

# Instructions for Using Models to List Species as EX or CR(PE)

Prepared by the Standards and Petitions Committee of the IUCN Species Survival Commission  
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## 1. Introduction

This document describes the use of new methods for determining when to list species as Extinct (EX) and Critically Endangered (Possibly Extinct) (CR(PE)) on the IUCN Red List. These methods also apply to determining whether a species is Extinct in the Wild (EW) or Critically Endangered (Possibly Extinct in the Wild) (CR(PEW)). These instructions should be used in conjunction with the [Red List Guidelines \(section 11\)](#), the data entry template **EX\_data.xlsx**, and the R script **RecordsSurveysModel.R**. The methods described here are based on a series of papers that proposed two different and complementary models, and a framework for combining their results:

**The Threats Model** (Keith et al. 2017) estimates the probability that the species is extinct,  $P(E)$ , based on qualitative and, where available, quantitative information about the severity, duration and scope of threats and their interaction with the life history traits that determine the species' susceptibility to these threats.

**The Records and Surveys Model** (Thompson et al. 2017) is an iterative model to estimate the probability that the species is extinct,  $P(E)$ , based on a time series of records of the species, and the timing, comprehensiveness and adequacy of any targeted surveys designed to detect the species after the last known record.

**The Framework** (Akçakaya et al. 2017) combines the results of the two models to set thresholds of  $P(E)$  for classifying species as extinct, possibly extinct, and extant, based on the potential costs and benefits of classifying extinct and extant species.

Taken together, this approach will bring greater consistency to how species are listed on the IUCN Red List. Consistent listings will improve assessment of the extinction rates and reduce costs of incorrect classifications. If you have any questions, please contact the Red List Standards and Petitions Committee (SPC) at [redliststandardssubcommittee@ssc.iucn.org](mailto:redliststandardssubcommittee@ssc.iucn.org).

## 2. Applying the Models

Applying the two models (the Threats Model and the Records and Surveys Model) will provide two estimates of the probability that the species is extinct. It is important to note that the two models will not necessarily provide the same answer because they examine different aspects of the evidence that contributes to a judgment. Applying both methods is important because it is not uncommon for one or other to lead to over-estimation of extinction risk.

To apply these models, follow these steps:

1. Download the Excel spreadsheet file **EX\_data.xlsx** (see [Red List Guidelines, section 11](#)). Make a copy of this file for each species you assess, and name it with the species name, such as Alaotra Grebe.xlsx. **Do not add any rows, columns or sheets in this file, or change any cell other than those with a blue background.**
2. In the Threats worksheet, enter the **Scientific name** of the species being assessed, and other general information. For "Assessment Year", enter the year when this assessment was done (not necessarily the Red List assessment).

3. In the Threats, Records, and Surveys worksheets, enter the numerical data (and associated notes, references and justification). These data are discussed in detail below, in sections 3, 4, and 5. Enter only in blue-shaded cells.
4. Use the R script **RecordsSurveysModel.R** to calculate the probability that the species is extinct according to the Records and Surveys Model (see section 6). If you don't have experience running R scripts, send the completed file for each species to the SPC.
5. Examine the results, and interpret the probabilities to determine the listing category and/or tag (see section 7).

### 3. Threats worksheet

Based on expert knowledge of the threats faced by the species, estimate two subjective probabilities:

1.  $P(local)$ , the probability that the combination of threats affecting the species occurred for a sufficient duration and were sufficiently severe that they caused local extinction;
2.  $P(spatial)$ , the probability that the threats occurred over the entire range of the species.

Estimating  $P(local)$  requires assessors to draw on the history of the impacts of threats on populations of the target taxon. A relevant historical observation, for example, would be that the taxon disappeared from an area shortly after the introduction of an invasive alien predator. It may also draw on examples where the threats have caused ecologically similar or phylogenetically related taxa to become extinct at a particular location. Inferences about which taxa are 'ecologically similar or related' may be based on life history (e.g. life cycle structure, dependence on hosts, body size, diet), habitat ecology (e.g. microhabitat type, breeding sites) and/or phylogeny.

