Nest Distribution of *Formica yessensis* Forel in Ishikari Shore, in Reference to Plant Zonation[1)2)]

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(*With 5 Text-figures and 1 Table*)

Formica (*Formica*) *yessensis* Forel is a Japanese representative of subgenus *Formica* Linné or so-called wood ants famous by its dominance and economic importance in north temperate woodlands. The bionomic characters of *F. yessensis* are different in some aspects from typical forms of *Formica rufa*-group intensively studied in Europe. As the first report on the bionomics and ecology of this species, the present paper deals with nest distribution studied at a littoral ecotone vegetation in Ishikari Shore.

The ecological distribution of ants in a given area has been studied by many authors in relation to environmental factors, dealing either with the local myrmecofauna (Gösswald, 1932; Talbot, 1934; Hayashida, 1959, 1960, 1963; etc.) or with a single species (Andrews, 1926; Dreyer and Park, 1932). Through these studies habitat preference, interspecific relations, limiting factors, etc. have gradually been brought to light, but there still remain numerous problems unsolved concerning the complicated relations between ants and their environments. One of the promising ways to clarify such relations is, in the author's opinion, to study nest distribution at an area, within which the successive change of environmental conditions is clearly recognized. The distribution exhibited in such situation, which can be regarded as an experiment made by the nature itself, may reflect some adaptive responses of ants to environmental changes. This approach has been adopted to some degree for local myrmecofauna surveys (for instance, Talbot, 1934 Hayashida, 1959) but virtually ignored for the study of a single ant species. Keeping the idea mentioned, the present author surveyed nest distribution of *F. yessensis* by a simple belt transect method at Ishikari Shore, the area ideal for such study by the abundance of ant colonies and clear spatial succession of vegetation.

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The Area Studied

1) General description of the area

Ishikari Shore forms the northern margin of Ishikari Lowland connecting mainland of Hokkaido with the Oshima Peninsula. Facing the Japan Sea, the shore extends over 20 km from the estuary of the Ishikari River to Zenibako, drawing a gentle arc (Fig. 1). About 160 to 220 m apart from the shore, the primary oak forest continues in parallel with shore line.

The littoral vegetation changes from the shore line to oak forest with the following succession; Tidal zone — arid aphytal zone — American dunegrass (*Elymus mollis*) — kobomugi sedge (*Carex kobomugi*)—sea-bells (*Calystegia soldanella*)—sweet brier (*Rosa rugosa*)—eulalia (*Miscanthus sinensis*)—vines (*Rubus paryitolius, Vitis coignetiae*, etc.) and oak forest with thick undergrowth of bamboo-grass (*Quercus dentata* and *Sasa palmata*) (Fig. 1-III).

The topography and vegetation given above vary but little throughout the shore. A path 2 m wide runs through the area parallel to the shore line about 70 m distant there from.

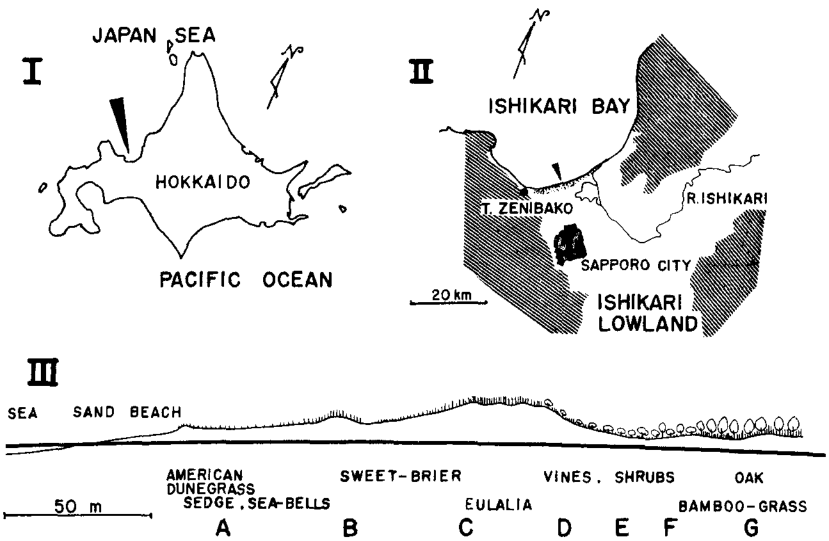

Fig. 1. Location and topography of area studied. I. Location of Ishikari Shore. II. Ditto enlarged. III. Cross section of the area surveyed showing shift of vegetation schematically.

