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Dynamics of Reestablishment of Vegetation in an Anthropogenically Disturbed Sphagnum Bog in the Territory of an Oil Field in the Middle Ob Region

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Abstract—Total coverage and coverage of individual plant species were estimated four times during six years in a sphagnum bog, which experienced a strong anthropogenic impact five years prior to the beginning of the study. No signs of the recovery of primary communities were revealed. Slow process of the formation of a new plant cover was observed in areas with completely destroyed vegetation. During the period of study, the total coverage (including that of mosses and annual plants) in different sites reached 12.6–90.4%, depending on degree of disturbance and the local conditions determining the peculiarities of species composition and the stability of reestablishment of the vegetation.

Forecasting the dynamics of reestablishment of vegetation in northern oil-extracting regions is a serious problem in applied ecology (Kershaw, Kershaw, 1986; Gruzdev *et al.*, 1989; Chalysheva, 1992; Kazantseva, 1994). It is significant that disturbances of natural ecosystems in the process of oil extraction are complex and usually include mechanical damage to landscapes, causing changes in their hydrologic regime, and pollution by oil, mud and salt water. We consider the results of long-term stationary observations to be insufficient for evaluating the dynamics of vegetation reestablishment. In this work, we performed long-term observations in permanent sampling plots to analyze the dynamics of this process in a sphagnum bog that experienced the complex effects of human activities.

MATERIAL AND METHODS

The study was conducted in the region of the oil well group no. 80 in the Western Surgut Oil Field, 25 km to the west of the city of Surgut, Tumen oblast (figure). This territory is located approximately 9 km to the north of the Ob River, which flows from northwest to southeast. The network of concrete and dirt roads running along and across the water current has been built since the development of the oil field in the 1960s. The hydrologic regime of the territory of group no. 80 is significantly affected by the impact from the Surgut–Nefteyugansk highway (about 3 km to the south, parallel to the Ob River), its branch leading to the Fedorovskoe Oil Field (east of the group no. 80), and the road running across the watercourse north of the group. Zones of local waterlogging and drying of the territory are shown in the figure. In March of 1983, during the development of the well group no. 80, the flood washed away the banking of the slime reservoir, and its contents (virtually pure oil and a large amount of drilling reagents) spilled over the depressions. At the same time, the collector of oil-field water proved to be broken, and leakage probably continued for several months. By this manner, the territory experienced a strong anthropogenic impact (the disturbance of hydrologic regime combined with pollution with oil and saline water).

Apparently, a sphagnum bog previously existed on this territory. Judging by the remaining well-preserved site (figure, at the bottom), it consisted of sphagnum banks with sparse low pines (*Pinus sylvestris* L.)[1] overgrown with dwarf birch (*Betula nana* L.), leatherleaf (*Chamaedaphne calyculata* (L.) Moench), andromeda (*Andromeda polifolia* L.), wild rosemary (*Ledum palustre* L.), cranberry (*Oxycoccus microcarpus* Turcz.), and cloudberry (*Rubus chamaemorus* L.) and alternating with hollows covered with cranberry (*Oxycoccus palustris* Pers.), and cottongrass (*Eriophorum vaginatum* L.). The thickness of peat layer was 0.3–0.7 m. This is the description of one of the cuts: horizon 0–13 cm, slightly decomposed wet peat; 13–25 (30 cm)—well-decomposed (decayed) wet peat; 25 (30)–40 cm, sandy horizon; 40 cm and deeper, ferruginous sandy horizon; pH_{KCl} ranged along the profile from 7.45 to 8.68. In the largest part of the studied territory, the bog has dried and was completely covered with reedgrass (*Calamagrostis epigeios* (L.) Roth.) The northwestern part of the site is covered by dead pine-birch forest. Its death was apparently caused by the saline water. The hatched area in the figure indicates spills of the oil and saline oil-field water. The figure also shows seven permanent

[1] Latin names of plants are given according to Cherepanov, 1981.

