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# An Oil Spill in an Alpine Habitat

**Abstract**

A study was made of the vegetational damage caused by a spill of 7,000 gal of diesel fuel into an alpine meadow near Mt. Baker, Washington. Most of the herbaceous plants in the *Carex nigricans* and *Phyllodoce empetriformis-Cassiope mertensiana* associations were killed; the woody species were severely damaged but survived the effects of the oil. The root systems of the plants escaped major damage, possibly due to the oil flowing over the water-saturated soil surface. One year later, *Carex nigricans, Carex lenticularis*, and various mosses were invading the area.

During the past few years, periodicals have described environmental damage caused by crude-oil spills in the ocean. Dead fish, oil-soaked birds, economic losses, and despoiled recreational facilities have dramatized the ecological situation and initiated many investigations into oil in the marine environment. However, little is known about the effects of crude or refined oil on terrestrial ecosystems, particularly on extreme environments such as alpine meadows. Therefore, when a spill of diesel fuel occurred on an alpine meadow near Mt. Baker in northwestern Washington on U.S. Forest Service land leased by the University of Washington, I became interested in studying the effects of the oil on the vegetation. Such a study has special relevance in view of the Trans-Alaska Pipeline now being built. Spills of crude oil during drilling in and transport over the Alaskan arctic tundra can be envisioned; thus the potential for environmental damage must be evaluated. Also, the increased construction of alpine-zone recreational facilities presents a hazard to high elevation communities from heating-oil spills. Alpine and arctic tundra areas are, in many respects, similar, fragile ecosystems; long, cold winters and short growing seasons lead to slow soil development and decomposition of organic materials, to slow plant growth and regeneration, and to decreased plant diversity. The arctic and alpine ecosystems, however, differ in other important aspects (Billings, 1973).

Descriptions of damage and regrowth of an alpine meadow after an accidental spill of refined oil will be useful in planning for alpine and arctic tundra facilities and for rehabilitation of plant communities after oil spills.

## Background

During March and early April, 1972, and oil spill occurred at the Cascade Field Station (the former Austen Pass Warming Hut) at an elevation of 1,330 m, near the terminus of Washington State Highway 542 on Mt. Baker, Washington. Approximately 7,000 gal of No. 2 diesel fuel slowly leaked out of storage tanks adjacent to the station when they were crushed by a heavy snow pack. Over a period of several months, the fuel (SSU Viscosity = 35 at 122° compared to SSU = 170 for crude oil) percolated through a snow-water mixture which was under 10 m of snow. The fuel slowly flowed down a hill and drained into Bagley Lake (elevation, 1262 m).

I visited the area immediately after the snow had melted in mid-September, 1972. Damage to the vegetation was confined to three areas: (1) the basin adjacent to the hut, (2) a wet sedge meadow 10 m below, and (3) a 0.3-0.6-m-deep water course, which dissects the meadow and empties into the former Bagley Lake. The effect of the oil on Bagley Lake was not investigated since this manmade lake has been allowed to drain. Figure 1 is a sketch map of the area showing the regions of damage.

Three areas of inquiry were suggested by this unique situation, a fresh oil spill on an alpine community: (1) what is the influence of diesel fuel on alpine plants and communities, (2) how does succession proceed in an alpine community after a seemingly severe perturbation by diesel fuel, and (3) what sound ecological techniques can be used to rehabilitate the meadow? This paper addresses the first question and describes the initial stages of succession. Succession and rehabilitation will be the subjects of a subsequent paper.

#### Description of Study Site, 1972

When the snow melted from the meadow in September, 1972, the area smelled of diesel fuel and an oil sheen was seen on all standing water. The nature of the damage visible at this time was particularly interesting. Although all the vegetation showed oil damage and, at first inspection, was completely brown or black, most plants retained small patches of green, living tissue distributed randomly throughout the otherwise brown plants.

