Red List of Japanese Vascular Plants: Summary of Methods and Results

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In the Red List of Japanese Plants, 1,428 taxa are listed as threatened or extinct. These include 17 taxa which qualify as EX, 12 as EW, 471 as CR, 410 as EN and 518 as VU. In addition, 108 taxa are listed as nearly threatened. These 1,428 taxa amount to 20% of the 7,087 total. We herein summarize the methods of survey and extinction risk assessment employed and characteristics of the results obtained in RLJP.

On August 28, 1997, a new version of the Red List of Japanese Plants was published by the Environmental Agency of Japanese Government. We were given the task of compiling the section on vascular plants at their request. The Red List of Japanese Vascular Plants is remarkable in that it is based on intensive quantitative surveys into the risk of extinction for 2,100 taxa. We herein summarize the organization, term and methods of survey, criteria employed, methods of computing extinction risks, and characteristics of the results obtained.

1. Organization of surveys

We asked ca. 400 botanists to carry out field surveys on the current population size of vascular plants under possible threat of extinction. We asked one botanist per prefecture to serve as the head of the survey group in that prefecture, except for a few large prefectures where we asked two or three botanists to serve as heads. During 1994, we held meetings of these head surveyors three times and discussed various methods of survey.

2. Term of surveys

We carried out a hearing to select candidate taxa in 1993. From 1994 to 1995, we carried out field surveys. The entire year of 1996 was spent imputing the data into computers. Even during 1996, some surveyors continued their field surveys and sent additional data to the committee. In 1997, we carried out computer simulations to quantify extinction risks and then either qualified taxa as CR (critically endangered), EN (endangered), VU (vulnerable), NT (nearly threatened), LC (least concern), or else classified them as DD (data deficient).

3. Methods of survey

The committee prepared a list of 1959 candidate taxa. These candidate taxa include species, subspecies and varieties, but did not include forma or sterile hybrids. They were selected using two qualitative criteria: rare (restricted to narrow ranges or scattered over a few

localities), or rapidly declining. For rare taxa, we listed most taxa occurring in rather restricted localities comprising less than four prefectures. For rapidly declining taxa, the committee members listed taxa based on their empirical impressions. In addition, all taxa listed in the previous version of the Red List (Anonymous 1989, JSPT 1993) were listed. We distributed the list of 1,959 taxa to surveyors and accepted nominations for additions to the list. Finally, we selected 2,100 candidate taxa.

In field surveys, we asked surveyors to visit localities where the candidate taxa were reported as occurring and record their approximate population sizes. We defined population size as the number of mature individuals. In addition, we asked surveyors to estimate reduction rate during the last decade (or somewhat longer or shorter periods), if possible. Most surveyors were previously engaged in local floristic surveys prior to this survey and are therefore specialists as regards local flora. Thus, they could easily estimate the reduction rate in case where some of them had visited the locality before.

Based on data gathered by surveyors, head surveyors estimated the population size and rate of decline per grid, which corresponded to a single geographic map of 1/25,000 (11.8 km x 9.4 km) published by the government, except in the case of some grids where more than one geographic map with a restricted area were merged. The country was divided into 4,457 grids. Data were recorded in the form of a questionnaire according to the following scale.

With regard to population size,
1: less than 10,
2: less than 100,
3: less than 1000,
4: 1000 or more,
9: uncertain.

With regard to rate of decline,
1: less than 1/100
2: less than 1/10,
3: less than 1/2,
4: less than 1,
5: no decline,
8: extinct,
9: uncertain.

As is evident from the above description, the data obtained from this survey were largely dependent upon the tremendous effort undertaken by surveyors during the 20 years or more prior to this survey. It was, however, impossible for the surveyors to visit all the known localities of all the candidate taxa during the term of this survey. Therefore, the data gathered in this survey do not cover all the grids, nor all the localities.

4. Criteria

New IUCN Red List Categories (IUCN, 1994) are defined by five numerical criteria. We used these criteria with some modifications as described below. Since the IUCN criteria are intended for global evaluation, and since they still present some ambiguities, we thought it appropriate to modify them to make them applicable to our data set gathered on a national scale. We hoped that these modifications would form a useful basis for a review of the new IUCN Red List Categories, which is now under way.

Among the five numerical criteria, criterion B is based on the extent of occurrence or area of occupancy. This criterion is considered to be set for those taxa for which an estimation of population size is impractical. Since we obtained data regarding population size and rate of decline, we did not need to use criterion B.

