurred at three sites. Both total sediment deposition (R2 = 0.86, p 0.01) and bank erosion (R2 = 0.77, p 0.01) were strongly related to bankfull height, and channel sinuosity and valley confinement helped to explain additional variability among sites. The texture and organic fraction of eroded and deposited sediment were relatively similar in most sites and varied among sites by watershed position. Our results indicate that bank erosion generally balances sediment deposition in riverine wetlands, and we found no distinct zones of sediment retention versus export on a watershed continuum. Zones of apparent disequilibrium can occur in unregulated rivers due to factors such as incised channels, beaver activity, and cattle grazing. A primary function of many western riverine wetlands is sediment exchange, not retention, which may operate by transforming materials and compounds in temporary sediment pools on floodplains. These results are considered in the context of the Hydrogeomorphic approach being implemented by the U.S. government for wetland resource management.

1220. **Assessment of hydraulic restoration of San Pablo Marsh, California.**
Grismer, Mark E.; Kollar, J.; and Syder, J.
Environmental Monitoring and Assessment 98(1-3): 69-92. (2004)
NAL Call #: TD194; *ISSN:* 0167-6369
Descriptors: biodiversity/ conservation/ terrestrial ecology: ecology, environmental sciences/ aerial survey/ applied and field techniques/ channel survey/ applied and field techniques/ ground truthing/ applied and field techniques/ agricultural development/ biodiversity/ drainage channel/ hydraulics/ inter tidal marsh/ ocean environment/ restoration strategy/ salt marsh hydrodynamics/ sediment accretion process/ terrestrial environment/ tidal circulation/ tidal level/ water quality
Abstract: Inter-tidal marshes are dynamic diverse ecosystems at the transition zone between terrestrial and ocean environments. Geomorphologically, inter-tidal salt marshes are vegetated landforms at elevations slightly greater than mean tidal levels that have distributed channels formed under ebb (drainage) tidal flows that widen and deepen in the seaward direction. The drainage channels enable tidal flows to circulate sediments and nutrients through the marsh system during normal tidal events, while depositing sediments during storm or seismic events. This dynamic system encourages considerable biodiversity while simultaneously providing water quality enhancement features that service marsh terrestrial life and marine life in the estuary. Reservoir creation limiting sediment transport, anticipated large increases in sea levels as well as agricultural and urban development have resulted in significant loss of inter-tidal marshes and subsequent adverse impacts on waterfowl, infauna and fisheries. The complex and continuously changing marsh channel hydraulics and sedimentary processes have severely constrained quantitative modeling of these marsh systems such that restoration/creation efforts remain something of an empirical science and further assessments are needed. The purpose of this paper is to outline current understanding of salt marsh hydrodynamics, sediment accretion processes and subsequent response of marsh

vegetation to set the stage for assessment of a marsh restoration effort along San Pablo Bay near San Francisco, California. Several kilometers of drainage channels were constructed in a 624 ha disturbed salt marsh to restore tidal circulation and vegetation so as to enhance habitat for threatened species (e.g. clapper rail, harvest mouse, delta smelt and potentially anadromous fish species). Two distinct drainage channel systems ('east' and 'west') were installed having similar channel dimensions common to salt marshes in the region, but having design bankfull tidal prism volumes differing by a factor of two. Following channel excavation, main channel tidal flows and sediment loads as well as marsh sediment accretion rates were monitored to assess the relative success of the excavation in restoring tidal circulation and vegetation (Salicornia spp.) to the marsh. Annual aerial surveys corroborated with ground-truthing indicated that marsh vegetation rapidly expanded, from 40 to 85% coverage several years following excavation. The 'east' channel intake was nearly completely silted in within three years. However, channel surveys and flow measurements indicated that the 'east' channel system tidal prism was only about 1200 m3, more than an order of magnitude less than that of the stable 'west' channel system. Marsh sediment accretion rates were on the order of 7-8 mm yr-1, a rate common to the Pacific coast region that exceeds estimated sea level rise rates of apprx2 mm yr-1. East channel network siltation resulted in storm and spring tidal flood ponding such that marsh vegetation coverage decreased to 51% of the marsh area and related habitat expansion decreased. These results are considered in terms of the primary inter-tidal marsh factors affecting possible restoration/creation strategies.