The alpine meadow partially damaged by the oil is a mosaic of alpine plant communities which seem to be distributed along gradients of moisture associated with

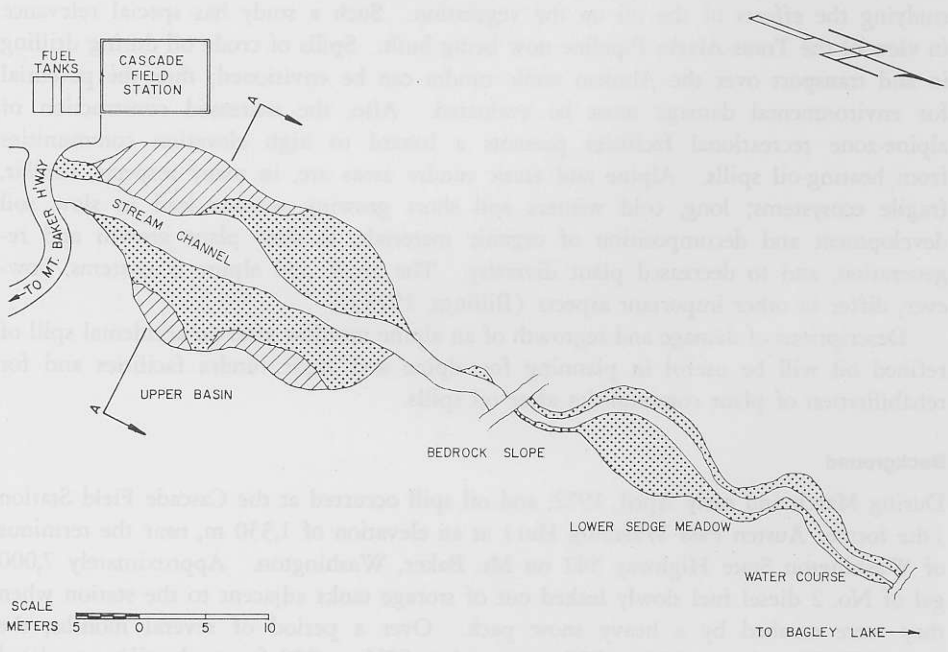


Figure 1. Sketch map of oil-damaged alpine communities, Cascade Field Station, Mt. Baker National Forest, Washington. Dots indicate *Carex nigricans* association; stripes indicate *Phyllodoce empetriformis* association.

topography. The shallow residual soil is underlain by columnar basalt, and there are bare areas of rock and gravel in the channel. The original associations were described using a series of quadrats distributed on undisturbed portions of the meadow. Nomenclature for all species of vascular plants follows Hitchcock *et. al.* (1973); nomenclature for mosses follows Lawton (1971).

A *Carex nigricans* association (Douglas, 1971) covers the flat, wet parts of the meadow. Based on 20 0.1-$m^2$ quadrats, *C. nigricans* shows a mean of 79±20 percent cover and a frequency of 100 percent. A small amount of *Juncus mertensiana* is present in very wet depressions, and *Carex lenticularis* var. *lenticularis* is locally present along the banks of the channel. Moss, lichens, and bare patches occupy the remaining spaces.

On better-drained, sloping ground a few centimeters above the *Carex* community, the sedge is abruptly replaced by a *Phyllodoce empetriformis-Cassiope mertensiana* association (Douglas, 1971) dominated by these species and *Luetkea pectinata*. The constituents of the *P. empetriformis-C. mertensiana* association are derived from ten 1.0-$m^2$ quadrats distributed on undisturbed portions of the better-drained meadow and are described in Table 1.

TABLE 1. *Phyllodoce empetriformis-Cassiope mertensiana* association surrounding impacted area.

| | Cover (%) | Frequency (%) |
|---|---|---|
| *Cassiope mertensiana* | 32±30 | 60 |
| *Phyllodoce empetriformis* | 25±20 | 70 |
| *Luetkea pectinata* | 23±20 | 90 |
| *Carex nigricans* | 18±30 | 60 |
| *Carex* sp. | 4±12 | 40 |
| *Vaccinium deliciosum* | 3± 4 | 60 |
| *Tsuga mertensiana* | 2± 4 | 30 |
| *Deschampsia sp.* | trace | 50 |
| *Hieraceum* sp. | trace | 60 |
| *Mimulus lewisii* | trace | 10 |
| *Juncus martensiana* | trace | 10 |
| *Saxifraga ferruginea* | trace | 10 |

The basin adjacent to the station received the greatest penetration by the oil, with 290 $m^2$ of vegetation being damaged. The original distribution of the vegetation can be reconstructed on the basis of observations in the immediate vicinity and at the margins of destruction (Fig. 2). The moss, *Rhacomitrium sudeticum* var. *alpinum*, and the herbs, *Saxifraga ferruginea, Luetkea pectinata,* and *Hieraceum* sp., seemed to be completely killed by the oil. However, the woody heathers, *C. mertensiana* and *P. empetriformis,* and the mountain hemlock, *Tsuga mertensiana,* retained some undamaged green leaves arranged in random 1-2-$cm^2$ patches throughout the oil-killed, brown leaves. The plants were usually 85-95 percent brown. Although plants in the lowest part of the basin were completely dead, most *Carex nigricans* individuals retained oily-green leaf bases which persisted throughout the first growing season.