Crossing this path, several unpaved paths or roads run from inland through oak forest and littoral vegetations to the shore, about 600 m distant for one another. Except these paths, the vegetations described are still more or less kept undisturbed over the shore. However, sand digging is furiously in progress in some parts and the serious destruction of vegetation is presumed by the development of Ishikari Port now under the governmental plan.

2) The census area selected

The census area was selected along Route 6, Bannagro, with two subareas (E and W in Fig. 5), respectively east and west of the route (respectively left and right in Fig. 2), in total about 1.25 km long parallel to the shore line, covering the area between shore line and oak forest, in average 200 m wide, thus, about 25 ha in total extent. The transverse section of the area is illustrated in Fig. 1-III and plant zonation in Fig. 2 and Table 1.

The change of plant zonation is obviously gradual so that the sea-side boundary of each zone was conveniently determined as follows:

Zone A ....First appearance of plants.
Zone B ....Appearance of sweet brier.
Zone C ....Appearance of eulalia or crowding of sweet briers.
Zone D ....Appearance of vines and relative increase of plant cover, with patched admixture of shrubs and oaks.
Zone E ....Appearance of more or less continuous growth of low and sparse shrubs.
Zone F ....Thick growth of shrubs making walking through trouble.
Zone G ....Appearance of thick bamboo-grass or oak forest with bamboo undergrowth.

Two subareas (E and W) show slight differences in topography and vegetation: 1) main dunes have gentle but distinct slopes in both sea- and inland sides in W, whereas forming irregular plateaux in E. Japanese scorring-rush (***Equisetum** lanceolata*) is common in W but absent in E, and Zone G is more advanced in W, resulting in the relative decrease of Zones C, D, E and F. (Fig. 2).

Method Employed

In order to clarify the change of relative abundance of nests and spatial succession of plants, the author employed a belt transect method, choosing 34 prospecting parallel courses, about 40m distant for each other and running against the shore line at right-angle. In each course the census was started at the seaside boundary of Zone A and completed at the points at least 5m deep in Zone G. Nest census was continuously carried out from the start to the end of each course acccompanied with recording of environmental conditions. The location of nests detected was mapped together with some external characters such as diameter, shape, etc. The proper orientation was kept by checking with a compass one or two times during each procedure. Width of each course, determined as one meter wide, was practically calibrated by the elbow to elbow distance if necessary.

Nest sites of *F. yessensis* is easily recognized by the scarcity or lack of vegetation and pouring out of workers from nest openings, when the nest was stamped. It is believed that colony foundation of *F. yessensis* is mainy practiced by budding (Hayashida, 1963). Further, being a polydomous species, intranidal connections seem to be a rule in the life mode of this species. Correspondingly, nests are often distributed so closely on another that impossible to determine how many nests compose one commune. Therefore, whenever encountered with such instance, it was identified with one nest as far as these nests were situated within the communal nest area without vegetation. For convenience' sake the locations of nests detected were determined by pacing, and converted later into the metric system.

The census was carried out from September 20 to October 9 in 1970.

Results and Discussions

126 active nests and 31 relatively recently abandoned ones were recorded from census courses, involving three nests of *Formica* (*Serviformica*) *japonica* Motschulsky and one of *Lasius* (*Lasius*) *flavus* Fabricius. From these records, some asepcts on the nest distribution of *F. yessensis* are briefly described and discussed.

1) Nest density in Ishikari Shore

Based upon the result obtained, the nest density in the census area is roughly estimated as follows: $122 \times 1{,}250/34 = 4{,}485.3$, where 122 are the number of *F. yessensis* nests found in 34 census courses, each one meter wide, and the total length of the census area is 1.25 km. In other words, approximately 4,500 nests exist in the census area between shore line and oak forest. Therefore the mean density in the studied area is estimated about $0.022/m^2$, and the economic density dealing with Zones C$\sim$F alone, about $0.038/m^2$. The nest density may obviously vary within Ishikari Shore according to the local situation as partly suggested above, but the crude estimation of the total number of nests established in the shore is given as $4{,}500 \times 20/1.25 = 72{,}000$, (the distance between Zenibako and Ishikari estuary is approximately 20 km.), or 21,000 /km^2. Probably this figure overestimates the actual number, because the nest density may decrease at the both limits of the shore near the urban areas and along certain roads crossing the shore. Naturally these estimations are still of a preliminary nature, but could serve as first approximation for further studies. Comparing these figures with information of other ant species summarized by Scherba (1963), the density is more or less similar to that of *Formica ulkei*, ($0.02/m^2$, after Dreyer, 1942).

