# 草地生態系における生産および分解の平衡 第7報 Na,Fe,Mn,Cu,Zn,Co 並びに Ni の動き



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# Balance of Producers and Decomposers in a Grassland Ecosystem in Obihiro

## VII. Movement of Na, Fe, Mn, Zn, Cu, Co and Ni

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### Introduction

The authors (1971 d, e & f) reported cycles of nitrogen, phosphorus, potassium, calcium and magnesium in a semi-natural grassland ecosystem of a steady state condition. These suggest that if we harvest large amount of forage crops in a tame grassland, such element cycles will be destroyed. To prevent this, we must put back as much as we take out, or more. Fertilizers containing major elements are currently used on the tame grassland.

One of the problems facing man who manages a good pasture is deficiency of minor elements, such as Fe, Mn, Zn, Cu, Co, Ni etc. Acute deficiencies of minor elements in forage crops or livestocks induce easily recognisable symptoms but marginal (sub-acute) deficiencies are difficult to recognise, and the distribution of their occurrence is very difficult to define.

In this investigation, observations only were made on the movement of minor elements, that is, accumulation and release by plants in the steady state grasslands of *Phragmites longivalvis*, *Reynoutria sachalinensis*, and *Sasa purpurascens* at the Satsunai Riverside area in Obihiro. The results are discussed in relation to the ability of soils to supply minor elements.

### Materials and Method

The litter samples were collected by the same method as in the previous papers (OOHARA et al. 1971 a, b, c, and d) out of the *P. longivalvis*-, R. *sachalinensis*-, and *S. purpurascens* grasslands. These samples were air-dried and ground to a 100-mesh size. Following the ashing procedure briefly indicated elsewhere (ANDREWS 1965 and 1966), analyses for total Na, Fe, Mn, Cu, Zn, Co and Ni were determined by atomic absorption spectrophotometer (Model 303). Exchangeable elements were extracted with 1.00 N $CH_3COONH_4$ solution of pH 7.00 and determined. As a check on the efficiency of replication, pH was measured in a sample water suspension of 1:2.5 for Ao and H samples, of 1:5 for F and L samples.

## Results and Discussion

(1) Minor element contents in the litter

Mean contents of minor elements in the litter samples of some grasslands at the Satsunai Riverside area are given in Table 1. The content of each element was estimated as the difference between total and exchangeable element,

Table 1. The contents of Na and minor elements in the litter in the *P. longivalvis*-, *R. sachalinensis*-, and *S. purpurascens* grasslands

| Grassland type | Horizon | pH | Na (%) | Excangeable Na (%) | Fe (ppm) | Mn (ppm) | Zn (ppm) | Cu (ppm) | Co (ppm) | Ni (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|
| *P. longivalvis* | L | 6.11 | 0.123 | 0.085 | 181.7 | 27.1 | 18.0 | 11.3 | 0.45 | 0.33 |
| | F | 5.79 | 0.172 | 0.063 | 340.1 | 59.2 | 29.6 | 12.9 | 0.90 | 0.38 |
| | H | 6.18 | 0.463 | 0.061 | 366.3 | 200.9 | 52.4 | 24.5 | 1.10 | 0.46 |
| | $A_0$ | 6.21 | 0.413 | 0.056 | 365.5 | 192.1 | 42.8 | 19.6 | 1.38 | 0.68 |
| *R. Sachalinensis* | L | 6.75 | 0.278 | 0.074 | 186.3 | 139.6 | 23.3 | 12.1 | 0.53 | 0.48 |
| | F | 6.38 | 0.297 | 0.058 | 314.5 | 181.2 | 43.8 | 17.0 | 0.68 | 0.49 |
| | H | 6.47 | 0.516 | 0.055 | 381.8 | 247.5 | 71.8 | 24.8 | 2.45 | 0.59 |
| | $A_0$ | 6.64 | 0.463 | 0.062 | 383.4 | 239.2 | 43.2 | 18.7 | 2.95 | 0.58 |
| *S. purpurascens* | L | 6.55 | 0.143 | 0.071 | 260.8 | 103.8 | 41.1 | 12.5 | 0.43 | 0.36 |
| | F | 6.17 | 0.177 | 0.068 | 322.6 | 120.0 | 44.8 | 12.6 | 0.58 | 0.37 |
| | H | 6.07 | 0.543 | 0.063 | 396.3 | 282.1 | 48.7 | 21.3 | 0.95 | 0.43 |
| | $A_0$ | 6.23 | 0.585 | 0.061 | 394.5 | 282.6 | 48.4 | 19.8 | 1.15 | 0.57 |

Exchangeable Fe, Mn, Zn, Cu, Co and Ni were very small in amount and negligible, so they were not included in the table.

