APPENDIX C

ACCOUNTS OF FOCAL AQUATIC ECOSYSTEMS AND ECOLOGICALLY SIGNIFICANT AREAS

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ACCOUNTS OF FOCAL AQUATIC ECOSYSTEMS AND ECOLOGICALLY SIGNIFICANT AREAS

Matthew D. Schlesinger and Erik M. Holst, editors

Focal Aquatic Ecosystem: Upper Truckee River
By Erik M. Holst

General

From its headwaters at approximately 2,804 m (9,200 ft), near Red Lake Peak, the Upper Truckee River flows north for a distance of 34.6 km (21.5 mi) into Lake Tahoe (CDFG 1987). Within the 146.6 km^2 (56.6 mi^2) drainage, 24 tributaries flow into the Upper Truckee River (CDFG 1987). The Upper Truckee River and the tributaries which make up the Upper Truckee River Watershed comprise the largest contribution to the waters of Lake Tahoe (CWQCB 1999).

Using Moyle's (1996) aquatic habitat classification, the Upper Truckee River can be divided into two aquatic habitat types: alpine streams and mainstem rivers and their larger tributaries. (See Issue 5, Chapter 5 for further discussion of this classification.) Mainstem rivers and their larger tributaries are widespread and of special concern in the Great Basin Province. That is, they are "declining in abundance and quality but many examples still exist" (Moyle 1996, p. 946). However, as noted in Issue 5, Chapter 5, only mainstem rivers received the highest concern rating of "imperiled" in the Lake Tahoe Basin; the lower reaches of the Upper Truckee River comprise the only representative of a mainstem river in the basin.

History

Between 1852 and 1857 emigrants moved thousands of sheep and cattle through the Lake Tahoe basin on their way to the gold fields of California (Supernowicz 1999). Transient grazing patterns persisted until the later part of the 1850s at which time more defined, less transient, patterns of grazing evolved along with human settlement patterns (Supernowicz pers. comm.). By the late nineteenth century in the Lake Valley area of the Upper Truckee River watershed, harvested land was being grazed by dairy cattle, and indiscriminate, unregulated sheep grazing was occurring in those areas not suitable for cattle (see Chapter 2; Supernowicz pers. comm.). During this same period, land use activities in the headwaters of the Upper Truckee River were primarily limited to grazing; no commercial logging occurred. By the 1910s, the development of a seasonal grazing allotment system throughout the watershed dedicated land to specific uses and limitations. The allotment system attempted to reduce the previous levels of resource damage and essentially eliminated indiscriminate sheep grazing (Supernowicz pers. comm.). However, four decades later the California Department of Fish and Game noted the Upper Truckee River was experiencing erosion problems due to past cattle grazing (CDFG 1957).

Commercial logging first occurred in the Lake Valley portions of the Upper Truckee River watershed in the 1860s (Supernowicz pers. comm.). Harvest data from 1887 to 1890 in T.12N., R.18E indicate a stand composition of Jeffrey pine (*Pinus jeffreyi*), sugar pine (*Pinus lambertiana*), and incense cedar (*Calocedrus* decrurrens) with an average diameter of 67 cm (26.4 in) (see Chapter 2). By 1897 the aforementioned township, and Lake Valley in general, was almost entirely cut over (see Chapter 2; Supernowicz pers. comm.). In 1936, parcels of this township were acquired by the USDA Forest Service from the Carson and Tahoe Timber and Flume Company; this acquisition included both harvested and unharvested lands. The harvested areas included stands or portions of stands that were clearcut as early as 1860, along with other areas that were selectively logged in the 1900s (USDA 1935). Most of the timber harvest occurred on flatter ground, and stands within the same land survey section in which clearcuts occurred were noted to contain trees between 75 and 300 years of age (USDA 1935). The acquisition included two main areas of 'virgin timber.' The 227 ha (560 ac) tract of late seral timber adjacent to the sawmill operated by C. G. Celio and Sons was described as having Jeffrey pine averaging 122 cm (48 in) in diameter at breast height in some areas (USDA 1935). All age classes were represented in this stand with 95 percent of the volume being classified as 'mature and overmature'; the species characteristics for the entire 227 ha (560 ac) tract are described in Table C-1.

By 1996 the stand composition in this area had shifted to Jeffrey pine, lodgepole, white fir, and incense cedar with average diameters of 35.5 to 40.5 cm (14 to 16 in) with the largest diameter being about 76 cm (30 in) (see Chapter 2). (For further discussion of historical land uses, see Chapter 2.)

In general, land use along the Upper Truckee River in the Lake Valley area from the 1850s to the 1920s/1930s was expansive and intensive in nature insofar as logging, ranching, and grazing created openings and meadows where they had not previously existed (Supernowicz pers. comm.). However, after the 1920s/1930s land use patterns changed, and vegetation began to encroach into the openings created during the Comstock Era (Supernowicz pers. comm.). In addition, during the Comstock Era and shortly thereafter, impoundments were placed along the Upper Truckee River and its tributaries to provide water for domestic and/or agricultural use (Supernowicz pers. comm.). Sanders, in his 1932 'Field Correspondence' to Chief Macaulay of the California Department of Natural Resources, Division of Fish and Game, notes the existence of dams along the Upper Truckee River that were used to irrigate cattle pastures in the summer months; during the fall, winter, and spring, gates on these dams were opened to facilitate fish passage (CDFG 1932). Celio (1930) notes the existence of a fish trap built by the Fish Commission on the Upper Truckee. Effects of these impoundments and fish traps on water flows and the aquatic biota are unknown. However, it should be noted that during this same time period, the Mt. Ralston Fish Planting Club was introducing exotic species such as water lilies, water hyacinth, and parrot feather into numerous high elevation lakes (Pierce 1932). They also introduced *Gammarus* (a fresh water shrimp) in shallow lakes and streams in the Lake Tahoe basin area (Pierce 1932). Similarly, during the late 1920s, private individuals were stocking sections of the Upper Truckee River with brook trout (*Salvelinus fontinalis*) supplied by the Fish Commission[1] (Celio 1930). At the urging of the Mt. Ralston Fish Planting Club, the California Division of Fish and Game (which was to become the California Department of Fish and Game) closed the Upper Truckee to fishing in the late 1920s for a period of two to three years (Supernowicz pers. comm., Celio 1930). This closure precipitated a disagreement during the late 1920s and early 1930s between the fish planting club, the California Division of Fish and Game, and private interests in the basin. Neither the extent nor the effect of such introductions and closures is well documented (Supernowicz pers. comm.).

Ecology

The California Department of Fish and Game evaluates water management strategies and manages fish resources in the Upper Truckee River based, in part, on instream fish flow requirements (CDFG 1987). Based on channel morphology, substrate, water flows, and habitat type, the Department has divided the entire 34.6 km (21.5 mi) Upper Truckee River into five segments (Table C-2) (CDFG 1987).

Native fish species presently occurring in the Upper Truckee River include Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*), Lahontan redside

[1]The California Fish and Game Commission and the California Department of Fish and Game are different entities; the California Fish and Game Commission has been in existence since 1870 (CDFG 1999a). Ms. Celio's letter does not clarify the agency affiliation of the 'Fish Commission.'

Table C-1—Timber species characteristics and estimated volume for a timber stand within lands acquired from Carson and Tahoe Timber and Flume Company (USDA 1936).

