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DEVELOPING A STRUCTURE FOR QUANTITATIVE LISTING CRITERIA FOR THE U.S. ENDANGERED SPECIES ACT USING PERFORMANCE TESTING
PHASE 1 REPORT

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Marta Nammack, Scott Rumsey, Katherine Ralls, and Michael Runge

With contributed expertise from
Lynn Maguire and Dan Goodman

and guidance from the Quantitative Listing Criteria Steering Committee
Jim Lecky, Chair, Angela Somma, Douglas DeMaster, Richard Merrick,
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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

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National Marine Fisheries Service
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Executive Summary

The criteria under which species qualify for listing under the ESA have not been clearly defined and, consequently, the levels of threat facing the species which have been listed have been inconsistent and listing decision have been cumbersome. Here we develop and test the structure for a system to list species under the Endangered Species Act (ESA) using quantitative listing criteria. A flow diagram of the process of developing quantitative criteria (Figure 1) is provided at the end of the Executive Summary. The effort to develop quantitative listing criteria was based on a set of Guiding Principles (Appendix 1) developed by the Steering Committee. The Steering Committee is largely composed of high-level managers from the two agencies responsible for ESA implementation (NOAA Fisheries and Fish and Wildlife Service). Agency scientists (called the Quantitative Working Group (QWG)) were charged with developing quantitative criteria (DeMaster et al. 2004). They proposed the following process for developing this system: (1) *overarching definitions* (OADs) for both endangered and threatened should be adopted, (2) values of any *policy parameters* associated with the overarching definitions (e.g., the level of extinction risk corresponding to "endangered") should be specified, (3) *decision metrics* that can be used as proxies for (1) and (2) in data-poor cases should be developed for an appropriate range of taxonomic groups or life history types, and (4) all of the above should be done in the context of *performance testing* (use of simulations to evaluate how well an alternative performs relative to the objective). The Performance Testing Working Group (PTWG) was formed as the successor to the QWG with a large overlap of the scientists involved. The current Report presents 3 years of work done by the PTWG as part of this process. It covers the performance testing of OADs that could be used to accomplish points 1 and 2 above, which could then facilitate the development of point 3. The work was presented to the Steering Committee and an OAD was chosen together with candidate policy parameters. This report summarizes the rationale of the PTWG in developing the structure, results of the performance testing, and rationale of the Steering Committee in choosing an OAD. Technical details are given in appendices.

The QWG developed three alternative overarching definitions for "endangered" (EN). The **Probability of Extinction Threshold (OAD1)** definition states that a species is EN if its probability of extinction within a specified time horizon exceeds some cutoff percentage. The **Depensatory Threshold (OAD2)** definition states that a species is EN if its abundance, area of distribution, or other relevant metric falls below the level at which depensatory (Allee) effects are likely to predominate or population processes are largely unknown. The **Comprehensive Threshold (OAD3)** definition is similar to the definition for the Probability of Extinction Threshold, except that instead of looking at a single time horizon, the likelihood of extinction at each point in time is weighted appropriately to arrive at a comprehensive measure of risk. The PTWG found OAD1 to be a special form of OAD3 and both were conducive to performance testing, which uses simulations to reveal performance of different listing criteria given different quantities and qualities of available data. Most PTWG members agreed that OAD2 was not conducive to performance testing and it was not considered further in this exercise. A different working group will study the feasibility of using OAD2 for listing decisions in the future.

One of the first choices made by the PTWG was to use years rather than generation time as the time unit. One rationale was that using a "currency" of years was easier for all people affected by the ESA to understand (and hence more transparent) and easier for the agencies to implement, since recovery actions are expressed in years. Performance testing required the PTWG to specify candidate values for *policy parameters* associated with the overarching definitions (e.g., the level of extinction risk corresponding to "endangered"). We did this in two ways. First, cutoff values of extinction risk were selected using a set of species for which there was consensus in the PTWG about the listing status for those species (as Endangered (EN), Threatened (TH) or Not Warranted (NW)). Because this exercise generated the cutoff values of extinction risk, we call it the "cutoff elicitation". We conducted the cutoff elicitation for three potential definitions of "extinction": absolute extinction (less than or equal to one individual), and two candidates for near-extinction: 50 mature individuals and 250 mature individuals. Members were given basic information on 20 species, which they then categorized as EN, TH, and NW. The entire group agreed on the classification of a subset of these species, which we called our "consensus species". We used these "consensus species" to set candidate quantitative cutoff values of extinction risk for listing endangered, threatened or not warranted. Differences in performance between different OADs were evaluated, in part, by how well the consensus species were categorized when different quantities and qualities of data were available for decision making.

The Comprehensive Threshold definition (OAD3) also required a function that weighted, on a relative scale, how bad the loss of a species was as a function of time (assuming that extinctions occurring sooner are worse than those occurring later). This loss function was the second set of policy parameters that needed to be specified. The PTWG did a second elicitation exercise to develop possible forms of this loss function for use in performance testing. Here we test three loss functions that were chosen to reveal how sensitive performance is to very differently shaped loss functions.

The three different functional forms were compared using "challenge simulations", a set of hypothetical species with population parameters within the range of those plausible for which petitions to list are filed. There may be petitions to list species at extremely high risk or extremely low risk that would be easily classified correctly by all OAD forms, but such comparisons would not inform how to choose among listing criteria alternatives. We therefore chose parameters for our hypothetical species in a narrower range that would emphasize performance differences between the OADs. For each simulation, the true classification category is known (given the already specified cutoff values for extinction risk for each loss function and the probability of extinction with time from the simulation) and the estimated classification category, based on inference from simulated data, was compared with the truth. An example simulated species that was truly Threatened could be classified correctly (using the quantitative listing criteria and the level of risk inferred from the simulated data) or misclassified. Misclassifications can either over- or under-protect a species (in our example species as EN or NW respectively). Misclassifications can also differ in magnitude (for example, a species that was truly EN but was classified as TH would be a misclassification error of smaller magnitude than if it had been misclassified as NW). These misclassification errors can be weighted based on relative consequences. These weights constitute another set of policy parameters. For example, a precautionary weighting table might give twice the weight to misclassifying an EN species as NW than it would to misclassifying an NW species as EN. The PTWG developed a set of four weighting tables ranging from equal weight for all errors to a precautionary table that weights under-protection errors at twice the level as over-protection errors. The Steering Committee unanimously chose the weighting table called "list versus not-list" that does not distinguish between threatened and endangered. Thus, an endangered species listed as threatened (or visa versa) is considered a correct decision for the purpose of weighting errors. Correct decisions receive a weight of zero. It is also precautionary and assigns double the weight to an under-protection error (a weight of 2) as to an over-protection error (a weight of 1).

The system we have developed and tested to make an ESA listing uses the measure of risk of extinction, which is derived from the probability of extinction over time. Although the probability of extinction over time can be computed from a Population Viability Analysis (PVA), the same can be achieved from an expert opinion exercise, of which an example is given in this report for black abalone (*Haliotis cracherodii*) (under Results see An example using the quantitative listing criteria structure with an expert opinion approach: black abalone).

The Steering Committee reviewed the candidate policy parameters and the results of performance testing. They found that although the candidate listing criteria did differ in performance, those differences were outweighed by the ease of explaining OAD1 (i.e. the goal of transparency to the public given in the Guiding Principles Appendix 1). The Steering Committee also felt that defining "extinction" as "equal to or less than one individual" was too extreme and could result in taxa not receiving equivalent treatment (another Guiding Principle). They requested that the PTWG do performance testing for two near-extinction values. The PTWG chose 50 and 250 mature individuals as potential values for near-extinction. Both succeeded in treating long-lived species more equitably with short-lived species given that the quantitative listing criteria are in a timescale of years. Using a shorter time threshold in the criteria also reduces modeling uncertainties that accrue with time.

Candidate quantitative listing criteria definitions

For purposes of testing, the candidate quantitative listing criteria used by the PTWG are as follows for the different values for near-extinction:

When near-extinction is defined as 50 mature individuals

> ***Endangered*** *is defined as a species with a probability of reaching near-extinction in 50 years that exceeds 10%. Near-extinction means that the population has declined to a size at which the probability of extinction in the near future (50 years or the expected maximum age in the species whichever is the longer) is extremely high. A default value of 50 mature individuals should be used in the absence of a species-specific near-extinction value.*
>
> ***Threatened*** *is defined as a species with a probability of reaching near-extinction in 100 years that exceeds 5%.*

When near-extinction is defined as 250 mature individuals

> ***Endangered*** *is defined as a species with a probability of reaching near-extinction in 50 years that exceeds 28%. Near-extinction means that the population has declined to a size at which the probability of extinction in the near future (50 years or the expected maximum age of the species whichever is the longer) is extremely high. A default value of 250 mature individuals should be used in the absence of a species-specific near-extinction value.*
>
> ***Threatened*** *is defined as a species with a probability of reaching near-extinction in 100 years that exceeds 2%.*

The Steering Committee also recognized that data-poor species present a special problem for a listing process driven strongly by quantitative criteria and recommended development of a hierarchical decision tree that strives to base listing decisions on both quantitative listing criteria and the analysis of threats (the factors listed under section 4(a)(1) of the ESA), but allows making a reasoned qualitative listing primarily based on the analysis of threats, keeping in mind the quantitative listing criteria. The question of how to treat poor-data species needs continued research. The Steering Committee recommended that the resulting candidate quantitative listing criteria be applied to a set of already listed species, to allow further examination of the consistency of the candidate cutoff values with past decisions.

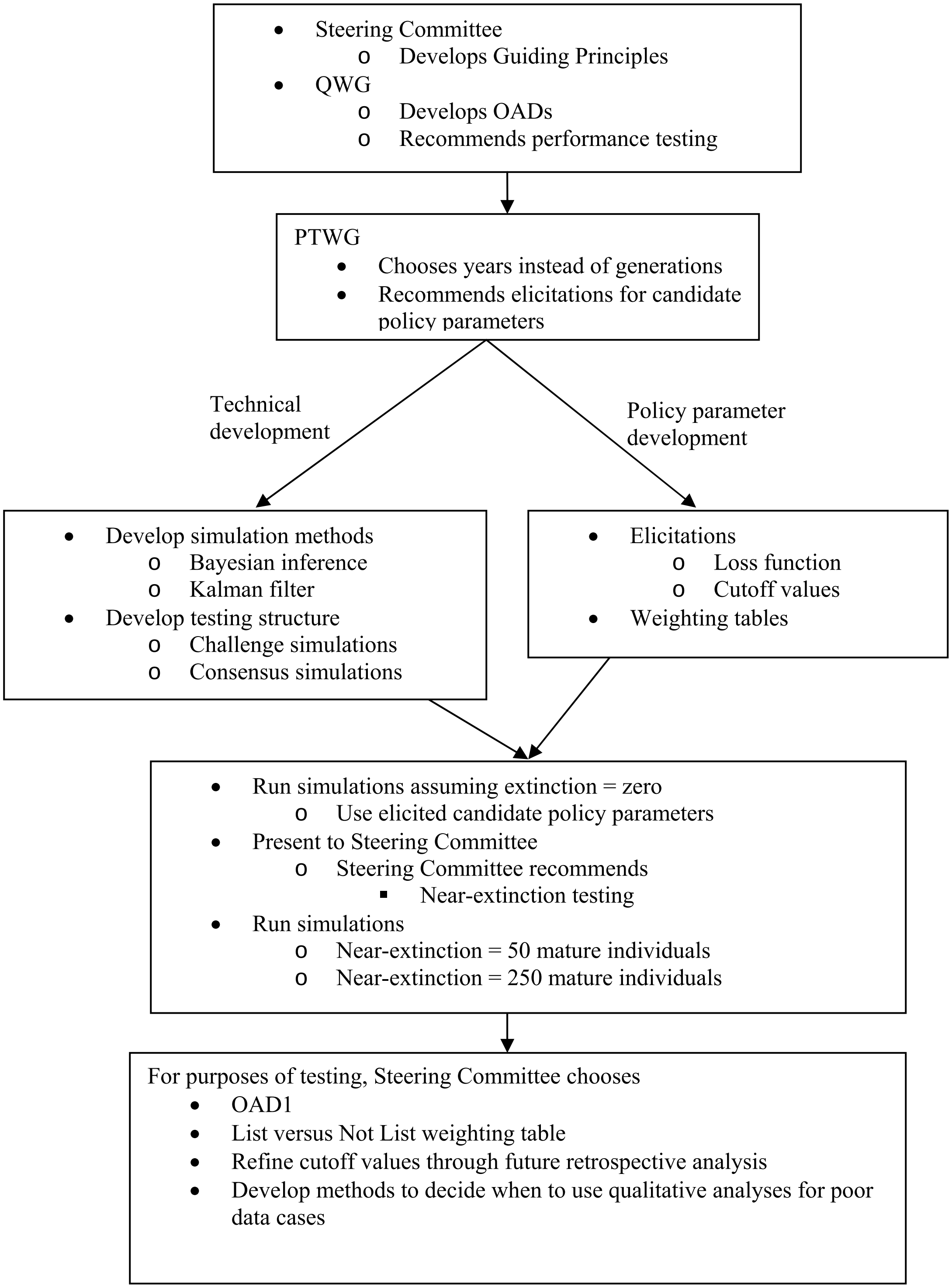


Figure 1. A flow diagram of the process the development of quantitative listing criteria. Acronyms are: QWG—quantitative working group, OAD—overarching definition, PTWG—performance testing working group, OAD1—probability of extinction threshold definition.

Introduction

The Endangered Species Act (ESA) is intended to prevent species from going extinct by listing species at risk of extinction and recovering such species to healthy levels, thereby allowing delisting from the List of Endangered and Threatened Species. The ESA defines the two categories of threat with vague language that has proven problematic for the implementing agencies. The definition of Endangered is: a species which is in danger of extinction throughout all or a significant portion of its range, and Threatened: likely to become Endangered within the foreseeable future throughout all or a significant portion of its range. The philosophy of the ESA is, however, fairly straightforward in that a successful outcome is preventing extinction and recovering species to a healthy state that allows de-listing and removal of special protections.

Decisions on whether a species should be listed as Threatened or Endangered are similar to decisions about whether to admit sick patients to a hospital. The agencies (the Fish and Wildlife Service (FWS) and the NOAA Fisheries Service (where NOAA is the National Oceanographic and Atmospheric Administration)) serve as the admitting staff that must decide whether a particular case warrants admission and if so whether the patient needs life-saving efforts (like surgery; Endangered) or serious care (like intravenous antibiotics; Threatened) or should not be admitted at this time (Not Warranted). There are consequences for incorrect decisions, for example: 1) losing a species that was in need of urgent care that was wrongly *not* admitted (a false negative) and 2) listing species that are not warranted and using scarce resources that should be devoted to more needy cases (false positives). A good decision rule for listing species under the ESA would rank species according to need, admit species by rank, and not admit a large number that do not need immediate care.

Unfortunately, uncertainty about the actual risk of extinction for species means that the ranking will be imperfect. Further, even though the value placed on losing a species is understood to be very high, the funds devoted to endangered species are finite. Using our hospital analogy, since health care funds are finite, urgent care efforts will be compromised if all patients who come to the hospital are admitted. Similarly, if all petitions resulted in listing, listing those where the risk is unknown because the ignorance about their status is great could compromise the quality of recovery efforts for species known to be at high risk. Listing all petitioned species would also raise questions about the significance of being listed under the ESA. The listing system developed here explicitly incorporates uncertainty and allows a balance to be chosen to achieve management objectives.

The Quantitative Listing Criteria Working Group (QWG) was created to formulate quantitative listing criteria using a set of guiding principles developed by the Steering Committee (Appendix 1). The QWG agreed that the ESA should have Overarching Definitions (OADs), but could not agree on what those definitions should be. In decision theory the OADs would be called decision rules. In this report we use the terms OADs, listing criteria and decision rules interchangeably. The QWG felt that no further progress could be made without making the differences between the rules more transparent through performance testing. A Performance Testing Working Group (PTWG) was formed and a post-doc hired (see Appendix 2 for the statement of work).