Quantitative evaluation based on criterion E

Among the five criteria of the new Red List Categories, criterion E is based on extinction probabilities. If the extinction probability is greater than 10%, the taxon qualifies as "threatened". A threatened taxon qualifies for one of the following three categories, based on its extinction probabilities.

CR (Critically Endangered): extinction probability estimated to be at least 50% within 10 years or 3 generations, whichever is longer.

EN (Endangered): extinction probability estimated to be at least 20% within 20 years or 5 generations, whichever is longer.
VU (Vulnerable): extinction probability estimated to be at least 10% within 100 years.

In the Red List of Japanese Vascular Plants, we estimated extinction probabilities using the method described below and employed criterion E to determine the category. However, we used extinction probabilities after next 10, 20 or 100 years, and we did not use generation time even in cases where three or five generations were considered to be longer than 10 or 20 years. There are two major reasons for this modification. Firstly, generation time is uncertain for almost all candidate taxa and it is therefore not practical to use it to determine the category. Secondly, five generations are often longer than 100 years in long-living perennials and trees, and thus many taxa qualify as EN but not as VU if we follow the precise definition of criterion E.

In the new IUCN Red List Categories, there is no numerical criterion for nt (nearly threatened). We defined "nearly threatened" as the situation where the extinction probability of 100 years later is estimated to be greater than 0.1%.

Quantitative evaluation based on criterion ACD (integration of criteria A, C and D)

Among the five numerical criteria of the new Red List Categories, criterion A is based solely on the rate of decline. The numerical definition of the three categories in criterion A is as follows.

CR: rate of decline at least 80% within 10 years or 3 generations, whichever is longer.
EN: rate of decline at least 50% within 10 years or 3 generations, whichever is longer.
VU: rate of decline at least 20% within 10 years or 3 generations, whichever is longer.

It has been pointed out that this criterion qualifies some taxa which are still abundant as "threatened" (even as CR) if past rates of decline have been very high.

On the other hand, criterion D is based solely on population size (defined as number of mature individuals). The numerical definition of the three categories in criterion D is as follows.

CR: population size of less than 50.
EN: population size of less than 250.
VU: population size of less than 1,000.

Criterion C, which is applied to continuously declining taxa, is also based on population size. However, numerical definitions of the three categories are different from those of criterion D.

CR: population size of less than 250.
EN: population size of less than 2,500.
VU: population size of less than 10,000.

In the Red List of Vascular Plants, we integrated these three criteria to form a single criterion (here, designated as criterion ACD), and we determined the category using the following numerical definitions. Mean rate of decline was estimated from the data set obtained in this survey. The method of estimation is described in the following section.

CR: population size expected after 10 years under mean rate of decline is less than 50.
EN: population size expected after 25 years under mean rate of decline is less than 250.
VU: population size expected after 100 years under mean rate of decline is less than 1,000.

Qualifications based on criterion ACD and criterion E were in accordance in most cases. If the two criteria resulted in different categories for any one taxon, we adopted the higher category based on the precautionary principle.

Semi-quantitative evaluation based on criterion ACD

There remained a considerable number of taxa for which no surveys sent data to the committee, or for which most surveys reported that the population size and/or rate of decline were uncertain. In some of these cases, the committee members could gather and/or supply data regarding current population size and rate of decline for total area of each taxon, but not for each grid. For these taxa, we determined categories using criterion ACD. However, we did not compute their population size in the future by the method described below, because the data obtained were too limited to be used for computation. For example, let us consider a taxon whose current population size is approximately 500 individuals, and whose rate of decline during the last 10
years is approximately 0.5. Assuming that the rate of decline will be constant in the future, the population size 10 years later is expected to be more than 50, however that of 25 years later is expected to be less than 250. Thus, it is ranked as EN.

5. Methods of computation

Computation of extinction probability or extinction risk

Let us consider the case of Primula sieboldii as an example, on which we obtained data from 131 grids. Distributions of population size and decline rate among grids are as follows.

(Low of population size $1, 2, 3, 4, 8, 9) = (12, 60, 15, 8, 13, 23)$

(Low of rate of decline $1, 2, 3, 4, 5, 8, 9) = (8, 23, 24, 12, 6, 13, 45$)

We neglected grids of class 9 (data deficient). Due to the reasons described below, we added a dummy grid in which a taxon under consideration is extinct (class 8) to all our simulations. Thus, we used population size data of 95 (=12+60+15+8) grids, and decline rate data of 86 (=131-45+1) grids in the subsequent simulation. Extinction probabilities during the forthcoming 10, 20 and 100 years were estimated by 1000 time iterations of computer simulations using this data set. To carry out the simulations we made the following assumptions.