		DBH				
		Av.		Max.		Estimated Percent cut
Common Name	**Scientific Name**	cm	(in)	cm	(in)	by Species
Jeffrey pine	*Pinus jeffreyi*	76	(30)	127	(50)	66.2
Sugar pine	*Pinus lambertiana*	107	(42)	152	(60)	12.3
White fir	*Abies concolor*	91	(36)	137	(54)	11.3
Red fir	*Abies magnifica*	66	(26)	76	(30)	6.6
Incense cedar	*Calocedrus decurrens*	99	(39)	152	(60)	3.6

Table C-2—Segment lengths and substrate characteristics of the Upper Truckee River as delineated by the California Department of Fish and Game (CDFG 1987).

Segment	Length		Location	Characteristics
1	10.5 km	(6.5 mi)	Lake Tahoe to Angora Creek	silt, sand and mud substrate
2	3.2 km	(2.0 mi)	Angora Creek to Echo Creek	cobble and gravel riffles; sandy pools
3	4.5 km	(2.8 mi)	Echo Creek to Benwood Creek	silt, sand, gravel, and boulder
4	1.8 km	(1.1 mi)	Benwood Creek to the end of Christmas Valley (base of Hawley Grade)	low gradient of approximately 0.7 percent
5	14.6 km	(9.1 mi)	Benwood Creek to the headwaters near Red Lake Peak	5 to 6 percent gradient with interspersed flat meadows

(*Richardsonius egregius*), Paiute sculpin (*Cottus beldingii*), and Tahoe sucker (*Catostomus tahoensis*) (CDFG 1987). Introduced species include brook trout (*Salvelinus fontinalis*), brown bullhead (*Ameiurus nebulosus*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*).

Rainbow trout and Paiute sculpin occur throughout most of the drainage. With the exception of Lahontan cutthroat trout which are stocked in the Upper Truckee River's headwaters, the remaining species generally occur in the lower gradient reaches downstream of the base of Hawley Grade (Segment 4) (CDFG 1987). Spawning and rearing of lake run rainbow trout, brown trout, Lahontan redside, and Tahoe sucker also occur in the lower gradient reaches downstream of the base of Hawley Grade (CDFG 1987). Table C-3 notes the California Department of Fish and Game optimum flow regimes for each of the segments of the Upper Truckee River; these regimes were determined independently for each segment (CDFG 1987).

Adult Lahontan cutthroat of the Heenan Lake strain were introduced annually in Taylor Creek and the Upper Truckee River from 1956 through 1964. However, it is believed that competition from, and to a lesser extent predation by brook trout and other non-native species prevented the establishment of a self-sustaining cutthroat population (Elliott pers. comm.). After the removal of brook trout in 1989, the California Department of Fish and Game restored Lahontan cutthroat trout to 6.4 km (4 mi) of the Upper Truckee River and its tributaries, upstream (south) of the confluence of

Table C-3—California Department of Fish and Game optimum flow regimes for each of the segments of the Upper Truckee River (CDFG 1987).

Segment	Optimization strategy
1	Optimize flows for brown trout spawning and incubation habitat from October 1 to March 31; optimize for rainbow trout spawning and incubation habitat April 1 to July 15; and, optimize for brown trout rearing habitat July 16 to October 1.
2	Optimize flows for lake run rainbow habitat from April 1 and July 15; optimize for rainbow trout rearing habitat July 16 to September 30; and, optimize for brown trout spawning and rainbow trout rearing habitat October 1 to March 30.
3	Optimize flows for rainbow trout spawning and incubation habitat from April 1 to July 15; optimize for rainbow trout rearing habitat from July 16 to September 30; and, optimize for brown trout spawning and rainbow trout rearing habitat October 1 to March 30.
4	Optimize flows for lake run rainbow trout habitat†.
5	The California Department of Fish and Game noted no specific flow objective for Segment 5 in their "Stream Evaluation Report 87-1" (CDFG 1987); however, the California Heritage Trout Program notes that Lahontan cutthroat trout have been restored to the Upper Truckee River, including tributaries, upstream of the confluence with Showers Creek (CDFG 1999b).

† Segment 4 requires maintenance of natural flow conditions all year long.

Showers Creek (CDFG 1987). Since 1989 annual removal efforts have continued and will continue as long as this effort indicates brook trout are present in this portion of the Upper Truckee River (Reiner pers. comm).

Grass Lake Natural Research Area and Osgood Swamp are two *Sphagnum* bogs located with in the Upper Truckee River watershed. For further discussion on these areas, see the account for bogs and fens in this appendix.

Effects of Human Activities

Aquatic communities of the Lake Tahoe basin have undergone a significant transformation since the arrival of Euro-American settlers. Grazing, logging, and development have affected virtually all aquatic ecosystems in the basin, and the stocking of exotic fish in waters in the Lake Tahoe basin (including naturally fishless lakes and drainages) has changed the character of the basin's fishery. Similarly, the Upper Truckee River has undergone notable change during this time period. Construction of the Tahoe Keys subdivision displaced Rowland's Marsh at the river's mouth, and the lower reaches of the Upper Truckee River were channelized and hydrologically modified by the construction of the South Lake Tahoe Airport (CDFG 1963, CWQCB 1999). Additionally, lower portions of the Upper Truckee River watershed have been adversely affected by the urbanization of Tahoe Valley. Activities such as the construction of housing developments, the construction and maintenance of two golf courses and Highway 50 have altered landscape features, changed surface run-off patterns, contributed to degraded water quality and introduced exotic plant species.

Effects from recreational activities to the Upper Truckee River watershed are somewhat difficult to quantify. Some lands in the drainage have been, and are being adversely affected to varying degrees by a variety of uses including dispersed motorized and nonmotorized recreation (USDA 1988). Additionally, concentrated recreation may trample vegetation, adversely affect streambank stability, and degrade water quality. In the past there was expressed concern regarding public access to certain portions of the river. However, recent land acquisitions such as the December 1998 purchase of Sunset Ranch by the California Tahoe Conservancy, will provide for future access (O'Daly pers. comm.). Specific impacts to aquatic and terrestrial components of the watershed from such stream-oriented recreation are difficult to predict, but could be expected to correlate roughly with the degree of development of recreational facilities.

Increasing human population levels in the basin also create other problems. To avoid eutrophication of Lake Tahoe, sewage is currently pumped out of the basin. Treated sewage has spilled several times in recent years along the Luther Pass pipeline that generally runs parallel to the Upper Truckee River, and on November 7, 1996 a spill of 5,000 gallons of treated wastewater went directly into the Upper Truckee (NDWP 1997). In an aquatic environment, wastewater spills have the potential to introduce viral and/or parasitic pathogens, raise bacteria levels, reduce dissolved oxygen, increase suspended solids, and/or stimulate algal blooms (EPA 1996, USGS 1997, USGS 1999). However, wastewater treated at the South Tahoe Public Utility District (STPUD) facility receives secondary treatment[2] and is pressure filtered before transport (Solbrig pers. comm.). Thus, the STPUD treatment facility is considered 'filter secondary' or 'advanced secondary' (Johnson pers. comm). Because such secondary wastewater treatment removes dissolved organic matter, is chlorinated, but does not appreciably reduce nitrates or phosphates, any impacts to the aquatic environment from wastewater spills would be expected to be related to ammonia (20 mg/l) and various chlorine compounds (3 mg/l), as opposed to pathogens (Johnson pers. comm, Solbrig pers. comm.). Given the degree of treatment and considering dilution rates, impacts from small wastewater spills from the STPUD sewage transport line would be expected to be minimal. (To reduce the potential for wastewater spills, the South Tahoe Public Utility District is actively replacing older segments of the sewage transport line [O'Daly pers. comm.].)