The OADs are:

OAD1: Probability of Extinction Threshold: a species is EN if its probability of extinction within a specified time horizon exceeds some cutoff percentage

OAD2: Depensatory Threshold: a species is EN if its abundance, area of distribution, or other relevant metric falls below the level at which depensatory (Allee) effects are likely to predominate or population processes are largely unknown

OAD3: Comprehensive Threshold: is similar to the definition for the Probability of Extinction Threshold, except that instead of looking at a single time horizon, the likelihood of extinction at each point in time is weighted appropriately using a loss function to arrive at a comprehensive measure of risk.

The PTWG decided to focus on testing OAD1 and OAD3 deciding that OAD2 was not conducive to the type of simulation performance testing envisioned. A different working group will study the feasibility of using OAD2 for listing decisions in the future. It was recognized that OAD1 was a special case of OAD3. To compare performance required establishment of some candidate policy values for the levels of risk that warrants listing as Endangered (EN) and Threatened (TH). Two elicitation exercises were done to this end.

The PTWG decided that listing decisions should be based on a scale of years rather than generation times, as is done in IUCN listings. One rationale was that using a “currency” of years was easier for all people affected by the ESA to understand (and hence more transparent) and easier for the agencies to implement since recovery actions are expressed in years. Some PTWG members also felt that measuring time in units of years rather than generations was required by the guiding principle of equal treatment across taxa (Appendix 1), because measuring time in units of generations would imply a preference for preservation of long-lived species. However, the opposite viewpoint was also expressed by members who felt that the guiding principle to treat taxa equally could be compromised by measuring time in units of years, particularly for long-lived species. To remedy this potential inequity, the Steering Committee asked that the PTWG investigate numbers other than zero to define extinction. Such non-zero numbers could reduce time-lags to extinction that resulted from long-lived species lingering for decades while the last few individuals lived out their lives. Such a time-lag is not possible for short-lived species. The PTWG examined two “near-extinction” values: 50 mature individuals and 250 mature individuals. Results for all three definitions of extinction (less than one individual, 50 mature individuals and 250 mature individuals) are given in Appendices.

The objective of this report is to summarize both the work of the PTWG over the past 3 years and the decisions made by the Steering Committee based on that work. We begin by presenting the development of the candidate policy values needed to carry out performance testing. The structure of performance testing is then described, leading to a section on results. We present the single set of results corresponding to the Steering Committee’s choice of OAD and associated near-extinction level and put the remaining sets of scenarios into Appendices. As requested in the Guiding Principles, terms are defined in a Glossary (Appendix 3).

Methods

Defining “extinction”

The first step in developing quantitative listing criteria was to operationally define extinction. The PTWG examined three candidate definitions. The first was absolute extinction. The next two were different definitions for near-extinction.

Defining “near-extinction”

By near-extinction we mean that the population has declined to a size at which the probability of extinction in the near future (50 years or the average maximum age in the species whichever is the longer) is extremely high.

Why should we run our models to near-extinction rather than absolute extinction?

There are a number of good reasons for using a near-extinction value rather than absolute extinction. Using a near-extinction value rather than absolute extinction will make corrections for long-lived species that may “linger” at a few individuals for decades. The PTWG chose to use years rather than generation time as used by the IUCN Redlist criteria (IUCN, 2001). Using years makes ESA implementation easier but has the side-effect mentioned here of potentially treating long-lived species with less precaution. (On the other hand, some PTWG members felt that measuring time in units of generations rather than years would mean that long-lived species are valued more highly than short-lived ones, thereby violating the guiding principle of equal treatment.) Another positive consequence of using a near-extinction value is that the time horizon that models need to be run can be shortened. Because uncertainty increases with time, using shorter time-scales should allow a better ranking of species by risk than using longer time-scales (e.g., Fieberg and Ellner 2000).

Using a near-extinction value also takes into consideration the special population dynamics at low population size noted in the conservation biology literature. A population that has reached extremely low abundance will likely experience an accelerated rate of decline through the *combined* forces of demographic stochasticity and density depensation (Figure 2). Species that have reached the point of near-extinction may be unable to recover unless extremely intensive management such as captive breeding can be undertaken. The reasons for their inability to recover include Allee effects like an inability to find mates or defend against predators and genetic effects such as reduced survival, fecundity or disease resistance due to inbreeding depression. Once species reach very low numbers, a synergism between different risk factors can accelerate decline. This synergism is called the “extinction vortex” (Gilpin and Soulé 1986). Not all species that decline to the point of near-extinction will go extinct, as some species have recovered from a very small population size. However, a species that has reached the level of near-extinction has some real danger of slipping into the extinction vortex. Letting a species decline to such a precarious state is a management failure.

Many ESA status assessments have used values other than absolute extinction. We chose to coin a new term “near-extinction” because other terms used for species that are at high risk have a number of different definitions in the literature, none of which exactly match our needs. For example, Ginzburg et al. (1982) coined the term quasi-extinction to mean a small population size somewhat above absolute extinction, but it does not have a standard quantitative definition. We give more context to the term quasi-extinction in Appendix 4.

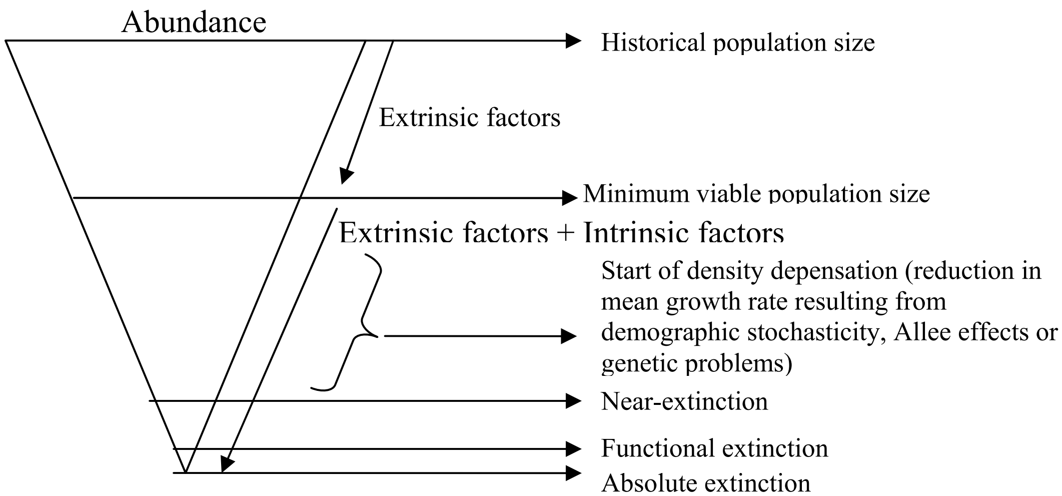


Figure 2. The relationship between different stages on the path to absolute extinction depicted as an inverted triangle with the largest population at the top and absolute extinction at the bottom. Due to the extrinsic factors that form the threats to the population, it declines to the minimum viable population size. As it declines below this size, intrinsic factors, such as Allee effects, genetic problems and demographic stochasticity, also begin to contribute to a reduction in population growth. Different intrinsic factors may initiate density depensation at different levels of abundance relative to historical levels. Eventually these intrinsic factors begin to interact leading to an even faster decline towards extinction. Near-extinction marks the point where the population has a very high probability of extinction in the near future unless intensive management is undertaken. Functional extinction is when no further reproduction is possible, as when only old, post-senescent individuals remain alive and the species will cease to exist once the extant individuals have perished.

What near-extinction does *not* mean

Near-extinction is not synonymous with minimum viable population (MVP). MVP is a number above which populations could persist in perpetuity without human intervention (Figure 2). Near-extinction should represent a much smaller population size that is highly likely to go extinct very soon. Abundances proposed for MVP need to be large enough to survive environmental stochasticity and maintain genetic variability to respond to the challenges of environmental and biological fluctuations and disease. In contrast, a population at the near-extinction value is not capable of long-term survival at that abundance.

Near-extinction is not functional extinction. Functional extinction is a state when it is *certain* that no further reproduction is possible, in which case the species will cease to exist once the extant individuals have perished. An example of functional extinction is a population with no breeding females.

Why use a single default value for near-extinction?

Arguments could be made that the true number for near-extinction differs for each species. Any listing criterion strikes a balance between simplicity and ease of application on the one hand and complexities inherent in the biology and risks faced by each species on the other. Using a single **default value** of mature individuals (see definition below) allows listing decisions to be relatively simple and yet captures some of the life history characteristics important to the goals of the ESA to save species from extinction. Given the definition of near-extinction in italics above, if sufficient information is available, a Biological Review Team could and should make a cogent argument for the number that would fit that definition for their particular case, but the default value is there for the many cases where data are insufficient to determine such a value. Below we consider two different values for near-extinction, 50 mature individuals and 250 mature individuals.

Near-extinction equals 50 mature individuals

The rule: Near-extinction is defined as 50 mature individuals. See definition of mature individuals below.

The rationale: It is difficult to argue that any species that has declined to only 50 mature individuals will not be at very high risk of extinction. Compared to absolute extinction, using a value of 50 mature individuals for "near-extinction" allows earlier listing of long-lived species where individuals may "linger" for a period of decades. An example would be killer whales that can live to be over 50 years old and can therefore have living individuals for decades past the point when, for example, no males were present and therefore reproduction was not possible.

The IUCN redlist "critically endangered" category also uses an abundance cutoff of 50 mature individuals. Although no rationale is given in the IUCN redlist guidelines for the number 50, it corresponds to a number that is known to result in irreversible genetic losses if numbers remain this low for very long. Because the original IUCN proposal for quantitative listing guidelines specified an effective population size of 50 rather than 50 mature individuals (Mace and Lande 1991), it is very likely that this number traces back to theoretical estimates of the minimum effective population size required to avoid extremely deleterious effects of inbreeding (Soulé 1980, Franklin 1980). It is also the number below which some species of birds have been known to go extinct rapidly (Soulé et al. 1988).

Near-extinction equals 250 mature individuals

The rule: Near-extinction is defined as 250 mature individuals. See definition of mature individuals below.

The rationale: Although populations with 50 mature individuals are certainly in danger of immediate loss of genetic variability, this number may be too low to use as the near-extinction value for a number of reasons. Many species that are naturally abundant may have extreme difficulties with proper biological function at a much higher level than 50 mature individuals. For example, some species of marine fish, like grouper, require a certain density to trigger the largest female to turn into an adult male. Because this is a default value for all species, an argument could be made that the near-extinction value should be something like an average of the true near-extinction values for all species. Arguments have also been made that effective population sizes may be as low as one tenth of absolute abundance. Thus, for some species, 50 individuals that are actually contributing genes to future generations may correspond to an overall abundance of 500. Given a default assumption that 50% of the population consists of mature individuals, an abundance of 500 would correspond to 250 mature individuals. Using only 50 mature individuals for near-extinction may also be too low to mitigate against catastrophes. An overall population of 500 would be more likely to have a geographic range that would be less vulnerable to a single catastrophic event like a fire.

Estimating the number of mature individuals

We adopt the IUCN definition of mature individuals (IUCN, 2001). The term "mature individuals" is defined as: The number of individuals known, estimated or inferred to be capable of reproduction. When only total population size is available, a default value of 50% of that size will be used as the proportion mature. The value 50% as a proportion mature is relatively common for long-lived species like whales (Taylor et al. 2007). Since the purpose of near-extinction is to treat long-lived species more equitably, this value seemed appropriate at a default value.

When estimating this quantity, the following points should be borne in mind:

- Mature individuals that will never produce new recruits should not be counted (e.g., densities are too low for fertilization).
- In the case of populations with biased adult or breeding sex ratios, it is appropriate to use lower estimates for the number of mature individuals, which take this into account.
- Where the population size fluctuates, use a lower estimate. In most cases this will be much less than the mean.
- Reproducing units within a clone should be counted as individuals, except where such units are unable to survive alone (e.g. corals).
- In the case of taxa that naturally lose all or a subset of mature individuals at some point in their life cycle, the estimate should be made at the appropriate time, when mature individuals are available for breeding.
- Re-introduced individuals must have produced viable offspring before they are counted as mature individuals.

Development of candidate policy parameter values

Choosing the cutoff values between listing categories: cutoff elicitations

The aim of this exercise was to provide a set of data that, once combined with a candidate loss function (see Elicitation of the value of extinction through time), could generate candidate parameter values for the levels of risk associated with different listing categories: EN and TH. We did three elicitations for the three different definitions of extinction (absolute extinction and the two near-extinction values of 50 and 250 mature individuals). We asked PTWG members to categorize a series of cases that covered a wide spectrum of risk, with each case having a non-zero risk of extinction within the next 500 years. We wanted as much agreement as possible among PTWG members to form the basis for developing cutoff values for EN and TH once candidate loss functions had been specified. The case studies were mainly drawn from a text using Population Viability Analysis (PVA) programs that produced extinction distributions and had some basic life history (Akçakaya *et al.* 2004). A few cases were added that were actually listed under the ESA and also had PVAs[1]. These cases allowed us to gauge whether our decision rules were producing classifications that were similar to those that have been made under the ESA to date. Elicitations for the near-extinction values eliminated some cases that fell below the near-extinction values and made other cases more extreme (with very high probabilities of reaching near-extinction in a few decades). We therefore added a few other cases to fill in gaps in risk for the near-extinction values so that we could get a better representation of the respondents' thresholds between EN, TH, and NW.

Details of the exercise including the information given to PTWG members are given in Appendix 5 (for absolute extinction and near-extinction values of 50 and 250 mature individuals). The elicitation was done by email and a few cases were discussed by the PTWG to see whether we could add more species with high agreement (where "high" is when all but 1 member agreed on the listing category).

The resulting sets of consensus species (Table 1, Table 2 and Table 3) were used to set the cutoff values of extinction risk. However, before cutoff values of extinction risk could be determined, it was necessary to specify candidate loss functions. This subject is presented in the next section.

Table 1. Species used as "consensus species" to set the cutoff values for the listing decision criteria for absolute extinction. The subject number refers to the PTWG member but retains anonymity. The categories used in performance testing are in the next to last column. Species with high agreement (all but one subject in agreement) are noted in bold in the Category column. The mean growth rate per year, shown in the last column, gives a rough idea of the level of risk. Full extinction distributions are given in Appendix 5.

		Subject number									
Species #	Species name	1	2	3	4	5	6	7	8	Category	Mean growth rate
6	snake	EN	EN	EN	EN	EN	EN	EN	EN	**EN**	-0.182
10	mudminnow	EN	EN	EN	EN	EN	EN	EN	EN	**EN**	-0.190
1	passerine	EN	TH	EN	EN	EN	EN	EN	EN	**EN**	-0.078
11	herring	TH	EN	EN	EN	EN	EN	EN	EN	**EN**	-0.516
12	pinniped 1	TH	EN	EN	EN	EN	EN	EN	EN	**EN**	-0.069
15	killer whale	EN	TH	TH	TH	EN	EN	EN	EN	TH	-0.018
16	Grevillea	TH	TH	TH	EN	EN	EN	EN	EN	TH	-0.0875
3	sparrow	TH	TH	TH	EN	TH	EN	TH	EN	TH	-0.026
17	Erodium	TH	TH	TH	TH	TH	TH	EN	EN	TH	-0.053
14	pinniped 2	TH	TH	TH	TH	TH	TH	TH	EN	**TH**	-0.055
4	newt	NW	NW	NW	NW	NW	NW	NW	TH	**NW**	-0.0266
7	desert lizard	NW	NW	NW	NW	NW	NW	NW	NW	**NW**	-0.0004
9	tortoise	NW	NW	NW	NW	NW	NW	NW	NW	**NW**	-0.0284

[1] Thanks to Paul Wade for the killer whale example extracted from Krahn et al. (2002) and to Albert Harting (Harting Biological Consulting, 8898 Sandy Creek Lane, Bozeman, MT 59715) for pinniped1 (Harting 2002) and pinniped2 PVAs.

Table 2. Species used as "consensus species" to set the cutoff values for the listing decision criteria using a near-extinction value of 50 mature individuals. The subject number refers to the PTWG member but retains anonymity. Full extinction distributions are given in Appendix 5.