In general, soil pH goes down to F horizon and rises up from F to $A_0$. Therefore, its value of F is the lowest of four soil horizons. As the soil horizon goes down to H, the Na, Fe, Mn, Cu, Co, and Ni contents increase steadily and show maximum values at H or $A_0$, but exchangeable Na decreases and shows minimum values at H or $A_0$ (Table 1). It suggests that these elements are released very slowly from the organic matter in the litter. The Na, Mn, Co and Ni contents in the litter samples of *R. sachalinensis* were the highest of three species. Differences of those element contents between *R. sachalinensis* and *P. longivalvis*, or *S. purpurascens* were highly significant at 1% level, but there were no significant differences of those elements between *P. longivalvis* and *S. purpurascens*.

It is evident that the Fe and Zn contents in the litter samples of *S. purpurascens* showed highly significant difference from each other. There was no significant difference among the Cu contents in the litter of the three species. WIDDOWSON (1966 a & b) discussed that chlorotic plants which were deficient in Zn for growth contained 9.5 ppm compared with 15 ppm of Zn in normal plants. It was also assumed by RICEMEN and JONES (1958) that as for most clovers, plants with less than 15 ppm of Zn in the leaves can be suspected of Zn deficiency. BEESON and GUILLERMO-GOMEZ (1970) has demonstrated that in the Huallaga valley of the upper Amazon basin of Peru where grazing animals in the region respond to Co supplements, the forage generally contains less than 0.04—0.07 ppm and in the Ucayali valley where animals show no indication of the Co deficiency, the forage generally contains more than 0.1 ppm of Co. As shown in Table 1, contents of minor elements in the litter are the same or higher than those in forage samples discussed above. It is, therefore, possible to state that in the present time there are no deficiency of minor elements in this area. However, the ability for the soil to supply minor elements to plants can not be discussed by this experiment. Clearly this is a problem where further study is needed.

(2) Annual addition of minor elements on the grassland floor

Table 2 presents annual addition of Na, Fe, Mn, Zn, Cu, Co and Ni in the three grasslands of a steady state condition.

Table 2. The production of Na and minor elements of the litter in the three grassrands in Obihiro

| Grassland type | Horizon | Na $(g/m)^2$ | Fe $(mg/m)^2$ | Mn $(mg/m)^2$ | Zn $(mg/m)^2$ | Cu $(mg/m)^2$ | Co $(mg/m)^2$ | Ni $(mg/m)^2$ |
|---|---|---|---|---|---|---|---|---|
| *P. longivalvis* | L | 0.763 | 112.76 | 16.81 | 11.17 | 7.01 | 0.279 | 0.204 |
| | F | 1.897 | 374.45 | 65.17 | 32.59 | 14.20 | 0.991 | 0.418 |
| | H | 9.465 | 748.79 | 410.68 | 107.12 | 50.83 | 2.249 | 0.940 |
| | $A_0$ | 12.068 | 1068.03 | 561.34 | 125.07 | 57.27 | 4.032 | 1.987 |
| *R. sachalinensis* | L | 1.804 | 120.91 | 90.60 | 15.12 | 7.85 | 0.344 | 0.312 |
| | F | 2.066 | 218.77 | 126.04 | 30.47 | 11.83 | 0.473 | 0.341 |
| | H | 7.535 | 557.50 | 361.40 | 104.84 | 36.21 | 3.577 | 0.862 |
| | $A_0$ | 12.996 | 1076.20 | 671.43 | 121.26 | 52.49 | 8.281 | 1.628 |
| *S. purpurascens* | L | 0.193 | 35.21 | 14.01 | 5.55 | 1.69 | 0.058 | 0.049 |
| | F | 0.651 | 118.59 | 44.11 | 16.47 | 4.63 | 0.213 | 0.136 |
| | H | 2.939 | 214.48 | 152.67 | 26.36 | 11.53 | 0.514 | 0.233 |
| | $A_0$ | 9.802 | 661.02 | 473.52 | 81.10 | 33.18 | 1.927 | 0.955 |