1221. **Bird use of restoration and reference marshes within the Barn Island Wildlife Management Area, Stonington, Connecticut, USA.**
Brawley, A. H.; Warren, R. S.; and Askins, R. A.
Environmental Management 22(4): 625-633. (1998)
NAL Call #: HC79.E5E5; *ISSN:* 0364-152X
Descriptors: ecosystem management/ environment management/ salt marshes/ impoundments/ species diversity/ population density/ aquatic birds/ USA, Connecticut/ tidal marshes/ birds/ habitats/ estuaries/ vegetation/ artificial wetlands/ environmental restoration/ habitat utilization/ Aves/ USA, Connecticut, Stonington, Barn Island Wildlife Management Area/ restoration/ birds/ habitat community studies/ mechanical and natural changes/ estuaries/ reclamation
Abstract: Tidal marshes have been actively restored in Connecticut for nearly 20 years, but evaluations of these projects are typically based solely on observations of vegetation change. A formerly impounded valley marsh at the Barn Island Wildlife Management Area is a notable exception; previous research at this site has also included assessments of primary productivity, macroinvertebrates, and use by fishes. To determine the effects of marsh restoration on higher trophic levels, we monitored bird use at five sites within the Barn Island complex, including both restoration and reference marshes. Use by summer bird populations within fixed plots was monitored over two years at all sites. Our principal focus was Impoundment One, a previously impounded valley marsh reopened to full tidal exchange in 1982. This restoration site supported a greater abundance of wetland birds than our other sites, indicating that it is at least equivalent to reference marshes within the same system for this ecological function. Moreover, the species richness of birds and their frequency of occurrence at Impoundment One was greater than at 11 other estuarine marshes in southeastern Connecticut surveyed in a related investigation. A second marsh, under restoration for approximately ten years, appears to be developing in a similar fashion. These results complement previous studies on vegetation, macroinvertebrates, and fish use in this system to show that, over time, the reintroduction of tidal flooding can effectively restore important ecological functions to previously impounded tidal marshes.

1222. **Fish assemblage composition in constructed and natural tidal marshes of San Diego Bay: Relative influence of channel morphology and restoration history.**
Williams, G. D. and Zedler, J. B.
Estuaries 22(3A): 702-716. (Sept. 1999)
NAL Call #: GC96.E79; *ISSN:* 0160-8347
Descriptors: wetlands/ tides/ environmental restoration/ habitat utilization/ USA, California/ USA, California, San Diego Bay/ tidal marshes/ morphology/ rehabilitation/ channel morphology/ species composition/ aquatic habitats/ population density/ killifish/ multivariate analysis/ monitoring/ biological sampling/ physical properties/ environment management/ river engineering/ ecosystem disturbance/ environmental impact/ community composition/ fluvial morphology/ environmental factors/ Pisces/ Fundulus parvipinnis/ California killifish/ reclamation/ water quality control/ mechanical and natural changes/ multi-disciplinary studies/ environmental effects/ erosion and sedimentation
Abstract: This study evaluated the use by fish of restored tidal wetlands and identified links between fish species composition and habitat characteristics. We compared the attributes of natural and constructed channel habitats in Sweetwater Marsh National Wildlife Refuge, San Diego Bay, California, by using fish monitoring data to explore the relationships between channel environmental characteristics and fish species composition. Fishes were sampled annually for 8 yr (1989-1996) at eight sampling sites, four in constructed marshes and four in natural marshes, using beach seines and blocking nets. We also measured channel habitat characteristics, including channel hydrology (stream order), width and maximum depth, bank slope, water quality (DO, temperature, salinity), and sediment composition. Fish colonization was rapid in constructed channels, and there was no obvious relationship between channel age and species richness or density. Total richness and total density did not differ significantly between constructed and natural channels, although California killifish (Fundulus parvipinnis) were found in significantly higher densities in constructed channels. Multivariate analyses showed fish assemblage composition was related to channel habitat characteristics, suggesting a channel's physical properties were more important in determining fish use than its restoration status. This relationship highlights the importance of designing restoration projects with natural hydrologic features and choosing proper assessment criteria in order to avoid misleading interpretations of constructed channel success. We recommend that future projects be designed to mimic

natural marsh hydrogeomorphology and diversity more closely, the assessment process utilize better estimates of fish habitat function (e.g., individual and community-based species trends, residence time, feeding, growth) and reference site choice, and experimental research be further incorporated into the restoration process.

1223. **Hydrologic restoration of a fen in Rocky Mountain National Park, Colorado, USA.**
Cooper, D. J.; MacDonald, L. H.; Wenger, S. K.; and Woods, S. W.
Wetlands 18(3): 335-345. (Sept. 1998)
NAL Call #: QH75.A1W47; *ISSN:* 0277-5212
Descriptors: wetlands/ marshes/ hydrology/ environment management/ soil mechanics/ ground water/ water levels/ rainfall/ USA, Colorado, Rocky Mountain National Park, Big meadows/ rehabilitation/ fens/ national parks/ water table fluctuations/ anaerobic conditions/ precipitation/ mountains/ hydrological regime/ ditches/ laminar flow/ environmental restoration/ USA, Colorado, Rocky Mountain National Park/ USA, Colorado, Rocky Mountain Natl. Park, Big meadows/ ditch blocking/ conservation, wildlife management and recreation/ environmental action
Abstract: Big Meadows, a 63-ha fen in Rocky Mountain National Park (RMNP), was ditched for agricultural purposes in the early part of this century. Although use of the ditch ceased after the establishment of RMNP in 1915, it continued to intercept sheet flows in the central and southern portions of the fen, causing the ground-water level to decrease and aerobic soil conditions to develop in the mid- to late-summer of most years. In 1990, the ditch was blocked in an attempt to restore the hydrologic regime in the central and southern portions of the fen. Water-level data from three years prior to restoration and four years after restoration show that blocking the ditch successfully restored surface sheet flow, high late-summer water-table levels, and anaerobic soil conditions in much of the central and southern portions of the fen. Conditions in these areas are now similar to those in the northern portion of the fen. The long-term data from this site also indicate that summer rainfall has a greater influence on the magnitude of late-summer drying than the size of the winter snowpack. In a post-restoration year with extremely low rainfall in July and August, water levels throughout the fen decreased to levels similar to those observed throughout most of the pre-restoration period. The study suggests that this and other fens in the southern Rocky Mountains are extremely sensitive to summer precipitation and the hydrologic changes created by even small ditches or water diversions.