		Subject number									
species name	species #	5	1	9	10	2	6	4	3	8	category
passerine	1	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
snake	4	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
mudminnow	7	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
herring	8	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
pinniped1	9	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Erodium	12	EN	TH	EN	EN	EN	EN	EN	EN	EN	EN
sparrow	2	NW	EN	EN	EN	EN	EN	EN	EN	EN	EN
sp19	19	TH	TH	TH	TH	TH	TH	EN	EN	EN	EN/TH
pinniped2	10	TH	TH	TH	TH	TH	TH	EN	EN	EN	EN/TH
sp20	20	TH	TH	TH	TH	TH	TH	TH	TH	EN	TH
Epacris	13	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
sp16	16	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
sp17	16	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
sp18	16	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW

Table 3. Species used as "consensus species" to set the cutoff values for the listing decision criteria using a near-extinction value of 250 mature individuals. The subject number refers to the PTWG member but retains anonymity. Full extinction distributions are given in Appendix 5.

		Subject number									
species name	species #	10	2	6	5	9	1	8	3	4	category
passerine	1	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
sparrow	2	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
snake	4	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
mudminnow	7	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
herring	8	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
pinniped1	9	EN	EN	EN	EN	EN	EN	EN	EN	EN	EN
Grevillea	11	EN	EN	EN	EN	EN	TH	EN	EN	EN	EN
Erodium	12	EN	EN	EN	EN	EN	TH	EN	EN	EN	EN
sp19	19	EN	EN	EN	TH	EN	NW	EN	EN	EN	EN/TH
sp20	20	TH	EN	TH	TH	EN	NW	EN	EN	EN	EN/TH
newt	3	TH	TH	TH	EN	TH	NW	EN	TH	EN	EN/TH
pinniped2	10	TH	TH	TH	TH	TH	TH	EN	TH	EN	EN/TH
tortoise	6	NW	NW	NW	NW	NW	NW	TH	NW	NW	NW
sp16	16	NW	NW	NW	NW	NW	NW	TH	NW	NW	NW
sp18	18	NW	NW	NW	TH	NW	NW	NW	NW	NW	NW
Epacris	13	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW

Elicitation of the value of extinction through time

A smaller team (Cochrane, Maguire, Thompson, and Regan) conducted a separate and independent elicitation exercise to derive a candidate loss function. This function is required for OAD3, the Comprehensive Threshold definition. Details of the exercise are given in a separate report

(Cochrane et al. in prep) and summarized in Appendix 6. This loss function gives species with high probabilities of extinction in the near future a higher weight (or a greater loss) than those species with probabilities of extinction that occur in the more distant future. Following our hospital analogy, this would give a greater weight to critical conditions, like a massive heart attack, than for chronic conditions, like heart disease. Although both are likely to be fatal if untreated, the critical condition requires immediate treatment to save the patient.

Twenty-one scientists and agency managers were interviewed, all of whom had expertise in extinction concepts but varied levels of experience with the ESA. In a series of exercises, these subjects provided estimates for their valuing or degree of concern about hypothetical extinction given how far into the future it would occur. Using results from an exercise that included uncertainty in extinction timing, we estimated average parameters for a loss function for exploratory performance testing (note: this function should not be considered a final, consensus description of attitudes about extinction time because the exercise had some technical limitations and the tasks were novel for the subjects, such that we acknowledge the loss function shape could change with additional work). The average functional form for the discounting of concern about extinction through time is shown in Figure 3 as the blue (shoulder function) curve.

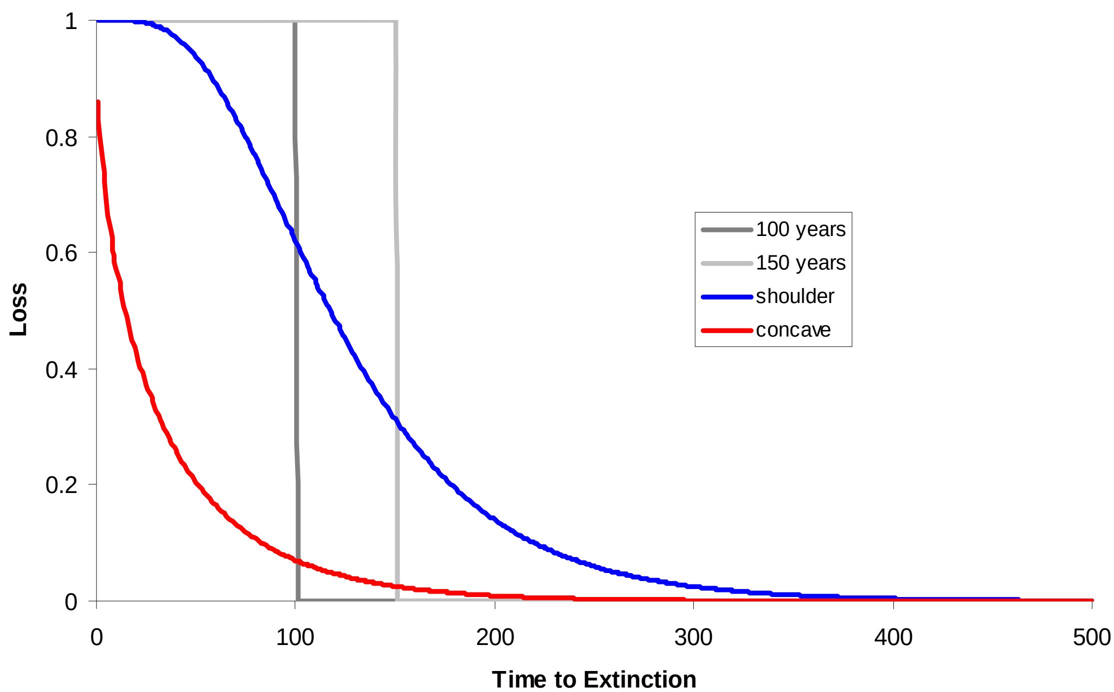


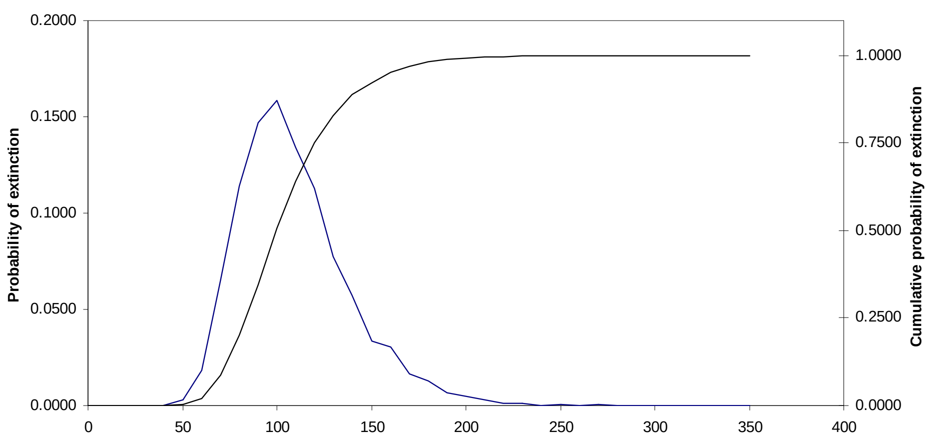
Figure 3. Three different loss functions for use in calculating Risk. The blue (shoulder) function is the function resulting from the Extinction Elicitation Exercise. The gray (step) functions represent two examples of OAD1, with a 100 year and 150 year time horizons. The red (concave) curve was suggested by Thompson, based on a 2% discount rate with a relative risk aversion coefficient of 0.5 (see details in Appendix 7).

These three functions captured a range of functional forms that the technical working group (Regan, Thompson and Taylor) felt would reveal an interesting range of behavior for the decision rules. The level of risk (which for clarity we will refer to as Risk and symbolize with R) is calculated by multiplying the probability density function of the time to extinction for the species in question by the loss function and summing over time (see Box 1 below for an explanation of probability density functions).

Box 1. Extinction probability basics

The most fundamental data to understanding risk of extinction are: 1) trend in abundance, and 2) current abundance. Predicting the future for any particular species uses our best understanding of those data but also incorporates our ignorance of both of the actual abundance and trends and what may happen in the future. Simulations can project these uncertainties by repeating many possible scenarios. For a declining species, each individual simulation results in a year that the species went extinct. Unlucky scenarios will go extinct quickly, while other scenarios may result in extinctions in the more distant future. The accumulation of all these possible scenarios forms a distribution of possible extinction outcomes called a “probability density function” or pdf. The pdf allows you to see the probability of extinction at any given year (see bell-shaped function in figure). We often are interested in questions like “What chance is there that this species will go extinct in the next 20 years”? That question can be easily addressed by turning the pdf into a cumulative function (see monotonically increasing curve with scale on the right). In the figure below, some unlucky cases went extinct in year 50 while others lasted over 200 years.

An important concept to understand with Population Viability Analysis models and the results they produce (distributions of the probability of extinction by time) is that they are *not* truly predictive. It is more accurate to think of PVAs as conditionally predictive, being conditional on threats remaining at current levels. The purpose of the model is to rank species according to their present threats, assuming that these threats are not reduced in the future. The intent of the ESA is to greatly reduce or eliminate the threats such that extinction is avoided. Hence, the PVA is not intended to predict the future but to rank species by quantifying their risk in a common currency: the probability of extinction through time given that no actions are taken to alter the threat levels.



Candidate listing criteria: reconciling the consensus species with the loss functions

Completing the candidate listing criteria can now be done using both the consensus species and the 3 forms of the loss function. The PVA models of the consensus species used in the elicitation exercise were detailed multi-parameter models. The pdfs of time to extinction for each of the detailed models were approximated by an Inverse Gaussian distribution, resulting in a simpler (three parameter) model more conducive to the performance testing framework. While the Inverse Gaussian fits were very good, they did result in slight changes in the calculation of risk from the detailed models. Details of this procedure are outlined in Appendix 7. Risk values from the Inverse Gaussian models are given in Table 4, Table 5, and Table 6 for absolute extinction and near-extinction values of 50 and 250 mature individuals respectively. For OAD1, the risk values can be read as percents at the time threshold. For example, pinniped1 has a 57% chance of going extinct before year 100. For OAD3 the risk values are unit-less because they integrate the probability of extinction with the loss function over time.

Table 4. Consensus species with Risk calculated using the loss functions in Figure 3 and assuming absolute extinction. Species in yellow are consensus species for EN, in pink were consensus for "listed" but include species where some members chose EN and some TH, and in blue are consensus for NW. To classify the consensus species correctly, 2 different functions were needed for OAD1: one for EN (in 100 years) and one for TH (in 150 years).

Species	Category	OAD1 (100 yrs)	OAD1 (150 yrs)	OAD3 (Shoulder)	OAD3 (Concave)
Herring	EN	1.0000	1.0000	0.9849	0.3094
mudminnow	EN	1.0000	1.0000	0.9746	0.2901
Snake	EN	1.0000	1.0000	0.9316	0.2066
pinniped 1	EN	0.5700	0.9848	0.6307	0.0781
passerine	EN	0.3652	0.9072	0.5464	0.0627
Grevillea	TH	0.1011	0.9689	0.4917	0.0494
sparrow	TH	0.1770	0.3539	0.2691	0.0348
killer whale	TH	0.0562	0.2356	0.1898	0.0179
Erodium	TH	0.0094	0.7633	0.3832	0.0343
pinniped2	TH	0.0001	0.0953	0.1824	0.0134
Newt	NW	0.0000	0.0000	0.0234	0.0012
tortoise	NW	0.0000	0.0000	0.0062	0.0003
desert lizard	NW	0.0000	0.0008	0.0020	0.0001

Table 5. Consensus species with Risk calculated using the loss functions in Figure 3and assuming near-extinction at 50 mature individuals. Note the time scales for OAD1 have been reduced. Colors as in Table 4.

Species	Category	OAD1 (50 yrs)	OAD1 (100 yrs)	OAD3 (Shoulder)	OAD3 (Concave)
mudminnow	EN	1.00	1.00	1.00	0.49
herring	EN	1.00	1.00	1.00	0.39
snake	EN	1.00	1.00	0.99	0.38
pinniped 1	EN	0.93	1.00	0.98	0.32
passerine	EN	0.51	0.98	0.90	0.21
Erodium	EN	0.52	1.00	0.93	0.21
sparrow	EN	0.40	0.65	0.68	0.18
pinniped2	TH	0.00	0.42	0.57	0.07
spp19	TH	0.09	0.23	0.26	0.05
spp20	TH	0.01	0.12	0.20	0.03
Epacris	NW	0.00	0.00	0.09	0.01
tortoise	NW	0.00	0.00	0.06	0.00
spp18	NW	0.00	0.00	0.02	0.00
Spp 16	NW	0.00	0.00	0.01	0.00
Spp 17	NW	0.00	0.00	0.01	0.00

Table 6. Consensus species with Risk calculated using the loss functions in Figure 3Figure 3 and assuming near-extinction at 250 mature individuals. Note the time scales for OAD1 have been reduced. Colors as in Table 4.

Species	Category	OAD1 (50 yrs)	OAD1 (100 yrs)	OAD3 (Shoulder)	OAD3 (Concave)
mudminnow	EN	1.00	1.00	1.00	0.65
pinniped 1	EN	1.00	1.00	1.00	0.62
sparrow	EN	0.88	0.94	0.94	0.58
snake	EN	1.00	1.00	1.00	0.48
Erodium	EN	1.00	1.00	1.00	0.43
herring	EN	1.00	1.00	1.00	0.42
passerine	EN	0.89	1.00	0.97	0.33
Grevillea	EN	0.62	1.00	0.94	0.22
Newt	TH	0.00	1.00	0.83	0.13
spp19	TH	0.27	0.43	0.45	0.13
pinniped2	TH	0.06	0.85	0.76	0.12
spp20	TH	0.18	0.42	0.46	0.09
tortoise	NW	0.00	0.01	0.12	0.01
Epacris	NW	0.00	0.00	0.14	0.01
Spp 16	NW	0.00	0.00	0.08	0.01
Spp 18	NW	0.00	0.00	0.06	0.00

The cutoff values are listed in Table 7. Note that there is still a range of values that allows the Consensus species to be categorized correctly. The values chosen as the cutoffs were those that maximized the number of identical listing under the three OAD alternatives for the challenge simulations described later (see Figure 4).

Table 7. Cutoff values for Risk for the three candidate listing criteria with values used in performance testing in bold, and the range compatible with the consensus species in Table 4, Table 5, and Table 6 in parentheses. "Type" refers to the definition of extinction where E = Extinction and NE = near-extinction expressed in units of mature individuals.

Category	Type	Step function (OAD1)	Shoulder function (OAD3)	Concave function (OAD3)
EN	**E = 0**	**0.30 in 100 yrs** (0.18-0.37)	**0.54** (0.50-0.54)	**0.05** (0.05-0.06)
TH	**E = 0**	**0.08 in 150 yrs** (0.001-0.010)	**0.18** (0.02-0.18)	**0.01** (0.001-0.010)
EN	**NE = 50**	**0.10 in 50 years** (0.1-0.4)	**0.68** (0.58-0.68)	**0.17** (0.08-0.17)
TH	**NE = 50**	**0.05 in 100 years** (0.01-0.12)	**0.20** (0.1-0.2)	**0.03** (0.02-0.03)
EN	**NE = 250**	**0.28 in 50 years** (0.28-0.62)	**0.86** (0.83-0.94)	**0.14** (0.13-0.22)
TH	**NE = 250**	**0.02 in 100 years** (0.02-0.42)	**0.21** (0.17-0.44)	**0.02** (0.02-0.08)

Weighting misclassification errors

Another set of values relates to listing under the ESA: the relative consequence of making misclassification errors. An error not to admit a patient to the hospital at all, when the patient turned out to have a life-threatening condition like kidney cancer, would be of greater consequence than if the patient were admitted for observation but should have been admitted for immediate surgery. Both are errors but have different consequences. Misclassification of species has similar properties that can be explored in performance testing using a table that weights errors according to their gravity.

Although there are actual monetary costs to protecting species under the ESA, we consider these costs to be what society is willing to pay to protect species and therefore in the context of the ESA a correct decision incurs zero cost (seen in bold on the diagonals in Table 8). Each incorrect decision also incurs a cost. A true evaluation of these costs would be a difficult exercise since costs will vary greatly by species. Instead, it is assumed here that inter-specific differences in costs can be ignored, and that the effect of the relative costs can be evaluated through comparing some simple weighting systems. We examined four weighting systems (below) where true status is in the columns and estimated status in the rows. Underprotection errors (UPE) are below the diagonal for each of the four weighting systems (shown by the zeros in bold) and overprotection errors (OPE) above the diagonal.

