SPHAGNUM FENS ON THE OREGON COAST: DIMINISHING HABITAT AND NEED FOR MANAGEMENT

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Report to

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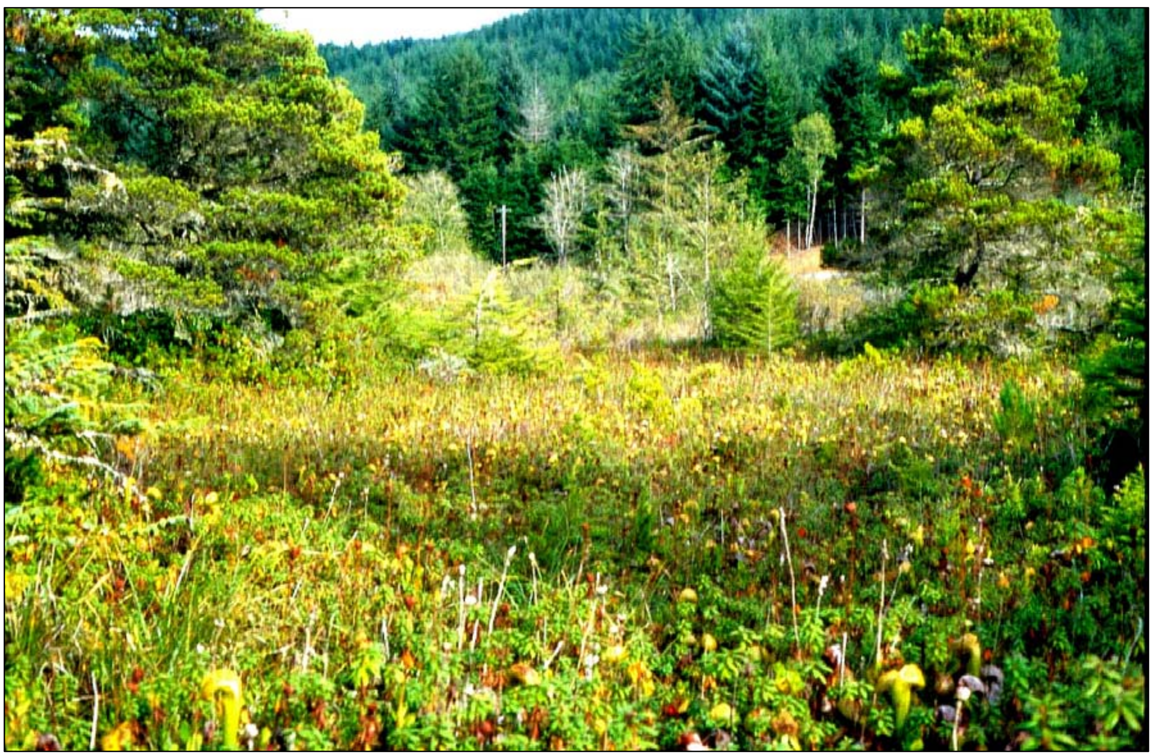

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SUMMARY

Sphagnum fens on the coast of Oregon are unique globally and contain a variety of rare plants and animals found nowhere else in the landscape. Evidence indicates that in the absence of disturbance, many open fens have converted to tall shrub and forest stands over the last 25-50 years, while fens on lake-fill mats show slower rates of change. Ditching in fens with deep peat appears to have hastened succession, while perched-water fens on soils underlain by hardpan exhibit the greatest rate of change because of lack of disturbance. Major disturbance regimes include fire, beaver, elk, tsunamis, windthrow, and people. Initial results of girdling and burning at New Lake Fen are encouraging, but it will take a number of fires over a period of years for conditions to improve. Management targets are early seral stages that favor growth of *Sphagnum* and other specialized fen species. Primary management objectives are restoration of the water table and its maintenance at a consistent level. Primary management tools to control woody vegetation include fire, manual removal, herbicides, and excavation followed by replanting.

BACKGROUND

Sphagnum wetlands have long been a subject of interest on the Oregon coast, but their soils, climate, and vegetation have only recently been described (Christy 1979, 2001a, 2004). Most sites occur below 1,000 feet in elevation, and are characterized by peaty soils and an abundance of *Ledum glandulosum, Sphagnum palustre,* and *Carex obnupta*. They are classified technically as fens rather than bogs because of the overwhelming influence of mineral-rich surface or groundwater, the lack of a domed peat profile, and a pH generally higher than 5.5. Many fens, however, contain localized *Sphagnum* hummocks or lawns with a pH as low as 4, and may be classified as "poor fen." They occur in depressions in various landforms, including interdunal depressions, headwall basins, ancient marine terraces, and floodplains. Many occur as floating mats around lakes, ponds, and slump or sag ponds in landslide topography, and are usually perennially saturated but local areas of seasonal surface drying are not uncommon. Most form deposits of peat, but some perched-water fens on soils underlain by hardpan ("vernal pool communities" of Christy 1979; Halsey et al. 2000) do not develop deep peats because of seasonal drying and oxidation. Because of dominance of *Ledum glandulosum* instead of *Ledum groenlandicum*, they are distinct from mires described from north of the Columbia River (e.g., Golinski 1999, Halsey et al. 2000) and those at higher elevations in the Cascade and Coast Ranges (Seyer 1979, 1981, 1983; Wilson 1986; Frenkel et al. 1986; Christy and Titus 1998; Murray 2000), and unique globally. They reach their southernmost limits along the coast of southern Oregon and northern California (Christy 1979).

Of 41 fens that were analyzed along the coast and in the Coast Range, 68 % are less than 5 acres in extent (Figure 1). These contain a number or rare animals, plants, and plant associations tracked by the Oregon Natural Heritage Information Center (ORNHIC), although their amphibian, small mammal, and invertebrate fauna remain largely unknown (Table 1). Drainage, filling, peat mining, conversion to commercial cranberry production, and plant succession have destroyed many sites, and losses continue to occur despite wetland regulations that were

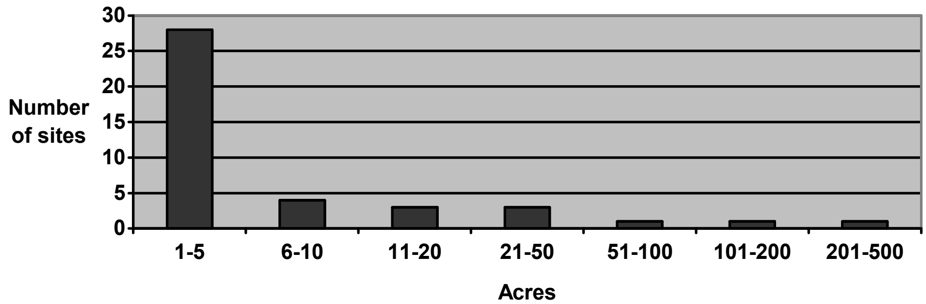


Figure 1. Relative size of 41 fens on Oregon coast (from Christy 2001a)

designed to protect them. The small area that fens occupy in the landscape is causing some conservation organizations to pass over them in a "bigger is better" philosophy, because of concerns of long-term viability and lack of control over water quality issues in watersheds with multiple ownerships and jurisdictions. It is important to properly document the components of these ecosystems now and to develop new conservation priorities to help protect representative examples remaining in the state.

Christy (2001a) noted that protection of *Sphagnum* fens on the Oregon coast has progressed markedly over what it was in 1979. Almost half (48%) of the sites inventoried reported on had some form of protection through either acquisition or easement. Oregon's land use and wetland laws have also added an additional layer of protection that was not available in 1979. Because of their wetland status and elevated profile as rare habitats, few of the remaining sites are likely to be damaged intentionally, although mistakes such as those that happened repeatedly at Harris Beach State Park will continue to be a problem until interagency communication improves. Larger sites are still without full protection because key parcels have not been acquired or easements negotiated. This process depends on willing sellers and it may take decades to acquire some parcels.