Conservation

For approximately the last 15 years, the water quality of tributaries to Lake Tahoe has been monitored to varying degrees by the following agencies and groups: Environmental Protection Agency, Joint Studies Group, Lahontan Region Water Quality Control Board, University of Nevada Reno, Nevada Division of Environmental Protection, Tahoe Research Group, USDA Forest Service, and US Geological Survey (TRPA 1996). Currently such monitoring is carried out by the latter 4 agencies and groups (TRPA 1996). Continuous monitoring data for an array of water quality components are lacking (e.g., pH, turbidity, fecal coliform bacteria). However, data compiled by Tahoe Regional Planning Agency indicate that the Upper Truckee River has exceeded the State of California's acceptable total nitrogen and biologically available iron levels for water years 1989 through 1993 and 1995; California total phosphorus concentrations were exceeded in water years 1981 through 1995 (TRPA 1996).

Pursuant to section 303(d) of the Clean Water Act, the Lake Tahoe watershed (ref. no. 16050101), has been listed by the State of California as a Category I (Impaired) Priority Watershed (CWRCB 1998). As such, it is subject to the Total Maximum Daily Load (TMDL) program. In accordance with section 303(d) criteria, TMDL monitoring levels for sediments and nutrients in the Lake Tahoe watershed are being developed by the Lahontan Region of the California Regional Water Quality Control Board. The Upper Truckee River is not noted on the 303(d) list; however, because of its contribution to the surface inflow to Lake Tahoe, restoration measures are needed to improve lake clarity (CWQCB 1999).

Although many of the water quality issues in the Upper Truckee River watershed are being coordinated at state and local levels, the majority of the watershed is presently managed by the USDA Forest Service, and while there is private ownership, both the USDA Forest Service and the State of California manage a significant portion of those lands immediately adjacent to the river. The

[2] Prior to 1989 wastewater from South Lake Tahoe received tertiary treatment and would meet potable drinking water standards (Solbrig pers. comm.).

California Department of Parks and Recreation manages the majority of state lands; however, several state agencies have agency-specific management priorities for the Upper Truckee River. As noted above, the California Department of Fish and Game manages fish resources based on optimum flow regimes. The Watershed Management Initiative of the California Department of Water Resources has directed their efforts in the Upper Truckee River to reduce sedimentation and nutrification, to restore wetland function, and to restore riparian areas and/or river morphology and function (CDWR 1998). The California Regional Water Quality Control Board is responsible for prioritizing activities in individual watersheds. They have established the following objectives: 1) "to enhance water quality in the Upper Truckee watershed of Lake Tahoe, through a concerted effort of implementing watershed projects improvement"; 2) "Use the Upper Truckee River Focused Watershed Group[3] as a clearinghouse for existing information"; 3) "Implement solutions for restoration of watershed function (related to water quality), as well as a reduction of sediment and nutrient inputs"; 4) "Upper Truckee River Focus Watershed Group, in coordination with Tahoe Citizen Environmental Action network, implements a proactive program of community outreach;" and, 5) "Evaluate water quality response to watershed management efforts to develop more effective implementation strategies" (CWQCB 1999, p. 5-6).

Management direction for those federal lands administered by the Lake Tahoe Basin Management Unit (LTBMU) is guided by the Unit's Land and Resource Management Plan (USDA 1988). The majority of the Upper Truckee watershed lands administered by the LTBMU are included in the Tahoe Valley and Meiss Management Areas. The Tahoe Valley Management Area includes the lower gradient reaches of the Upper Truckee River downstream of the base of Hawley Grade; the Meiss Management Area encompasses those reaches of the Upper Truckee from that point south to the headwaters.

Issues and concerns for the two management areas are quite different. In the Tahoe Valley Management Unit, most of the national forest system land is at the urban interface. As such, many of the management issues involve concerns such as dispersed motorized and nonmotorized recreation, stream-oriented recreation, forest health, and risk of fire (USDA 1988). By contrast, the concerns for Meiss Management Area focus on wildlife management issues; the area is closed to all vehicles and grazing is permitted (USDA 1988). Currently Management Standards for the Meiss Grazing Allotment are being analyzed; the environmental analysis will consider water quality tests on the Upper Truckee River that indicate California standards for fecal coliform bacteria levels were exceeded several times in 1999 due to grazing allotment utilization (O'Daly 1999).

The primary resource management emphasis for the Tahoe Valley Management Area is meeting recreational, scenic and special use demands (USDA 1988). The primary resource management emphasis for the Meiss Management Area is to "…provide a variety of unroaded non-motorized recreation experiences and to protect scenic conditions" (USDA 1988, p. IV-140). Management Practices for both areas include 'nonstructural' and 'structural' fish habitat management strategies. However, the 'Standards and Guidelines' differ as noted in Table C-4. Differences in wildlife management habitat strategies are also noted in Table C-4.

Further protection may lie in the future for the Upper Truckee and its watershed. In February of 1999, the LTBMU Forest Supervisor recommended the National Forest portion of the Upper Truckee River, south of Christmas Valley, for Wild River designation under the Wild and Scenic Rivers Act authority. This recommendation has been forwarded to higher Forest Service levels, and planning direction is in place to protect the river corridor from changes that could adversely affect Congressional Wild River designation. (O'Daly pers. comm.)

[3] To coordinate and focus watershed improvement activities, the California Regional Water Quality Control Board, in cooperation with TRPA, established the Upper Truckee River Focused Watershed Group (UTRFWG) in 1995; the Regional Water Quality Control board serves as the group's facilitator (CWQCB 1999). UTRFWG "…is currently collaborating with the U.S. Army Corps of Engineers (Corps) to develop a comprehensive watershed plan…" (Adair pers. comm).

Table C-4—Lake Tahoe Basin Land and Resource Management Plan Practices, Standards and Guidelines for the Meiss and Tahoe Valley Management Areas† (USDA 1988).

Management Area	Practice	Standard and Guideline
Meiss	Nonstructural Wildlife Habitat Management	Protect or improve wildlife in meadow areas
	Nonstructural Fish Habitat Management	Assist the California Department of Fish and Game in the reintroduction of Lahontan cutthroat trout
	Structural Fish Habitat Management	Improve fish habitat in meadow areas.
Tahoe Valley	Structural Wildlife Habitat Management	Waterfowl nesting islands and tubs at Pope Marsh will be maintained. Tubs will be replaced by nesting islands in cooperation with the California Department of Fish and Game
	Nonstructural and Structural Fish Habitat Management	Improve conditions on the Upper Truckee River for migratory and resident trout.

† For a complete list of Practices, Standards and Guidelines for these areas, please consult the LTBMU Land and Resource Management Plan (USDA 1988).

Additionally, an executive order issued by President Clinton recently directed the Forest Service to prepare an Environmental Impact Statement affording roadless areas, including portions of the Upper Truckee watershed, protection from logging, road building, and other activities. This designation would not change the way the area is currently managed, as those activities are already prohibited (O'Daly pers. comm.).

While the aforementioned management directions provide for general conservation and management strategies, consideration should be given to developing a specific management plan for the Upper Truckee River in the context of how the biological integrity of aquatic ecosystems in the basin would be maintained and improved. Due to the diversity of issues and interests, such a plan should include a concerted effort to involve various local, state, and federal agencies, along with residents and special interest groups.