Table 8. Four weighting systems with relative outcome misclassification weights. The Equal weight system assigns equal weights to all errors. The Symmetrical weight system doubles the weight given to errors two categories away from the true category but gives the same relative weight to over- and under-protection errors. The Precautionary system gives double the weight to under-protection errors than to over-protection errors. The "List vs Not List" system gives no weight to errors made between the listed categories (EN and TH) and gives double the weight to under-protection errors (in this case not listing when a species should be listed) than to over-protection errors (listing a species when it should not have been listed).

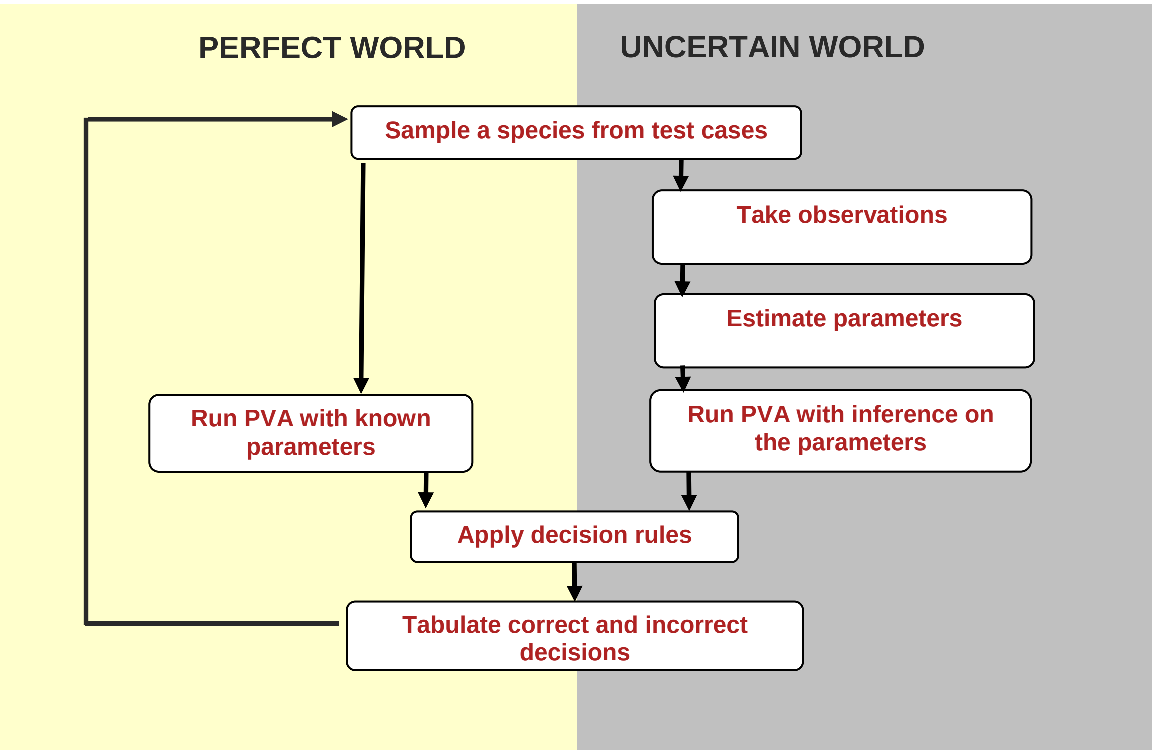
Weighting system name	Estimated category	True category: EN	TH	NW
Equal	EN	**0**	1	1
	TH	1	**0**	1
	NW	1	1	**0**
Symmetrical	EN	**0**	1	2
	TH	1	**0**	1
	NW	2	1	**0**
Precautionary	EN	**0**	0.5	1
	TH	1	**0**	0.5
	NW	2	1	**0**
List vs Not list	EN	**0**	0	1
	TH	0	**0**	1
	NW	2	2	**0**

We include these four weighting systems as a set that ranges from the case where all errors have equal weight to precautionary cases. Viewing the results from all systems allows comparison of results to see whether performance is robust across a range of misclassification weightings. The Equal system is provided for completeness but is not a logical choice as a truly endangered species misclassified as not warranted is certainly a more grave error than a misclassification as NW. An argument could also be made that the gravity and irreversible nature of extinction warrants a precautionary choice. Both the Precautionary system and the List vs Not List system are examples of a precautionary approach that weights underprotection errors at double the cost of overprotection errors. The Steering Committee chose the List vs Not List system because they thought a precautionary weighting was appropriate, given the potential irreversible nature of making under-protection errors (allowing possible extinction). We infer that this choice also indicates such little difference between protections extended to species listed as Threatened compared with those listed as Endangered that a separate weighting was not warranted (as would have been the case in the weighting table called "Precautionary").

Performance testing: challenge simulations

To compare the three decision rules (each with each of the 3 forms of loss function: step, shoulder and concave) we simulated making decisions using the rules but with uncertain data. Figure 4 shows the flow diagram for performance testing. A random sample is selected from the test cases. This is a set of three parameters, mean growth rate, standard deviation of the growth rate, and current population size. These parameters can be thought of as a species (more details about how the test cases are devised are explained in the next sections). The parameter values that make up the species are then viewed in two separate worlds. Firstly in the perfect world, the parameter values are known precisely, without any error. These can be used in a PVA directly, the risk of extinction calculated and the decision rules applied. This represents the "true" fate of the species. Secondly, the same species is viewed in the uncertain world. In this case the parameters values are not known precisely. Instead we have observations that are conditional on the true parameters. This data is then used to make an inference on the parameters. The estimates can then be used in a PVA, the risk of extinction calculated, and the decision rules applied. The estimated listing decision of the species can be compared with the true listing decision and correct and incorrect decisions can be tabulated. This is repeated many thousands of times to ensure a good representation of the universe and data possibilities. More detailed description of the performance testing procedure is explained in Appendix 7.

Figure 4. Flow diagram for performance testing.



Simulations: the Perfect World

The challenge simulations require specifying a range of test cases to evaluate performance. Population growth rate is the most influential parameter in the process of extinction. We assume a constant average growth rate. Any species with a negative average growth rate will go extinct eventually. Figure 5 shows the set of distributions, called a "universe", that together formed the challenge simulations for absolute extinction. We chose the distributions to give relatively equal proportions of challenge cases in each listing category (EN, TH, and NW). Because the cutoff criteria were quite different for absolute extinction and the near-extinction values of 50 and 250 mature individuals, the distributions were shifted to obtain similar proportions of cases in the listing categories (details in Appendix 7). Figure 5A shows the range of population growth rates that we felt would be challenging for listing decisions using absolute extinction. Note that this is a subset of growth rates for actual populations that may be petitioned for listing. For example, it is entirely plausible that some species may be experiencing very high rates of decline, say over 15%/year (which is the same as -0.15 in Figure 5A). In fact, 3 of our 5 consensus cases classified as EN have population declines exceeding 15%/year (Table 1). All the OADs would almost always correctly list these cases (as is shown later for these three consensus species), so we learn little about differences between the different decision rules. The objective of the challenge simulations is to learn about differences in performance. Therefore, the simulations focus on the challenging cases with growth rates concentrated between the risk categories, those that would just miss qualifying for TH and those that are not too far into the EN category. Figure 6 shows a schematic of the range of challenge simulations for one set of candidate listing criteria.

Figure 5B gives the distribution of standard deviation in population growth rates used for the simulations. The distribution allows a range of life history types to be captured in the testing process. Species with long lives, like killer whales, have low variance in population growth rates. Species with short lives, like annual plants or the songbird in our case study for the consensus species, have higher variance in population growth rates. Figure 5C shows the range of initial abundances used in the challenge simulations. Using these three parameters results in a range of extinction distributions with a good number of cases in each category: roughly 24% EN, 36% TH and 40% NW (depending on the set of listing criteria used). For each simulation a value was drawn from each distribution in Figure 5. The risk of extinction is calculated by multiplying the resulting time to extinction distribution with each of the loss functions and integrating across time. The candidate listing criteria (Table 7) are used to determine the true Category.

To make the comparisons between the absolute extinction case and the NE = 50 and NE = 250 cases the challenge simulations used slightly different distributions from those in Figure 5Figure 5. Firstly, the mean growth rate values were -0.05, -0.03 and -0.015 for E = 0, NE = 50, and NE = 250 respectively (using the same variance as shown in Figure 5A). Secondly, the cases were limited to those that had "true" population sizes that were greater than the near extinction value. This ensured approximately the same number of cases in each risk category as in the absolute extinction case. For the near-extinction challenge simulations the prior distribution for initial abundance was determined the same way as was done for the consensus species performance testing (described below).

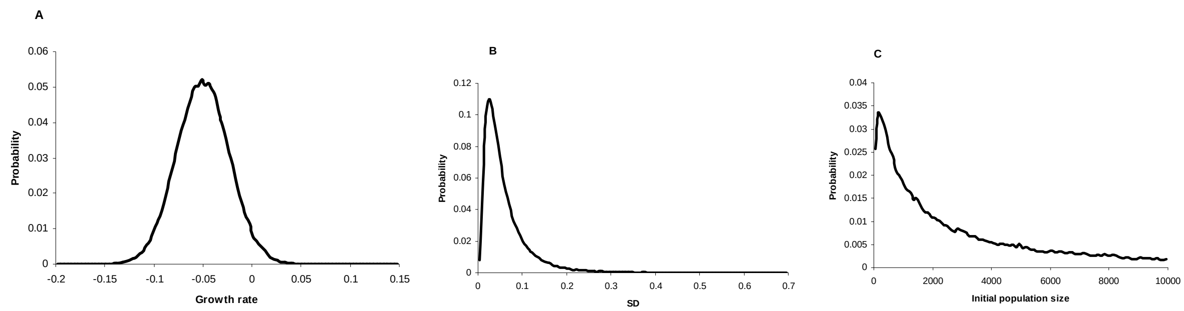


Figure 5. Distributions for parameters used in performance testing for absolute extinction where SD means standard deviation.

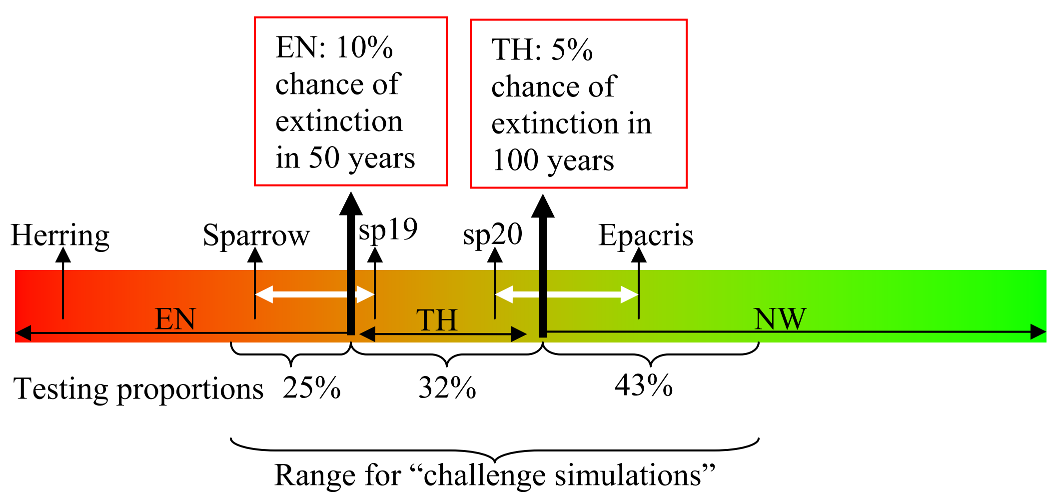


Figure 6. A schematic depicting high risk in red gradually shading to low risk in green. The bold vertical arrows show the boundary between the risk categories with the decision rules for the step-function using near-extinction = 50 mature adults. Some of the consensus species are also shown at various levels of risk: herring (100% probability of extinction in 50 years), sparrow (40% probability of extinction in 50 years), sp19 (9% probability of extinction in 50 years and a 23% probability in 100 years), sp20 (12% probability of extinction in 100 years) and Epacris (0% probability of extinction in 100 years). The decision rule could have been placed anywhere in the gaps depicted by the white arrows. The range for the challenge simulations is shown below with the percents of test simulations.

Simulations: the Uncertain World

In real listing decisions, biologists use data to draw inferences about the level of risk. Some cases are data rich and there is little uncertainty about factors like abundance or population growth rate. Unfortunately, the most common situation is that there are few data and the data often have low precision. In other words, our ignorance about the status of most species is great. Nevertheless, decisions must often be made when data quantity and quality are poor. Our performance testing simulates making decisions in the uncertain world by testing four different data gathering scenarios: 1) great data (20 years with annual abundance estimates with high precision (coefficient of variation (CV)) = 0.1), 2) low quantity/high quality (4 abundance estimates over a 10 year period with CV = 0.1), 3) high quantity/low quality (20 years of annual abundance estimates with CV = 0.8), and poor data (low quantity and quality with 4 abundance estimates over 10 years with CV = 0.8). For simplicity we focus on great and poor data results in the body of this report. Results for all data gathering scenarios appear in Appendices 9 and 10.

We use Bayes' theorem to incorporate uncertainty when drawing inferences from data on parameters used to compute extinction risk (population growth rate, variance in that rate, and abundance). Inference begins with prior distributions on the parameters to be estimated. The data are used to modify the priors into posterior distributions. The more data available, the closer the posterior distribution is to the underlying true parameter and the less difference the prior makes on the final outcome. In the case of ESA listings, where many species are known to have poor data (few data points with low precision), it is likely that the prior distributions will be influential. For the challenge simulations we use the distributions in Figure 5 (and described for NE = 50 and 250) as the prior distributions. We chose to use the same priors in this case because we know the underlying universe and the distribution of those parameters, but not the true value of them. To capture the full uncertainty, the level of precision of the abundance estimates is assumed to be known (from the sampling design used to make the abundance estimate) and the variability in population growth rate is inferred from the time series of abundance estimates using a Kalman filter (full details of the performance testing simulations are given in Appendix 7 and for the Kalman filter in Appendix 8).

Posterior distributions resulting from the Bayesian inferences on population growth rate, variance in that rate and abundance are projected forward in time to obtain the estimated distribution of the probability of extinction. The estimated distribution is then used with the different loss functions to calculate estimated risk. Estimated risks are then used with the candidate listing criteria to give an estimated risk category. The estimated category can be compared with the true category and tallied as a correct classification or tallied in the appropriate misclassification category. Repeating this simulation process many times results in a table with true categories in the columns and a tally of estimated categories in the rows. A decision table is the table with the simulation tallies normalized so that all columns add up to 1. This table is in the same form as the weighting table (Table 8). An example of results for the challenge simulations using the great data scenario and the step function is shown in Table 9.

Table 9. Decision table for the decision criteria using the step loss function and the case where data are great. For the challenge simulations using absolute extinction, these candidate criteria correctly categorized 82% of EN as EN, 18% of EN were misclassified as TH, and none that were truly EN were misclassified as NW. Decision rule cutoff values used are in Table 7.

		True Category		
Type	Estimated Category	EN	TH	NW
Extinction = 0	EN	**0.82**	0.19	0.01
	TH	0.18	**0.77**	0.43
	NW	0.00	0.04	**0.56**
NE = 50	EN	**0.90**	0.22	0.01
	TH	0.10	**0.75**	0.38
	NW	0.00	0.03	**0.61**
NE = 250	EN	**0.88**	0.20	0.01
	TH	0.12	**0.79**	0.54
	NW	0.00	0.01	**0.45**

Results

Results of the Challenge simulations

A simple example of calculating the weighted result for the absolute extinction scenario (top section Table 9) is to use the equal weight table (the first set in Table 8 where correct classifications are given a zero weight and all misclassifications are given a weight of 1). The total weight (or "cost") is 0.85 (0*0.82+1*0.18+1*0.00+1*0.19+0*0.77+1*0.04+1*0.01+1*0.43+0*0.56). Using the weighting table allows the candidate listing criteria to be compared in one single number that captures all the different misclassifications. Even so, the number of results in performance testing can be bewildering. We present all weighted results for the great and poor data cases and for all extinction definitions (Table 10) we emphasize the results for the chosen List v Not List weighting table. There is little difference between the criteria in the great data scenario. This is expected because the listing criteria are basically set to have about the same "boundaries" because all cutoff values are based on the consensus species. Differences are generally greater between the different criteria when data are poor. The full set of results is in Appendix 9.