Estimating  $P(spatial)$  requires assessors to evaluate two components: (i) the likelihood that the threats (with sufficient severity and duration to have caused local extinction) operated throughout the entire range of the taxon (i.e. distribution of habitat and/or individuals, as appropriate); and (ii) the certainty with which the range limits are known. Relevant considerations for the first component include whether the threats operated in such a pattern as to have caused extinction throughout the taxon's range. This may be influenced by the spatial occurrence of different threats, dispersal dynamics, migration patterns and patch dynamics, as well as species life-history traits and cultural factors that influence species susceptibility to threats. Relevant factors to consider for the second component (range limits) include taxonomic uncertainty, reliability of records and whether potential habitat outside the confirmed range has been adequately searched. These uncertainties are incorporated into estimates of  $P(spatial)$  by setting upper and lower bounds taking into account plausible maximum and minimum extents of the species' range.

For both  $P(local)$  and  $P(spatial)$ , estimate a plausible lower bound (minimum), an upper bound (maximum) and a mid-value (best estimate). Use **Table 1** below as a general guide in estimating these probabilities. For further discussion and details, see Keith et al. (2017).

A technical note: The Threats Model assumes that if threats caused local extinction, and they occurred over the entire range, then global extinction,  $E$ , has occurred. Thus,  $P(spatial)$  is actually the conditional probability  $P(E | local)$ , so that by definition the probability that the species is extinct,  $P(E)$ , is the product  $P(local) \cdot P(spatial)$ .

**Table 1. Guidance for estimating subjective probabilities  $P(local)$  and  $P(spatial)$ . The nominal thresholds in the left-hand column are given as general guidance; they are not intended to be prescriptive.**

Range of probabilities	Severity of threat(s) — $P(local)$	Geographic scope of threat(s) — $P(spatial)$
0.99 - 1.00	The severity and duration/timing of threats are virtually certain to have caused local extinction, i.e. would cause 99 of 100 species similar to the target to experience a local extinction.	It is virtually certain that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. The chance that the taxon persists within its known range or at an undiscovered location outside the known range is extremely low (1 in 100).
0.95 - 0.99	The severity and duration/timing of threats are very highly certain to have caused local extinction, i.e. would cause 49 of 50 to 19 of 20 similar species to experience a local extinction. There is a one in a hundred to one in twenty chance that a population of the taxon may persist despite the threats.	It is very highly certain that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. There is a 1-in-100 to 1-in-20 chance that the taxon persists within its known range or at an undiscovered location outside the known range.
0.75 - 0.94	The severity and duration/timing of threats are quite likely to have caused local extinction, i.e. would cause 19 of 20 to three in four similar species to experience a local extinction. There is a one in twenty to one in four chance that a population of the taxon may persist despite the threats.	It is quite likely that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. There is 1-in-20 to 1-in-4 chance that that the taxon persists within its known range or at an undiscovered location outside the known range.
0.50 - 0.74	The severity and duration/timing of threats are more likely than not to have caused local extinction, i.e. would cause one quarter to one half of similar species to experience a local extinction. There is a one in four to 50:50 chance that a population of the taxon may persist despite the threats.	It is more likely than not that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. There is 1-in-4 to 50:50 chance that that the taxon persists within its known range or at an undiscovered location outside the known range.
0.25 - 0.49	The severity and duration/timing of threats are quite possible but unlikely to have caused local extinction, i.e. would cause one tenth to one quarter of similar species to experience a local extinction. There is more than a 50:50 and up to a 3 in 4 chance that a population of the taxon may persist despite the threats.	It is quite possible but unlikely that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. There is more than a 50:50, but not more than 75% chance that that the taxon persists within its known range or at an undiscovered location outside the known range.
0.10 - 0.24	The severity and duration/timing of threats are quite unlikely to have caused local extinction, i.e. would cause one tenth to one quarter of similar species to experience a local extinction. There is 3 in 4 to 9 in 10 chance that a population of the taxon may persist despite the threats.	It is quite unlikely that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. There is a more than 75%, but not more than 90% chance that that the taxon persists within its known range or at an undiscovered location outside the known range.
0 - 0.09	The severity and duration/timing of threats are very unlikely to have caused local extinction, i.e. would cause up to one tenth of similar species to experience a local extinction. There is more than a 9 in 10 chance that a population of the taxon may persist despite the threats.	It is very unlikely that the threats affect or affected the entire range of the taxon, given any possibility that the taxon occurs or occurred outside its known range. There is more than 90% chance that that the taxon persists within its known range or at an undiscovered location outside the known range.

#### 4. Records worksheet

The Records Model and the Surveys Model are used iteratively to give a single estimate of the probability  $P(E)$  that the species is extinct, so they are also referred to as The Records and Surveys Model. This model estimates  $P(E)$  based on records (years when the species was recorded) and surveys, which are dedicated or opportunistic, but unsuccessful, efforts to find the species.