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Focal Aquatic Ecosystem and Ecologically Significant Area: Bogs and Fens
By Erik M. Holst

Distribution

Bogs

Moyle (1996) classified bogs as 'unique' in the Great Basin Province of the Sierra Nevada, i.e., only one or two examples exist. Burke (1987) noted that bogs were rare in Northern California, occurring in El Dorado, Nevada, Placer, Plumas, and Sierra counties. The following bogs have been noted in the Lake Tahoe basin (see Issue 5, Chapter 5):

Grass Lake (Grass Lake Moss Bog), a true quaking bog, comprises part of the 146 ha (360 acre) Grass Lake Research Natural Area (RNA) and is the largest quaking bog in California; it is located southeast of Lake Tahoe near Luther Pass (Burke 1987).

Osgood Swamp (Osgood Bog), with an area of approximately 6 ha (15 ac), is located south of Lake Tahoe near the bottom of Meyers Grade.

Hell Hole, with an area of approximately 4 to 6 ha (10 to 15 ac) at 2,560 m (8,400 ft) in elevation, is located south of Lake Tahoe and north northeast of Grass Lake.

No studies have been done to confirm the classification of the latter two sites as bogs.

Fens

Moyle (1996) considered fens 'unusual' in the Great Basin Province of the Sierra Nevada. The literature (Burke 1987, USDA 1988) suggests that there are no fens in the basin, a hypothesis supported by Smith (pers. comm.) and Allessio (pers. comm.). However, Sawyer and Keeler-Wolf (1995) note that bogs and fens are often quite difficult to distinguish from one another, and Burke (1987) notes that fens and bogs intergrade with each other. Thus, although the potential for fens exists in the Lake Tahoe basin, none are noted in this account.

Ecology

Bogs

Bogs are ombrotrophic (rain-fed) peat-containing wetland communities typically composed of species of bryophytes such as *Sphagnum* that form in areas with little or no drainage (Hale 1999). Because bogs primarily derive their nutrients directly from precipitation, they are oligotrophic (nutrient poor) (Purdue University 1997, Dennison and Berry 1993). Additionally, the accumulation of dead plant material (peat) and the nutrient poor water makes bogs highly acidic, with a pH between 3.0 and 4.5 (Burke 1987, Gore 1983).

In general, because bogs lack nutrients and mineral soil and are highly acidic, they have a low plant diversity relative to other wetland communities (Dennison and Berry 1993). However, they provide the only suitable habitat for some species in the Lake Tahoe basin. Various species of bryophytes and lichens may be present in bogs; however, *Sphagnum,* with a low mineral nutritional requirement and tolerance for acidic water, tends to dominate, growing in dense mats (UOP 1995). Acidic water is not required by *Sphagnum* (Dennison and Berry 1993), but "*Sphagnum* is capable of altering the chemistry of its environment in the direction of its own optimal growth conditions by releasing hydrogen ions and increasing the acidity of the surrounding water" (UOP 1995).

Dennison and Berry (1993) identify three types of bogs: basin bogs, blanket bogs, and string bogs. *Basin bogs* (also called raised bogs) occupy depressions in the landscape such as former ponds and shallow lakes. Peat develops in these depressions building up layers and emerging above the surrounding landscape, creating a domed profile. Peat can also grow out across the bodies of water forming a floating island of dense *Sphagnum* moss called a quaking bog (Dennison and Berry 1993). *Blanket bogs* grow across the landscape. Generally starting out in shallow depressions, blanket bogs are created as peat spreads out in a layer across the landscape on gentle slopes in association with a water source (Dennison and Berry 1993, Johnson 1985). *String bogs* develop on slopes on undulating topography; they are essentially a series of bogs broken up by pools (Dennison and Berry 1993). In each of these bog types, the final landform is created as peat layers accumulate, divorcing the surface vegetation from the underlying substrate (Dennison and Berry 1993).

The classification of the three bogs noted in this account is in doubt. Of the three bogs noted in this report, the Lake Tahoe Basin Management Unit only has water chemistry data for Grass Lake. With a pH of 5.5 to 6.0 (Stewart 1978), Grass Lake appears less acidic than most bogs (Burke 1987, Gore 1983). However, other chemical characteristics and an analysis of the Grass Lake phytoplankton and zooplankton indicate that it is basically consistent with Midwestern United States bog characteristics (Stewart 1978). No studies examining the water chemistry, physiography, or vegetation of the latter two sites have been done.

Grass Lake (Grass Lake Moss Bog)--Grass Lake has been described as a transition between a fen and a bog, and although water is derived from three permanent streams and several seeps, Grass Lake is considered a *Sphagnum* bog (Burke 1987). It is the largest *Sphagnum* bog in California, and at an elevation of 2,347 m (7,700 ft), it exceeds the characteristic elevational range for Sierran peatlands (Burke 1987).

Grass Lake hosts several bog associated orchids and carnivorous plants. Three species of orchids that occur in the Grass Lake bog are: *Platanthera leucostachys* (white-flowered bog-orchid), *Platanthera sparsiflora* (sparse-flowered bog-orchid), and *Spiranthes romanzoffiana* (Burke 1987). Carnivorous plants include *Dosera rotundifolia* (sundew), *Utricularia minor*, and *Utricularia vulgaris* (common bladderwort) (Burke 1987).

Burke (1987) notes that the bog and associated meadow plant communities of Grass Lake Research Natural Area (RNA) are diverse. Based on the work of Beguin and Major (1975), Burke (1987) noted five wetland plant associations of Grass Lake (Table C-5).

Millar et al. (1996) recognized Grass Lake as a Significant Natural Area.

Osgood Swamp (Osgood Bog)--Osgood Swamp is located near Highway 50 at the base of Flag Pole Peak near the bottom of Meyers grade. Under private ownership in the 1960s, Osgood Swamp was drained; however, after it was acquired by the Forest Service in the 1970s, the natural moraine dam was restored with gabion structures, bringing the water level back to approximately its natural depth (Allessio pers. comm.).

During the early 1990s, the water level in Osgood Swamp lowered allowing lodgepole pine (*Pinus contorta*) to encroach into the meadow area (Derrig pers. comm.). However, by 1997, beaver (*Castor* canadensis) activity reinforced the man-made gabion dams raising the water level and forming a year-round lake (Derrig pers. comm.). Prior to the water level receding in the early 1990s, Derrig (pers. comm.) noted brook trout in Osgood Swamp; however, the lake is presently fishless.

The lake at Osgood is fed by several sources and has one outlet stream. Derrig (pers. comm.) estimated the flow out of Osgood Swamp to vary between 0.06 and 0.34 cubic meters per second (2 and 12 cubic feet per second), depending on the season.

Millar et al. (1996) recognized Osgood Swamp as a Significant Natural Area.

Osgood Swamp is an area of interest to wildflower enthusiasts and botanists. Barbour and Major (1977, p. 620) describe the flora of Osgood Swamp as "similar to that at Grass Lake, but richer in uncommon species." Over 140 species of wildflowers can be found in Osgood Swamp and its environs (Carville 1997). Carville (1997) noted several "highlighted flowers" (flowers of particular appeal) at Osgood Swamp (Table C-6).

Hell Hole--Hell Hole is a boreal bog in a cirque basin with steep granitic walls. Ponds, up to one-quarter acre in size, are scattered throughout the bog. Hell Hole is the location of the only known population of mountain yellow-legged frogs (*Rana muscosa*) in the basin (Manley and Schlesinger in preparation). It is likely that the frogs are able to persist there because the drainage is fishless (Reiner pers. comm) and Hell Hole contains several deep sinkholes that allow frogs and tadpoles to overwinter (Schlesinger pers. comm.). Hell Hole has never been logged, and although it has been grazed, impacts are minimal to moderate (Reiner pers. comm). Although the Hell Hole area has been inventoried and the streams classified, no scientific studies aimed at

Table C-5—Wetland plant associations of Grass Lake (Burke 1987).