Table 10. Weighted results for the challenge simulations, where E = Extinction (absolute) and NE = near-extinction. The best performance is the criterion with the lowest weighted result and is shown in bold. The column for the List v Not List is in bold as the weighting table preferred by the Steering Committee.

Type	Data scenario	Listing criteria	Equal	Symmetrical	Precautionary	**List v Not list**
E = 0	Great	Step (OAD1)	0.85	0.86	0.54	0.51
		Shoulder (OAD3)	0.74	0.76	0.57	0.49
		Concave (OAD3)	**0.73**	**0.75**	**0.51**	**0.47**
E = 0	Poor	Step (OAD1)	1.87	2.48	1.29	**1.00**
		Shoulder (OAD3)	**1.77**	**1.86**	**1.24**	**1.00**
		Concave (OAD3)	1.88	2.56	1.32	**1.00**
NE = 50	Great	Step (OAD1)	0.74	0.75	**0.44**	**0.46**
		Shoulder (OAD3)	0.67	0.68	0.52	0.49
		Concave (OAD3)	**0.59**	**0.60**	**0.44**	**0.46**
NE = 50	Poor	Step (OAD1)	1.89	2.66	1.33	**1.00**
		Shoulder (OAD3)	1.67	1.84	1.18	**1.00**
		Concave (OAD3)	**1.45**	**1.68**	**0.93**	**1.00**
NE = 250	Great	Step (OAD1)	0.88	0.89	0.51	0.57
		Shoulder (OAD3)	0.79	0.81	0.63	0.50
		Concave (OAD3)	**0.71**	**0.73**	**0.49**	**0.49**
NE = 250	Poor	Step (OAD1)	1.70	2.28	1.15	**1.00**
		Shoulder (OAD3)	1.81	**1.88**	1.28	1.01
		Concave (OAD3)	**1.62**	2.18	**1.12**	1.01

Results for Consensus Species simulations

The challenge simulations give a good flavor for general performance but can be difficult to comprehend fully. For this reason, we also did performance simulations for the consensus species cases. Recall that these were chosen to obtain candidate cutoff values and therefore span a greater range than the challenge simulations. For example, the herring case had an initial abundance of 21.5 million individuals and is declining at 51.6%/year. Because actual cases that may be petitioned span a broader range than covered by the challenge simulations, we used different prior distributions (Figure 7). The prior for population growth rate was chosen to encompass a range that was observed in our consensus species. The most extreme growth rate among those species was a 52%/year decline. Hence, our prior gives some probability density for that value (-0.52) and allows for populations growing at a high but possible rate of 50%/year (or in the terms of exponential growth used in the model, 0.5). A broad vague lognormal prior where the likelihood is non-negligible was chosen for the process error term. We used much broader priors for the consensus species than the challenge simulations because the consensus species included more extreme cases (i.e. growth rates ranging from -0.5- 0.0, standard deviation ranging from 0.04-0.4).

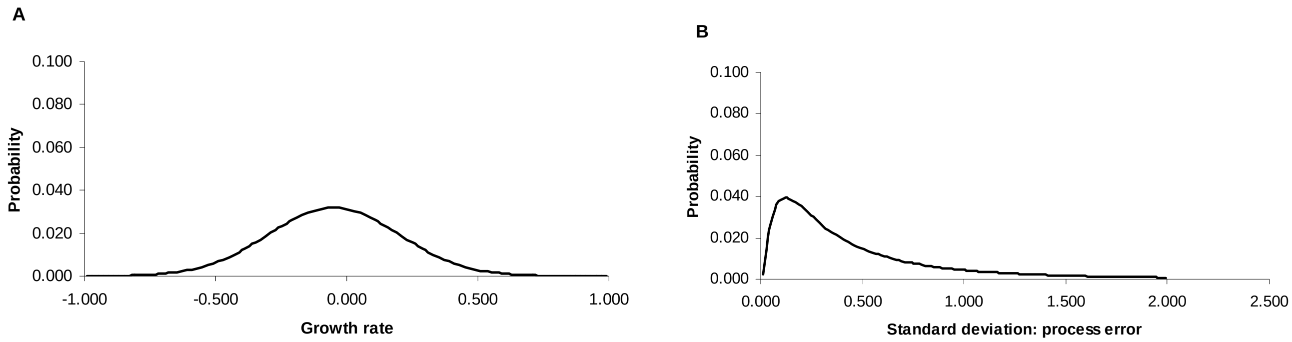


Figure 7. Prior distributions used for the consensus species for growth rate (A) and standard deviation of the growth rate (B).

The prior distribution for initial abundance presented a special problem because our consensus species ranged from 82 (killer whales) to 21.5 million (herring) individuals. To remedy this we created priors for each of the consensus species that were vague with a range such that the likelihood was non-negligible. Vague log-normal priors for initial abundance were created using the last data value as the mode and the standard deviation (details in Appendix 7). This allowed a very broad prior known to include the true value but not as broad a prior as a general prior that could include both killer whales and herring. This was repeated for multiple priors to determine if there was any significant bias. This reduced computational time and introduced little to no bias.

Results for all consensus species cases and all three definitions of "extinction" are given in Appendix 10. In summary, all decision criteria do well regardless of data quantity or quality if the case is either very high risk (herring, mudminnow, snake) or very low risk (newt). Species in the threatened category generally suffer more misclassifications. Here we highlight a few examples that reveal properties of the candidate decision criteria.

The first case we highlight is pinniped1. Pinniped1 is a consensus species classified as EN under all three definitions of extinction with a 69% chance of zero individuals in 100 years, a 93% chance of reaching 50 mature individuals in 50 years and a 99% chance of reaching 250 mature individuals in 50 years (Appendix 10). Table 11 reveals some interesting differences between the candidate decision criteria. Although all PTWG participants agreed this is a species at high risk, the Shoulder and the Concave function criteria have some chance of not listing even with great data and the Shoulder function criteria fails to list at all (EN or TH) 8% of the time when data are poor.

Table 11. Classification results using the NE = 50 definition for the pinniped1 consensus, which was a consensus species for an EN classification. The correct category is highlighted in bold.

Candidate listing criteria	Estimated category	Great data	Poor data
Step function (OAD1)	**EN**	**0.96**	**0.98**
	TH	0.04	0.02
	NW	0.00	0.00
Shoulder function (OAD3)	**EN**	**0.81**	**0.25**
	TH	0.16	0.67
	NW	0.03	0.08
Concave function (OAD3)	**EN**	**0.82**	**0.68**
	TH	0.16	0.32
	NW	0.02	0.00

The other extreme can be seen with species 16, an NW consensus species. The 3 candidate criteria perform quite differently even with great data (Table 12), with the Step function criteria misclassifying the newt as TH 51% of the time compared to 35% for the Shoulder function criterion and 24% for the concave function criterion. When data are poor the step and concave function criteria erroneously classify nearly all the time, while the shoulder function criterion correctly estimates the category as NW 20% of the time. These two examples reveal a tradeoff between the over- and under-protection error misclassifications.

Table 12. Classification results using the NE = 50 definition for species 16, which was a consensus species for an NW classification.

Candidate listing criteria	Estimated category	Great data	Poor data
Step function (OAD1)	EN	0.00	0.90
	TH	0.51	0.10
	NW	**0.49**	**0.00**
Shoulder function (OAD3)	EN	0.00	0.05
	TH	0.35	0.75
	NW	**0.65**	**0.20**
Concave function (OAD3)	EN	0.00	0.22
	TH	0.24	0.75
	NW	**0.76**	**0.03**

To illustrate the difference made by choice of the weighting table we present the weighted results summarizing the consensus species (Table 13). It is clear that the weighting table makes a strong difference in which candidate listing criterion is the "winner".

Table 13. Weighted results for the consensus species for great and poor data scenarios and for all weighting tables. "Winners" are denoted in bold.

Type	Data scenario	Listing criteria	Equal	Symmetrical	Precautionary	List v Not list
E = 0	Great	Step (OAD1)	1.11	1.15	**0.79**	**0.93**
		Shoulder (OAD3)	**1.03**	**1.10**	0.92	1.12
		Concave (OAD3)	1.09	1.14	0.81	0.96
E = 0	Poor	Step (OAD1)	1.66	1.97	**1.16**	1.05
		Shoulder (OAD3)	**1.63**	**1.81**	1.43	1.51
		Concave (OAD3)	1.72	2.14	**1.16**	**1.00**
NE = 50	Great	Step (OAD1)	1.02	1.07	**0.61**	**0.57**
		Shoulder (OAD3)	0.98	1.02	0.78	0.98
		Concave (OAD3)	**0.84**	**0.87**	0.69	0.82
NE = 50	Poor	Step (OAD1)	1.91	2.65	1.35	1.02
		Shoulder (OAD3)	1.78	1.91	1.48	1.48
		Concave (OAD3)	**1.61**	**1.76**	**1.10**	**1.00**
NE = 250	Great	Step (OAD1)	1.30	1.31	0.70	0.80
		Shoulder (OAD3)	**0.93**	**0.94**	0.68	0.77
		Concave (OAD3)	1.08	1.09	**0.61**	**0.61**
NE = 250	Poor	Step (OAD1)	1.75	2.09	1.12	1.00
		Shoulder (OAD3)	1.77	**1.82**	1.42	1.18
		Concave (OAD3)	**1.73**	2.01	**1.08**	**0.99**

The problem of over-protection classification when data are poor

Results indicating a fairly high chance of incorrectly listing species that were actually NW when data were poor led us to investigate whether this problem would persist even in cases that were far from the border-line cases we had used for performance testing. For example, would a population that had been growing consistently at 5%/year and now numbered 1 million individuals still have a chance of being classified as TH or EN? We ran our great and poor data scenarios for that case, using the absolute extinction decision rules (Table 14, Figure 8). The great data case (high/high) is annual abundance estimates over 20 years with high precision (CV=0.1). The poor data case (low/low) is four abundance estimates over 10 years with low precision (CV=0.8). Analysis of the data is performed within a Bayesian framework, where a prior distribution is specified and combined with the available data using Bayes theorem. It results in a posterior distribution for the parameters of interest (in our case, average growth rate, standard deviation of the growth rate and the current population size). If there is little difference between the posterior distribution and the prior distribution, then the data are having very little influence on the resulting posterior distribution.

Table 14. Classification results for a case with a constant growth rate increasing at 5%/year and ending at 1 million individuals for both the great data case (high/high) and the poor data case (low/low), using the absolute extinction decision rules.

	Estimated category	Step function	Shoulder function	Concave function
Great data	EN	0.00	0.00	0.00
	TH	0.00	0.00	0.00
	NW	1.00	1.00	1.00
Poor data	EN	0.04	0.00	0.13
	TH	0.81	0.28	0.78
	NW	0.15	0.72	0.09

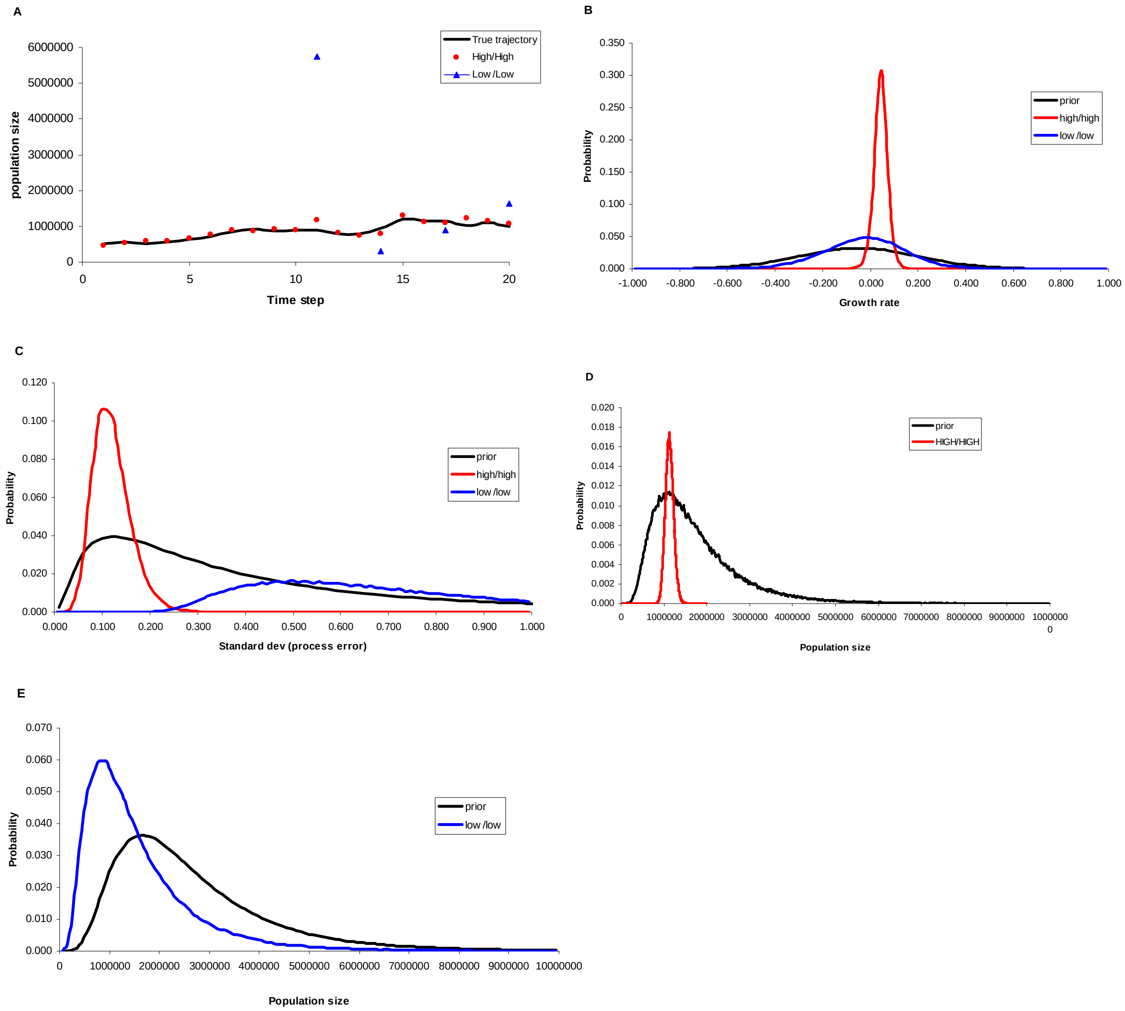


Figure 8. A sample case showing the population trajectory and abundance estimates (A) with the priors and posterior distributions for growth rate (B), standard deviation in growth rate (C), and abundance (D and E for the great and poor data scenarios respectively).

As expected, the great data scenario did great but the poor data scenario did very poorly. Within the poor data scenario, the shoulder function performed best, but even it mistakenly listed the species 28% of the time. A close look at Figure 8 reveals that the prior distributions strongly influence the posterior distributions when data are poor. Taken to the extreme when no data are available the priors would become the posteriors and the listing decision would be based on the chosen prior distributions. The prior distributions, therefore, should be carefully justified as they form the default decision when data are absent or poor.

An example using the quantitative listing criteria structure with an expert opinion approach: black abalone

The quantitative listing criteria structure developed in the report is ideally set up for very simple information on population growth rate and abundance. Inferences can be drawn on these parameters from many types of data. For example, inferences on population growth rate could come from data on changes in area of occupancy and abundance could come from density estimates. However, Phase 1 can also work using expert opinion approaches as long as the expert opinion elicitation is conducted so that the outcome is expressed in terms of a probability of extinction over time.