For population size per grid, we replaced intervals corresponding to four levels with their medians on a log scale, and thus we used 3, 31, 316, and 3162 for the levels from 1 to 4, respectively. Because the form of the questionnaire made no provision for more than 10,000 individuals, there may be some grids where more than 10,000 individuals remain, but where the data were recorded as level 4. Population size is underestimated in these cases. We did not use grids of level 9 (data deficient) in the subsequent calculation. This also led to underestimations. As a result, extinction probabilities obtained from the subsequent computation are often overestimated. We preferred overestimation to underestimation based on the precautionary principle.

For population decline rates per grid, we assumed that grids where the taxon is extinct had suffered a rate of decline of 1/1000 during the last 10 years. In fact, extinction may have resulted from a 1/10 decline of less than 10 individuals or from a 1/100 decline of less than 100 individuals. Because extinction per grid often occurred following large-scale developmental works or massive collection for horticulture, we adopted the assumption of 1/1,000 decline per decade, even though this may result in an overestimation of extinction probabilities, especially when extinction occurred prior to the last decade.

For grids where the rate of decline has been reported as level 1 (<1/100), we assumed that the rate was any value between 1/1,000 and 1/100. For grids where the rate of decline is answered as level 2, 3, or 4, the rate was assumed to be any value between 1/100 and 1/10, between 1/10 and 1/2, and between 1/2 and 1, respectively. In the simulation, the value for the rate of decline is determined randomly between two marginal values, and is not replaced with any particular value, such as the median.

Simulation procedures in the case of Primula sieboldii were as follows.

1. Prepare space with 95 grids, among which 12, 60, 15, and 8 grids have 3, 31, 316, and 3,162 initial individuals, respectively.

2. Prepare a distribution of decline rate with 86 elements from levels 1, 2, 3, 4, 5 and 8 as $(1, 2, 3, 4, 5, 8) = (8, 23, 24, 12, 6, 13+1)$. 45 data reported as "uncertain" were excluded.

3. For each grid, select a decline rate level randomly from 86 elements. If it is level 2, 3, or 4, fix a decline rate between two marginal values using a uniform random number.

4. In each grid, decrease the initial population size by a selected rate of decline, R. This procedure is achieved by multiplying the initial population size by the rate of 1-R. Then, we get the population size of each grid after the next 10 years. If the population size is less than one, the grid is regarded as extinct. If all the grids are classed as extinct, the taxon is regarded as extinct.

5. Again select a decline rate level randomly from 86 elements. If it is level 2, 3, or 4, fix a decline rate as described above.

6. In each grid, decrease the population size after the
next 10 years by a selected decline rate. Then, we get the population size of each grid after the next 20 years.
7. By repeating the above procedures, we can obtain the population size of each grid after n decades (n=1, 2, ..., 10).
8. Repeat the above calculation (procedures 1-7) 1,000 times. Proportion of taxon extinction after the next n decades among 1,000 time iterations gives a probability of extinction after the next n decades.

With previous methods of population viability analysis, extinction probability can be estimated only when the data of population dynamics in the past are available (Boyece 1992). Thus, it has been believed that criterion E is difficult to apply to most threatened organisms, although it is most objective and preferable as a criterion for extinction risk. In our method, we overcome this difficulty by treating the variation in decline rates between grids (geographical variation) as a temporal variation in decline rates. Of course, the result of simulation is not as exact as the estimate of extinction probability. However, the method developed and employed here is a practical and effective one for comparing extinction risks among various threatened taxa by a common standard.

The simulations assume that there is no correlation of decline rates between grids, and that decline rates vary randomly both spatially and temporally. In fact, however, a taxon may be declining rapidly in one particular area, while it may be stable in some other protected area. If we consider that a population will always be stable in the future and that extinction probability is zero in a currently stable area, then the extinction probability of any taxon for which at least one locality is well protected is zero, even if it is expected to become extinct in all other localities soon. Extinction probability defined this way is, however, not adequate as a means of measuring extinction risk. Thus, we assumed that all grids suffer the risk of extinction with an equal probability which follows a distribution of the rates of decline. The simulations also assume that the rate of decline is constant over time and does not vary with population size. In fact, a small population may be less frequently noticed by collectors and may thus decline less rapidly.