PLANT SUCCESSION IN COASTAL FENS

Despite gains in protection of coastal *Sphagnum* fens over the last 20 years, the long-term viability of these ecosystems is not assured. Their uniqueness is imperiled by their small size, making them vulnerable to intrinsic as well as extrinsic threats. In addition to the usual human-caused threats from surrounding land use, evidence suggests that in the absence of natural disturbance processes, fens are being invaded by trees and shrubs, and palustrine forests are converting to upland forest. Successional changes in these wetlands are to be expected over time, but it is not clear how fast they are changing or whether these changes threaten the continued existence of these small but important ecosystems.

If left undisturbed, most fens in western Oregon follow the classical linear successional trajectory from sedge fen, to *Sphagnum* mire, to willow and ericaceous shrub swamp, and finally to mixed conifer swamp of Sitka spruce, western hemlock, and red cedar. The few *Sphagnum*-containing types on sand dunes that do not form peat follow a similar but shorter trajectory, with shore pine invading relatively early, and eventual replacement by Douglas fir and Sitka spruce when sand and sediment fill the depressions. The classical trajectory may be intercepted by fire or beaver flooding, which essentially resets the successional sequence, as long as other factors such as water supply and water quality remain stable.

In most cases, successional change is slow and is most easily monitored by repeat photography. However, trends in wetlands are often not obvious after even 20 years. Air photography provides the most reliable record because photopoints are relocatable and repeatable, but the photographic record only dates back to 1939. Ground photography can provide detailed information not visible in air photography, but photopoints are often difficult or impossible to relocate if background features are lacking.

Table 1. Rare animals, plants, and plant associations of peatlands on the Oregon coast. LE = Listed endangered.			
	Oregon rank	Federal status	ORNHIC list
Animals			
Rana aurora aurora	G4T4S3S4		4
Plants			
Calypogeia sphagnicola	G4S2		2
Carex leptalea ssp. *leptalea*	G5T5S3		4
Carex pluriflora	G4S1		2
Cephaloziella spinigera	G4S1		3
Darlingtonia californica	G3G4S3S4		4
Eriophorum chamissonis	G5S1		2
Lilium occidentale	G1S1	LE	1
Lophozia laxa	G4S2		2
Myrica gale	G5S1?		3
Pohlia sphagnicola	G2G3S1		2
Polytrichum strictum	G4S1		2
Senecio triangularis var. *angustifolius*	G5TNRS1?		3
Triglochin striata	G5SNR		3
Vaccinium oxycoccos	G5S4		4
Plant associations			
Calamagrostis nutkaensis	G3S1		
Carex aquatilis var. *dives - Comarum palustre*	G3S2		
Carex obnupta	G3S2		
Ledum glandulosum / Carex obnupta	G2S2		
Ledum glandulosum / Darlingtonia californica	G2S2		
Ledum glandulosum - Gaultheria shallon / Carex obnupta	G2S2		
Ledum glandulosum - Myrica gale	G1S1		
Ledum glandulosum / Sanguisorba officinalis	G2S2		
Picea sitchensis / Carex obnupta - Lysichiton americanum	G3S1		
Pinus contorta ssp. *contorta / Carex obnupta*	G2S1		
Populus tremuloides / Carex obnupta	G1S1		
Tsuga heterophylla / Ledum glandulosum / Carex obnupta - Lysichiton americanum	G1S1		
Vaccinium uliginosum / Carex obnupta	G2S2		
Vaccinium uliginosum / Deschampsia cespitosa - Carex obnupta	G2S2		

METHODS

The U.S. Fish and Wildlife Service asked the author to identify successional trends in Oregon coastal fens, to establish baseline data for New Lake Fen in Coos County prior to any additional management activity, to evaluate responses of dominant fen plant species to various management tools, and to formulate a variety of vegetation management options specific to coastal fens.

Successional trends in coastal fens were assessed by comparison of historical and modern air and ground photography. Baseline data for New Lake Fen was compiled in July and November 2005. The author assessed and mapped existing vegetation, established photopoints, and sampled vegetation plots to describe species composition, cover, and structure prior to major changes from restoration activities.

Responses of fen vegetation to fire and cutting, and various management options were assessed by reviewing literature, internet websites, and personal knowledge from peatlands seen in Oregon and elsewhere in North America.

Air photographs of 13 coastal fens were examined at the University of Oregon's Aerial Photography Collection. Sequences of photos were sought for each site that would depict vegetation in about 1940, 1960, 1980, and 2000.

Photographs taken by the author over a span of 25 years were used to compare changes in five coastal fens (Clatsop Co.: Lily Pond Lake Fen; Coos Co.: Croft Lake Outlet Fen, Hauser Fen, New Lake Fen; Lane Co.: Woahink Bog, Woahink Lake Fen). Veva Stansell also provided a photograph taken at New Lake Fen in 1978.

RESULTS

Some sites have excellent photo coverage and show dramatic change over time, while others show very little change. Stands of *Ledum, Darlingtonia,* and *Sphagnum* on floating lake-fill mats exhibited the slowest rate of vegetation change, presumably because the hydrology has remained unaltered over time, although at one site adjacent sedge fen converted reapidly to shrub swamp. Fens in other landscape settings show more rapid invasion by woody vegetation. Those with deep peat deposits but with adjacent ditching show moderate to rapid rates of infilling over the last 25-50 years. Perched-water fens on soils underlain by hardpan exhibit the most severe infilling and forest encroachment. While these areas usually have not been ditched and perched water tables remain largely intact, invading trees and shrubs remove much of the water and shade out early-seral fen communities. Historically, perched-water fens were burned by Indians, as they were often adjacent to villages. After Euroamerican settlement, burning and grazing kept these areas open, but this disturbance ceased as agriculture declined along much of the coast in the 1950s and 1960s, enabling woody vegetation to invade.

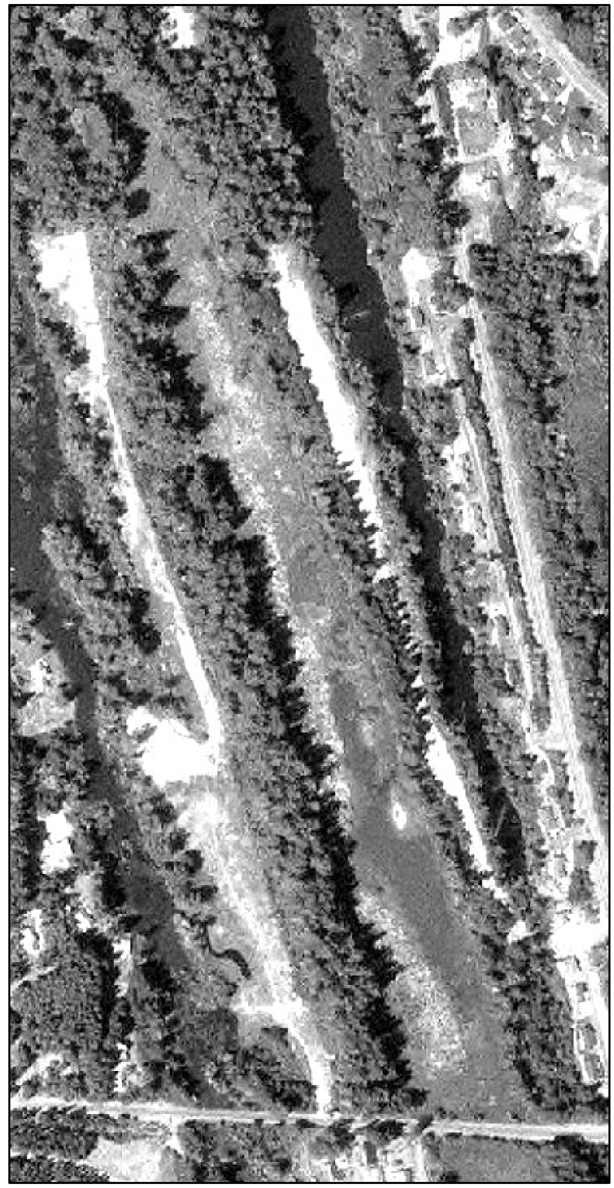
Clatsop Co.: Lily Pond Lake Fen

October 1989 November 2005

October 1989 November 2005

Changes in vegetation: This fen is a classic floating lake-fill mat in a eutrophic dune lake and General Land Office survey notes indicate that it may only be about 150 years old. The only obvious change over the 15-year period is due to seasonality. Aquatic bed vegetation, comprised mostly of *Nuphar*, has died back in the November photo and open water is more apparent. The floating fen mat has not accreted noticeably in 15 years, but unseen sedimentation from the aquatic vegetation continues to slowly fill the lake basin and will eventually enable the floating fen mat to expand. Although not evident in the photos, *Ledum* and red alder exhibited modest growth on the mat, but many shore pines and Sitka spruce had died. Conditions remain too wet for successful invasion of conifers beyond 6-8 feet in height.