In the lower wet meadows, large patches of *C. nigricans* were damaged where the water course had flooded its channels during snow-melt. The vegetation on a 0.2-0.3-m strip along the entire length of the course was also damaged by oil overflowing the banks.

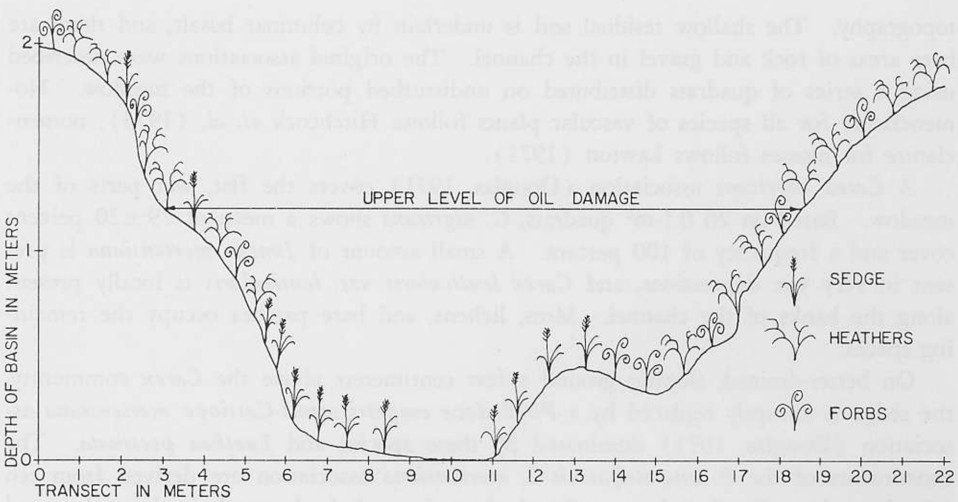


Figure 2. Cross-section and vegetational cover of upper basin along Transect A noted in Figure 1. Upper level of oil damage is indicated by arrow. "Sedge" refers to *Carex nigricans* and *Carex* spp.; "heathers" refer to *Cassiope mertensiana* and *Phyllodoce empetriformis;* and "forbs" refer to *Luetkea pectinata, Vaccinium deliciosum, Hieraceum* sp., *Mimulus lewisii, Saxifraga ferruginea,* etc.

### Recovery, 1973 and 1974

I visited the site several times during late summer, 1973, two growing seasons after the spill. Though the area was still superficially brown and the oil smell and the layer on the water still detectable, there was evidence of regrowth with some changes in vegetational composition.

The *Tsuga mertensiana* and most of the *C. mertensiana* had lost the rest of their leaves and had died, but the *P. empetriformis* and a few *C. mertensiana* individuals were forming profuse terminal and lateral buds. The few remaining green leaves from the preceding summer had died, so the plants consisted of stem and new growth. The *C. nigricans* in all areas seemed dead, the green centers being gone, but there were a few seedlings or sprouts of the sedge appearing in the otherwise dead sedge mat and in oil-covered muddy areas in the lower meadow. No new herbaceous plants were invading the area; but the *Rhacomitrium* was beginning to grow throughout and, by the end of the summer, was forming green mats. Along the damaged part of the water course the bright green sedge, *C. lenticularis,* was growing vigorously. It seems to be much more tolerant of the oily soil than is the *C. nigricans.*

In 1974, the disturbed meadows were covered by an unusually deep snow pack until late September. In spite of the extremely short growing season, the successional trends seen the year before were continuing. The heathers developed a second year's growth of leaves; and patches of *Rhacomitrium,* sometimes a decimeter in diameter, seemed to be growing vigorously and forming a new, green ground cover. New plants of *C. nigricans* were growing through the dead mat, and *C. lenticularis* was growing profusely along the stream bank.