For each record of the taxon, estimate a lower bound (min), a best estimate, and an upper bound (max) for  $p(ci)$ , the probability that the taxon is correctly identified as extant. This probability depends on the type and quality of evidence, similarity of the individual recorded to taxa with which it could potentially be confused, circumstances of the record and the skill and experience of the recorder.

If the taxon has been recorded multiple times in a given year, **enter only one row**, with the  $p(ci)$  value for the record with the highest likelihood of being valid (i.e., enter only 1 line for each year with at least 1 record, regardless of the number of records during that year).

The larger the number of records entered, the more reliable the estimates will be. However, if available resources do not allow entering all records of a species, the priority should be the final sequence of 5 or more records that include the last highly reliable record ( $p(ci) > 0.9$ ).

Before estimating  $p(ci)$ , it may be helpful to create a default table of probabilities for each of the common types of records available for the species you are assessing, to act as a guide and to ensure consistency, rather than being prescriptive (see Table 2 for an example used by BirdLife International).

**Table 2. An example of estimating  $p(ci)$ , the probability that the taxon is correctly identified, for different types of records, as used by BirdLife International in testing the Records Model. Note that the suggested probabilities are for guidance and are not prescriptive.**

$p(ci)$	Type of record
0.95 - 0.99	Specimen(s). Note that if the Type specimen is the only record for the species then the score has to be 1.0. if there are multiple specimens, either the later ones could be misidentified (i.e. <1) or the original one could be misidentified (i.e. <1).
0.90 - 0.94	Photograph or sound recording scrutinized for authenticity
0.8 - 0.9	Record described as being based on collected individual, but specimen no longer exists
0.6 - 0.8	Record based on observation described in literature as 'confirmed' or considered fairly convincing
0.4 - 0.8	Record based on observation (with no qualification in literature or with no additional information upon which to judge veracity)
0.1 - 0.4	Record described in literature as (or judged to be) unconfirmed or questionable
0.1 - 0.3	Local report with no/little documentation and/or judged to be of low reliability

## 5. Surveys worksheet

In the context of this method, surveys are **unsuccessful** efforts to locate the species (in other words, surveys do not result in a record). *Dedicated surveys* are planned surveys devoted to searching for the taxon, in an attempt to determine whether it persists, or surveys for other taxa that would have almost certainly documented the presence of the target taxon if it had been recorded. In the absence of dedicated surveys, it is assumed that there may nevertheless have been opportunities for interested professional or amateur scientists/conservation practitioners to look for or observe the taxon in some unplanned way, or for local people to have recorded and reported the taxon to scientists or conservation practitioners. Such opportunities are called *passive surveys* (passive surveillance); even when these do not result in a record, it's important to include them (i.e., to specify the following parameters for these passive surveys). Please note that the method assumes passive surveillance was conducted at the same level of effort **every year** since the first record, with the exception of years with records or dedicated surveys. If years with passive surveillance differ in terms of effort (i.e., they differ in the values for  $\epsilon$ ,  $p(i)$  and  $p(r)$ ), you can enter these as separate dedicated survey years.

For each year with one or more dedicated surveys, **enter only one row** (i.e. if there were multiple surveys in one year, estimate the parameters below such that these surveys are combined over the whole year).

For both passive and dedicated surveys, 3 parameters are required, each estimated with a lower bound (min), a best estimate, and an upper bound (max):

**(1)  $\epsilon$  (epsilon)**, the proportion of the taxon's habitat within its likely entire range that was surveyed (or covered by passive surveillance). If there were several dedicated surveys within a year in different areas of the range, **enter only one row**, with the total proportion of the taxon's habitat surveyed in all the surveys.

(2)  $p(r)$ , the probability that the taxon, or recent evidence of it, would have been recorded in the area that was surveyed, if it were present. This depends on aspects of detectability, including body size, behavior (e.g., activity and movement patterns, shyness, tendency to skulk, phenology, vocalization, sociality), degree of crypsis, local abundance, and accessibility to/searchability of its habitat and microhabitat.

Assessors should also consider the adequacy of the survey considering:

- (i) its timing (seasonality, diurnality, time since disturbance);
- (ii) its duration;
- (iii) sampling and detection skill of the observers;
- (iv) appropriateness of the techniques used (e.g., trap style, mist-net, sound recording, playback) and their application (e.g., height of mist-nets, location of cameras, positioning of malaise traps); and
- (v) sampling intensity (e.g., length of transects, density of cameras) and design (e.g., sample stratification).