Lily Pond Lake Fen, 1939



Lily Pond Lake Fen, 2000

Lily Pond Lake has been eutrophic for since at least 1939, its surface filled with aquatic vegetation and distinctly opaque, in contrast to the adjoining lake with an open water surface. The floating mats of vegetation were well established by 1939 and the configuration has not really changed in the intervening 61 years. White areas on the floating mats are probably lawns of *Sphagnum*, and appear to be more abundant in the 2000 photo.

Coos Co.: Bastendorff Fen

1939

Outlined areas were habitat for *Darlingtonia* and *Lilium occidentale*, remnants of seasonally wet prairie on Blacklock soils that had been present for at least 200 years (Guerrant et al. 1998), no doubt maintained by aboriginal burning. The stand to the right is now owned by The Nature Conservancy, and that on the left by the Oregon Parks and Recreation Department.

2000

In the absence of disturbance, the entire area has almost completely filled in with woody vegetation, primarily salal, evergreen huckleberry, cascara, and Pacific waxmyrtle. Shore pine, Sitka spruce, Port Orford cedar and red cedar are also becoming established. Similar exclusion of perched-water fens on Blacklock and other hardpan soils has occurred in Curry, Lane, and Lincoln counties.

Coos Co.: Hauser Fen

February 1980

November 2005

February 1980

November 2005

Changes in vegetation: This is a nutrient-poor fen in a depression with a seasonally perched water table over iron-cemented hardpan. Once a cultivated cranberry bog, it was partially filled during rebuilding of Highway 101 in the 1950's, and once supported a large population of *Darlingtonia californica* (Christy 1979; Stansell 1980). A population of *Lilium occidentale* also occurs here immediately adjacent to ongoing highway work. Aside from obvious mechanical clearing of upland in the upper photo pair and winter ponding in the lower photo pair, the primary change is increased density of *Spiraea.* It replaced much of the *Ledum* and *Darlingtonia* in the upper photo pair (north end), and much of the graminoid vegetation (mainly Sitka sedge) in the lower photos (south end).

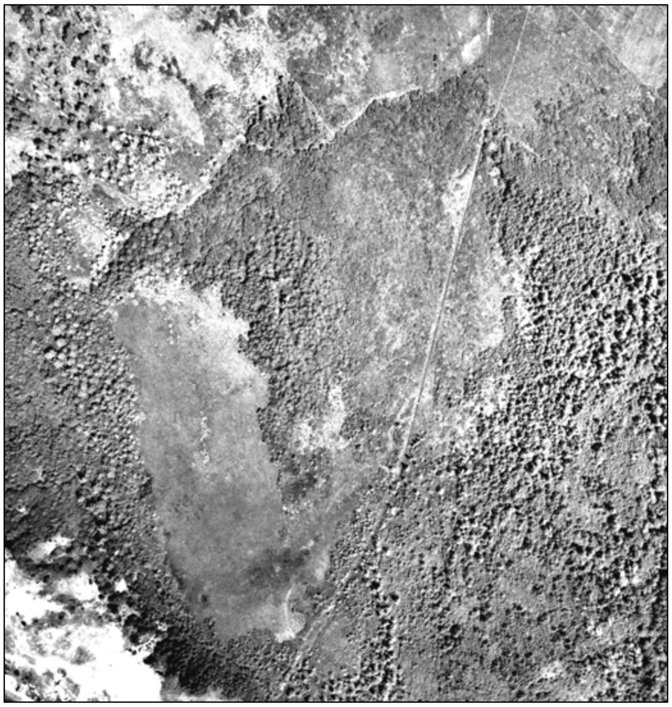
Coos Co.: Croft Lake Outlet Fen

July 1981 November 2005

July 1981 November 2005

Changes in vegetation: This is a nutrient-poor fen irrigated by a perennial flow of groundwater over iron-cemented hardpan, irregularly flooded by eutrophic water backed up when dunes impounding New River are not artificially breached. Water levels were reportedly six feet higher than normal in 2005 because breaching had not occurred. Much of the western edge of the fen was flooded and vegetation will be killed if water levels remain high during into the 2006 growing season. Other than this difference in water level, very little change appeared to have occurred over the intervening 24 years. A population of *Lilium occidentale* occurs here.

Curry Co.: Cape Blanco Fen



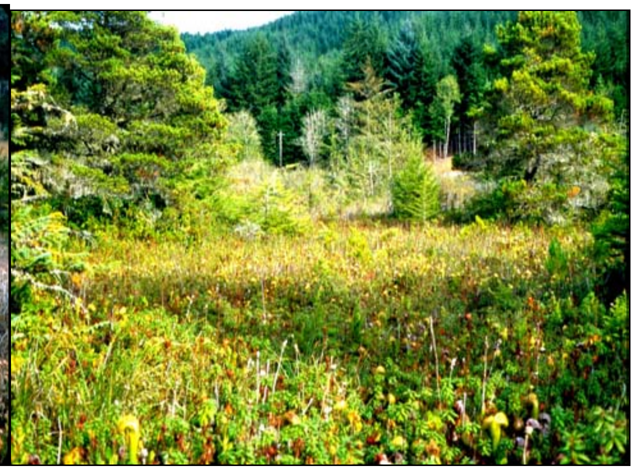
1939

This extensive fen had been ditched, but adjoining forest had not been logged. The northeastern portion was shrub swamp but the southwestern portion was open fen with *Darlingtonia californica* and *Calamagrostis nutkaensis*. Cattle had access to the site but did not penetrate the interior of the fen.

2000

Adjoining forest was logged in the 1950s. The southwestern portion is now much more brushy, and *Darlingtonia* is reduced to less than an acre. Cattle have been excluded by the Oregon Parks and Recreation Department but an elk herd is present.

Lane Co.: Woahink Fen



March 1980 November 2005

September 1989 November 2005

Changes in vegetation: This wetland contains nutrient-poor fen on a floating lake-fill mat, and minerotrophic sedge fen and shrub swamp. Woahink Lake itself is oligotrophic. Over a span of 25 years, the uplands had been logged and Clear Lake Road widened and repaved. Shore pine and Sitka spruce present in the fen in 1980 have increased in size and density. The apparent dearth of *Darlingtonia* in the upper photo from 1980 is due to winter die-back, but density in 2005 is thought to be about the same. Cover or *Ledum* has increased, although its stature remains dwarfed because of nutrient-poor conditions. The sedge fen in the lower photo pair has dramatically changed from Sitka sedge with scattered *Ledum* to a tall stand of *Ledum* and *Spiraea*.