Computation of mean rate of decline for qualification using the criterion ACD

For qualification using the criterion ACD, we need to know the current population size and mean rate of decline. We determined the current population size by summing up the per-grid population size which was 3, 31, 316 or 3,162. The mean rate of decline should be an average not only over grids, but also over time. By continuing the simulation described above until populations became extinct in all the grids, we can determine the waiting time for extinction. Using the waiting time for extinction and current population size of a taxon under consideration, we calculated the mean rate of decline per decade.

Resolution of incongruence between criterion E and criterion ACD by adding a dummy grid

The five criteria of the IUCN Red List Categories do not always produce results which are in accordance. In our qualification of extinction risks, we resolved the incongruence among criteria A, C, and D by integrating them into a single criterion, ACD. However, there still remains incongruence between criterion E based on extinction probabilities and criterion ACD based on deterministic properties. Let us consider a taxon, for example, in which a single population with less than 50 mature individuals remains but which has been stable during recent decades. The taxon qualifies as CR using criteria C (and ACD). Extinction probability is, however, estimated to be negligible if we consider stability during recent decades alone, and the taxon then qualifies as non-threatened. To resolve this incongruence, we assumed a priori that the extinction probability after the next 10 years in a single population with less than 50 mature individuals is 50%, by adding a dummy grid which became extinct during the last decade into the data set for simulation.

6. Characteristics of the results

(1) 20% of the taxa native to Japan are either threatened or already extinct, at least in the wild
In the Red List of Japanese vascular plants, 1,428 taxa are listed as threatened or extinct, at least in the wild. These include 17 taxa which qualify as EX, 12 as EW, 471 as CR, 410 as EN and 518 as VU. In addition, 108 taxa are listed as nearly threatened. In our count, vascular plants native to Japan number 7,087 taxa (5,629 species, 88 subspecies and 1,370 varieties). Thus, 1,428 taxa amount to 20% of the 7,087 total. In the previous version of the Red List of Japanese vascular plants, 895 taxa were listed. The 1,428 taxa listed in the current version are 1.6 times the number listed previously.

In the Red List, 365 taxa are listed as DD because we could not obtain data on their current population size or past rate of decline. Most of them are extremely rare and would qualify as EX, EW, CR, EN or VU if data on their population size or rate of decline were to be supplied.

(2) Taxa which qualify as CR amount to 1/3 of the threatened taxa

A total of 471 taxa are listed as CR, which amounts to 33.7% of the threatened and 6.6% (approximately 1/15) of the total vascular taxa native to Japan. This figure demonstrates that native vascular plants in Japan are facing the threat of rapid mass extinction. According to the definition of CR in criterion E, we can consider that half of the 471 taxa listed as CR will become extinct after next 10 years. This forecast is an overestimation because we assumed a priori that the extinction probability after the next 10 years in a single population with less than 50 mature individuals is 50%, we also neglected grids for which data are deciscient in the simulations, and we assumed that all grids suffer the risk of extinction with an equal probability. It is, however, certain that taxa listed as CR will become extinct rather soon except in well-protected areas unless effective conservation programs are urgently introduced.

(3) Some widely distributed species such as Platycodon grandiflorum are listed

In the previous version of the Red List, the listing of some widely distributed species such as Eupatorium japonicum, Habenaria radiata, and Pulsatilla cernua attracted public interest. The current version of the Red List gives quantitative support for this trend: extinction probabilities after the next century of these three species are determined to be 0.99, 0.99, and 1.00, respectively, and so these qualify as VU.

In addition to these three species, widespread, previously common species such as Platycodon grandiflorum, Euphorbia adenochlora, Calanthe discolor, and Cephalanthera falcata are listed as VU. Although many of the localities of these species still remain, the rates of decline are so high that extinction probabilities after the next century are 1.00, 0.77, 1.00, and 0.93, respectively.

On the other hand, extinction probabilities of Salvia plebeia, Sparganium erectum and Sparganium japonicum, which are widespread but which were listed as vulnerable in the previous version of the Red List, are computed to be 0.28, 0.27 and 0.24, respectively, and these species are not listed as threatened in the current version. Instead, they are listed as nearly threatened.

(4) 16 species are added to the Red List as EX or EW.