Association	Association name	Common name	Primary species
Moss and *Sphagnum*	Drepanoclado-Utricularietum	Brown Moss-Bladderwort	*Drepanocladus fluitans, Utricularia vulgaris*
	Mimulo-Caricetum limnosae	Monkeyflower-Shoresedge	*Carex limosa, Menyanthes trifoliata, Drepanocladus fluitans, Sphagnum squarrosum*
Large Sedge	Caricetum simulato-rostratate	Long & Short-beaked Sedges	*Carex utriculata, Carex simulata,*
	Caricetum simulato-vesicariae	Shortbeak-Inflated Sedge	*Carex vesicaria*
	Caricetum nebraskesis	Nebraska Sedge	*Deschampsia caespitosa, Muhlenbergia filiformis, Aster alpigenus var. andersonii*
Meadow	Junco-nev.-Welecharitetum	Nevada Rush-Spikerush	*Juncus nevadensis, Eleocharis pauciflora, Carex simlata*
	Poa-Caricetum intefrae	Mountain Bluegrass-Smooth Beaked Sedge	*Carex integra, Poa cusicka ssp. epilis, Penstemon oreocharis var. rydbergii, Erigeron penegrinus.*
Shrubby	Kalmino-Pinetum	Alpine Laurel-Lodgepole Pine	*Pinus contorta, Kalmia polifolia ssp. microphylla, Vaccinium uliginosum ssp. occidentale, Salix orestera, Lonicera cauriana, Ledum glandulosa*
	Salicetum rigidae	Willow Thicket	*Salix rigida**
Streamside Ephemeral	Sagino-Gnaphalietum		*Sagina saginoides, Gnaphalium palustre, Rorippa curvisiliqua, Tofieldia occidentalis ssp. occidentalis, Mimulus suksdorfii*
	Torreyochloetum pauciflorae		*Torreyochloea pauciflorae*

*Taxonomy as stated in Burke (1987); not found in other sources.

Table C-6—Highlighted flowers of Osgood Swamp Botanical Preserve (Carville 1997).

Scientific name	Common name
Aconitum columbianum	Monkshood
Triteleia hyacinthina	White brodiaea
Gentianopsis simlex	Hiker's Gentain
Lupinus fulcratus	Green-stipuled lupine
Nuphar luteum ssp. polysepalum	Yellow pond lily
Pyrola minor	Common wintergreen
Sisyrinchium elmeri	Mountain yellow-eyed grass
Sisyrinchium idahoense	Blue-eyed grass

classifying the site have been undertaken (Reiner pers. comm).

Fens

Fens, in contrast to bogs, are minerotrophic peatlands (receiving nutrients from the rock substrate via water flow); they receive nutrients from groundwater as well as precipitation (Sawyer and Keeler-Wolf 1995). The water in fens is less acidic than that of bogs; the pH in fens ranges between 5.0 and 8.0 (Burke 1987, Gore 1983). No fens have been identified in the Lake Tahoe Basin.

Effects of Human Activities

As an RNA, Grass Lake is managed according to the established "Protection and Management Standards" for RNAs (USDA 1994); it is managed to maintain natural processes and biodiversity. It is worth noting that prior to the establishment of Grass Lake as a RNA in 1991, Burke (1987) cited camping and firewood collection as having damaging impacts to the Grass Lake bog. Under present RNA management direction, camping and firewood collection are not permitted; cross country skiing is permitted (USDA 1988). Additionally, the RNA has been withdrawn from mineral entry and excluded from grazing allotments (USDA 1991).

Burke (1987) considered salt run-off from the deicing of Highway 89 to be the most serious impact to the Grass Lake bog. The "Establishment Record for Grass Lake RNA" similarly notes salting to de-ice as a concern and indicates coordination efforts to develop a 'highway maintenance prescription' (USDA 1991); however, the California Department of Transportation states that road salt continues to be used to de-ice Highway 89 adjacent to Grass Lake RNA (Brannon pers. comm.).

Recently it was discovered that a sewer line belonging to the South Tahoe Public Utility District runs through the Grass Lake RNA. The sewer line needs replacing, and although the District has an easement that includes the right to replace it in the present alignment (through the RNA), they have agreed to place the new sewer line along the shoulder of Highway 89 (O'Daly pers. comm.).

Osgood Swamp is included in the Tahoe Valley Management Area of the Lake Tahoe Basin Management Unit Land and Resource Management Plan (USDA 1988). It is managed as a wetland under 'Management Prescription #8,' which states, "Manage wetlands for their watershed, wildlife, fish, and scenic values. The prescription recognizes the critical importance of wetlands in filtering sediment and nutrients before they reach Lake Tahoe. In most situations, protection from disturbance or unnatural encroachment would be the principal action" (USDA 1988, p. IV-48). 'Management Practice 35' of the Lake Tahoe Basin Management Unit Land and Resource Management Plan provides for monitoring and management of Osgood Swamp to protect its special features for possible future evaluation as a special study area such as a RNA (USDA 1988).

Hell Hole is included in the Freel Peak Management Area of the Lake Tahoe Basin Management Unit Land and Resource Management Plan and is recognized as a recreational attraction (USDA 1988). Like Osgood Swamp, Hell Hole is included in 'Management Prescription #8' and 'Management Practice 35' and is being managed and monitored to protect its special features (USDA 1988). Unlike at Osgood Swamp, grazing is permitted in the Hell Hole area (O'Daly pers. comm.). The effects of grazing at Hell Hole have not been quantified, but could include removing riparian vegetation, degrading water quality, trampling vegetation, and eroding stream banks (Moyle et al. 1996).

In general, any human activities that change water flow into or out of bog areas have the potential to seriously degrade or destroy the bog environment. Similarly, activities that change the water chemistry of bogs may adversely affect these wetland communities. At present, management considerations of the above described *Sphagnum* bogs in the Lake Tahoe basin essentially preclude such potentially damaging land use activities. However, other human activities that could potentially degrade bogs in the Lake Tahoe basin include introduction of exotic species, grazing, off-highway vehicle use, mountain biking, equestrian use, firewood collection, and trampling by recreationists.

Conservation

Wetland areas across the lower 48 states have declined 53 percent over approximately the last 200 years (Doyle 1998). Although this overall percentage includes wetlands and riparian areas that were lost to agriculture along mainstem rivers and floodplains, Kondolf et al. (1996) noted that riparian areas in the Sierra Nevada have also been impacted by human activities. Similarly, Moyle (1996, p. 948) noted, "The diversity of natural aquatic habitat types in the Sierra Nevada is in the process of being diminished."

In the Great Basin Province of the Sierra Nevada, *Sphagnum* bogs were found to be 'unique' and of 'special concern' (Moyle 1996) and as such, merit a high degree of conservation. However, as previously noted in this chapter, the first step in the monitoring and conservation of an aquatic system is to have an accurate inventory of their number and locations within the Lake Tahoe basin. The location of three bogs is known, but others, particularly those of smaller size, potentially exist. Thus, it is apparent that while protecting the known *Sphagnum* bogs, additional conservation efforts should include inventory. If other *Sphagnum* bogs are noted in an inventory process, conservation efforts similar to those in place for Grass Lake could be considered.