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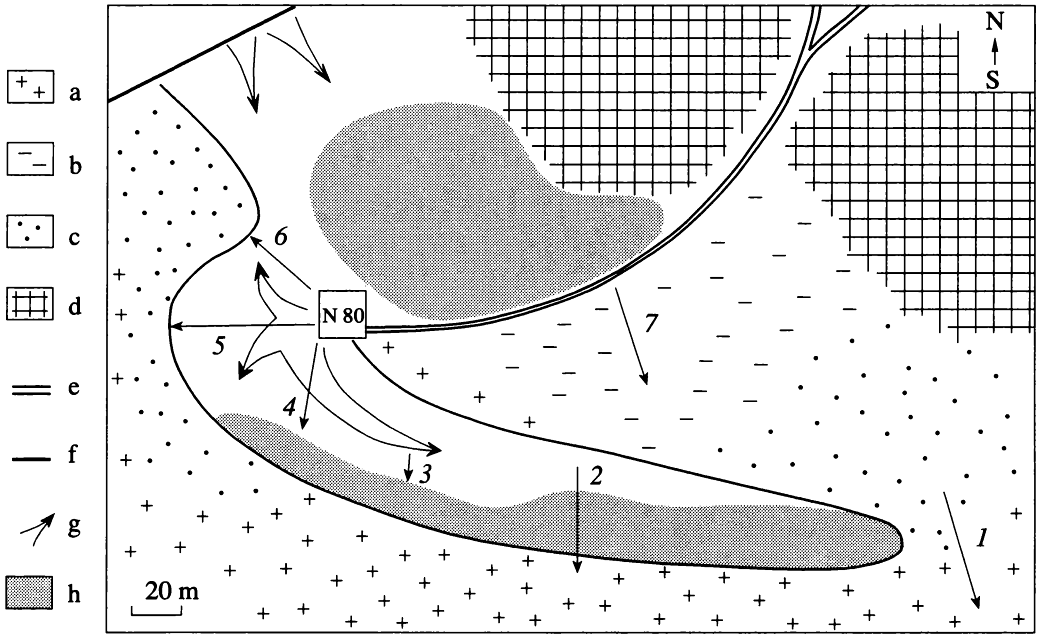

Scheme of studied territory: (a) living sphagnum bog, (b) dried bog, (c) bog covered with reedgrass, (d) dead forest, (e) dirt road, (f) oil-field water collector; (g) spread direction of oil and oil-field water spills, (h) waterlogged areas, (*1–7*), geobotanical transects.

transects laid in the summer of 1989. The territory has not been reclaimed until the winter of 1988, when the area from the midpoint between transects *3* and *4* to transect 6 and beyond was plowed. We first surveyed this area in the summer of 1988. The territory from about the midpoint between transects *4* and *5* to transect 6 represented an "ecological desert" with black ground surface (covered with crust, lumps and sheets of bitumen), locally wet or dry, completely without vegetation, and strongly smelling of petroleum. This territory was plowed again in the winter of 1988/1989. Separate groups of plants, often depressed, remained on elevations along transect 4. A similar picture was observed along the unplowed transect. In 1990, we estimated the "oil crust covering" here; it ranged from 20 to 100%, averaging at 73.5%. The degree of moistening in different parts of the territory varied in different years. For example, transect 3 was laid in 1989 over 30 m, and transect *4*, over 60 m (beyond the limit of the spill). However, in the following years, including a relatively dry 1990, we failed to move along these transects for more than 17 and 43 m, respectively, because swamping made them impassable. Clearly defined oil marks were observed in bog hollows along the spill toward transect *2*. For example, transect *2* was subdivided into five parts: 2(1), dead sphagnum hummock at the edge of the spill; 2(2) and 2(4), bog hollows (in 1990, covered with a continuous oil crust with peat saturated with oil to the depth of 10 cm; 2(3), completely dead, continuously covered with oil crust) part of the hummock between the former two parts; and 2(5), the transition to undisturbed sphagnum bog (the last 4 m).