Before estimating  $p(r)$ , it may be helpful to create a default table of probabilities for species with different characteristics in the taxonomic group you are assessing (see Table 3 for an example used by BirdLife International).

This parameter is often overestimated; see section 7 for a discussion about detecting possible overestimation of  $p(r)$ .

**Table 3. Examples of suggested default values for  $p(r)$ . These are to be reduced if survey effort was limited, or of inappropriate timing/techniques etc. Note that the suggested probabilities are for guidance and are not prescriptive.**

suggested values for $p(r)$	Species and survey characteristics
0.7 - 0.9	Species that are conspicuous, and that were searched for exhaustively and with appropriate techniques
0.5 - 0.7	Species that are not particularly inconspicuous and that were searched for with reasonable effort and appropriate techniques
0.3 - 0.5	Species that are moderately inconspicuous or rare and that were searched for with reasonable effort and appropriate techniques
0.2 - 0.4	Nocturnal, skulking, cryptic, and/or rare species that were searched for with reasonable effort and appropriate techniques

(3)  $p(i)$ , the probability that the taxon, or recent evidence of it, could have been reliably identified in the survey if it had been recorded. This depends on the verifiability of the record; that is, the likelihood that the recorded taxon could be distinguished from a similar taxon (e.g., a congener) given its distinctiveness (e.g., in appearance, morphology, vocalizations, behaviour), and the identification skill of the observers. Assessors must consider all signs of recent evidence (e.g. scat, spoor, nests, owl pellets, woodpecker bark peelings, shells, etc.) and all life-stages at the time of the survey; for example, the mature life-form may be highly distinctive, but the juvenile/seed/ larval/dormant life-stages may be extremely difficult to distinguish from similar taxa.

Before estimating  $p(i)$ , it may be helpful to create a default table of probabilities for species with different characteristics in the taxonomic group you are assessing (see Table 4 for an example used by BirdLife International).

**Table 4. Examples of suggested default values for  $p(i)$ . These are to be reduced if surveyor competence/experience may be limited or is questioned. Note that the suggested probabilities are for guidance and are not prescriptive.**

suggested values for $p(i)$	Species characteristics
0.7 - 0.9	Species that are not particularly difficult to identify or distinguish from other similar species, and that were searched for by seemingly competent surveyors
0.4 - 0.7	Species that are somewhat difficult to identify or distinguish from other similar species, and that were searched for by seemingly competent surveyors
0.2 - 0.4	Species that are difficult to identify or distinguish from other similar species, and that were searched for by seemingly competent surveyors

**Please note the following, and make sure that your entries follow these guidelines:**

1. Do not add any rows, columns or sheets to the Excel file, or change any cell other than those with a blue background.
2. The earliest data point must be a record, not a survey (remember that surveys do **not** result in a record).
3. For each year with one or more records, enter only one row.
4. For each year with one or more dedicated surveys, enter only one row.
5. The minimum and maximum values of a parameter should represent the uncertainty the assessors have about that parameter. They should reflect the assessors' judgments about the realistic (plausible) limits of the true value.
6. Instead of estimating min, max and best values for an input parameter, it's acceptable to estimate only min and max, and assume that the best estimate is the mid-point.
7. The method assumes that passive surveillance occurs during every year that is without a record or a dedicated survey. If there was no passive surveillance in some years, you must specify zeros for all passive survey parameters, and enter every year in which there was passive surveillance as a separate dedicated survey year.
8. If passive surveys differ in terms of effort through years (i.e., they differ in the values for  $\epsilon$ ,  $p(i)$  and  $p(r)$ ), enter these as separate dedicated survey years.

## 6. Running the Records and Surveys Model

If you have experience running R scripts, you can carry out the calculation of  $P(E)$  with the Records and Surveys Model. Download the file **RecordsSurveysModel.R** and follow the instructions below.

**Step 1:** Fill in the Excel file template for each species as detailed above, and save the file with the species name (e.g., **Alaotra Grebe.xlsx**). Do not add any rows, columns or sheets, or change any cell other than those with a blue background.