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Ecologically Significant Area: Deep-water Plant Beds
By Erik M. Holst

Distribution

The deep-water plant bed (macrohydrophyte) assemblage was first documented in Lake Tahoe by Frantz and Cordone (1966) while taking benthic samples using an Ekman grab. They noted deep-water plant beds to a depth of 100 m (328 ft), at which point plant densities decreased, apparently due to the reduction in light. Further analysis by Frantz and Cordone (1967) indicated macrohydrophytes were most dense between approximately 45 m and 105 m (150 and 350 ft) in depth. Beauchamp et al. (1992) noted that each of the two deep water plant beds in the southeast part of Lake Tahoe occupied an area of approximately 2,000 m^2.

Only two occurrences of deep-water plant beds in Lake Tahoe have been confirmed (see Issue 6, Chapter 5). Complete surveys for these plant beds have not been conducted, but Hall (in preparation) has developed a model of potential locations of deep-water plant beds (see Issue 6, Chapter 5). The model used depth and substrate information from Frantz and Cordone (1967) and Loeb and Hackley (1988) as well as Lake Tahoe bathymetry data (Gardner et al. 1998) to predict the occurrence of deep-water macrophytes in the lake. Preliminary surveys to confirm the presence of these deep-water plant beds are planned (K. Johnson, pers. comm.).

Ecology

Frantz and Cordone (1967) described 6 species of algae, 10 mosses, and 2 liverworts as components of Tahoe's deep-water plant bed assemblage (Table C-7); however, several moss identifications have recently been questioned (Shevock pers. comm.). Macrohydrophyte composition varied with depth. *Chara* was frequent at depths less than 30.5 m (100 ft); bryophytes were prevalent between approximately 31—137 m (100—450 ft), and algae generally occurred at depths of 61—137 m (200—450 ft), (Frantz and Cordone 1967).

The overall distribution of these deep-water macrohydrophytes appears to be controlled by light penetration and substrate type (Frantz and Cordone 1967). This hypothesis is based on plant density, depth, and substrate distribution data. Plants were most abundant under reduced light and did not appear to tolerate light intensities of shallower depths. Deep-water macrohydrophyte densities were low at depths less than 30 m (100 ft) and declined rapidly after approximately 100 m (328 ft) (Frantz and Cordone 1967). Deep-water plant bed distribution appeared to be restricted to substrates consisting of mud and silt (Frantz and Cordone 1967).

Distribution of the plant beds across Lake Tahoe was fairly consistent with the above criteria, the only exception being the presence of *Chara* at a depth of approximately 6 m (20 ft) at the south end of the lake. The presence of this associate of deep-water plant beds was attributed to a substrate formed by deposition of fine sediment by the Upper Truckee River (Frantz and Cordone 1967). Additionally, carbon dioxide levels and thermal considerations resulting from strong currents in shallower depths of Tahoe may influence deep-water plant bed distribution (Frantz and Cordone 1967).

Frantz and Cordone (1996) noted that deep-water plant beds provided habitat for invertebrates, including several species endemic to Lake Tahoe. Further, they noted that the depth distribution of gastropods, plecopterans, and pelecypods essentially correlated with that of the deep-water plant beds. *Capnia lacustra* is a small wingless stonefly that is endemic to Lake Tahoe and is associated with the deep-water macrohydrophyte assemblage (Frantz and Cordone 1996). This unique stonefly spends its entire life cycle at depths ranging from 60 to almost 275 m (200 to 900 ft) in Lake Tahoe (Frantz and Cordone 1996). (For further discussion, see the focal species account for the Lake Tahoe benthic stonefly, Issue 7, Chapter 5.)

Data on the potential impacts to Tahoe's deep-water plant beds by the nonnative crayfish (*Pacifastacus leniusculus*) are incomplete and somewhat conflicting. Frantz and Cordone (1967, p. 713) suggested, "Crayfish may exert some influence on the distribution of exotic plants. They (crayfish) are

Table C-7—Deep-water plants found in Lake Tahoe (Frantz and Cordone 1967)

Category	Family	Taxon	Depth in meters
Chlorophyta	Charophyceae	*Chara contraria*	38.7
	(stoneworts)	*Chara delicatula var. annulata*	7.0—45.7
		Chara delicatula var. barbata	61.0
	Chlorophyceae	*Cladophora glomerata*	59.1—125.3
	(grass-green algae)	*Zoochlorella parasitira*	38.7
Chrysophyta	Xanthophyceae (yellow-green algae)	*Vaucheria sp.*	53.3—110.3
Cyanophyta (blue-green algae)	Myxophyceae	*Schizothrix calcicola*	30.5
Bryophyta	Amblystegiaceae	*Hygrohypnum sp.**	121.9
(mosses)		*Hygrohypnum molle*	68.6—91.1
		Hygrohypnum palustre	88.4
		Leptodictyum riparium	30.5—121.9
		Leptodictyum riparium forma fruitans	76.5
	Brachytheciaceae	*Brachythecium sp.*	104.2
		Eurhynchium sp.	100.3—121.9
	Fissidentaceae	*Fissidens adiantoides*	68.3
		Fissidens grandifrons	74.4—121.9
	Fontinalaceae	*Fontinalis nitida*	121.9
	Neckeraceae	*Porothamnium bigelovii*	100.3—119.5
Hepatophyta	Blepharostomataceae	*Blepharostoma arachnoideum*	100.3—110.3
(liverworts)	Geocalycaceae	*Chiloscyphus fragilis*	60.7—121.9

Species and depth information from Frantz and Cordone (1967). Taxonomy from Schuester (1979) and Vitt (1984).

*Identification not certain

very abundant in Lake Tahoe and are known to feed on vegetation." Beauchamp et al. (1992) documented crayfish to a depth of 40 m (131 ft) in autumn and winter in the vicinity of the macrohydrophytes in the southeast region of Lake Tahoe, but crayfish were not found in the beds of *Chara*. Further research is needed on the potential effects of crayfish grazing.

In addition to providing habitat for invertebrates, deep-water plant beds are used by nonnative fish. Beauchamp et al. (1992) noted lake trout (*Salvelinus namaycush*) spawning over beds of *Chara delicatula*. They further documented lake trout congregating around mounds of macrohydrophytes in the southeast region of Lake Tahoe at a depth of 45—55 m (147.6—180.0 ft) during the months of September, October and November. Given the significance of the introduced lake trout as a Tahoe game fish, this unusual spawning behavior has important fishery management implications; however, little is known of the potential ecological impacts of lake trout to the deep-water macrohydrophyte assemblage.

Frantz and Cordone (1966, 1967, and 1996) provide baseline information regarding the unique deep-water plant bed complex. However, given the decline in Lake Tahoe's clarity since these data were collected (see Chapter 4), changes in this assemblage have no doubt occurred. Detailed, long-term scientific research is needed to assess Tahoe's deep-water macrohydrophytes and their associations. Given the decline in lake clarity and increase in algal growth (discussed below), it is clear that such research and coordination should begin immediately. The contribution of universities toward this scientific research should not be overlooked; to the contrary, land management agencies and academic institutions should both encourage dialogue and coordinate research efforts.