2) Relation between nest density and plant zonation

The distribution of nests shows a remarkable correlation with the spatial change of vegetation. As shown in Fig. 2 and Table 1, the nests are absent in Zones A, B, and G, sparse in E and F, while dense in C and D, giving a decreasing order of $D > C > E > F > A \fallingdotseq B \fallingdotseq G$. Among them Zone C is in average longer and more heterogeneous than other zones. It was conveniently subdivided into three subzones, C-1, C-2, C-3, approximately equal in extent, but not particularly different in vegetation and soil condition. Although the general correspondence between nest distribution and plant zonation is clearly shown, more ecological examinations on the density are required, judged from that the nest densities of subdivided zones in C increase toward inland as in Table 1.

Then how developed this gradient of nest density parallel to the spatial change of vegetation ? The lack of nests in Zones A and B is not difficult to explain. These zones are certainly unfavorable for ants by adverse environmental conditions. Strong insolation and wind, unstability of sand, violent diurnal change of

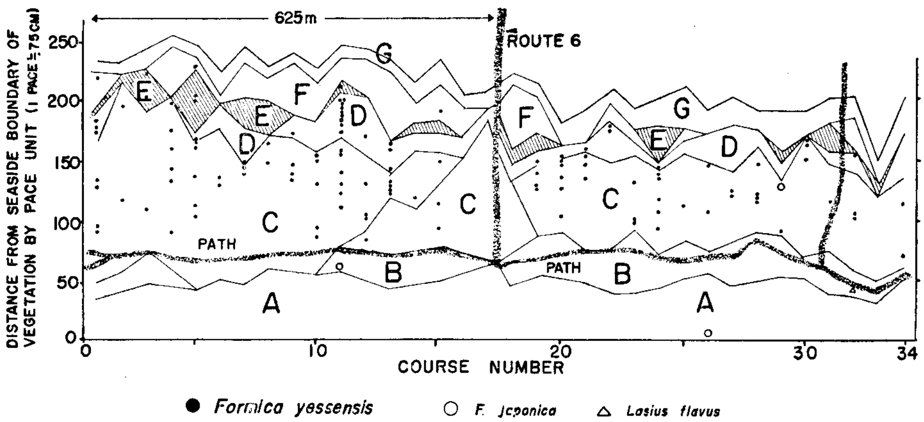

Fig. 2. Relation between nest distribution and plant zonation. Explanation of each zone is given in text.

various microclimatic conditions, high salinity at sea side and arid microclimate at inland side must severely control the establishment and maintenance of ant nests both directly and indirectly through the impoverishment of vegetation which results in the food deficiency. As the record nearest to the shoreline, the author once found a nest at the point only 60 meter apart from the tidal-line, (namely about 30 meter from the seaside boundary of Zone A.), made in and around an abandoned decayed beam. Therefore, nest establishment is not always impossible in Zone A, provided some materials suitable for nest cores are available. But such materials are scarse in this zone, and Zones A and B are apparently the areas beyond the average tolerance zone of *F. yessensis,* only exceptionally and, in all probability, not continuously colonized.

On the other hand, the marked decrease of nests in Zones E and F and the lack in G is not so easy to explain as the decrease tendency of C-B-A. Besides the nest density, the mean nest diameter slightly decreases from C to F and from C-3 to C-1. The tendency is statistically insignificant within the available sample size. But this character is worth to notice in further studies, for it could be used as an index of habitat evaluation by the species.

In parallel to the decrease of nest density from C, D to E, F, G, the intense growth of plant matrix is conspicuous. This results in the formation of dense foliage, thick humus layer on one side and weak light penetration, decreased wind velocity, increased soil water contents, stabilized diurnal rhythm of microclimates on the other hand.