The first two-thirds of transect *1*, 1(1) and 1(2), were only slightly affected by the spill, and in the last part 1(3), the bog was clean.

To evaluate the dynamics of petroleum products and chlorides in the soil is actually impossible. In the samples taken at 0.5-m intervals from 1989 to 1993, their contents varied over a great range: 0.1–118 g/kg for petroleum products and 270–1800 mg/kg for chlorides. From 1983 until 1990, the sites crossed by transects *4* to *1* suffered from the chronic effect of petroleum products brought by flood water every spring. Hence, pollution of this territory was highly nonuniform. In some sites of transects *2* and *3*, petroleum products penetrated peat to a depth of 10–15 cm, and chlorides, to 20 cm. The zone 1(3) is clean, which was confirmed by the microbiological tests. The total number of saprophytic microorganisms was 63×10^5 per g of the soil, and that of microorganisms grown in agar with the addition of crude oil, 2.2×10^5 (values characteristic of nonpolluted soils). The test suggested the pollution in the plot 1(1), in which the respective values were 730×10^5 and 49×10^5.

Transect 7 is a special case. In this site, oil-field water polluted a drying bog crossed by a dirt road (figure). Pollution was apparently insignificant, because microbiological tests gave uncertain results: the number of saprophytes was 319×10^5 per g of the soil, and number of microorganisms in oil-containing agar was 2.7×10^5. This plot was plowed in 1990.

Coverage of individual species and total projective coverage were estimated along the transects in the adjacent square sampling plots (1 m^2) in late August–early September of 1989, 1990, 1991, and 1994. The sum of

Table 1. Coverage in native and disturbed sphagnum bogs

Species, group of species	Transect and its length				
	1(3), 19 m	1(1), 25 m	1(2), 26 m	2(1), 11 m	2(5), 14 m
Total coverage	97.2	54.3(87.6)*	86.5	47.7	74.8
Sphagnum spp.	88.3	10.8	38.1	0	46.5
Polytrichum strictum	6.2	0.77	6.8	11.8	5.5
Ceratodon sp.	0.21	20.5	6.7	11.9	12.9
Cladonia sp.	0.90	0.06	0.16	11.7	0.02
Eriophorum vaginatum	8.9	10.2(47.6)	31.6	4.1	12.0
Calamagrostis epigeios	0	18.6(3.5)	0.70	2.3	1.5
Ledum palustre	21.2	0.36	4.4	2.7	11.9
Chamaedaphne calyculata	17.8	0	0.47	0.18	1.0
Andromeda polifolia	0.04	0	0.27	0.02	0.002
Rubus chamaemorus	13.1	0.56	4.0	4.0	5.2
Oxycoccus palustris	2.1	7.2(28.8)	13.0	0	0.66
Oxycoccus microcarpus	18.0	0.07	10.2	2.1	1.7
Betula nana	7.5	4.6	12.0	11.1	11.6
Pinus sylvestris	0.35	0.20	0.38	0	0.09
Populus tremula	0	2.2	0.55	0.07	1.4
Salix spp., *Betula pubescens*					

* Average over the period from 1989 to 1991; values in parentheses are the data of 1994.

individual species can exceed the total coverage, because coverages of individual species may superimpose on one another, even within the same layer. Average values of coverage were calculated for the entire transects or their relatively uniform parts. Statistical analysis of coverage in consecutive years was performed using pairwise comparison of plots by the sign test.