The evaluation of the petition to list black abalone, which was recently listed as EN (74 FR 1937; January 14, 2009), allows a retrospective look at how the Phase 1 structure would perform in that case. The biological review team reduced the risk problem to a simple equation that said, "The probability of effective extinction very soon (P) is equal to the probability that the northward spread of the disease (withering foot syndrome) will not cease very soon (S) times the probability that resistance will not emerge very soon (R)." Members of the team allocated 10 points across a range for each unknown parameter (S and R). Terms were defined as follows: "very soon"—within the life span of black abalone (30 years), "effective extinction"—density less than spawning threshold density such that there are no reproducing individuals left, "resistance"—positive population growth that persists through temperature fluctuations, and "emerge"—resistance appears at some locations throughout the range (VanBlaricom et al. 2009). The result of the exercise yielded a 97% chance of effective extinction by year 30. Although the available information is insufficient to compute Risk *per se*, it is sufficient to compute a lower bound on Risk (Rmin) as the product of extinction probability by year 30 and the value of the loss function at year 30 (given that all three loss functions are non-increasing functions of extinction time, Rmin is a lower bound because it ignores any extinction probability after year 30 and it assumes that all extinction probability *by* year 30 is actually concentrated *in* year 30). All the candidate listing criteria for all the different definitions of extinction (absolute, NE = 50 or NE = 250) would list the black abalone as EN (probability at year 30 times loss at year 30: step-- Rmin = 0.97*1.0 = 0.97, EN if Risk > 0.30 before year 100; shoulder—Rmin = 0.97*0.99 = 0.96, EN if Risk > 0.54; concave—Rmin = 0.97*0.33 = 0.32, EN if Risk > 0.05).

Discussion

The general idea behind performance testing of a proposed management system is to use simulations to gain insight into how a proposed management system would perform when applied. Particularly when management involves scarce natural resources, real testing *in situ* cases is not desirable. For example, it would not be desirable to implement a management system to list species in danger of extinction and have actual extinctions result from testing the management system.

Another benefit from exploring the behavior of management systems with simulations is that very complex systems with many non-independent components can be beyond our capacity to intuit basic behavior of how the different components interact. Quantitative listing criteria involve several such interactive components: how extinction events are valued over time, the cutoff values corresponding to different levels of protection, and weight given to different types of errors (either over- or under-protection of species).

The inability of the original Quantitative Working Group to understand the full implications between the different Over-Arching Definitions led to the recommendation to use simulations to gain a better understanding. Although the group felt that there would be differences between OAD1 (the extinction probability threshold definition referred to here as the step-function) and OAD3 (the comprehensive definition, for which we tested two functional forms--the shoulder and the concave functions), we could not guess in advance just how different they would be much less what the consequences for listing would be.

The best insight into the performance of a candidate management system would be to use a set of test cases that accurately represented future management cases. For example, to get a good simulated representation of the listing process for the ESA it would be ideal to have a database of all petitions for ESA listing together with the amount and quality of data available for each petitioned species. Assuming that future petitioned species will be similar to past petitioned species, at least the state of knowledge and estimated levels of risk could be well represented.

Unfortunately, no such database exists for ESA petitioned species. What, then, can be learned about proposed management systems by simulations? The PTWG did two sets of simulations to understand better the behavior of 3 candidate listing criteria described by different forms of the loss function: step, shoulder and concave. The first set, the challenge simulations, were aimed at revealing general behavior of the functional forms. Would there be striking differences between the OADs? What would be the effect of using different weighting tables? For example, would one functional form generally have the lowest total "cost" regardless of the weighting table? The second set of simulations, the consensus species simulations, allowed a more in depth look at behavior in specific cases. We could learn features such as: 1) the likely magnitude of errors (see Appendix 7 for definition of "error") for species we knew to be relatively close to the cutoff boundaries and 2) how those errors change across different levels of available data. In addition, 3 different extinction definitions were explored: absolute, 50 mature individuals and 250 mature individuals.

How do the loss functions differ in the way they list simulated species?

If "precautionary" is defined as being more tolerant of over-protection errors than of under-protection errors, then the challenge simulations suggest that the step-function is the most precautionary within the context of the assumed universe and prior distributions. Some properties of these different functional forms can be seen in Table 15. The simulations run (called the "universe") were chosen to give roughly equal proportions in the three categories of EN, TH and NW. We structured our set of simulations so that about 40% were truly NW cases under each of the different extinction definitions. The table reveals that the shoulder function exhibited a very symmetrical error pattern with roughly equal percents of over- and under-protection errors for the great data scenario. However, when data were poor the shoulder function made more over- than under-protection errors. Both the step and the concave functions tended to have more over-protection errors than under-protection errors. As uncertainty in the data increase the step and concave functions produce an ever higher proportion of over-protection errors.

Table 15. Comparison of the tendency to over- or under-protect species for the different functional forms. Results are for challenge simulations for the great data scenario (white) and poor data scenario (gray).

	Absolute extinction			Near-extinction = 50 mature			Near-extinction = 250 mature		
Loss Function	Percent correct	Percent under	Percent over	Percent correct	Percent under	Percent over	Percent correct	Percent under	Percent over
Step	72	7	21	75	4	20	71	4	25
Shoulder	75	13	12	78	11	11	74	14	12
Concave	76	9	15	80	9	10	76	8	16
Step	38	3	59	37	0	63	43	1	55
Shoulder	41	21	38	44	17	39	40	23	37
Concave	37	3	60	52	6	42	46	2	52

It may appear counter-intuitive that the step function, which seems in shape to be a more extreme form of the shoulder function, should behave more like the concave function with respect to a tendency to over-protect species (see Figure 3). One could imagine, for example, explaining the shoulder function like this: "I think any extinction out to about 30 years is equally bad. After that, I think that species with later extinction times have some chance of being dealt with later so I'm less concerned about protecting them right now and would give them a lower ranking, than those with extinction probabilities in the next few decades. That concern drops essentially to zero by year 400." Similarly, one could imagine describing the step-function as: "I have a very high concern for any species that may go extinct in the next 100 years. Species that may go extinct in the next 150 years are also a serious concern. All risks after 150 years can be postponed for future consideration and don't warrant a high ranking now." The concave function seems very different from the step function and yet both consistently tend to overprotect species. One could imagine describing the concave function as: "My highest concern is for species that will go extinct tomorrow and my concern drops off at a constant exponential rate until almost reaching zero at year 200." The cutoff values for each of the functions were based on the same set of consensus species and were chosen to make the proportion in each listing category roughly the same, given the set of test challenge cases.

A similar pattern for the different functions is seen in simulations for the consensus species. Table 16 shows the four most challenging consensus species that were consensus species with the same risk category for all the definitions of extinction. The step function is always most protective, which also results in incorrectly listing the tortoise (considered NW by consensus) more than half the time even with great data and being the only functional form to have no correct listing decisions for tortoise (NW) when data are poor. Contrast in performance between the different functional forms is larger for the poor data case. Both the shoulder and the concave make rather large under-protection errors for the EN species. The poor-data case for the pinniped2, the only TH species highlighted here, shows the large tendency to over-protect by the step-function. Note that using the list versus not list weighting table that this "error" receives a weight of zero (i.e. is not considered an error). The shoulder and concave function correctly list as TH at about the same level but when they do make errors, they make them in opposite directions with the shoulder under-protecting and the concave over-protecting. For high risk consensus species not shown here (herring, mudminnow and snake) all three functions correctly listed 100% of the time for all data scenarios and loss functions with the exception of the shoulder function with poor data which incorrectly inferred NW for both mudminnow and snake 4% of the time.

Table 16. Percent of estimated listings for consensus species for the great data scenario (white) and poor data scenario (gray) and using near-extinction = 50 mature individuals. The true category for the species is indicated in bold.

Species	Step function			Shoulder function			Concave function		
	EN	TH	NW	EN	TH	NW	EN	TH	NW
Pinniped1	**96**	4	0	**81**	16	3	**82**	16	2
Passerine	**89**	8	3	**64**	31	5	**56**	38	6
Pinniped2	31	**62**	7	19	**63**	18	4	**72**	24
Tortoise	02	52	**46**	1	47	**52**	0	39	**61**
Pinniped1	**98**	2	0	**25**	67	8	**68**	32	0
Passerine	**94**	6	0	**18**	70	12	**45**	54	1
Pinniped2	89	**11**	1	9	**75**	16	21	**76**	3
Tortoise	57	43	**0**	2	60	**38**	5	79	**16**

What can the performance testing results tell us about the choice of definition for extinction?

The cutoff values for each of the three definitions of extinction (absolute, near-extinction = 50 and 250 mature individuals) were based on the cutoff elicitations of the PTWG. The 20 species used for the absolute extinction elicitation included several species that were already below either 50 mature individual or 250 mature individuals. One of these was killer whales, which was considered as TH for absolute extinction according to the elicitation. By definition it would be EN for either of the near-extinction definitions with less than 50 mature individuals remaining. Compared to the absolute extinction consensus species, Erodium and sparrow were added as EN species using NE = 50, and in addition to those, Grevillea was added to EN using NE = 250. So, as the value for "extinction" increased from zero to 250, the number of EN consensus species increased. This shift in cutoff values makes comparisons of the performance testing simulations somewhat questionable.

Nevertheless, we did try to shift the challenge cases (the universe) to achieve about the same proportion of cases in each category (EN, TH and NW) (Table 17).

Table 17. The percent of challenge cases in each of the threat categories for each of the functional forms and for the different extinction definition types.

Type		EN	TH	NW
Ext = 0	Step	20	35	45
	Shoulder	24	37	40
	Concave	27	37	36
NE = 50	Step	25	32	43
	Shoulder	39	29	32
	Concave	22	38	40
NE = 250	Step	34	20	46
	Shoulder	27	31	43
	Concave	33	26	42

Using the List-v-Not-List weighting table we can compare the expected "costs" across the different extinction definition types. Table 18 shows expected costs for all four data scenarios. There is no over-all winner across data scenarios within any of the extinction definitions (though the concave function is clearly superior for NE = 50 with the step function only tied for best with great data).

Table 18. Expected costs for different extinction types for the great data scenario and assuming the List v Not List weighting table.

Data scenario	Function	Absolute extinction	Near-extinction = 50	Near-extinction = 250
Great (high/high)	Step	0.51	**0.46**	0.57
	Shoulder	0.49	0.49	0.50
	Concave	**0.47**	**0.46**	**0.49**
Low/high	Step	0.82	0.79	0.91
	Shoulder	**0.74**	0.72	**0.70**
	Concave	0.75	**0.67**	0.74
High/low	Step	0.99	0.99	1.00
	Shoulder	**0.88**	0.99	**0.93**
	Concave	0.95	**0.91**	0.94
Poor (low/low)	Step	**1.00**	**1.00**	**1.00**
	Shoulder	**1.00**	**1.00**	1.01
	Concave	**1.00**	**1.00**	1.01

Some of what we learned about limitations to the performance testing approach.

Developing quantitative listing criteria for the ESA involves complex integration of policy and management. This research has used computer simulations to gain understanding of candidate criteria that differed in form. Here we offer some of the limitations we encountered that may assist in future developments of methods to assess proposed management systems. The results in this report were generated just before the report was written and were voluminous. No doubt there are more lessons to be learned as results are further digested.

The results of performance testing are sensitive to the choice of cutoff value (given that there is usually a range). The approach of using consensus species, which are cases where all PTWG members (or all PTWG members except one) agreed on the listing category, means that there are bound to be gaps near the areas in which we are most interested: the boundaries between the categories. Getting agreement on extremely endangered species, like the herring, actually provided rather little value. Herring were far from the boundary between EN and TH and also had a very high chance of being properly listed as EN regardless of function form choice, definition of "endangered" choice, or cutoff value choice. The gaps between consensus species were often quite large. For example, for near-extinction = 50 mature individuals, the sparrow had the lowest level of risk in 50 years of any EN consensus species at a 40% chance in 50 years. The closest consensus species in TH (species 19) had a 9% chance of extinction in 50 years. Thus, any value between 9% and 40% could serve as the cutoff value (see depiction in Figure 6). We chose values that allowed us to come as close as possible to equal proportions in the different listing categories in the challenge simulations for the different functional forms. While this allowed us some insight into how the functional forms performed, it may not correspond to the correct value when it comes to actual listing. This is one of the reasons the Steering Committee recommended retrospective analysis.

Another shortcoming of our performance testing is the sensitivity to the choice of the "universe" for the challenge simulations. Interpreting the results from performance testing is not as straightforward as one would wish without distributions that truly represent the levels of risk embodied by species that have actually been petitioned for listing. For example, if species were only considered for listing that were at very high risk of extinction in the coming 50 years and data were always great, then all functional forms would perform well, at least with respect to petitioned species. If, on the other hand, species were primarily at high risk but had medium to poor data, then the concave function would perform the best given a precautionary weighting table. If most species were actually not warranted, then choosing the shoulder function would reduce overall errors regardless of data quality. Thus, quantifying the risk levels, data quantity and data quality for the set of species that likely will be considered for listing could indeed alter the choice of which function to use. This would be a major undertaking that was not possible given the resources so far available.

The Guiding Principles used here have played an important role in shaping the development of quantitative listing criteria. Were it not for the principle to "be implementable by the agency and transparent to the public" the Steering Committee's likely choice given the performance testing would have been OAD3 using the concave function, given the performance testing results which suggest the concave function as the "winner" in most simulation scenarios. Thus, the quantitative measure of the expected cost from the simulations was only one element in choosing which criteria would perform best in listing species under the Endangered Species Act. No formal performance measures were developed for the Guiding Principles as it is difficult if not impossible to assign numbers to concepts like "transparent". The choice to use years rather than generation time was based in part on ease of implementation. Similarly, the principle to "ensure different taxa receive equivalent levels of protection" in part drove the Steering Committee's decision to use "near-extinction" rather than absolute extinction. The principle to "cover data rich and data poor conditions" resulted in recommending that while the quantitative listing criteria should be adopted, that a decision tree also be developed for guiding application of those criteria when data are too poor for managers to be comfortable making decisions from quantitative PVA modeling. Each one of the Guiding Principles adds dimension to the problem of choosing listing criteria, making the problem multi-dimensional with no obvious way to combine the different Principles into a single measure of performance. The influence of the guiding principles is not a short-coming of performance testing as much as a demonstration that choosing quantitative listing criteria is a true blend of policy and science and that the best choice will likely not be determined by performance testing alone, but rather informed by the insights that such simulations can provide.

Summary of the Steering Committee's Decisions

Follow is our rapportage of decisions made by the Steering Committee following submission of our draft report.

Choice of the Overarching Definition

Steering Committee members saw merit in all of the loss functions examined (step (OAD1), shoulder (OAD3) and concave (OAD3). The Steering Committee chose OAD1 because it was easiest to explain and because the performance testing revealed that its performance was acceptable and similar to the performance of the other options.

Definition of "extinction"

Steering Committee members agreed that using absolute exinction was not done in practice and that other values that reflect near-extinction should be investigated and included in the final report.

Another concern was that ongoing risk assessments for some petitioned species did not go 100 years into the future when models were considered unreliable beyond 50 years. This was the case for models of sea ice that are used in evaluating risk for ice-dependent species that have already been petitioned. The Steering Committee requested that the cutoff elicitation be repeated with 2 different quasi-extinction values and that the time scale for the step-function be shortened if possible based on the result of the elicitation from the PTWG.

Weighting table choice

Steering Committee members all preferred the List versus Not List weighting table that was precautionary (assigned twice the weight to under-protection errors than to over-protection errors).

Treatment of poor data cases

Using the quantitative listing criteria and our Bayesian analysis, the most likely outcome for poor-data species is to list as EN or TH even for a case that was clearly not warranted (one million individuals increasing at 5%/year). The Steering Committee had mixed reactions to this problem. Some believed that precautionary listing of such species was a positive outcome that was warranted given the gravity of potential extinction for petitioned species. A listing would presumably spur reduction in ignorance about the risk the species faced, and increases in data would allow de- or down-listing for species that were misclassified and were truly NW. The cost of falsely listing NW species was felt to be smaller than the cost of not listing EN or TH species where data were poor. Others felt that making a decision based on prior distributions that had been little influenced by data was not “transparent to the public” (one of the Steering Committee’s guidelines). Thus, the decision seemed to be based on numerical data but was instead based on whatever process led to the choice of prior distributions.

The Steering Committee recommended development of a hierarchical decision tree that strives to base listing decisions on both quantitative listing criteria and the analysis of threats (the factors listed under section 4(a)(1) of the ESA), but allows using a reasoned qualitative analysis based on an evaluation of threats, keeping in mind the quantitative listing criteria. The question of how to treat poor-data species needs continued research.