Obviously these biotic and abiotic factors must reciprocally coact for each other and in average increase the amounts of food, enemies, and competitors than in Zone C and D. It is generally known that forest edge harbours for its ecotonal character more animals than openland and forest interior, both in species and

Table 1. Abundance and density of nests in each zone, with dominant or conspicuous plant species. The zone C was conveniently subdivided into three subareas (cf. in text). The figures in parentheses are those omitting the area with exceptionally dense nest aggregation.

Zone	Dominant or conspicuous species of plant	Aspect of vegetation	Total range covered by transect belts (m^2)	Number of nest detected	Density per square meters	Mean nest diameter (cm)
A	*Elymus mollis* *Ixeris repens* *Calystegia soldanella* *Carex kobmugi*	grassy	1270			
B	*Rosa rugosa* *Calystegia soldanella* *Lathyrus maritimus*	grassy	760			
C	*Miscanthus sinensis* *Rosa rugosa*	grassy	2210 C-1 737 C-2 737 C-3 737	88 9 31 48	0.036 0.012 0.042 0.065	49.0 46.1 46.8 51.0
D	*Miscanthus sinensis* *Rubus paryitolius* *Vitis coignetiae* *Solidago japonica*	grassy herby	410 (386)	26 (17)	0.063 (0.044)	49.2 (49.9)
E	*Miscanthus sinensis* *Ligustrum tschonoskii* *Lonicera glehni*	herby shrub	220	5	0.023	45.6
F	*Ligustrum tschonoskii* *Euonymus sieboldianus* *Quercus dentata*	shrub	330	3	0.009	39.0
G	*Sasa palmata* *Quercus dentata*	bushy woodland	460			
Total			5660	122	0.022	48.7

individual. Apparently each species may occupy the optimum range within the forest edge, some preferring forest side and others openland side. In the present case, *F. yessensis* could be classified to the species preferring openland side, as seen from Fig. 2 or Table 1, and the information given by Hayashida (1960) and Yamauchi (1968). Such preference is also observed in *F.* (*F.*) *exsectoides* (Andrews, 1926), and *F.* (*F.*) *ulkei* (Dreyer and Park, 1932). However it is difficult to point out the factors primarily responsible to the decrease of nest density from C, D to E, F, G. The author's opinion is inclining to assume the decreased light intensity as the principal factor, partly because all nests except one in Zones E and F were

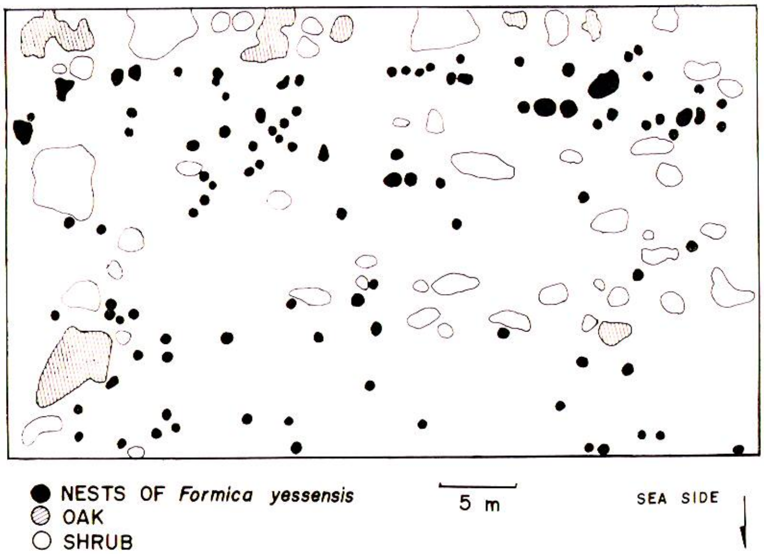

Fig. 3. The area with exceptionally dense nest aggregation. (Prepared by Mr. K. Yamauchi and Dr. K. Hayashida in 1967, unpubl.).