RESULTS AND DISCUSSION

First, we will characterize the plots where the cenosis of sphagnum bog was disturbed but not destroyed completely—1(1), 1(2), 2(1), and 2(5)—and compare these plots with control (native) vegetation of the plot 1(3). Data on coverages in these cenoses are given in Table 1. These are average data of four observations in different years (except one value), because no dynamics of coverage was observed, and the results for different years were very close. The exception concerns coverage of reedgrass, cottongrass, cranberry, and, consequently, the total coverage in transect 1(1) in 1994 present the exclusion. A significant increase in coverage of cottongrass (+37.4) and cranberry (+21.6) and a decrease in reedgrass coverage (–51.1) can be explained apparently by very wet weather in 1994, which stimulated growth of cottongrass and cranberry, but suppressed growth of reedgrass. It can be seen from the Table 1 that plot 1(3) corresponds to a typical cenosis of the sphagnum bog, whereas cenoses of all other plots are disturbed to a similar degree. Characteristic signs include a decrease in the amount of sphagnum and an increase in the proportion of other mosses. In the plot 2(1), sphagnum disappeared completely, whereas coverage of lichens increased. In plot 1(2), transitional to a disturbed bog, cottongrass coverage increased, and reedgrass appeared everywhere. Coverage of wild rosemary, leatherleaf, cloudberry, and cranberry markedly decreased. Tree species of trembling aspen, willow, and pubescent birch—not characteristic of the primary community—invaded the disturbed plots (although in small numbers). Single annual plants, including toad rush (*Juncus bufonius* L.), mountain willowweed (*Epilobium montanum* L.), and goosefoot (*Chenopodium rubrum* L.), appeared only in plot 2(5).

Sphagnum communities were completely destroyed by the spill in plots 2(2), 2(3), 2(4), and 3. Reestablishment of plant cover in these places occurred slowly and in different ways, depending on the local distribution of oil accumulations, soil moistening, etc. Total coverage in bog hollows 2(2) and 2(4) was relatively high during the entire observational period: 30.7–38.7%, without any regular changes. It was accounted for mostly by cottongrass and reedgrass. The ratio of these species varied in different years, depending on moistening. Annual plants were relatively abundant. They included the following species: *Juncus bufonius* L., *J. gerardii* Loisel, *Chenopodium rubrum* L., *Rumex reticulatus* L., *Senecio paludosus* L., and *Epilobium montanum* L. Coverage of toad rush reached 31.6 percent in 1989. Total coverage in the completely destroyed part of the

Table 2. Dynamics of coverage in plowed transects (total and for individual species)

Transect	Transect length, m	Species	Year			
			1989	1990	1991	1994
7	56	Total	7.9	11.3	24.4	90.4
		Shagnum sp.	0.09	1.0	1.9	1.2
		Polytrichum strictum	0	0.70	2.6	40.3
		Bog species[1]	1.5	6.9	4.0	11.0
		Eriphorum vaginatum	4.1	3.5	9.1	37.1
		Regrowth of tree species[2]				
		coverage	0.21	0.36	1.7	2.8
		frequency	12.5	19.6	58.9	55.4
4	43	Total	13.1	17.5	25.1	45.4
		Calamagrostis epigeios	2.4	4.2	12.2	6.0
		Annual plants[3]	7.6	9.4	5.8	5.5
		Ceratodon sp.	0.91	5.4	10.4	21.3
		Regrowth of tree species[2]				
		coverage	0.09	0.21	2.6	8.3
		frequency	2.3	11.6	62.8	65.1
5	75	Total	0.50	15.7	19.6	27.7
		Calamagrostis epigeios	0.20	5.2	12.5	13.7
		Annual plants[3]	0.20	9.6	5.1	5.5
		Ceratodon sp.	0	0.04	1.7	1.7
		Eriphorum vaginatum	0	0.01	0.03	1.9
		Regrowth of tree species				
		coverage	0	0	0.36	0.84
		frequency	0	0	30.7	36.0
6	38	Total	19.4	20.7	17.6	32.3
		Calamagrostis epigeios	2.3	11.6	17.6	12.2
		Annual plants[3]	17.3	11.4	1.8	11.2
		Ceratodon sp.	0	0	0.66	9.2
		Regrowth of tree species				
		coverage	0	0	0.16	0.29
		frequency	0	0	13.2	18.4