Broad-based panel elicitation

Steering Committee members agreed that the elicitation work done by the PTWG already had been helpful, but that further elicitation from subjects without extensive training in risk analysis plus experience in ESA implementation was not necessary. Steering Committee members thought a productive way to refine cutoff values was through examination of retrospective analyses (see below) by a small work group led by Barbara Taylor, with direct reporting to the Steering Committee.

Next steps

Phase 1, performance testing of the OADs, advanced the development of quantitative listing criteria by allowing choice of candidate criteria. The Steering Committee thought that retrospective analyses on a selection of already listed cases should be the next step. These cases should range from species with good data to species with very poor data. A range of life histories could also provide insight on the utility of proxy criteria (Phase 2 as envisioned by the Quantitative Working Group) and the amount of effort that would be required to create proxy criteria. The retrospective analyses will allow the cutoff values to be refined as needed. The amount of effort to do PVAs within a Bayesian framework can also be assessed.

OAD2

OAD2 was not conducive to the type of performance testing described in this report. It was agreed that further consideration of OAD2 would require further development by another group (not the PTWG).

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Appendix 1: Guiding Principles

The Steering Committee established the following Guiding Principles for the QWG.

Listing criteria should:

- be applicable to all species, subspecies, and distinct population segments (DPSs), first to NMFS species and then to all species (including species managed by the FWS)
- be implementable by the agency and transparent to the public
- be written in such a way as to provide flexibility for unique circumstances or biology
- ensure different taxa receive equivalent levels of protection
- cover data rich and data poor conditions
- include definitions for terms used
- address adding, downlisting, and uplisting species under the ESA

Appendix 2: Terms of Reference for Performance Testing of Quantitative Listing Criteria

October 20, 2004

The Endangered Species Act employs a two-category system, listing species either as endangered (in danger of extinction throughout all or a significant portion of its range) or threatened (likely to become endangered in the foreseeable future). Absence of Congressional guidance on how to interpret the terms used in the statutory definitions of these categories has left the task of defining them to the U.S. Fish and Wildlife Service (USFWS) and NOAA Fisheries. To date, the lack of uniform guidelines for listing decisions has led to inconsistencies and inequities in the listing process. NOAA Fisheries, in consultation with the USFWS, has responded to this problem by establishing a Steering Committee and a Quantitative Working Group (QWG) to work toward developing quantitative procedures that will make listing decisions "more transparent, consistent, and scientifically and legally defensible." The Steering Committee, in turn, has provided the QWG with a set of Guiding Principles which state that these procedures should possess characteristics such as applicability, implementability, transparency, flexibility, and equitability. The QWG has completed its work and provided in its final report a roadmap by which NOAA Fisheries could eventually develop uniform guidelines for listing, reclassifying, or delisting species.

Briefly, the QWG proposed the following process: (1) *overarching definitions* for both endangered and threatened should be adopted, (2) values of any *policy parameters* associated with the overarching definitions (e.g., the level of extinction risk corresponding to "endangered") should be specified, (3) *decision metrics* that can be used as proxies for (1) and (2) in data-poor cases should be developed for an appropriate range of taxonomic groups or life history types, and (4) all of the above should be done in the context of *performance testing* (use of simulations to evaluate how well an alternative performs relative to the objective).

The purpose of performance testing is to evaluate how alternative listing criteria and decision metrics perform relative to one or more management objectives. This can be accomplished by simulating the performance of the alternatives and using a set of performance measures to translate the simulation output and the objective into a common currency. Performance testing will be conducted in two phases:

- **Phase 1** will focus on the listing criterion for Endangered (EN) and Threatened (TH). Here, the purpose will be to evaluate the three alternative overarching definitions proposed by the QWG (e.g., the Probability of Extinction Threshold definition), and alternative values of any associated policy parameters (e.g., P_{ex}, t_{ex}). At the conclusion of the first phase, a listing criterion for EN and a listing criterion for TH should be adopted, at least provisionally.
- **Phase 2** will focus on the decision metrics. Here, the purpose would be to determine which decision metrics serve as the best proxies for the EN and TH listing criteria. Performance testing would be used to evaluate alternative decision metrics given the chosen listing criterion. In the event that the listing criterion for EN proves too difficult to approximate by any particular decision metric, the first phase could be repeated with a new set of alternatives.

Performance testing is likely to be an iterative process, as intermediate results will likely lead to new alternatives to test.

This testing will be conducted over at least two years, and perhaps three years. At least one modeler will be dedicated full-time to the task of carrying out the performance testing. This will be a post-doctoral or equivalent position, with the individual to be housed at the SWFSC, and mentored by NOAA Fisheries staff at the SWFSC and AFSC. Some of the performance testing may also be conducted by existing NOAA and USFWS staff.

This work will be guided by a steering committee that includes modelers and species specialists. Best results will be achieved through an iterative process between the steering committee and the modeler(s). To this end, it is proposed that the steering committee meet with the performance modeling team at the beginning of the project, and then on an annual basis.

The QWG further recommended that once the performance testing is concluded that a broad-based panel be established and empowered to evaluate the results of the performance tests.

Appendix 3. Acronyms and definitions

Acronyms

AFS	American Fisheries Society
BRT	Biological Review Team
DPS	Distinct Population Segment
EN	Endangered
ESA	Endangered Species Act
FACA	Federal Advisory Committee Act
FEMAT	Forest Ecosystem Management Assessment Team
IUCN	International Union for Conservation of Nature
MMPA	Marine Mammal Protection Act
NE	Near Extinction
NMFS	National Marine Fisheries Service referred to here as NOAA Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NL	Not listed
NOAA Fisheries	National Marine Fisheries Service, National Oceanic and Atmospheric Administration
NW	Not Warranted
OAD	Over-Arching Definition
PDF	Probability Density Function
PTWG	Performance Testing Working Group
PVA	Population Viability Analysis
QWG	Quantitative Working Group
TH	Threatened
USFWS	U.S. Fish and Wildlife Service

Definitions

A

Allee effect: A behavioral effect that causes population growth to decrease at low density. Examples are increased predation cause by insufficient numbers to defend effectively, inability to find mates, change in social structure or sex ratio resulting from insufficient numbers, etc. One factor leading to density depensation.

B

Bayes' Theorem: In probability theory **Bayes' theorem** (often called **Bayes' law** after Reverend Thomas Bayes) relates the conditional and marginal probabilities of two random events. It is often used to compute posterior probabilities given observations. For example, a patient may be observed to have certain symptoms. Bayes' theorem can be used to compute the probability that a proposed diagnosis is correct, given that observation.

C

Compensation: A process where population growth rates are higher than expected at lower abundances because of reduced intraspecific competition.

Comprehensive Threshold Definition (OAD 3): similar to the Probability of Extinction Threshold Definition except that instead of looking at a single time horizon, the likelihood of extinction at each point in time is weighted according to a loss function to arrive at a comprehensive measure of risk. The risk is calculated as the weighted sum of the time to extinction probability distribution and a loss function.

Consensus species: A set of reference cases where all or all but one PTWG member agreed the listing status. Consensus species are used to determine cutoff values between the listing categories.

D

Data poor condition: Either data with low precision (Coefficients of variation (CVs) > 0.5) or low quantities of data that lead to high uncertainty in levels of risk.

Data rich condition: Either long time series (large quantity of data) or data of high precision (CVs < 0.1) that lead to low uncertainty in levels of risk.

Decision Metrics: see Proxy Criteria

Decision rule: See Listing Criterion

Default parameter: A parameter not derived using direct data for a species. Default parameters often use estimates for parameters (such as generation time) from similar well-studied species.

Demographic stochasticity: An increase in the variance of population growth rate when abundance becomes low due to the finite probabilities of birth and death. For example, a population of 100 with an annual survival probability of 0.95 would on average have 95 individuals survive. However, a population of 10 could only have 8, 9 or 10 individuals survive. The increased variance results in a reduction in the average population growth rate.

Density depensation: a process where population growth rates are reduced at low densities. Factors resulting in growth rate reduction are Allee effects, genetic issues and demographic stochasticity.

Despensatory Threshold Definitioan (OAD 2): definition states that a species is EN if its abundance, area of distribution, or other relevant metric falls below the level at which depensatory (Allee) effects are likely to predominate or population processes are largely unknown.

E

Environmental stochasticity: see Process variation

Estimation error (inference error): inaccuracy and imprecision introduced by the method of statistical inference used to estimate system parameters from observations.

Extinction Profile: the average number of future extinctions as a function of time that represents what society expects and would tolerate from an appropriately crafted listing criterion.

F

False Positive: A false detection. A test result that is positive when in actual fact should be negative. For listing decisions, a false-positive is when a species is listed but should not be. Also referred to as an over-protection error.

False Negative: A test result that is negative when in actual fact should be positive. For listing decisions, a false-negative is when a species is not listed but should be. Also referred to as an under-protection error.

Functional Extinction: Functional extinction is a state when it is *certain* that no further reproduction is possible, in which case the species will cease to exist once the extant individuals have perished. An example of functional extinction is a population with no breeding females.

G

Generation Time: The average age of parents of the current cohort (i.e. newborn individuals in the population).

I

Implementation error: imperfect policy implementation resulting from economic forces or the management process (such as delays in establishing protected areas or inadequate protection).

Inbreeding depression: Reduced fitness (birth and/or death rates) resulting from genetics (exposure of lethal or semi-lethal recessive genes).

K

Kalman filter: An efficient recursive filter that estimates the state of a linear dynamic system from a series of noisy measurements.

L

Life History Group: A grouping of species that share life history strategies that place give them similar vulnerabilities to risk. For example, long-lived organisms tend to have low maximum growth rates and lower variability in growth rate. As such, they are more vulnerable to relatively low kill rates because their maximum growth rate can be easily exceeded. They are also slow to recover and hence less resilient to population reduction. Within this group there are differing levels of reliance on social structure that may warrant different levels of abundance as critical abundance thresholds.

Listing Categories: The different categories available under the Endangered Species Act (EN—endangered, TH—threatened, and NW—not warranted.

Listing Criterion: An overarching definition together with values of any associated policy parameters constitutes a *listing criterion*. E.g. For the Probability of Extinction Threshold definition, a listing criterion may be: A species is listed as EN if the Probability of Extinction within the next 100 years is $\geq$ 0.01. Also referred to as a Decision Rule and a Standard.

Loss Function (Loss/Utility/Cost): The loss function describes the relative importance of alternative states or outcomes across time, independent of the likelihood of those states or outcomes. The loss function is used in calculating the risk of extinction in the Comprehensive Threshold definition. The shape of the loss function should ideally represent the preferences to extinction over time. Also referred to as a weighting function.

M

Management objectives: The goals the conservation action aims to achieve in measurable quantitative terms. In this case, the objectives should be the relevant part of the guiding principles put in quantitative terms. For example, the guiding principle "cover data rich and data poor conditions" and "ensure different taxa receive equivalent levels of protection" could have the management objective "90% of species warranting protection as EN shall be listed as EN". (Note: there is nothing in the guiding principles to guard against over-protection errors.). Can also be referred to as a performance measure, or performance requirement.

Measurement error: a consequence of the way in which observations are taken (e.g. the choice of sampling strategy, or errors in data collection)

Model error: error arising from the incomplete, and potentially misleading, representation of system dynamics. Consequences are: contributing to estimation error through inferential process, and inducing further errors if the model is used in forecasting.

N

Near-extinction: a population that has declined to a size at which the probability of extinction in the near future (50 years or the lifespan of the species whichever is the longer) is extremely high. The term is used to account for time-lag effects when risk is evaluated in years rather than generations.

O

Observation error (census error, sampling error and)**:** Composed of measurement error and estimation error.

Operating model: a plausible model of an ecological system used to test the robustness of management procedures to uncertain system structures, and to evaluate the tradeoffs between conflicting objectives.

Over-Arching Definitions (OADs): general description of the extinction risk corresponding to Endangered or Threatened. There are three overarching definitions: 1) The Probability of Extinction Threshold definition, 2) the Despensatory Threshold definition and 3) the Comprehensive Threshold definition.

OAD1: Probability of Extinction Threshold definition states that a species is EN if its probability of extinction within a specified time horizon exceeds some cutoff percentage

OAD2: Depensatory Threshold definition states that a species is EN if its abundance, area of distribution, or other relevant metric falls below the level at which depensatory (Allee) effects are likely to predominate or population processes are largely unknown

OAD3: Comprehensive Threshold definition (OAD3) is similar to the definition for the Probability of Extinction Threshold, except that instead of looking at a single time horizon, the likelihood of extinction at each point in time is weighted appropriately using a loss function to arrive at a comprehensive measure of risk.

P

Performance measures: the quantitative basis by which performance is assessed and gauged. Includes performance objectives and criteria, performance indicators, and any other means that evaluate the success in achieving a specified goal. In the context of listing criteria, the performance measures should reflect the goals outlined in the guiding principles. Also referred to as management objectives.

Performance testing: In the context of evaluating alternative listing criteria, performance testing is testing (often output from simulations) conducted to evaluate the compliance of a listing criterion with specified performance requirements and measures. Performance testing can also compare two listing criteria to find which performs better and can identify and measure what causes a listing criterion to perform badly.

Policy parameters: Parameters expressing societal preference. In the context of listing, parameters that express the level of risk tolerance before granting a species the protection of the ESA. An example for the threshold definition would be the values "100" and "1%" in the over-arching definition "a 1% chance of extinction in 100 years".

Population Viability Analysis (PVA): A mathematical modeling approach that uses data on the species in question along with prior knowledge gained from similar species to project the species fate into the future together with all the uncertainties it faces. A PVA can be used to estimate the extinction time probability function of a species.

Probability of Extinction Threshold Definition (OAD 1): A species is EN if its probability of extinction within a specified time horizon exceeds some cutoff probability.

Process variation (Process stochasticity, Process error, Environmental variation, Environmental stochasticity, Natural variation, Process noise)**:** The variation that arises as a consequence of demographic and environmental stochasticity (biotic or abiotic).

Proxy Criteria (Decision Metrics): Used for listing decisions in data poor circumstances in lieu of a PVA. Examples of metrics could include specified levels of absolute abundance, specified rates of decline in abundance, specified fractions of historical habitat loss, etc. These metrics could be used singularly or in combination.

Q

Quasi-extinction: a small population size somewhat above absolute extinction. Quasi-extinction does not have a standard quantitative definition.

R

Reference cases: Cases using data from well-known real species for which a PVA has been done so that an extinction distribution is available. These cases can be used as a reference set where listings resulting from different time loss functions can be compared.

S

Safe abundance: An abundance not requiring active management to remain at levels in no immediate danger either from catastrophes or a normal run of correlated environmental events (like a series of drought years). As a rule of thumb, safe abundance should be ten times higher than the critical abundance threshold.

Sampling error: See Observation Error

Standard: See Listing Criterion.

Stable: A population growth that maintains about the same abundance through time ($r = 0$).

T

Time discount function: (see Loss Function) A function that discounts the weight given to an extinction event through time. Generally this will be a monotonically decreasing function that embodies more concern about imminent extinctions than about extinctions occurring in the more distant future.

True negative: A test result that is negative and is truly negative. For listing decisions, a True-negative is when a species is not listed correctly.

True positive: A test result that is positive and is truly positive. For listing decisions, a True-positive is when a species is listed correctly.

Tuning parameters: model parameters used to alter performance

Comprehensive—shape of loss function, risk factor

Threshold—policy parameters, proportion of variance assigned to process or sampling error

U

Uncertainty: incomplete information about a particular subject. Two major types of uncertainty are epistemic uncertainty (uncertainty in things that can be measured) and linguistic uncertainty (uncertainty in the language used to describe or classify states). See also the four separate sources of epistemic uncertainty: Process variation, Observation error, Model error, and Implementation error.

Utility: the value to society associated with a potential outcome of management action; it can be assigned or arrived at by consensus. Utility is the inverse of “loss”.

W

Weighting Function: see Loss Function

Appendix 4. Quasi-extinction

Since population modeling for ESA status assessments has more often used some number greater than absolute extinction projections, the Steering Committee requested that performance testing be completed for one or more potential near-extinction levels to help inform listing criteria development. We chose to use the term "near-extinction" rather than the more commonly used "quasi-extinction" because the latter term has been used in several quite different ways and therefore ran the risk of introducing linguistic uncertainty. Nevertheless, reviewing quasi-extinction concepts gives context to near-extinction.