**Step 2:** In the R code (lines 20-22), specify Species, data folder, and PX0 (the probability that the species is extant a year before the first record or survey). The default value for PX0 is 1. The Species text must be the same as in the name of the Excel file, but without the file extension. For example:

```
Species <- "Alaotra Grebe"
DataFolder <- "C:/RedList/SpeciesData"
PX0 <- 1
```

**Step 3:** Run the R code. **Check if there were any error messages.** If not, the program will create 5 files, all starting with the same *Species* name you entered.

**Species-EXTINCT.csv** includes estimates of  $P(E)$ , the probability that the species is extinct, together with the year for which the estimate is made. The labels are PE\_min (for the minimum estimate), PE\_best, and PE\_max.

**Species-PEx.jpg** is a plot of the estimates of  $P(E)$ , the probability that the species is extinct, based on both of the models. This is similar to the figure in the 'Results' worksheet (tab) of the Excel spreadsheet file (see below). See [Red List Guidelines, section 11](#) for guidance on interpreting this graph.

**Species-Xt.csv** includes estimates of  $P(X_t)$ , the probability that the species is extant, for each year, including the minimum, maximum and best estimates (PXt.min, PXt.max, PXt.best), as well as the estimates for mid point (PXt) and the 95% confidence intervals (PXt\_lower, PXt\_upper) based on an assumption of normal distribution.

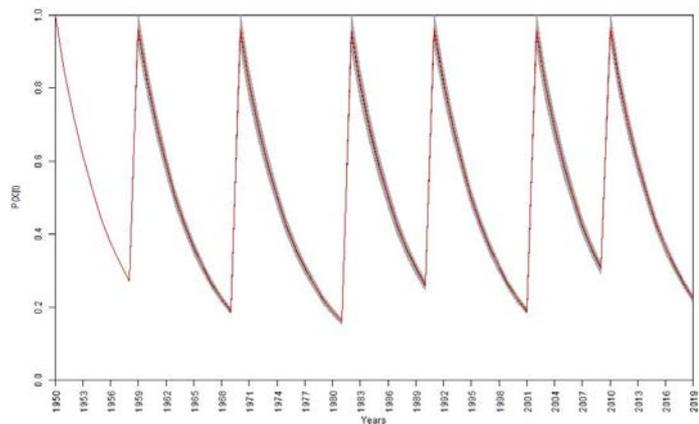
**Species-Xt.jpg** is a plot of  $P(X_t)$  through time (see the figure below, and Figure 1 in Thompson et al. 2017). The confidence interval is in dark gray, the min-max interval is in light gray, the best estimate is the red curve and the mid-point estimate is the black curve. See the next section about interpreting this graph.

**Species-input.csv** includes the input data you entered; this is created by the program for future error-checking.

## 7. Displaying, Checking, and Interpreting the Results

First, check if there are any error messages. Then, check the results to see if there are unusual patterns that may suggest a mistake or bias in estimating and entering the parameters.

One common problem is overestimating the value of  $p(r)$ , the probability that a survey would have recorded the taxon if it were present. If the plot of  $P(X_t)$  through time shows that the probability of species being extant repeatedly goes well below 0.5 between records (see the figure to the right for an example), this may indicate that  $p(r)$  was overestimated, for dedicated surveys, passive surveys, or both.



After checking the results, and correcting and re-running the model if necessary, copy the results from **Species-EXTINCT.csv** to the 'Results' worksheet of the Excel spreadsheet file. The results of both models will be displayed in a graph.

See [Red List Guidelines, section 11](#) for guidance on how to interpret the results.

The spreadsheet of input estimates and the output extinction probabilities calculated using these methods should be documented and referenced (if published) or submitted (as supplementary materials) as part of Red List assessments for the relevant taxa.

## 8. References

- Akçakaya, H.R., Keith, D.A., Burgman, M., Butchart, S.H.M., Hoffmann, M., Regan, H.M., Harrison, I. and Boakes, E. 2017. [Inferring extinctions III: a cost-benefit framework for listing extinct species](#). *Biological Conservation* 214: 336-342.
- Keith, D.A., Butchart, S.H.M., Regan, H.M., Harrison, I., Akçakaya, H.R., Solow, A.R. and Burgman, M.A. 2017. [Inferring extinctions I: a structured method using information on threats](#). *Biological Conservation* 214: 320-327.
- Thompson, C.J., Koshkina, V., Burgman, M.A., Butchart, S.H.M. and Stone, L. 2017. [Inferring extinctions II: a practical, iterative model based on records and surveys](#). *Biological Conservation* 214: 328-335.