As shown in Table 2, annual addition of minor elements is very high in the *R. sachalinensis* grassland. It is medium in the *P. longivalvis* grassland. Data of the *S. purpurascens* grassland shows low addition of minor elements. The increasing order of the amount of annual addition on each minor element in the three grasslands was Ni, Co, Cu, Zn, Mn, Fe and Na. It seems that the amount of annual addition of minor elements is not only related to those contents in the litter and annual litter production but is affected by the amount of minor elements contained in the soil too.

As soil horizon goes down to $A_0$, the amount of each minor element increases clearly. That of $A_0$ is, therefore, a maximum level (Table 2). It means that the release of each minor element due to the decomposition of the litter are very slow as compared with mineralization of major elements (OOHARA *et al.* d, e & f).

(3) The release rate of minor elements from the litter

The estimates of the release constant r for Na, Fe, Mn, Zn, Cu, Co and Ni in the grasslands of *P. longivalvis*, *R. sachalinensis* and *S. purpurascens* are shown in Fig. 1 and

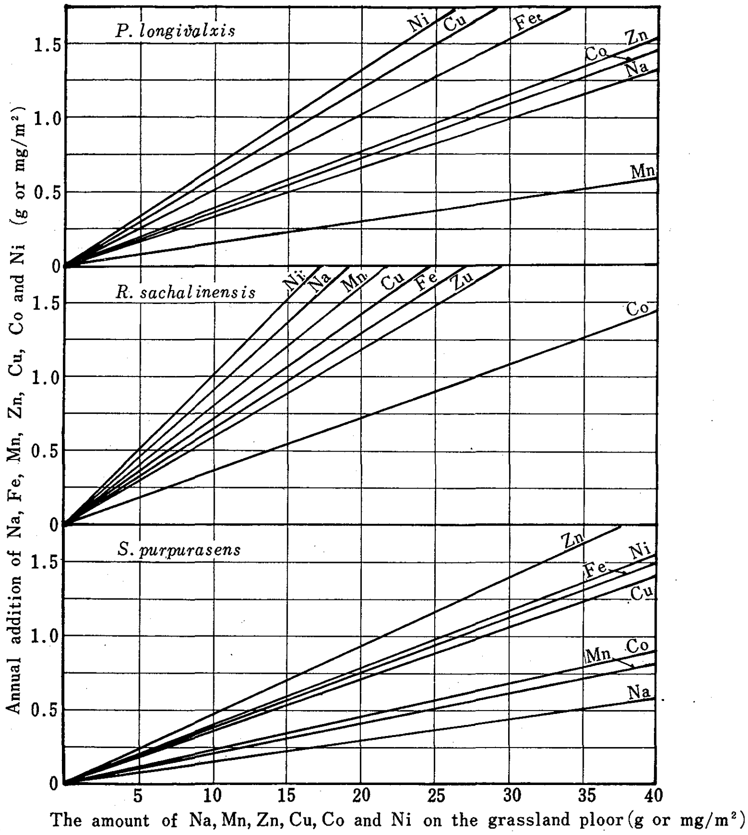


Fig. 1. Estimates of the release constans for Na, Fe, Mn, Zn, Cu, Co and Ni in the three grasslands.

Table 3. In this case, the release constant was determined by the ratio of annual addition to steady state total, as the ratio of the vertical axis over the horizontal axis of Fig. 1 (OOHARA et al. 1971 a). The estimates of r of minor elements range from 0.0610 down to 0.0162 for the *P. longivalvis* grassland. The *R. sachalinensis* grssland has their values of 0.0279 to 0.1100, while the *S. purpurascens* grssland ranges from 0.0144 to 0.0448. Those constants differ by each minor element and species. It means that the amounts of minor elements needed and absorbed by the species are different from one another.