Among species regarded as endangered or vulnerable in the previous version of the Red List, six taxa are listed as EX and nine as EW in the current version. The six taxa which qualify as EX are Ophioglossum nudicaule, Eucrema tenuis var. okinosimensis, Veronicastrum likiuense, Lycoris sanguinea var. koreana, Odontochilus hatusimianus and Renanthera labrosa. The nine taxa which qualify as EW are Deparia minamitanii, Hylotelephium sieboldii var. ettyuense, Kalanchoe integra, Photinia serrulata, Pieris japonica var. koidzumiana, Lilium nobiliissimum, Rhoea japonica var. latifolia, Acanthephippium striatum and Liparis nigra var. sootenzanensis.

7. Future projects

(1) Publication of the Red Data Book of Japanese vascular plants.
We were urged to compile the Red List in order for the results of our survey to be utilized in governmental and non-governmental conservation programs. Due to the fixed deadline, we were not able to qualify 365 taxa which are listed as DD. Quantifications of taxa listed as threatened still need to be reviewed. We intend to gather data on these 365 DD taxa and review the Red List thoroughly. The resulting revision will be compiled as the Red Data Book of Japanese vascular plants in 1999 in which basic information such as extinction probabilities and statistics on factors of threats will also be included.

(2) Selection of candidate taxa for which the Endangered Species Act should be applied

Following the publication of the Red List, the Environmental Agency will begin to apply the Endangered Species Act to additional species. However, even the CR taxa amount to 471, and we need to select a more restricted number of the most critical taxa for which top priority should be given immediately. We intend to submit a list of such taxa to the Environmental Agency based on the results of our survey.

(3) Proposal for the IUCN Red List Categories

IUCN called for an international review of the IUCN Red List Categories. Based on our work, we made proposals to the IUCN regarding the following points.

- At least in the case of plants, it is not necessary to use generation time in the criteria, since this only increases ambiguity.
- Criteria A, C and D should be integrated. Criterion A based solely on the rate of decline results in the listing of taxa which are still abundant (Mace et al. 1992).
- Criterion C based solely on current population size is useful, however the resulting incongruence between criteria C and E should be resolved.
- Criterion E can be more widely applied. Quantitative methods for applying criterion E should not be restricted to the so-called PVA for which detailed population data are required.

(4) Utilization of the data base for environmental assessments

In environmental assessments for developmental works, presence or absence of threatened taxa in the area should be examined. The data base constructed in our work made it possible to check presence or absence of threatened taxa in each grid of 11.8 km x 9.4 km. On the other hand, publication of the data base is expected to increase extinction risk by collection because anybody will be able to know where threatened taxa are still found and how abundant those are there. Thus, we will classify threatened taxa to significantly collected and negligibly collected categories. The data base will be distributed only for the latter.

(5) Improvement in the method for quantification of extinction risks.

Due to the fixed deadline, our method for quantification of extinction risks remains tentative. We still need to resolve the following problems.

- We could not afford to use information on data-deficient grids in our simulations, such as when a surveyor has reported that a taxon under consideration is or was found in a particular grid, but when its population size and/or rate of decline were uncertain in that grid. It is desirable to use such information in the simulation by determining population size and/or rates of decline in data-deficient grids based on some adequate assumptions.
- Grid data reported by surveyors do not always cover all the known localities of a taxon. From publications on local flora and other reliable literature, we are able to estimate how many grids remain unsurveyed. It is desirable to use this information in the simulation.
- We replaced extinction in the past with 1/1,000 decline per decade in the simulation. By changing the replaced rates of decline, the sensitivity and validity of the simulated probabilities should be examined.
- Effects of adding a dummy grid in the simulation should be carefully examined.
- Mean rate of decline varies with the number of decades for which the decline in population is simulated.
The effects of this variation need to be examined.

The data compiled are based on long-term surveys of local flora by approximately 400 surveyors. We thank them for their enthusiasm in carrying out their surveys and for their devoted co-operation to our project of compiling the Red List. We are largely indebted to Dr. Hiroyuki Matsuda of the University of Tokyo for the quantitative methods employed in simulating extinction probabilities and mean rates of decline. Details of the methods employed will be published elsewhere by Dr. Matsuda himself. We thank him for his kind and essential support for our project. The project was supported by the Environmental Agency. The English used in this Summary was revised by Miss K. Miller (Royal English Language Centre, Fukuoka, Japan).

References