[1] Bog species: *Ledum palustre, Chamaedaphne calyculata, Rubus chamaemorus, Andromeda polifolia, Oxycoccus microcarpus, O. palustris.*
[2] Tree species: *Betula pubescens, Populus tremula, Salix* spp.
[3] Annual plants: *Rumex reticulatus, Senecio paludosus, Juncus bufonius, J. gerardii, Chenopodium rubrum, Epilobium montanum.*

sphagnum hummock 2(3) gradually increased from 10.8 to 28.0%. This increase, however, was accounted for mostly by lichens (up to 19.6% in 1994) and partly by reedgrass (maximum 13.0% in 1991). Total coverage along transect 3 was low and varied irregularly from 7.8 to 14.8%. The vegetation consisted mainly of *Calamagrostis epigeios, Ceratodon* sp., and annual species.

In 1991 and 1994, single plants of bog species began to appear and grow in all disturbed plots. These were *Ledum palustre* L., *Vaccinium uliginosum* L., *Betula nana* L., *Polytrichum* sp., and also species characteristic of marshlands: *Carex* sp., *Eleocharis acicularis* (L.) Roem. et Schult., and *Typha latifolia* L. However their numbers are as yet small, and their fate may significantly depend on temperature and fluctuations in moistening. Certain individuals of trembling aspen and willow grow well. Relatively many their seedlings appeared in 1994. Weak reestablishment of plant cover in the places of destroyed sphagnum cenoses is explained apparently by the abundance of thick bitumen crusts and by changes in physical properties of the soil. Toxic effects of salts and oil can manifest themselves even today. First, even in 1994 we sensed the smell of oil after breaking the bitumen crust. This was evidence for the presence of light petroleum fractions that have not evaporated and remained in the soil. Second, in 1990 we sowed plantations of *Calamagrostis epigeios* by scattering its panicles over a large area near transects *2* and *3*. Many seedlings were found in 1991, but they all disappeared subsequently. It is known that plants at early stages of development are especially sensitive to the toxic effects of petroleum products (Kazantseva, 1994).

Table 2 shows the data on the dynamics of coverage in total and for individual species that largely account for total coverage and specific features of the vegetation along the plowed transects. Reestablishment of vegetation proceeded more successfully in transect 7 (dried bog with slight salt contamination). Total coverage in August 1989 was 7.9%, although the site was plowed as recently as in June of that year; *Calamagrostis epigeios* coverage never exceed 3%, annual plants were rare, newly appearing and well-growing tree species were represented by trembling aspen and willow. However, most plants remaining and expanding over a greater part of this plot are representatives of bog cenosis. In 1994, even some amount of *Sphagnum* sp. was found, and an increase in coverage was observed for *Polytrichum strictum, Eriophorum vaginatum, Chamaedaphne calyculata, Andromeda polyfolia, Ledum palustre*, both *Oxycoccus* species, and *Rubus chamaemorus* (Table 2). Total projective coverage reached 90.4% in 1994.

Vegetation in other three heavily polluted transects differed from that described above. It is represented by slowly growing *Calamagrostis epigeios* and plants unstable in time, such as perennial species and mosses. Cottongrass appeared only in transect *5*. Coverage of all perennial species comprised 12–20%. The increase in the number of trees (willow, trembling aspen, pubescent birch, and single pine) and their good growth in all transects reflects a general trend toward a greater stability of plant cover.

CONCLUSION

The results described above show that plowing of heavily polluted sphagnum bog (in our case, an absolutely necessary measure) promotes the recovery of vegetation. Of course, plowing was performed too late (Oborin *et al.*, 1988). This measure should have been taken in winter of 1983 or 1984, and the toxic effects on the adjacent plots would have been less pronounced. The structure of sphagnum bog is so complex (Nitsenko, 1967; Boch and Mazing, 1979) that any obvious trends toward its recovery after such heavy disturbances may manifest themselves only after many decades.

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