As shown in Fig. 1, the general trend of the releases of minor elements is very rapid in the *R. sachalinensis* grassland, medium in the *P. longivalvis* grassland, and very slow in the *S. purpurascens* grassland.

(4) The release and accumulation of minor elements on the grassland floor

Since values of r of Na, Fe, Mn, Zn, Cu, Co, and Ni have been estimated, the release models of these elements can be defined as the basic concept of decomposition (OOHARA *et al.* 1971 a, b, c, d, e & f); in the case of Na

$$Na = Nao e^{-rt} \qquad (1)$$

in the case of Fe

$$Fe = Feoe^{-rt} \quad (2)$$

in the case of Mn

$$Mn = Mnoe^{-rt} \quad (3)$$

in the case of Zn

$$Zn = Znoe^{-rt} \quad (4)$$

in the case of Cu

$$Cu = Cuoe^{-rt} \quad (5)$$

in the case of Co

$$Co = Cooe^{-rt} \quad (6)$$

in the case of Ni

$$Ni = Nioe^{-rt} \quad (7)$$

where Nao, Feo, Mno, Zno, Cuo, Coo and Nio are the amounts of Na, Fe, Mn, Zn, Cu,

Table. 3. Parameters and periods for release or accumulation of Na, Fe, Mn, Zn, Cu, Co and Ni in the litter in the three grasslands in Obihiro

| Mineral elements | Grassland type | r | 1/r | Half time (years) | 95% time (years) | 99% time (years) |
|---|---|---|---|---|---|---|
| Na | *P. longivalvis* | 0.0326 | 30.675 | 21.3 | 93.0 | 135.4 |
| | *R. sachalinensis* | 0.0798 | 12.531 | 8.7 | 37.6 | 62.7 |
| | *S. purpurascens* | 0.0144 | 69.444 | 48.1 | 208.3 | 347.2 |
| Fe | *P. longivalvis* | 0.0515 | 19.417 | 13.5 | 58.3 | 97.1 |
| | *R. sachalinensis* | 0.0653 | 15.314 | 10.6 | 45.9 | 76.6 |
| | *S. purpurascens* | 0.0354 | 28.249 | 19.6 | 84.7 | 141.2 |
| Mn | *P. longivalvis* | 0.0162 | 61.728 | 42.8 | 185.2 | 308.6 |
| | *R. sachalinensis* | 0.0782 | 12.788 | 8.9 | 38.4 | 63.9 |
| | *S. puvpurascens* | 0.0209 | 47.847 | 33.2 | 143.5 | 239.2 |
| Zn | *P. longivalvis* | 0.0422 | 23.697 | 16.4 | 71.1 | 118.5 |
| | *R. sachalinensis* | 0.0589 | 16.978 | 11.8 | 50.9 | 84.9 |
| | *S. purpurascens* | 0.0448 | 22.321 | 15.5 | 67.0 | 111.6 |
| Cu | *P. longivalvis* | 0.0573 | 17.452 | 12.1 | 52.4 | 87.3 |
| | *R. sachalinensis* | 0.0781 | 12.804 | 8.9 | 37.0 | 64.0 |
| | *S. purpurascens* | 0.0343 | 29.155 | 20.2 | 87.5 | 145.8 |
| Co | *P. longivalvis* | 0.0384 | 26.042 | 18.0 | 78.1 | 130.2 |
| | *R. sachalinensis* | 0.0279 | 35.843 | 24.8 | 107.5 | 179.2 |
| | *S. purpurascens* | 0.0219 | 45.662 | 31.6 | 137.0 | 228.3 |
| Ni | *P. longivalvis* | 0.0610 | 16.393 | 11.4 | 49.2 | 82.0 |
| | *R. sachalinensis* | 0.1100 | 9.091 | 6.3 | 27.3 | 45.5 |
| | *S. purpurascens* | 0.0370 | 27.027 | 18.7 | 81.1 | 135.1 |

Co, and Ni on the grassland floor initially, and t is time.