Lane Co.: Woahink Lake Fen


September 1989 November 2005

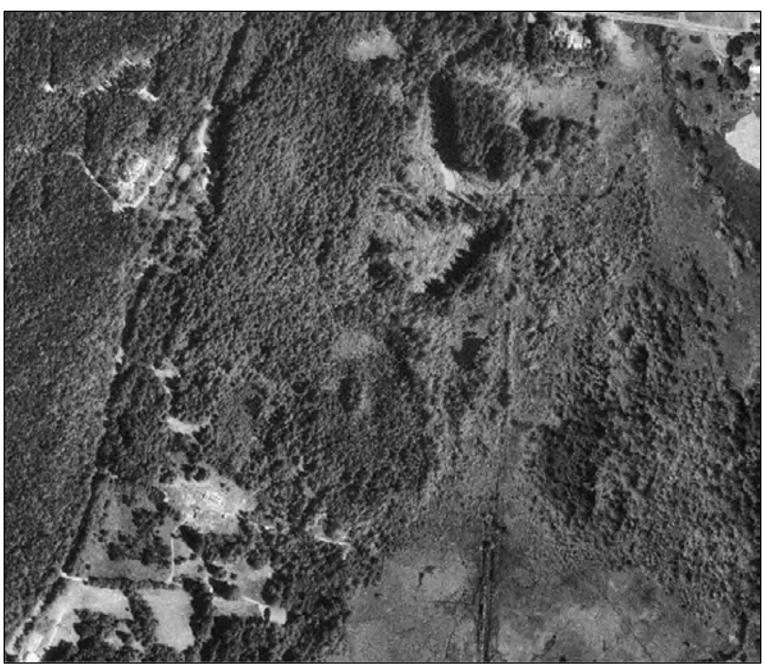

September 1989 November 2005

Changes in vegetation: This is a moderately nutrient-poor fen on a floating lake-fill mat of intermediate age on an oligotrophic lake, with a stream running through it. Vegetation in the fen has been continually cropped by beavers over the intervening 16 years. Deciduous shrubs (cascara, willow, twinberry) have disappeared, but most shore pines show continued slow growth. Cover of *Ledum* and *Darlingtonia* has increased markedly in the upper photo pair but has not changed appreciably in the lower pair.

Tillamook Co.: Sand Lake Fen

1953

This fen contains the northernmost known occurrence of *Darlingtonia californica* in the world. The whitish area surrounding a stand of shore pine is all *Sphagnum* fen. This area was logged and burned about 1918, and *Sphagnum* was collected from this site intermittently from 1918 to about 1960. Drainage ditches were cut along the northern and eastern edges, no doubt lowering the water table. A small area next to the road at the north end was mined for peat, creating a lake.



2000

The area of *Sphagnum* has mostly infilled with shore pine, wax myrtle, salal, and Sitka spruce. Forest to the north has been logged since this picture was taken.

NEW LAKE FEN

New Lake Fen is examined here in more detail than the previous four sites because it provides an opportunity to restore and manage a small fen on private land. Previous work done at the site by owner Rick McKenzie, and botanists Veva Stansell, John Christy, and Scott Sundberg provided 27 years of perspective on its composition and condition.

Air photos from 1939, 1951, 1970, 1980, and 2000 show a progressive picture of ditching in and around the fen, and gradual infilling of the interior of the fen by shore pine and Sitka spruce.

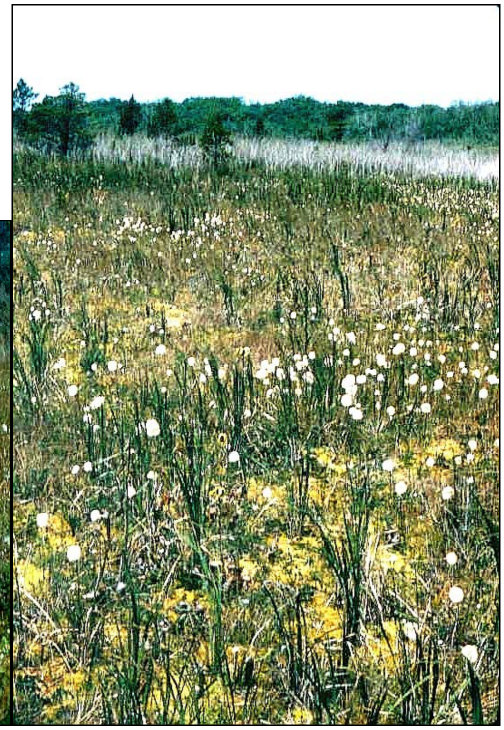
The 24-acre site had been managed with fire until about 1980, and at that time contained about four acres of open *Ledum glandulosum* / *Darlingtonia californica* fen in the northeastern corner of the wetland. In 1980, the open fen had number of shore pines scattered around the perimeter but only a few in the interior, most of which were less than three feet in height. When released from burning after 1980, the *Ledum* grew rapidly to the tall shrub phase, and shore pines rapidly invaded the open fen. By 2005, 3.7 acres of open fen had converted to a dense stand of shore pine and Sitka spruce overtopping an equally dense shrub layer of *Ledum glandulosum* and *Spiraea douglasii*. Within 25 years, pines had reached heights of 15-25 feet and diameters of 6-15 inches, while the tall *Ledum* had lost nearly all of its herbaceous and *Sphagnum* understory, and in turn began to be shaded out by shore pines.

In 2004, Rick McKenzie agreed to resume burning to help restore the open fen. Dave Pitkin of the U.S. Fish and Wildlife Service girdled numerous trees and felled others adjacent to the remaining 0.3 acres of open fen. In February 2005, Rick McKenzie's crew set fire to the bulrush (*Schoenoplectus acutus*) stand in the fen, but fuels were not dry enough to burn very far. The fire top-killed some *Ledum*, scorched some pines, and briefly burned some of the trees felled by Dave Pitkin (see photos below). Girdled trees are slowly dying and will provide an ongoing supply of fuel for future burns. Initial results of girdling and burning are encouraging, but it will take a number of fires over a period of years for desired results to show. The site is ideally suited for burning because it is surrounded by pastures and a lake.

When compared to retrospective photography from other fen sites along the coast, the invasion of New Lake Fen by woody vegetation seems to have occurred unusually rapidly once burning ceased about 1980. Few other disturbance factors were at work in the fen, since there are hardly any elk in the New River area bottoms (Dave Pitkin, pers. com.), and commercial collecting of *Darlingtonia* has not occurred since 1980 (Stansell 1980; Rick McKenzie pers. com.). Beaver are present throughout the New Lake area and no doubt regulate water levels in some areas, but do not appear to have done much flooding or cropping of vegetation in the fen. Ditching of the New River bottoms prior to the 1990's may have altered water supply to the fen, and the annual breaching of New River has probably caused seasonal fluctuations in water levels that favor invasion by trees. If alterations in water supply created conditions favorable to forest encroachment, the only factor preventing earlier invasion may have been the periodic burning. Once released from fire, the fen converted rapidly to a pine and spruce forest.

Photographs from New Lake Fen, 1978 and 1980

1978 (by Veva Stansell)



June 1980

Two views of the four-acre *Ledum glandulosum* / *Darlingtonia californica* stand present at New Lake Fen in the 1980's. The shore pines in the background are now 15-25 feet tall, with diameters of 6-15 inches, and cover all but 0.3 acre of formerly open fen.

Existing vegetation at New Lake Fen, 2005

1 -- Schoenoplectus acutus
2 -- Incipient Sphagnum fen, grazed
3 -- Ledum glandulosum / Darlingtonia californica
4 -- Ledum glandulosum - Spiraea douglasii
5 -- Mixed Pinus contorta var. contorta - Picea sitchensis with senescent Ledum glandulosum
6 -- Picea sitchensis / Carex obnupta - Lysichiton americanus
7 -- Pinus contorta var. contorta - (Thuja plicata) / Ledum glandulosum
8 -- Carex aquatilis var. dives - Comarum palustre
9 -- Spiraea douglasii
10 -- Alnus rubra / Rubus spectabilis
11 -- Salix hookeriana - (Malus fusca) / Carex obnupta - Lysichiton americanus
12 -- Ledum glandulosum - Spiraea douglasii with remnant Darlingtonia californica

Vegetation management at New Lake Fen, 2004-2005

Effects of winter 2005 burn, as seen in July 2005. In foreground, *Ledum*, *Lonicera*, and *Frangula* were top-killed and are resprouting. In background, scorching on shore pine. This is the 0.3-acre remnant of open *Darlingtonia* fen.