Effects of Human Activities

Data on effects of human activities on Lake Tahoe's deep-water plant beds and their associated benthic invertebrate assemblages are sparse. However, various studies (e.g., Frantz and Cordone

1996, Jassby et al. 1999) have made clear that human activities that lead directly or indirectly to increases in phytoplankton and/or sediment transport will decrease lake clarity; such decreases in clarity will have an adverse impact on deep-water plant beds. As Frantz and Cordone stated (1966, p. 30) stated, "Should further significant enrichment occur, reduced light penetration might permanently eliminate this unique plant community." Recent Lake Tahoe clarity data indicate that the average annual Secchi depth has dropped approximately 7.5 m (24.8 feet) in the last 30 years (Jassby et al. 1999); the 1998 Secchi depth of approximately 20 m (66 ft) was the second worst year on record behind 1997 (UCD 1999). Correspondingly, data indicate that algal growth, which along with suspended fine sediments directly decrease lake clarity and light penetration, has been increasing at a rate of greater than 5 percent per year (Reuter et al. 1996).

Given the dependence of Lake Tahoe's unique deep-water macrohydrophyte assemblage on water clarity, management scenarios that directly or indirectly promote eutrophication or sediment transport should be approached cautiously. Actions such as prescribed fire should, at a minimum, employ Best Management Practices (BMPs) to prevent sediment transport into aquatic systems. Jassby et al. (1999 p. 294) note "[I]n deep lakes such as Tahoe, it is not enough to institute erosion control measures that target total suspended sediment discharge if the relevant-sized (light-attenuating) particles continue to get through unhampered. Indeed, the larger, less important particles are most likely to be removed by watershed management practices, and the resulting improvements to the lake may be far less than anticipated." Thus, there may be a need to reevaluate, redesign, and/or institute new BMPs in order prevent transport of these smaller size particles. Finally, atmospheric deposition or airborne pollutants is known to decrease lake clarity (see Chapters 3 and 4), so management scenarios should also consider impacts to air quality (Jassby et al. 1999, Reuter et al. 1996).

Conservation

Efforts should be made to protect known and discovered deep-water plant beds from anthropogenic stresses. Additionally, management considerations might include actions targeted at improving lake clarity and reducing potentially damaging ecological impacts from introduced fauna and flora.

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Ecologically Significant Area: Aspen
By J. Shane Romsos

Distribution

Quaking aspen (*Populus tremuloides*) is the most widely distributed tree in North America (Howard and Tirmenstein 1996). In the Sierra Nevada, more than 80 percent of aspen is distributed north of the Middle Fork of the San Joaquin River (Potter 1994). In the Lake Tahoe Basin, aspen communities occur infrequently in relatively small and irregularly distributed patches that range from a few square meters to 23 hectares (57 acres) (USDA 1991). Aspen communities can be found at all elevations in the basin except alpine ridgelines, and are most common between 6,230 and 8,000 feet (1920 – 2468 m). The distribution of aspen communities in the basin appears to be related to the availability of a consistent source of moisture. In general, aspens are associated with climates with long and cold winters and a heavy snow pack (Verner 1988).

Potter (1994) identified two quaking aspen plant associations in the central and southern Sierra Nevada: the quaking aspen/California corn lily (*Veratrum californicum*) association (POTR/VECA) and the quaking aspen/mountain pennyroyal (*Monardella odoratissima*) association (POTR/MOOD). The POTR/MOOD association differs from the POTR/VECA association in that it typically occurs on relatively dryer upland sites (Potter 1994). In the Lake Tahoe Basin, both quaking aspen plant associations occur.

Ecology

Key Physical and Biological Characteristics

Aspen communities are good indicators of mesic soil conditions as a high water table during the early part of the growing season is necessary for aspens' establishment and productivity (Verner 1988). Soils that support aspen are derived from volcanic and granitic parent material and stands are typically situated on alluvial and colluvial deposits or glacial outwash deposits (Potter 1994). Topsoils that support aspen range from 5 to 94 cm (2 – 38 inches) deep (average topsoil depth = 30 cm [12 inches]) (Potter 1994) and most productive stands are established on well drained sandy to silt loam soils (Debyle and Zasada 1980). In general, deep soils, finer soil textures, and a low amount of coarse fragments throughout the soil profile support a high water holding capacity thought to be ideal for supporting aspen (Potter 1994). Soils typically lie over fractured parent material, which allows rooting and supplies additional moisture (Potter 1994).

Aspen communities are typically found on gentle to moderate slopes (< 33 percent, averaging 12 to 18 percent), occupy toeslopes, benches and valley-like situations, and do not require a specific aspect as long as solar radiation is moderately high to high (Potter 1994). Streams, creeks, seeps, lake shores, and meadows typify ideal growing conditions for aspen (Verner 1988, Potter 1994). Aspen communities are located within red fir (*Abies magnifica*), Jeffrey pine (*Pinus jeffreyii*), white fir (*Abies concolor*), lodgepole pine (*Pinus contorta*), western juniper (*Juniperus occidentalis*) and mixed conifer zones (Verner 1988, Potter 1994). High aspen cover, with relatively little hardwood and conifer tree species co-dominating, is characteristic of the upper tree canopy in aspen communities (Potter 1994). Aspen can also occur as an understory layer beneath a scattered overstory layer of conifers. Canopy cover is lower in mature aspen stands (25 to 60 percent) than in young and intermediate aged stands (60 to 100 percent) (Verner 1988). Aspens can reach a height of 18 m (60 feet) and a diameter of 0.6 m (2 feet) with extreme tree heights of up to 30 m (100 feet) and diameters of up to 1 m (3 feet) (Verner 1988). Trees within an aspen stand are genetically similar as new individuals are cloned from a few pioneer trees (Verner 1988). Aspens most commonly spread by root suckering (Verner 1988, Howard and Tirmenstein 1996), where stems sprout from roots, and to a lesser extent from seed (Howard and Tirmenstein 1996). Stands are composed of a few to thousands of stems usually in a mosaic of clones of different ages and sizes (Verner 1988).

A shrub layer is generally not predominant in aspen communities. However, creeping snowberry (*Symphoricarpos acutus*), sagebrush (*Artemisia tridentata*), squaw currant (*Ribes cereum*), and Sierra gooseberry (*Ribes roezlii*) are known as shrub associates (Potter 1994).

A rich variety of ground cover plants known as moist site indicators is common in aspen communites (Potter 1994). Ground cover is generally dominated by a mix of mountain sweet-cicely (*Osmorhiza chilensis*), Fendler's meadow rue (*Thalictrum californicum*), arrowhead butterweed (*Senecio triangularis*), California corn lily, Kellogg's bedstraw (*Kelloggia galioides*), Gray's lovage (*Ligusticum grayi*), common yarrow (*Achillea lanuosa*), yellow brodiaea (*Brodiaea lutea*), wandering daisy (*Erigeron peregrinus angustiflolius*), white-flowered *hawkweed (Hieracium albiflorum*), pine-woods lousewort

(*Pedicularis semibarbata*), Parish's yampa (*Perideridia parishii*), western bracken fern (*Pteridium aquilinum*), mountain violet (*Viola purpurea*), Wright's blue-eyed mary (*Collinsia torreyi wrightii*), mountain tansy mustard (*Descurainia richardsonii incisa*), mountain pennyroyal, Anderson's thistle (*Cirsium andersonii*), narrow-leaved collomia (*Collomia linearis*), Jessica's stickseed (*Hackelia jessicae*), Coville's gayophytum (*Gayophytum eriospermum*), California butterweed (*Senecio aroniciodes*), Brewer's angelica (*Angelica breweri*), Sierra wallflower (*Erysimum perenne*), Douglas' knotweed (*Polygonum douglasii*), and mountain mule-ears (*Wyethia mollis*) (Potter 1994).