The release equations of those elements in each grassland are given by substitution of each release constant (Table 3) in the equations (1) to (7). Their curves are shown in Fig. 2. OOHARA *et al.* (1971 b & c) elucidated that the crude protein of the litter in a grassland ecosystem decayed with the slowest velocity of some chemical components. However, as shown in Fig. 2, the release of minor elements is slower than that of crude protein. It suggests that minor elements which constitute the prosthetic group of enzyme in plant are released very slowly from apo-enzyme, while enzymatic protein is decomposed more slowly than structural protein.

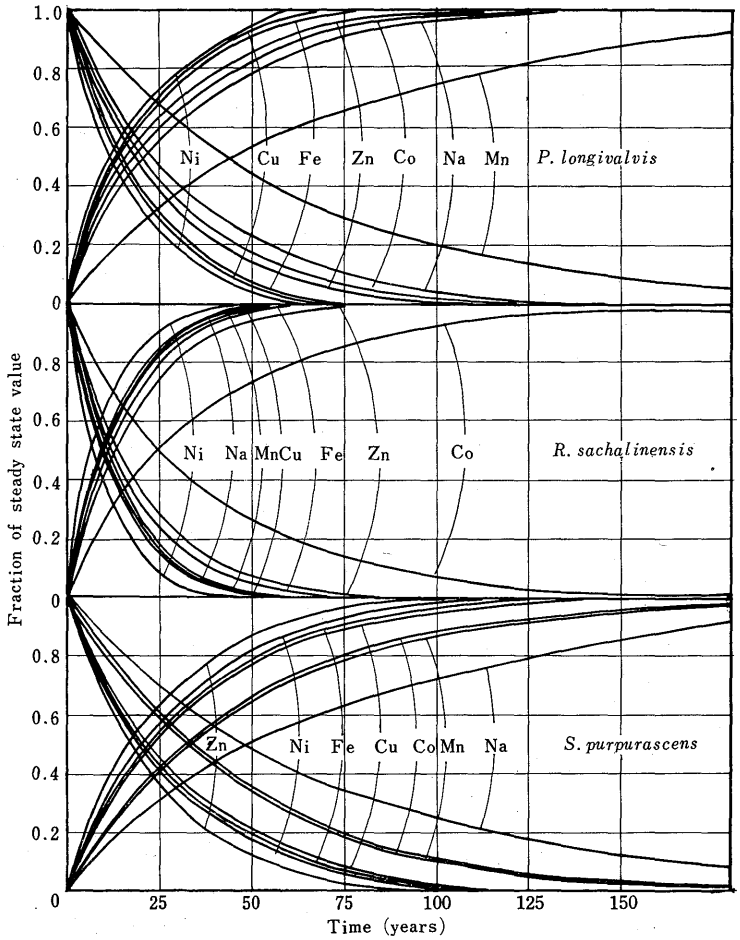


Fig. 2. The curves of release and accumulative models of Na and minor elements in the approximately steady state ecosystems of the *P. longivalvis*-, *R. sachalinensis*- and *S. purpurascens* grasslands in Obihiro.

Because those release parameters are determined in each grassland, the accumulative models of Na, Fe, Mn, Zn, Cu, Co, and Ni of the litter in the three grassland ecosystems at the Satsunai Riverside can be obtained from the basic concept of accumulation (OOHARA et al. 1971 a, b, c, d, e & f); for Na

$$\mathrm{Naa}=\frac{\mathrm{LNa}}{r}(1-e^{-rt}) \tag{8}$$

for Fe

$$\mathrm{Fea}=\frac{\mathrm{LFe}}{r}(1-e^{-rt}) \tag{9}$$

for Mn

$$\mathrm{Mna}=\frac{\mathrm{LMn}}{r}(1-e^{-rt}) \tag{10}$$

for Zn

$$\mathrm{Zna}=\frac{\mathrm{LZn}}{r}(1-e^{-rt}) \tag{11}$$

for Cu

$$\mathrm{Cua}=\frac{\mathrm{LCu}}{r}(1=e^{-rt}) \tag{12}$$

for Co

$$\mathrm{Coa}=\frac{\mathrm{LCo}}{r}(1-e^{-rt}) \tag{13}$$

and for Ni

$$\mathrm{Nia}=\frac{\mathrm{LNi}}{r}(1-e^{-rt}) \tag{14}$$

where Naa, Fea, Mna, Cua, Zna, Coa, and Nia are the amounts of accumulation of Na and minor elemets on the grassland floor, and LNa, LFe, LMn, LZn, LCu, LCo and LNi express the amounts of annual addition of those elements. Their graphical curves on the three grasslands are given as the mirror images of the curves of release (Fig. 2). Their curves indicate that the slower the release of a minor element is, the more the amount of its accumulation is.