### Discussion and Conclusion

Continued observations in the field and a review of literature on the effects of oil on plants have given sufficient information concerning the function of the plants and the system to suggest hypotheses about the differential damage to the plants in the upper basin. The oil seeped from the storage tanks into the snow and migrated horizontally on ice lenses in the snow as well as vertically to the ground. This flow outward in the snow might account for the intermittent damage to the plants up to 1.5 m above the bottom of the basin. Horizontal oil seepage, plus the possibility that ice might have been frozen on the leaves, allowed random patches of leaves to escape damage. Under the snow, the soil was probably saturated with water. The bulk of the 7,000 gal of diesel fuel, therefore, flowed over the soil surface and down the hill. Wein and Bliss (1973) found that the lightweight oil did not penetrate permafrost layers or the water table and that roots within these saturaed layers were protected from damage. This might account in part for the minimal damage to soil fertility and to root systems. Some of the oil probably penetrated the soil, but the melt-water from 10.0 m of snow plus that from higher ground would have leached out most of it. After the snow melted, any remaining lighter oil fractions would have evaporated. According to Wein and Bliss (1973), in Alaska the summer evaporation rate of crude oil is from 28 percent to 36 percent as measured with a miniature evaporimeter.

There are indications that the root anatomy itself guards the plant from oil damage. Unlike the lipophilic cuticle and stomatal openings covering the aerial parts of terrestrial plants, the roots have no stomatal openings and are surrounded by soil water. Though some crude oil fractions are water soluble (Baker, 1970), distilled petroleum components are generally insoluble (McCown, Brown, and Murrman, 1971). In any case, roots seem to be less sensitive to oil than are stems and leaves (Baker, 1970).

The few records of oil spills or experimental oil applications on terrestrial plant communities indicate that stems which are thick or woody are protected from oil damage. Baker (1971) found that, in salt marsh communities, perennials received less damage from crude oil than did annuals. In the arctic, dwarf shrubs showed greater recovery from various levels of oil application than did mosses and herbs (Wein and Bliss, 1973). Inspection of spills made along the Haines-Fairbanks Military Pipeline in Alaska (Rickard and Deneke, 1972) show that only woody plants, if any, survived crude oil spills.

My observations agree with these reports. The woody stems of *P. empetriformis, C. mertensiana,* and *Tsuga mertensiana* survived the first year, while the herbaceous plants did not. *P. empetriformis,* which has twice the stem diameter of *C. mertensiana,* is more resistant to the oil and survived to the second growing season in greater numbers. The thick, woody stems of the heathers and mountain hemlock must protect the vascular systems of these plants. I can only speculate as to why *C. mertensiana* and *T. mertensiana* died during the second winter, while *P. empetriformis* survived. *P. empetriformis* may have more storage materials in its roots and stems. The plants must have had a negative net productivity during 1972 due to their vastly reduced photosynthetic surface. The *C. mertensiana* and *T. mertensiana* may simply have 'starved.' Or perhaps the meristematic tissues of the *P. empetriformis* stayed intact while those of the other two plants were destroyed and could put on no new growth.

Finally, the seemingly increased fertility of the soil in 1973, seen in the growth of the sedges and moss, might be attributed to: (1) continued cycles of snow-melt and leaching, (2) an increase in the soil's organic matter content from the oil-killed vegetation, and (3) the activity of microbes which can decompose hydrocarbons. Work by Plice (1948) and Adams and Ellis (1960) shows that the number of soil microbes increases dramatically when crude oil or natural gas is added to the soil. This increase of microflora results in an increase in nitrogen and organic carbon in the soil. In Barrow, Alaska, McCown and Benoit (1970) found that five liters of crude oil/m$^2$ caused a two-to-three-fold increase in bacterial numbers. A similar increase was recorded by Bliss *et al.* (1973) in the arctic tundra.

It is still too early to make any statements concerning secondary succession in an alpine meadow after an oil spill. The only vegetative recovery thus far is by the heathers, *P. empetriformis* and *C. mertensiana,* by the carexes, *C. nigricans* and *C. lenticularis,* and by the moss, *Rhacomitrium sudeticum.*. This study is continuing.

With increased building of recreational facilities in temperate alpine areas and with construction of oil wells and pipelines in the arctic, the incidence of refined- and crude-oil spills in alpine and arctic tundra will probably become more frequent in the future. The results from this study at Mt. Baker are encouraging in that they suggest that the impact of spills of refined oil might be of shorter duration that has commonly been predicted.

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