Successional Stages

Succession proceeds rapidly following natural disturbances such as fire. Typically an herbaceous layer is the first to establish followed by shrub and tree seedlings approximately 5 years after disturbance, given ideal conditions and an absence of grazing (Verner 1988, Howard and Tirmenstein 1996). Within 10 to 15 years, a pole-stage develops and matures within 30 years (Verner 1988). Because aspens are intolerant of shade, shade tolerant conifer species may eventually replace an aspen community (Verner 1988). However, conifer tree invasion into aspen stands is very slow (Verner 1988). Intact stands of aspen have been reported to reach ages of 200 years (Debyle and Zasada 1980).

Contribution to Biological Diversity

Maintaining aspen communities in the Lake Tahoe Basin is critical because they provide important landscape features used by a diversity of wildlife (Manley and Schlesinger in prep.), invertebrates, fungi, and plants (Debyle and Zasada 1980, Verner 1988, Potter 1994). Birds and mammals use aspen for hiding, nesting, thermal cover, and foraging, though they are not entirely dependent on aspen communities (Verner 1988). Young stands of aspen, especially during fall and winter when protein content of aspen is high relative to other shrub species, provides forage for deer (Tew 1970, Bartos and Johnson 1978). Black bears (*Ursus americanus*) forage on berry-producing plants and forbs that establish in the understory of aspen stands and can provide suitable denning sites (DeByle 1985). Lagomorphs eat quaking aspen buds, twigs, and bark year-round (Brinkman and Roe 1975, DeByle 1985). Aspen is an important plant species for beavers (*Castor canadensis*) as stems are used to construct dens and lodges, and leaves, twigs, and bark provide food. Small rodents, including squirrels, pocket gophers, mice and voles, feed on aspen during at least part of the year (Jones and DeByle 1985). The highest densities of rodents in aspen communities are generally found in mature stands (Probst and Rakstad 1987).

Aspen communities attract a variety of bird species due to microclimatic features and physical characteristics. Because aspen communities occur on mesic sites, insect production compared to dryer and adjacent forest and shrubland is greater, making aspen communities more attractive to insectivorous birds (Verner 1988). Brinkman and Roe (1975) reported that aspen were also important for herbivorous birds, such as Ruffed Grouse (*Bonasa umbellus*), because aspen catkins, buds, and leaves provided a substantial and nutritious food source. Not only do aspen communities provide opportunities to forage, they also are suitable for cover and nesting. DeByle (1981) estimated bird densities of 22 to 65 breeding pairs in aspen stands measuring 4 hectares (9.8 acres). Because aspen is a relatively soft wood, and often times is infected with a variety of fungi, many cavity excavating and cavity nesting birds commonly occur in aspen stands during the nesting season. Other birds, such as Dark-eyed Juncos (*Junco hyemalis*) and White-crowned Sparrows (*Zonotrichia leucophrys*), find suitable ground nesting habitat in the leaf litter of aspen. Canopy nesting birds, such as Northern Goshawk (*Accipiter gentilis*), Western Wood-pewee (*Contopus sordidulus*), Western Tanager (*Piranga ludoviciana*), and vireos (*Vireo spp*.) will also nest in aspen groves (DeByle 1985).

Response to Disturbance

Soil type, solar exposure, and disturbance appear to be important for the stability of aspen communities (Verner 1988, Cryer and Murray 1992, Potter 1994). As an aspen stand matures, a nutrient rich mollic soil layer develops. Aspens thrive in this rich humus layer, but over time stands will degenerate without disturbance. As a stand deteriorates, amendments to and nutrients in the organic layer are reduced, and in turn the demise of the stand is perpetuated. Low to moderate intensity burning tends to maintain productive aspen stands on ideal soil types (Schier and Campbell 1978, Howard and Tirmenstein 1996). A deteriorating aspen stand that is burned may be more likely to revert back to a more productive stand because burning increases soil pH and adds organic carbon and nutrients to the soil (Cryer and Murray 1992). Potter (1994) recommends that treatments involving the mechanical pushing of aspen followed by broadcast burning may rejuvenate aspen stands showing stagnation. Heavy grazing by domestic livestock, such as sheep and cattle, and intense overbrowsing by wildlife of young aspen sprouts can retard aspen growth and reproduction (Verner 1988, Greenway 1990, Potter 1994).

Research Needs

We used remotely sensed data to describe the distribution of aspen communities in the Lake Tahoe Basin (Issue 6, Chapter 5). A more intensive effort is needed to map aspen communities and record stand conditions. A modeling exercise might be able to predict the occurrence of aspen communities, which could then be field validated. Opportunities for restoration and regeneration may be highlighted by these exercises. In terms of biological diversity, research is needed to identify what minimum size of aspen community is needed to support a diverse assemblage of taxa.

Effects of Human Activities

Human activity may directly and indirectly affect the integrity of aspen communities. Trail and road development through aspen stands may interrupt natural water and moisture (evapotranspiration) balances, cause fragmentation, cause soil compaction, interrupt soil development, disturb native wildlife, and serve as an import route of non-native plant and animal species. Domestic animal grazing can also significantly retard the regeneration of aspen communities (Verner 1988, Greenway 1990, Potter 1994).

Conservation

According to the TRPA (1986), riparian plant communities are to be restored or expanded whenever and wherever possible to promote habitat for wildlife and improve water quality. The aspen community, because of its association with moist soil conditions, is considered a type of riparian community (Sinclair 1999) and thus is afforded protection under Chapter 74 of the TRPA Code of Ordinances (1987). Chapter 74 of TRPA (1987) does not allow projects or activities that convert riparian communities to urban environments unless such projects or activities are needed to improve vegetation health or fish and/or wildlife habitat improvements.

A conservation strategy that provides for the long-term maintenance of aspen communities will ensure the persistence of the diversity of aspen associated species. Several management strategies can be implemented to improve the quality and longevity of aspen communities, including burning, bulldozing, removing conifers, and clearcutting. In general, prescribed burning can result in vigorous sprouting of aspen although the long-term growth and survival of sprouts depends on the pre-fire carbohydrate level in roots, genetic variation in sprouting ability of clones, fire severity, and season of fire (Bartos and Mueggler 1981, Brown and Simmerman 1986). When carefully done, whole tree bulldozing (or tree pushing) exposes root-wads and can stimulate aspen sprouting (Shepperd 1996). However, when bulldozing operations cause deep cutting of soil and/or compaction, sprouting can be retarded. A rubber-tire skidder with the blade positioned so as not to disturb the soil provided the best results according to Shepperd (1996). Removing invading conifer trees can improve aspen stand vigor by reducing competition for water, nutrients and sunlight. Clearcutting aspen stands has resulted in increased suckering in degenerating aspen stands (Crouch 1981). However, for most vigorous sprouting, clearcutting a large proportion of an aspen stand is required because apical dominance is retained in standing stems.

An assessment of aspen stand quality is an important consideration when implementing a prescription to manage for long-term persistence of aspen communities. A simple prescription of clearcutting or burning a site to meet conservation goals of maintaining the vigor of an aspen community may not be enough. Careful forethought should be given to the treatment sites' characteristics. For example, Schier and Campbell (1978) found that concentrations of phosphorous and percent silt were significantly lower on soils with deteriorating stands than on soils with healthy stands. Thus, soil quality, availability of moisture, stand genetic variation, stand age (size) structure, impacts from grazing and browsing, solar exposure, disease and the effect of conifer encroachment should be considered prior to implementing a plan to manage or restore aspen communities.

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