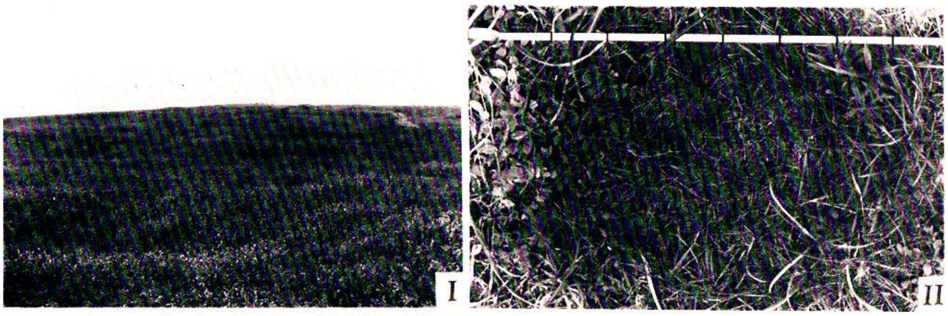

Fig. 4. I. Landscape of Ishikari Shore.
II. Nest of *Formica yessensis* Forel, seen from above. (Scale = 10 cm)

found at relatively open sites, and partly because it was often observed as already reported by Scherba (1958) of *F. ulkei* that an entire colony removes into a clearing out of the former nest which was being heavily shaded by any overgrowing plants. Dreyer and Park (1932) suggest also that light intensity might be one of the most important factors limiting the presence of nests of *F.* (*F.*) *ulkei* mentioned above, and Andrews (1926) of *F.* (*F.*) *exsectoides*.

Table 1 shows the maximum nest density at Zone D. But, this is in part brought by the presence of a dense nest aggregation in course 11 (Zone D, Fig. 2), where the plant matrix is thinner and more sparse than the other parts of Zone D. Such aggregation is of special interest from the standpoints of community ecology and sociology but will be dealt with elsewhere, only presenting a map prepared by Yamauchi and Hayashida in 1967 (unpubl.) (Fig. 3). Omitting this course from the calculation, then the density in D decreases to $0.044/m^2$. In C, most abundant zone, more than half of nests were found around or under the root system of eulalia, *Miscanthus sinensis*, and the absence of nests in course 16~18 coincides with the scarcity of this grass. Thus, although *F. yessensis* can make nests, contrary to *Formica rufa*-group in Europe (Gösswald, 1951), without appropriate cores, yet its nest establishment is seemingly facilitated by the presence of certain structures suitable as cores. Further studies in the cores utilized is required to clarify the ecological distribution of this species.

3) Miscellaneous notes

The comparison of the data obtained from two subareas, E and W, shows the higher density in E ($0.026/m^2$) than in W ($0.014/m^2$), probably due to the larger extent of Zone C preferred by the species, and the presence of dense nest aggregation in E (Fig. 2). But, it is also inferred that the difference reflects the change of habitat quality between two subareas, because more larger nests (nests with diameter more than 80 cm, 3.3% in E and 11.7% in W) and more abandoned nests (15.2% in E and 26.7% in W) were discovered from W than E as shown in Fig. 5. It is assumed, therefore, W was previously a favorable habitat for *F. yessensis* but now becoming unfavorable. Thus the measurement of nest size and ratio of active to abandoned nests could be used to detect the long-term movement of population as well as the gradual change of biotope.

The distribution of ants is controlled not only by abiotic and bioeconomic factors but also by the presense of competitors. Among them the distribution of other ant species is of particular importance, because different species of ants coact by three ways of competition, exploitation, environmental conditioning and interference. Moreover, they also coact often bioeconomically, becoming either food or predators of other species. In the present survey only a few nests of other ant species were discovered. Apparently the procedure employed can detect ants with conspicuous nests and active epigaeic activity alone. The survey made by another procedure (Yamauchi, unpubl.) shows the presence of much more nests of other species. But it must be noticed that even by his method nests of other species drastically decrease in Zones C and D, the area densely occupied by *F. yessensis*. It is famous that the species of subgenus *Formica* tend to monopolize the suitable habitat by their aggressive disposition and peculiar polydomous nest system. *F. yessensis* is not exceptional from this tendency. Leaving further relations with other ant species elsewhere, here is mentioned only the scarcity of *Formica japonica* in the area studied, nevertheless the nests of this species are so conspicuous that they could not be escaped from the procedure adopted. Its scarcity shows the monopolization of the area studied by *F. yessensis*, which coincides