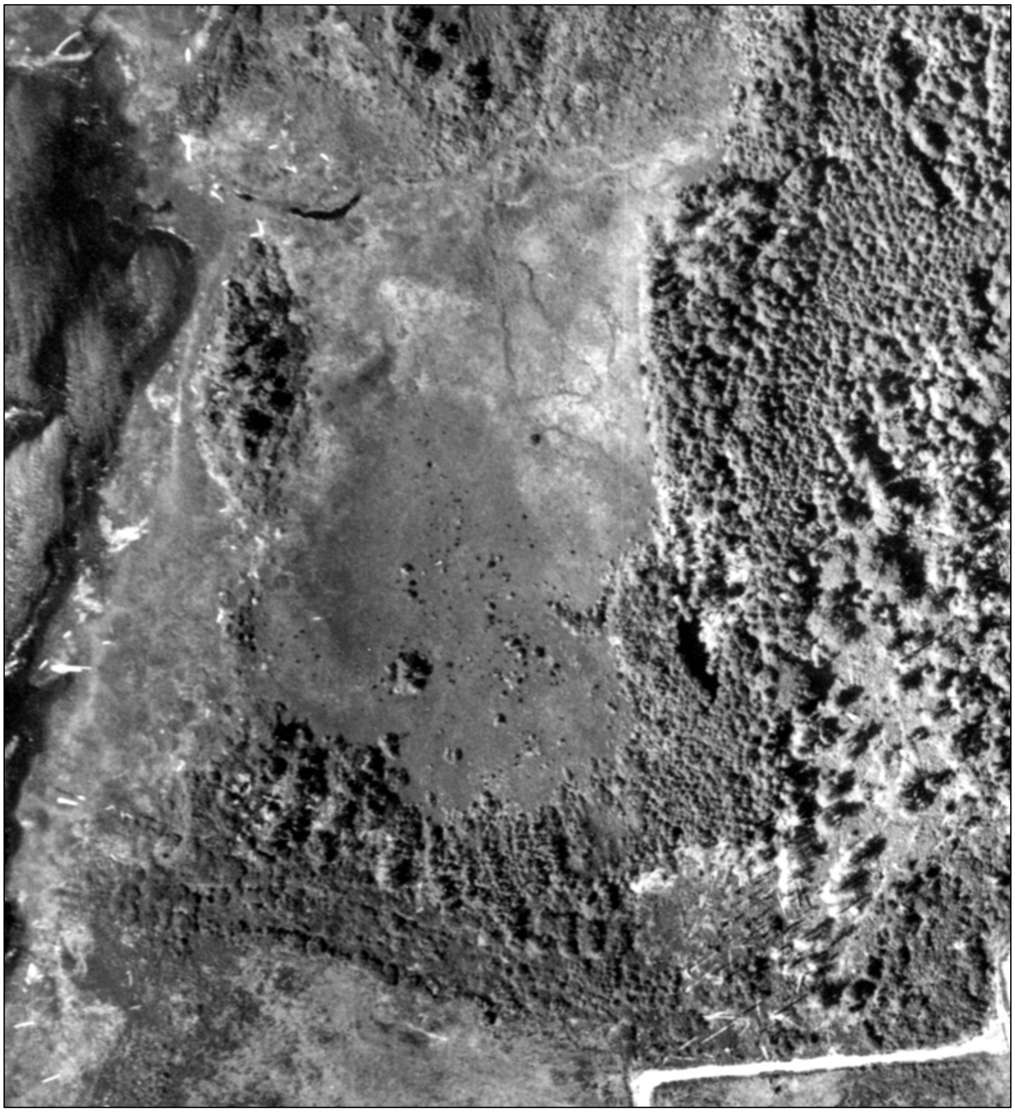
Effects of winter 2005 burn, as seen in July 2005. Scorching on shore pine indicates flame height. Not visible is fire's removal of *Schoenoplectus* litter from 2004 growing season.

Effects of winter 2005 burn, as seen in July 2005. Detail of top-killed *Ledum*, *Lonicera*, and *Frangula* with resprouting shoots at base. Note dead Sitka spruce seedling at base of pole.

Effects of girdling and felling of shore pines and cascara in fall 2004, as seen in July 2005. Downed wood is from felling, but was not burned in fire. Browning of standing trees is from girdling.

Air photographs of New Lake Fen, 1939-2000

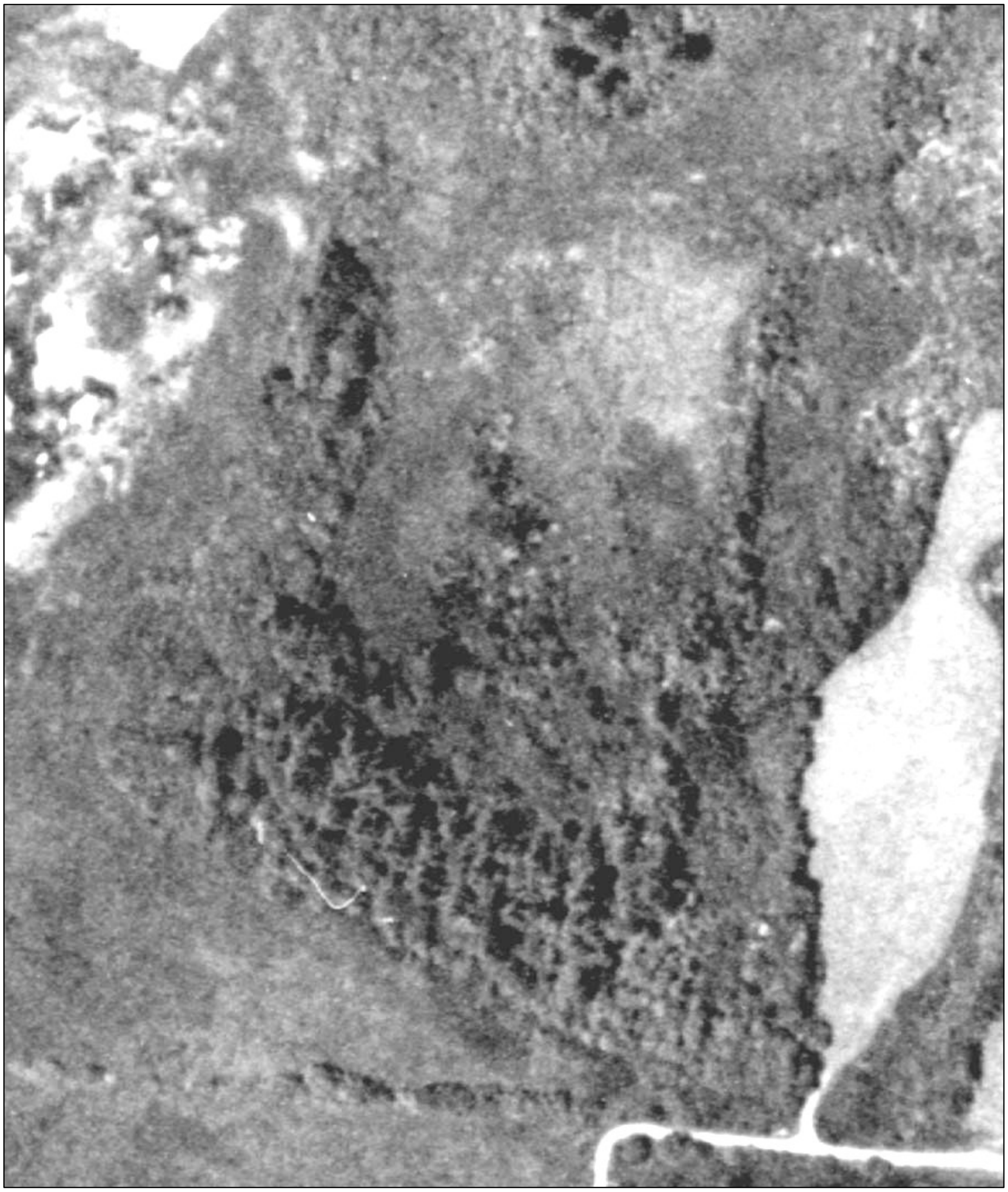
Air photos from 1939, 1951, 1970, 1980, and 2000 show a progressive picture of ditching in and around the fen, and gradual infilling of the interior of the fen by shore pine and Sitka spruce.