The time required to reach 50, 95 and 99% to the asymptotic level is the same time as that required for release of 50, 95 and 99% of the accumulated Na and minor elements. Those date are summarized in Table 3. There are the highly significant differences among those periods of Na and minor elements and also among the species.

(5) A hypothetical illustration of natural buildup of minor elements and their subsequent modification by man

The soil-minor element system is also dynamic. Therefore, any alternation in the environment shifts the system toward a now steady atate condition. Fig. 3 reveals how rapidly soils of the three grasslands, when put to the plow or to the harvester, decline minor elements. In that case the amounts of minor elements in the surface horizons such as L, F, H and $A_0$ may decrease to 1% of their steady state levels after about 50

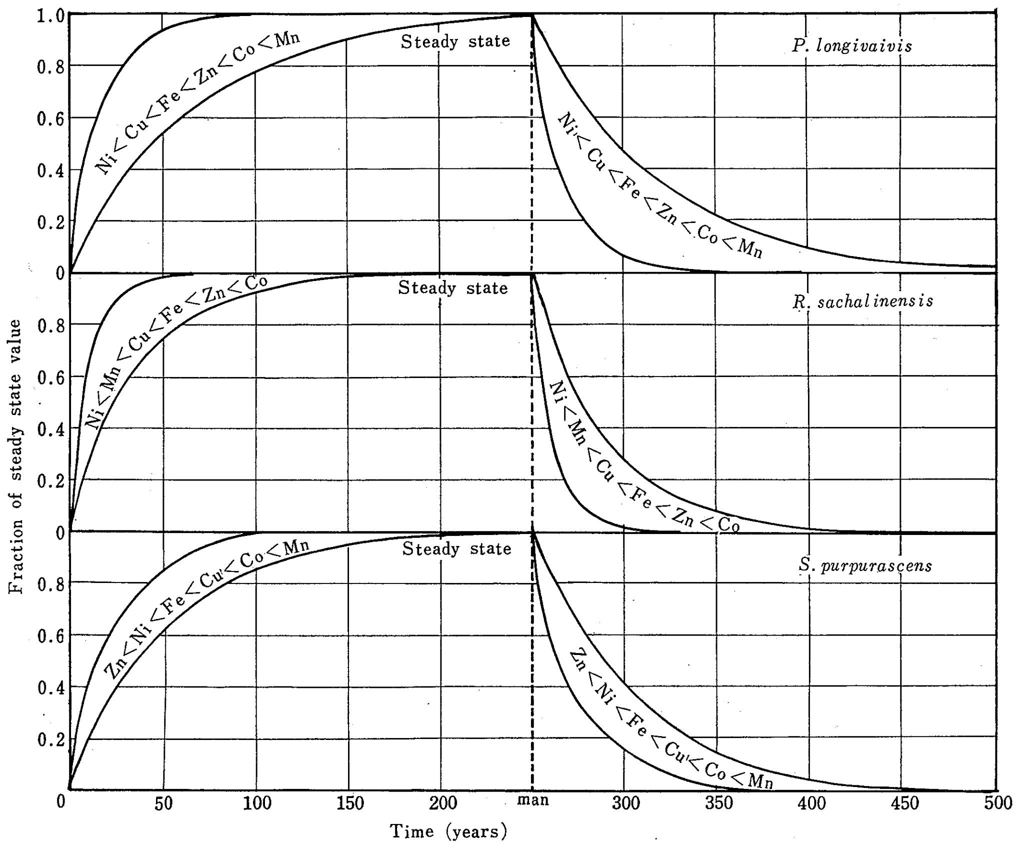


Fig. 3. A hypothetical illustration of natural buildup of minor elements in surface soils (L, F, H and $A_0$ horizons) and their subsequent modification by man.

to 310 years. It suggests that because of no application of minor elements as fertilizer, their contents in soils of the tame grassland decrease more and more. The problem of capability for soils to supply minor elements is very important for manager of a pasture but the more investigations on its capability must be carried out in future.