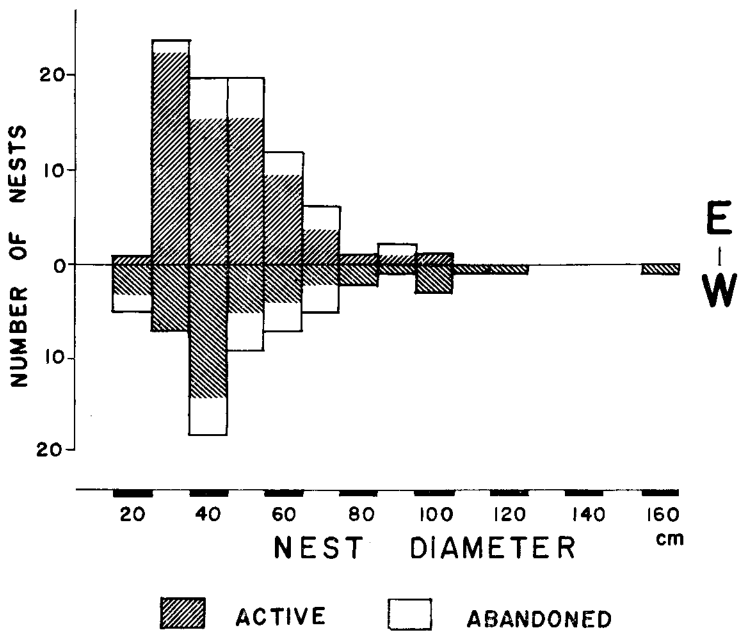

Fig. 5. Number and size of nests compared between two subareas, E and W. The figures of nest diameter represents the mean, for instance, class 40 cm includes nests with diameter, 35～45 cm.

with the conclusion made by Yasuno (1965a, b) concerning the influence of this species upon other ant species. This fact is interesting when the manner of nest foundation of *F. yessensis* is considered. Most species of the subgenus *Formica* can not found nest independently by a solitary queen, utilizing the colonies of other species of the subgenus *Serviformica* as a temporary base for their colony development. This may be true to *F. yessensis*, too, but nothing has actually been observed except for a single record of a mixed colony of *F. yessensis* and *F. japonica* by Sakagami (pers. comm.) found in Oshoro. In Ishikari Shore, the habitats of these two species are clearly segregated. Nests of *F. japonica* are found mainly in Zones A, B, the sea side of Zone C and the areas behind oak forest. This indicates that the enormous nest aggregation of *F. yessensis* in the shore is principally maintained by budding and probably by queen adoption, or in other words, by vegetative proliferation.

Finally a few words are given on the belt transect method adopted in the present study. Although the method is familiar in plant ecology, it has so far seldom been applied to animals except a few exceptions (Hayashida, 1959; Rajska, 1968). The method employed in the present survey is very efficient and convenient for the census of relatively sedentary objects such as ant nests distributing in open areas.

Finally, the author wishes to express his sincere thanks to Dr. S. F. Sakagami for his pertinent guidance and valuable suggestions in the course of the present study, and to Prof. M. Yamada, for his reading through the manuscript. Cordial thanks are also due to Dr. K. Hayashida and Mr. K. Yamauchi for their kind advices and permission of free use of unpublished data, and to Mr. T. Kawamichi for his kind information upon the census method and continuous stimulation for the present study.

Summary

1. As the first report of the comprehensive biological studies of *Formica* (*Formica*) *yessensis* Forel, the nest distribution was surveyed in relation to the plant zonation in Ishikari Shore, Hokkaido, using a belt transect method.

2. The total number of nests in the census area, 25 ha, was estimated as approximately 4,500, with the mean density and the economic density, 0.022 and 0.038/m^2 respectively, and the total number of nests in the shore, 400 ha, as 72,000.

3. Nest density showed a clear positive corelation with plant zonation, mostly confined within the zone occupied by eulalia, *Miscanthus sinensis*, and sweet brier, *Rosa rugosa*, and the zone occupied by vines, *Rubus paryitolius* etc., with moderately dense plant matrix, while absent both in sparse shore side vegetation and thick inland oak forest.

4. Sufficient light intensity and presence of suitable nest cores were regarded as the factors principally responsible for their relative abundance. Some bionomic peculialities of the species were also preliminarily referred to.

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