New Lake Fen, 1939. The fen is mostly open, with a scattering of shore pine and Sitka spruce in the south-central portion. A drainge ditch (partially hidden by brush) has been cut on the south side, running at a diagonal from near the bend in the road northwestward toward the lake. No ditch is evident on the north side. Logging is evident along the southeastern edge of the fen. Elk trails are also visible in the fen.

New Lake Fen, 1951. The fen is still mostly open, perhaps with more brush developing in the south-central portion, but difficult to see because of poor resolution. A new ditch has been dug in the pasture to the south, running west from the bend in the road. The logged area along the southeastern edge of the fen has grown up in alder. The white diagonal line at the northern end of the fen is either a ditch or a fenceline.

New Lake Fen, 1970. The south-central portion of the fen is filling in with shore pines. Ditches have been dug on the north side and through the middle of the fen, the latter entering from the southeast corner, trending northwest, then turning north to drain into the ditch on the north side. Woods on the northeast side have been cleared for pasture.



New Lake Fen, 1980. The south-central portion of the fen is filled with shore pines. The open fen area photographed in 1978 and 1980 by Veva Stansell and the author is the whitish patch in the northeastern part of the fen.

New Lake Fen, 2000. The extent of shore pine is clearly visible, having filled in most of the fen. The ditch on the north side has been re-excavated.

ROLE OF SELECTED FEN SPECIES IN SUCCESSION

In general, the slow rate of change evident in deep peat fens without ditches is similar to that observed in undisturbed montane wetlands (Christy and Titus 1998; Christy 2001b). Twenty years is often barely enough time to detect change in such sites. However, sites with ditching show dramatic change mediated by local conditions and the species involved.

Lake-fill mats have a slow rate of accretion because of the very slow process of sedimentation from aquatic bed vegetation and other sources. Shore pine, Sitka spruce, and alder may germinate and grow on these mats, but the peat substrate is too thin and too wet to support growth beyond six or eight feet. In contrast, older mats develop deeper peat deposits and will support larger trees that accelerate litter buildup and shrub invasion. Herbs and shrubs may remain dwarfed, with suppressed growth rates, for many decades if acidic, nutrient-poor hummocks develop at these sites. Some lake-fill sites experience significant cropping by beavers. Deciduous shrubs were nearly eliminated by beavers at one site over a 16-year period, while influence on conifers was minimal

Carex aquatilis var. *dives*, often with *Nuphar lutea* ssp. *polysepala*, occurs in minerotrophic marsh habitat around the edges of lakes and ponds, contributes to peat formation as fen vegetation encroaches on open water. It then persists in fens as a relict of formerly more open water, but appears to have a relatively short life as a community dominant. Within 25 years, stands at some sites were almost completely replaced by *Spiraea douglasii*, but the species has persisted at other sites.

Darlingtonia californica is capable of colonizing new areas within 20 years, but many stands are long-lived until overtopped by *Ledum* and *Spiraea* in 25-50 years.

Spiraea douglasii favors minerotrophic conditions in fens. It is poorly represented in nutrient-poor fens but forms dense stands in laggs surrounding these fens. Photographs show major invasion and conversion of sedge and some *Ledum* stands to *Spiraea* within 25 years.

Ledum glandulosum is the most important shrub of coastal fens, providing architecture for the development of tall *Sphagnum* hummocks that provide habitat for a variety of specialized fen plants, including *Lilium occidentale*. Species of *Sphagnum* on hummocks, particularly *S. fuscum*, in turn influence the nutrient status of the entire community. Vegetation on hummocks may be suppressed in nutrient-poor fens, but can be rapid under more minerotrophic conditions in the absence of disturbance. When ditching lowers the water table and when disturbance such as burning ceases, *Ledum* grows rapidly to the tall shrub phase and nearly all of the herbaceous and *Sphagnum* component disappears within 25 years. *Ledum* itself begins to be shaded out by shore pine and cascara shortly thereafter. Fen shrubs of lesser significance include *Myrica gale, Vaccinium uliginosum*, *Kalmia microphylla*, and *Spiraea douglasii*, all of which also disappear when the tree canopy begins to close. Only *Myrica gale* is important in the final tall shrub phase of fens, but it has become rare south of Clatsop County.

Once established, shore pine and Sitka spruce begin to grow rapidly once forest litter begins to accumulate. When released from burning at New Lake Fen after 1980, shore pine and spruce grew rapidly in size and density, and began shading out *Ledum* after about 25 years. Cascara is also part of this community, and together with shore pine appears to hasten conversion to forest.

New Lake Fen is the only site along the Oregon coast with recent disturbance, where regular burning by its owners maintained open *Ledum / Darlingtonia* fen until about 1980. The massive changes observed at that site over the last 25 years indicate that management using various disturbance prescriptions is the only way that open fen vegetation will be preserved at these sites. It is important to identify which processes are most pivotal in shaping fen vegetation and to apply these at a variety of sites.

NATURAL AND HUMAN DISTURBANCE PROCESSES

Major agents of disturbance in coastal fens are fire, beaver, elk, tsunamis, windthrow, and people. These forces mediate the supply, movement, and chemistry of water and sediments and shape the development of different types of vegetation.

Fire. Stand-replacing fire probably played a major role historically in maintaining coastal *Sphagnum* fens. Ignition sources in coastal fens were both aboriginal and by lightning, with Indian burning a major factor near villages on Blacklock soils. In Oregon, the role of fire has been well studied in upland conifer forests, but no studies have focused on fire in wetlands except for Willamette Valley prairie. Charred snags, burned peat, and charcoal in sediment cores are the only evidence of fire in these wetlands. Hansen (1941, 1944) noted charred peat at a depth of 7 feet at Bradley Bog (Tillamook Co.), and at 3 feet in a coastal mire near Ilwaco, Washington. Torgerson et al. (1949) reported evidence of fire in Brallier peat, including charred wood at depth. Martin and Frenkel (1978) reported fire scars and charcoal above and below ground throughout the Blacklock Point area. Schultz (1989) and Guerrant et al. (1998) observed that populations of *Lilium occidentale* required fire to suppress competing woody vegetation, and that plants began to disappear when canopy closure exceeded 50 percent.

Beaver. The primary effect of beavers on peatlands is water regulation and cropping of fen vegetation. While some peatlands formed in impoundments originally created by beavers, most developed in depressional landforms created by other processes that happened to provide habitat for beaver and in turn became influenced by their activities. Cyclical flooding by beaver dams can have major impacts on fens, and small fens typical of the Oregon coast can be completely inundated and lose all characteristic fen vegetation. This temporarily reverses succession and maintains the early seral conditions required for *Sphagnum* vegetation. Cropping of vegetation, particularly willows, helps keep woody plants suppressed and delays competition that eventually shades out fen communities. Cropping of invading shore pine is not uncommon, although conifers are not a preferred food. Although beavers are seemingly ubiquitous today, some researches have estimated that historic populations in Oregon were ten times larger than what they are now. Their numbers were decimated first by commercial trapping prior to 1845, then by diminishing wetland acreage caused by their trapping, and finally by a rush of agricultural drainage projects.

Elk. Although not well documented, trampling and browsing by elk is an important agent of disturbance in fen vegetation. Elk favor open to partially wooded mire vegetation for feeding and bedding. Where elk herds still exist and have access to coastal fens in Clatsop and Tillamook counties, extensive networks of elk trails and bedding sites are clearly visible on the ground and in air photos. These help trample vegetation and may have long-term effects on fens by suppressing woody vegetation and influencing the location and configuration of hummock-hollow topography. Elk manure supplies nutrients, particularly nitrogen, that under natural conditions are often in short supply in wetlands. The networks of trails serve to channel mineral-rich water through the mires and this in turn influences fen vegetation. Elk no longer have access to some coastal fens, particularly in heavily hunted areas or where extensive ranching has made access difficult, and at these sites plant succession has proceeded unchecked. While cattle may penetrate the edges of fens, they seldom venture into the interior of these wetlands and are not good surrogates for elk in wetland management. Unless forage values are enhanced in fens by clearing and seeding, cows generally avoid these areas because of perennially wet soils and lack of palatable food.