1224. **Rapid salinity mapping by electromagnetic induction for determining riparian restoration potential.**
Sheets, K. R.; Taylor, J. P.; and Hendrickx, J. M. H.
Restoration Ecology 2(4): 242-246. (1994)
NAL Call #: QH541.15.R45R515; *ISSN:* 1061-2971
Descriptors: wetlands/ mapping/ riparian environments/ environmental restoration/ flood plains/ ecosystem management/ nature conservation/ sediments/ conservation/ electromagnetic radiation/ sampling/ salinity/ soils/ sediment properties/ riparian waters/ saline soils/ environmental restoration/ salinity/ soils/ sediment properties/ riparian waters/ saline soils/ soil sampling/ riparian environments/ ecosystem management/ nature conservation/ electromagnetic radiation/ sampling/ reclamation/ methods and instruments/ protective measures and control/ evaluation, processing and publication/ freshwater pollution/ freshwater
Abstract: The feasibility of measuring soil salinity with electromagnetic induction (EM) for determining riparian restoration potential was investigated on a 28-hectare plot at the Bosque del Apache National Wildlife Refuge in central New Mexico. The plot was cleared of exotic Tamarix chinensis (saltcedar), surveyed and gridded into 1370.2 hectare sections. Soil samples and EM measurements were taken at each section. We compared laboratory-determined EC sub(e) values from the soil samples with EC sub(a) values calculated from the EM measurements using a model developed by Rhoades et al. (1990). Direct comparison of EC sub(e) values determined from the two methods yields a low correlation due to sample-size differences but the calculated EC sub(a) was able to accurately predict whether the measured EC sub(e) would lie above or below some threshold value. An assessment of general site suitability for riparian restoration with electromagnetic induction has proven to be a rapid, accurate, and cost-effective alternative to intensive soil sampling.

1225. **Seasonal performance of a wetland constructed to process dairy milkhouse wastewater in Connecticut.**
Newman, J. M.; Clausen, J. C.; and Neafsey, J. A.
Ecological Engineering 14(1-2): 181-198. (Jan. 2000)
NAL Call #: TD1.E26; *ISSN:* 0925-8574.
Notes: Special Issue: Nitrogen & phosphorus retention in wetlands
Descriptors: agricultural pollution/ wastewater treatment/ pollution control/ USA, Connecticut/ artificial wetlands/ construction/ dairy wastes/ nonpoint pollution sources/ water pollution/ biochemical oxygen demand/ seasonal variations/ dairies/ fecal coliforms/ nutrients/ denitrification/ building and construction/ dairy industry waste waters/ pollution (nonpoint sources)/ pollution (water)/ oxygen demand (biochemical)/ seasonal variations/ dairy milkhouse wastewaters/ performance assessment/ characteristics, behavior and fate/ wastewater treatment processes/ sewage & wastewater treatment/ water treatment
Abstract: Constructed wetlands are gaining increased attention for treatment of nonpoint sources of water pollution. Although constructed wetlands have been utilized for wastewater treatment in warm climates, their performance in cold climates has been questioned. A surface-flow wetland, designed to treat 2.65 m super(3) d super(-1) of milkhouse wastewater, was constructed on the University of Connecticut's Storrs campus in 1994. The purpose of the project was to determine the efficiency of the system in reducing nitrogen, phosphorus, five-day biochemical oxygen demand (BOD sub(5)), total suspended solids (TSS), and fecal coliform bacteria (FC). The wetland was designed to process an estimated BOD sub(5) loading rate of 7.3 g m super(-2) d super(-1), which was less than half of the average actual loading rate. The overall percentage of mass retention was 94, 85, 68, 60 and 53% for TSS, BOD sub(5), total phosphorus, nitrate-nitrite and total Kjeldahl-nitrogen, respectively. Although the wetland became a net source of ammonia nitrogen (NH sub(3)-N) following plant die back in fall 1994, NH sub(3)-N outflow concentrations have gradually declined over time.

Mass retention was significantly greater ($P < 0.05$) during the summer than during the winter for all variables except FC. Denitrification rates measured using the acetylene block method have shown denitrification to be a minor removal mechanism (<1%) for nitrogen in this wetland. The mass balance indicated that settling and increased storage was the largest removal mechanism. The treatment of wastewater in this wetland did not meet design outflow concentration criteria, most likely due to BOD sub(5) overloading.