## Summary

This report summarizes the study on the movement of Na, Fe, Mn, Zn, Cu, Co, and Ni in the grassland ecosystems of *P. longivalvis*, *R. sachalinensis* and *S. purpurascens* in Obihiro and on the ability of their surface soils to supply minor elements.

1. The Na, Mn, Co and Ni contents in the litter of *R· sachalinensis* were the highest of the three species but there were no significant differences of those elements between *P. longivvlvis* and *S. purpurascens*. The Fe and Zn contents in the litter of *S. purpurascens* showed highly significant difference from each other. There was no significant difference among the Cu contents in the litter of the three species.

2. As the soil horizon goes down to H, the Na, Fe, Mn, Zn, Cu Co and Ni contents increase steadily and show maximum values at H or $A_0$, but exchangeable Na decreases

and shows maximum values at H or $A_0$.

3. The Na, Fe, Mn, Zn, Co and Ni contents in the litter of the there species are 0.123—0.278%, 181.7—260.8 ppm, 27.1—139.6 ppm, 18.0—41.1 ppm, 11.3—12.5 ppm, 0.43—0.53 ppm and 0.33—0.48 ppm respectively. Therefore, in the present time three are no deficiency of minor elements in this area.

4. Annual addition of minor elements is very large in the *R. sachalinensis* grassland. It is medium in the *P. longivalvis* grassland, while the *S. purpurascens* grassland shows small addition.

5. Since it takes a period of about each 0.693/r, 3/r and 5/r years to release and accumulate 50, 95 and 99% of its steady state level, their estimates for Na, Fe, Mn, Zn, Cu, Co and Ni in the three grassland ecosystems are as in Table 3.

6. The models of release and accumulation of Na and minor elements on the grassland floor are expressed as the equations (1) to (14).

7. The amount of minor elements in the surface soils of those three grasslands, when put to the plow or to the harvester, may decrease to 1% of the steady state level after about 50 to 310 years.

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# 草地生態系における生産および分解の平衡

## 第7報 Na, Fe, Mn, Cu, Zn, Co 並びに Ni の動き

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### 要 約

ヨシ，オオイタドリおよびササの草地生態系における Na, Fe, Mn, Zn, Cu, Co 並びに Ni の動きと，これらの微量元素を供給する L, F, H および $A_0$ 層の能力について検討した結果を要約すると次のとおりである。

1. Na, Mn, Co および Ni 含量はオオイタドリの落葉がヨシ並びにササの落葉より高いがヨシとササの間には有意差が認められなかった。Fe と Zn はササの方がやや高い，Cu は各草類別にその含量の差が認められなかった。

2. LからH層までには Na, Fe, Mn, Zn, Cu, Co 並びに Ni の含量は増加して，H あるいは $A_0$ 層で最大値になるが，置換性 Na の場合には逆に H あるいは $A_0$ 層が最少値になった。

3. ヨシ，オオイタドリおよびササ群落の落葉の Na, Fe, Mn, Zn, Cu, Co, および Ni 含量は，各々 0.123～0.278%，181.7～260.8 ppm，27.1～139.6 ppm，18.0～41.1 ppm，11.3～12.5 ppm，0.43～0.53 ppm 並びに 0.33～0.40 ppm であり，したがってこの地域では微量元素の欠乏はない。

4. 微量元素の生産量を群落別に比較するとオオイタドリ群落＞ヨシ群落＞ササ群落の順である。

5. ヨシ，オオイタドリおよびササ群落における落葉の Na, Fe, Mn, Zn, Cu, Co 並びに Ni が平衡状態のレベルに対して50%，95%，99%無機化並びに蓄積されるに要する時間は表3のとおりである。

6. Na と微量元素の分解および蓄積のモデルは (1)～(14)式のとおりである。

7. これらの草地生態系における L, F, H および $A_0$ 層が破壊された場合平衡状態の微量元素のレベルに比較して99%減少するには約 50～310 年要する。