Tsunamis. Sediment cores indicate that tsunamis have inundated salt marshes, swamps, and peatlands along the coast of the Pacific Northwest. Catastrophic flooding by salt water, burial by marine sediments, and associated tectonic uplift or subsidence is thought to have occurred about every 300 years. These forces destroyed fens and created new ones along the coast, but their effects are not well documented in Oregon.

Windthrow. Windthrow was a minor agent of disturbance in fens and occurred mostly *Picea sitchensis* swamps on the coast. Roots of *Picea* cannot grow in perennially wet, anoxic soil and in wetlands they form wide-spreading but very shallow systems that, combined with buttresses at the base of the trunk, serve to keep the tree rocking back and forth on the spongy substrate. Windthrow is common in these stands, creating canopy gaps for the dense shrub layer and reproducing trees. Windthrow of small trees is sometimes seen in peatlands where the weight of the tree becomes insupportable in the soft ground.

People. Although people have lived in coastal Oregon for at least 10,000 years, large-scale human-caused changes to wetlands did not occur until after 1850. In general, the greatest loss of fens on the coast is directly attributable to settlement and land conversion. Agricultural drainage, peat mining, construction of cranberry bogs, groundwater pumping, urban and industrial development, nutrient runoff, and road construction have all taken their toll on fens. Paradoxically, in the absence of natural processes, particularly fire, some forms of human-caused disturbance have unwittingly served to maintain earlier seral stages in fens, although overall diversity within fen ecosystems has probably decreased from these activities.

1. Harvest of sphagnum moss. *Sphagnum* is known to have been harvested sporadically from a number of sites in Clatsop and Tillamook counties since at least 1918, first for surgical dressing and more recently for the horticultural trade. Harvest is done by hand or with a rake, has a relatively short-term impact on hummock-hollow formations, but may have longer-term benefit by slowing invasion of woody plants. The *Sphagnum* layer on hummocks is largely destroyed, along with rare hummock plants such as *Carex pluriflora* or *Carex leptalea*, but the shrub architechture on hummocks remains and *Sphagnum* seems to recover wthin 10-20 years. There is currently no commercial market for sphagnum moss in Oregon because of the large supply coming from the upper midwestern United States and Canada. The most recent harvest was seen by the author in Clatsop County in 1980.

2. Mining of peat. Two sites in Lane and Tillamook counties were mined for peat in the 1940s and 1950s, leaving a lake at one site and ditches and raw peat in the other that had not recovered after 20 years and was being invaded by woody vegetation (1980). Its current condition is unknown. In mined sites, lawns of *Sphagnum* may establish in flooded hollows, but specialized hummock species are slow to recover because of a lowered water table, compression of remaining peat, a lack of seed source, and a lack of shrub architechture.

3. Harvest of *Darlingtonia*. Commercial harvest of *Darlingtonia californica* for the specialty carnivorous plant market has occurred since at least 1950 (Stansell 1980). Harvested is done by hand or with a rake, has a relatively short-term impact on hummock-hollow formations, and may have longer-term benefit by slowing invasion of woody plants. Local populations of *Darlingtonia* may be decimated by harvest, and ancillary damage may occur to populations of other rare plants such as *Carex pluriflora* or *Carex leptalea* that grow on hummocks. Collecting of *Darlingtonia* on public lands has declined in the face heightened awareness by managers and the advent of tissue culture techniques, but collecting on private lands continues. It is difficult to obtain reliable statistics on the volume of harvest, and the extent of current harvest activity is unknown.

4. Logging. Sitka spruce, cedar, and shore pine muskeg have been logged in some coastal peatlands. While usually of marginal profitability, logging such stands causes them to temporarily revert to earlier seral stages favored by *Sphagnum* and its associates.

5. Road construction. Access roads that cross peatlands require large amounts of fill that disrupt surface and groundwater flows. When these roads cut across gradients, the local water table rises on the uphill side and drops on the downhill side. The effect of these changes in fens is visible in air photos, and is manifested by development of open fen on the uphill gradient and shrub swamp on the downhill gradient. In the absence of stand-replacing fire, fen vegetation is preserved or enhanced on the uphill gradient but lost to invasion of woody plants on the downhill gradient.

6. Fire and grazing. Aboriginal burning along the coast maintained prairies around populated areas, including perched-water fens on soils with hardpans. Some of these sites were habitat for *Lilium occidentale* and had been prairie for at least 200 years before white settlement (Guerrant et al. 1998). Some coastal fens were burned annually or every few years by local farmers and ranchers to enhance forage value for livestock and promote the growth of wild cranberries for domestic consumption. Forage values were never great in these wetlands and were inferior areas for pasture. With the proliferation of commercial cranberry bogs over the last century, management and harvest of wild cranberries has ceased.

7. Cranberry cultivation. Development of commercial cranberry bogs on the Oregon coast dates from about 1885, using a species of cranberry native to eastern North America. The first cranberry bogs in the state were installed near Hauser, Coos County. Until the 1980s, cranberry bogs were built in natural depressions where fens containing *Ledum, Sphagnum,* and *Darlingtonia* already existed, and the process largely eliminated any native vegetation. Despite the loss of hundreds of acres of native fen during this period of unregulated development, pockets of native fen vegetation persisted around the margins of commercial sites and in nearby wetlands too small to be developed profitably. Since the 1980s and the advent of wetland regulations, commercial cranberry beds have been constructed in upland settings. However, regulatory errors and unregulated development of cranberry bogs continue to cause incremental loss of fen habitat and species.

MANAGEMENT TARGETS

Most of the rare fen elements listed in Table 1 depend on early seral conditions with limited competition from trees and shrubs. There is a very real concern that these small ecosystems and the specialized biota that occur in them will eventually disappear completely from our region unless they are replaced through natural disturbance processes or maintained through active management. Given the species involved and the early seral ecosystems that they require, it makes sense to identify four seral stages of fen vegetation as management targets:

1. Native aquatic bed or emergent marsh vegetation that may contribute to peat formation and create a substrate for establishment of *Sphagnum*.

2. Incipient development of *Sphagnum* lawns and hummocks.

3. Open *Ledum glandulosum* fen with associated species (e.g., *Kalmia microphylla, Myrica gale, Spiraea douglasii, Vaccinium uliginosum*, *Vaccinium oxycoccos, Carex echinata* ssp. *phyllomanica, Carex leptalea, Darlingtonia californica, Drosera rotundifolia, Eriophorum chamissonis, Lysichiton americanus, Trientalis europaea* ssp. *arctica*).

3. Tall *Ledum glandulosum* shrub swamp, sometimes with *Myrica gale* and *Spiraea douglasii*, with ca. 0-90 percent closure of tree layer composed of *Pinus contorta* var. *contorta, Picea sitchensis*, *Thuja* plicata, and *Frangula purshiana*. Rejuvenation of open *Ledum glandulosum* fen is possible up to this point, after which *Ledum* and all remnant herbaceous fen species are shaded out and die. At this point, the trees have become large enough and the litter layer so thick that stands begin to develop upland characteristics.

MANAGEMENT OBJECTIVES

Restoration of peatlands is an evolving science and research and applications is ongoing in Canada, the eastern United States, and Europe. An excellent review is provided by Quinty and Rochefort (2003). Very little restoration work has been attempted in the Pacific Northwest, although management plans have been drafted for several sites in British Columbia, Washington, and Oregon. Kulzer et al. (2001) and the extensive documentation from the 1999 Burns Bog Environmental Assessment (British Columbia Environmental Assessment Office 1999) are currently the most comprehensive and authoritative sources of information for peatland ecology and management in the Pacific Northwest. In general, every fen has its own unique subset of environmental conditions and history of disturbance that must be researched for successful projects to occur.

The primary goal of restoration for deep-peat fens is to restore historical hydrological conditions that built the fen, including water supply, water elevation, hydroperiod, and chemistry. These conditions will reestablish peat formation and peatland vegetation. Peat can only form under anaerobic conditions, where soils are perennially saturated and seasonal fluctuation does not exceed about 20 inches. For optimal growth of *Sphagnum* and other plants that in turn affect pH, the water supply must also be low in nutrients.

Simplified steps for restoration objectives include:

1. Identify past and present water regimes.
2. Restore high water levels and keep them stable to maintain anaerobic conditions in the rooting zone. This prevents peat from oxidizing and subsiding, which reduces its water storage capacity and encourages forest encroachment. For deep-peat fens, restoring the water table may be as simple as plugging drainage ditches. If these conditions cannot be restored, they need to be duplicated through engineered solutions that include adequate water supply and impoundment structures to maintain water levels within the fen. For perched-water fens on hardpan soils, hydrology is often more or less intact, and it is more important to remove encroaching woody vegetation that depletes the water through transpiration.
3. Isolate the fen from nutrient enrichment, such as agricultural runoff. This is the function of the lagg (a natural moat occurring at the toe of slopes around the perimeter of the fen), which in many areas is still present and more or less intact.
4. Remove the trees, which will (1) restore light levels needed by desired early seral stages, (2) help raise water levels by removing the siphon effect caused by the trees' transpiration, and (3) remove a source of litter and nutrients that contribute to forest encroachment. Raised water levels will also discourage further invasion of trees.
5. After removal of trees, remaining or regenerating *Ledum* and *Spiraea* may grow rapidly, and other species such as alder, willows, cascara, *Juncus*, or exotic species may invade the site. These will need to be managed with fire, mowing, and herbicides.
6. Remove exotic species.
7. Reestablish *Sphagnum* and other species as needed.

MANAGEMENT TOOLS

The most common options and tools for management include:

Fire. The USDA Forest Service Fire Effects Information System database (FEIS) <http://www.fs.fed.us/database/feis> was searched to assess fire response in common native fen species (Table 2). Some of our species are not treated in FEIS, and *Ledum groenlandicum* was used as a surrogate for *Ledum glandulosum*, as no record exists for that species in the database. In general, deciduous trees, deciduous or evergreen shrubs, and herbaceous species in fens usually survive low to moderate intensity burns as long as the fire does not burn into the rooting zone in the peat. They may be top-killed but will readily resprout from the base of the plant. In contrast, most conifers will die and not resprout.

In wetlands, the best time to burn is in late summer or early fall, but most managers are afraid to burn at this time of year because of the danger of fire spreading to upland forest and residential areas. Winter and spring burning can be helpful as long as there are enough fuels left from the previous season to carry a fire, but a high water table prevents killing of woody material that might otherwise be a desired effect from a summer or fall burn. Livestock should be excluded from the wetland during the year prior to burning, in order to accumulate fine fuels that help carry a fire. Cutting trees and shrubs the previous season will also supplement the fuel load for a winter burn, and girdled trees provide an ongoing source of litter for fire.

Manual removal. Cutting, girdling, and mowing of woody vegetation in fens will produce effects similar to those of low to moderate intensity burns. Deciduous trees, deciduous or evergreen shrubs, and herbaceous species will survive these treatments and resprout, but conifers will not. Trees can be cut or girdled, while a combination of both provides ready downed fuel and an ongoing supply of litter from dead or dying standing trees. Removal of large-diameter trees for recovery of merchantable wood can be problematic because of excessive soil disturbance caused by tracked vehicles or even horses. This can be done on frozen ground in northern climates, but such conditions never occur on the coast of Oregon. Airlifting is effective if funding permits, or if helicopter services can be provided at no cost. Mowing of shrubs and small-diameter trees is feasible, but generally limited to hand-held brush cutters because conditions are usually too wet and the surface topography too rough to accommodate riding mowers or tractors.

Herbicides. Herbicides can be applied selectively to trees by injection or "hack and squirt" frill cuts. Stumps of deciduous trees and shrubs should be painted with herbicide to prevent resprouting, but it is not necessary to paint stumps of conifers. Herbicides or solarization are recommended for control of invasive species such as reed canary grass, purple loosestrife, or swamp loosestrife, but should not be applied to native herbaceous species because most of them are normal components of the system and not precursors for invasion by woody species.

Excavation and replanting. In areas where sufficient depth of forest litter has accumulated above the original peat surface (often identifiable by digging a hole through more recent litter), or where it is impossible to raise the water level permanently, excavators may be used to lower the soil surface to the original peat layer or water table. High-floatation vehicles are preferable to wheeled vehicles. Excavation will also remove nutrients and seeds of encroaching forest plants. Excavated areas can then be replanted with seeds, potted material, and fragments, or plugs of *Sphagnum*. Species used should be chosen to survive seasonal flooding, depending on microsite conditions, and care should be used in choosing different species for hummocks and hollows.

MANAGEMENT OF NEW LAKE FEN

The primary need at New Lake Fen is a restored and stable water table. Manipulation of New River water levels, specifically artificial breaching of the dunes to drain low-lying pastures along the river, may have had the most serious effect on the fen. The elevation of New River water controls the levels of New Lake, which in turn influences ground and surface water levels in the fen. Stabilization of New River, which depends on cooperation of a number of adjacent landowners, may be the only long-term solution to restoring New Lake Fen. Plugging the ditch on the north side of the fen will also help restore water levels locally. Old ditches on the south side and in the interior of the fen have silted in and probably no longer have much effect in lowering water levels.

Cutting and girdling of trees in the fen should continue, and the fen should be burned as needed to remove woody litter and keep recruitment of new trees under control. Preferably, trees should be cleared back to the area shown in the 1939 air photo, but the thickness of forest litter must be examined to determine how much area should be cleared for optimal chances for rewetting buried peat and reestablishment of fen vegetation. Removing all shore pine and smaller Sitka spruce will provide light necessary for specialized early-seral fen species, and will help raise the water table and discourage further establishment of trees. There may be areas where forest litter has accumulated to such an extent that upland forest will reestablish on cleared sites, instead of target fen species. These areas could be excavated with appropriate equipment to lower the soil profile and improve recruitment of wetland species.

Sphagnum and other fen species may reestablish spontaneously if conditions are correct. Planting of additional material, control of rebounding shrubs, and control of exotic species may be necessary in some places.

Table 2. Fire effects on common native or surrogate vascular fen species. Data from USFS Fire Effects Information System.	
Species	**Fire effect**
Agrostis exarata	no data, probable top kill only
Alnus rubra	top kill, resprouts
Alnus viridis ssp. *sinuata*	top kill, resprouts, rapid recovery, increaser
Calamagrostis canadensis	top kill, resprouts, rapid recovery, increaser
Carex aquatilis	top kill, resprouts, rapid recovery, increaser
Carex utriculata	top kill, resprouts, rapid recovery, increaser
Darlingtonia californica	top kill, resprouts
Deschampsia caespitosa	top kill, resprouts
Drosera rotundifolia	top kill, resprouts
Empetrum nigrum	top kill or complete kill, slow to recover
Gaultheria shallon	top kill, resprouts, rapid recovery, increaser
Ledum groenlandicum	top kill, resprouts, rapid recovery
Picea sitchensis	complete kill
Pinus contorta var. *contorta*	complete kill
Rhamnus purshiana	top kill, resprouts
Rubus ursinus	top kill, resprouts, rapid recovery, increaser
Spiraea douglasii	top kill, resprouts
Thuja plicata	complete kill
Tsuga heterophylla	complete kill
Vaccinium oxycoccos	top kill, resprouts, rapid recovery, increaser
Vaccinium uliginosum	top kill, resprouts, rapid recovery

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