Quasi-extinction (Ginzburg et al. 1982) means a small population size somewhat above absolute extinction (zero individuals or in our case less than or equal to one individual) although it does not have a standard quantitative definition. The biological rationale for evaluating species' risk based on quasi-extinction recognizes that population behavior typically changes at very small numbers such that it becomes relatively more difficult to predict the timing (or probability) of absolute extinction than the timing (or probability) of reaching small population sizes. One way "quasi-extinction" has been used is to represent any threshold population status where risks are unacceptably large for "conservation, management, economic or aesthetic purposes" (Burgman et al. 1993); in other words, a threshold representing social intolerance for risk, similar to the definition of an endangered species. The definition we use in the main body of the report is at a much higher level of risk (see Figure 2).

In their book, Quantitative Conservation Biology: theory and practice of population viability analysis, Morris and Doak (2002) explain why they feel that extinction risk should be estimated for quasi-extinction thresholds rather than absolute population extinction.

> *No good PVA should attempt to evaluate the risk of utter population extinction…* because… many additional, difficult-to-evaluate population processes complicate the behavior of truly tiny populations. The basic goal of PVA is to predict the future with some reasonable degree of assurance. We can do this much better if we don't try to predict when the very last desert tortoise in Las Vegas County may die, but, rather, when the populations will reach a small enough number that many additional genetic and ecological problems will further threaten it, making it perilously at risk. (Morris and Doak 2002)
>
> Apart from the practical fact that when [complete extinction] occurs, it is too late to save the population, setting a higher "quasi-extinction" threshold allows us to partially account for several factors, such as inbreeding depression at low population size, demographic stochasticity, and Allee effects, about which we will usually lack sufficient information to include in [PVA] model[s]… (Morris and Doak 2002)

Morris and Doak provide some practical guidelines for choosing a quasi-extinction level for PVA modeling, based on genetic and demographic processes. They recognize that the "challenge, of course, is to decide what that threshold should be" and offer their guidelines as "the best we can do" (Morris and Doak 2002) without further research.

Morris and Doak explain how demographic and environmental variation act synergistically to create an 'extinction vortex' at low population sizes and suggest a quasi-extinction threshold that avoids these processes:

> When environmental and demographic stochasticity combine… [they produce] qualitatively different [population] behavior… [and a] virtually inescapable slide to extinction… As population density falls, the variance in the population growth rate increases due to demographic stochasticity, and higher variance then leads to a lower geometric mean population growth rate, which causes the population to decline still more, further increasing the variance due to demographic stochasticity and further reducing the geometric mean, and so on, in an inevitable downward spiral. Thus environmental and demographic stochasticity conspire in a "one-two punch," the former acting to push populations below some fuzzy threshold at which the latter takes fatal hold. …It is precisely this threshold-like behavior of demographic stochasticity that argues for the use of a quasi-extinction threshold, rather than measuring the risk of outright extinction… (Morris and Doak 2002).

> Concern about demographic stochasticity would argue for a threshold of 20 or more individuals, and preferably 20 or more *reproductive* individuals (Morris and Doak 2002).

Allee effects or reductions in reproductive success or survival of individuals due to small population size (positive density dependence, such as mates not finding each other) also contribute to the 'extinction vortex.'

> Allee effects… can greatly increase the extinction risk of small populations. …if we can estimate a threshold population size below which Allee effects become strong enough to virtually guarantee population extinction, we can simply set the quasi-extinction threshold at or above the population size at which Allee effects become important (Morris and Doak 2002).

They do not suggest a guideline for an Allee-effect quasi-extinction threshold, however, because "in spite of some excellent efforts to document positive density dependence at low population sizes, evidence of population-level Allee effects has remained extremely weak" (Morris and Doak 2002).

To address genetic drift, inbreeding, and extinction processes, they suggest higher quasi-extinction levels:

> … setting a high enough quasi-extinction threshold to minimize the chances that genetic problems would dramatically change a PVA's conclusions. Here, "high enough," probably means an effective population size, N_e, on the order of 50 individuals, resulting in only a 1% loss of genetic diversity per generation. The relationship between N_e and total population size is complicated by many factors (Falconer 1989). However, one fairly well-substantiated generality is that for many birds and mammals, $N_e/N \approx$ one-half to two-thirds, where N is the total population size of *reproductive adults* (Nunney 1993; Nunney and Elam 1994), arguing for a quasi-extinction threshold of at least 100 breeding adults. This approach still basically ignores inbreeding problems and will always result in somewhat optimistic answers about population viability, since some significant inbreeding will occur even above this population size. (Morris and Doak 2002:42-43)

Appendix 5. Description of Cutoff Elicitation

To elicit cutoff values for listing criteria, PTWG members were sent a set of 20 example cases and asked to "list" each case as Endangered, Threatened or Not Warranted. The cases were mostly from Açkakaya (2004). A few cases were added that were recently listed so that we could see whether our classifications departed from recent decisions. These cases and the scientists who supplied the data were: killer whales (Paul Wade), monk seals (Albert Harting, Harting, 2002), and Steller sea lions (Albert Harting). The end of this appendix contains all cases given to PTWG members. For each case, the table shown on the right is truncated to 300 years for extinction probabilities and 30 years for the average abundance, but the full time series up to 500 years was in the original spreadsheets (Consensus-species-E-zero.xls, Consensus-species-NE-50.xls and Consensus-species-NE-250.xls). Classification choices can be seen in Table 19.

Table 19. Classification choices by PTWG members represented by subject number for the absolute extinction cutoff elicitation.

		Subject number							
Species name	Species #	3	5	4	7	6	2	1	8
snake	6	EN	EN	EN	EN	EN	EN	EN	EN
mudminnow	10	EN	EN	EN	EN	EN	EN	EN	EN
passerine	1	EN	EN	EN	EN	EN	TH	EN	EN
herring	11	EN	EN	EN	EN	EN	EN	TH	EN
pinniped 1	12	EN	EN	EN	EN	EN	EN	TH	EN
killer whale	15	TH	EN	TH	EN	EN	TH	EN	EN
Grevillea	16	TH	EN	EN	EN	EN	TH	TH	EN
songbird	2	NW	TH	EN	NW	EN	TH	EN	EN
sparrow	3	TH	TH	EN	TH	EN	TH	TH	EN
Erodium	17	TH	TH	TH	EN	TH	TH	TH	EN
grass tree	20	NW	NW	NW	TH	TH	TH	EN	EN
pinniped 2	14	TH	TH	TH	TH	TH	TH	TH	EN
Epacris	18	NW	NW	NW	TH	NW	TH	TH	EN
deer	13	NW	NW	NW	NW	TH	NW	TH	EN
pine tree	19	NW	TH	TH	TH	NW	TH	TH	TH
newt	4	NW	NW	NW	NW	NW	NW	NW	TH
sand lizard	8	NW	NW	NW	NW	NW	NW	TH	NW
toad	5	NW	NW	NW	NW	NW	NW	NW	NW
desert lizard	7	NW	NW	NW	NW	NW	NW	NW	NW
tortoise	9	NW	NW	NW	NW	NW	NW	NW	NW

To arrive at a set of "consensus species" we used a set of rules that eliminated cases from the original set of twenty that had "votes" cast in all listing categories (EN, TH, and NW). Of the remaining set, if only one vote differed from the rest, the species was considered to be "consensus". Finally, remaining cases that had more than one vote in both TH and NW or EN and NW (the boundary between listing and not listing, which was considered to be a point of serious disagreement) were eliminated. Thus, the TH was defined to be any case with more than one vote for TH and zero votes for NW. This means that the resulting criteria will make it more difficult to qualify as EN. A reasonable argument could be made to make the Threatened/Endangered cutoff value by majority vote, in which case killer whales and Grevillea would be classified as Endangered in the case of absolute extinction. The resulting cases are shown in Table 1, Table 2, and Table 3 in the main body of the report.

Most of the PVA models developed for the consensus species were very complex stage specific population models with many parameters. Our performance testing algorithm is only conducive to a simple three parameter model. Thus for each of the consensus species we fitted an inverse Gaussian distribution (Eqn 1) to the probability distributions of the time to extinction such that:

$$g(t \mid \mu, \sigma, d) = \frac{d}{\sqrt{2\pi\sigma^2 t^3}} \exp\left[\frac{-(d+\mu t)^2}{2\sigma^2 t}\right] \qquad (1)$$

Where d =log N_c –log N_x is the difference between the log of the current population size N_c and the log of the extinction threshold, N_x. μ is the mean growth rate, σ is the standard deviation of the growth rate due to process error, and t is time. The initial population size was known from each of the detailed models and we estimated the growth rate, μ, and the process error term σ. The inverse Gaussian model approximated the more complex PVA very well for all consensus species except the toad and the sand lizard. Thus these species were removed from our consensus species list. Figure 9 illustrates the comparison of the pdf for the detailed model for the passerine versus the fitted inverse Gaussian distribution. All the parameter estimates from the inverse Gaussian model fits for all species used as consensus species for either the absolute extinction or near extinction cases appear in Table 20.

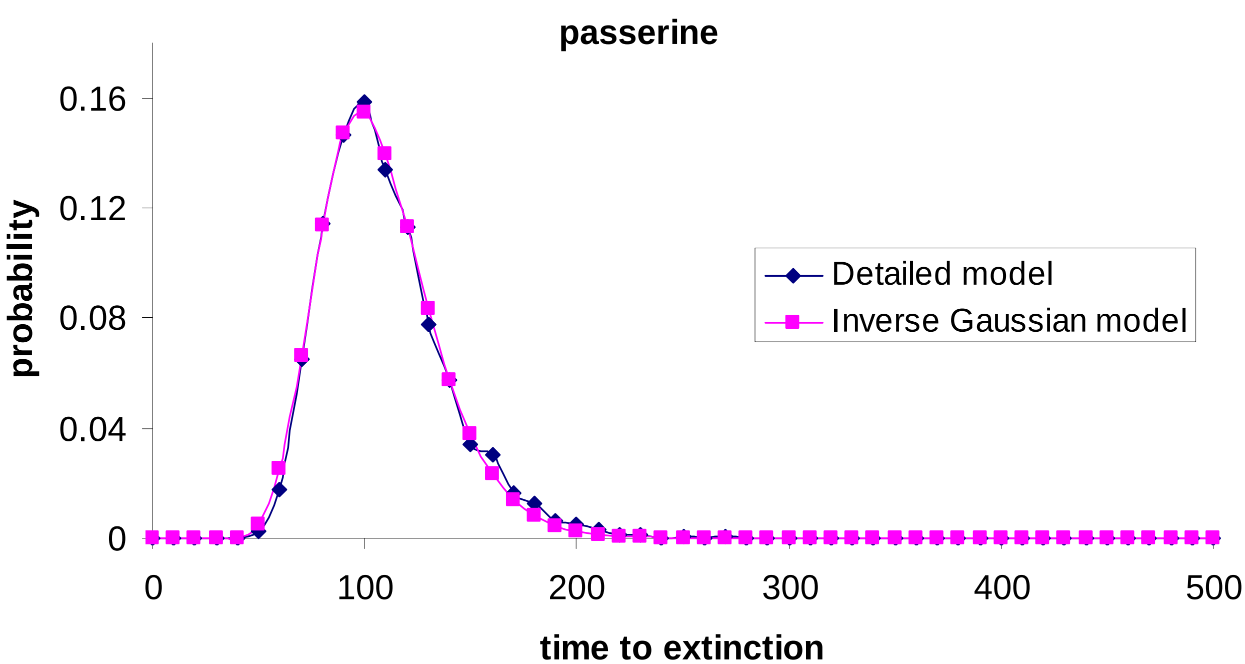


Figure 9: Example of the fitted inverse Gaussian model for the passerine compared with the pdf of time to extinction for the detailed PVA model

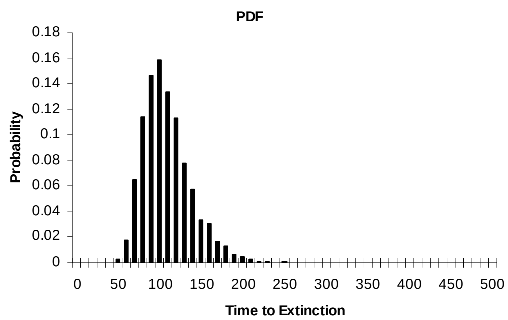
Table 20. Parameter estimates from Inverse Gaussian model fits for all species used as consensus species for either absolute extinction or near extinction cases.

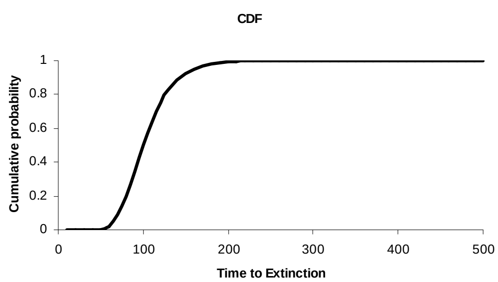
	Mean Growth rate μ	Standard Deviation of Growth rate σ	Initial population size N_c
snake	-0.182	0.202	9798
mudminnow	-0.190	0.282	962
herring	-0.516	0.423	21546900
pinniped 1	-0.069	0.141	935
Erodium	-0.053	0.082	1483
passerine	-0.078	0.202	6400
sparrow	-0.026	0.358	1010
pinniped2	-0.055	0.133	39500
Spp19	0.001	0.387	10000
spp20	-0.010	0.200	5000
tortoise	-0.028	0.177	811465
Epacris	-0.047	0.058	4818722
Spp16	-0.010	0.071	10000
Spp17	0.000	0.100	3000
Spp18	-0.020	0.045	85000
newt	-0.027	0.009	3200
Grevillea	-0.088	0.123	34472
Killer Whale	-0.018	0.141	82
Desert Lizard	-0.0004	0.212	6891

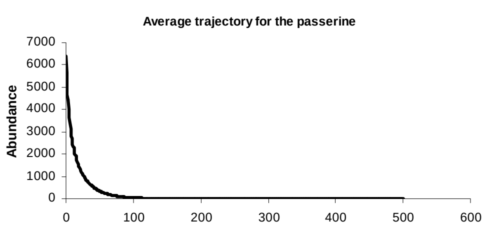
Section 6.1 Absolute extinction

Species 1. Passerine

Birds	**Passerine**
Initial abundance	6400
age at first reproduction	5 years
longevity	16 years
generation time	10 years
threats	habitat destruction and degradation



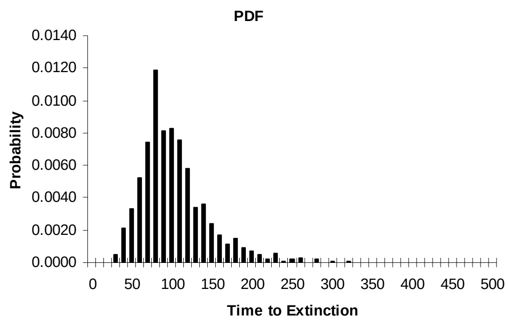


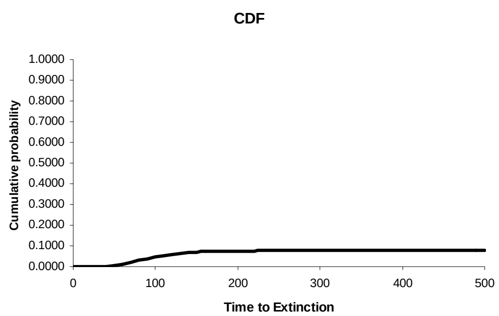


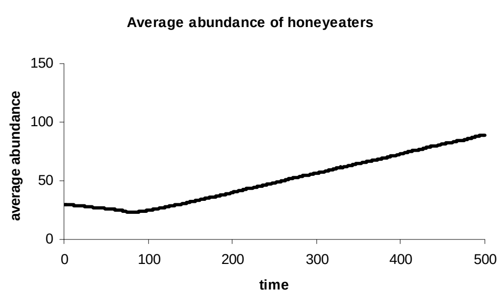
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	6400
10	0.0000	0.0000	1	5625
20	0.0000	0.0000	2	4966
30	0.0000	0.0000	3	4443
40	0.0002	0.0002	4	4005
50	0.0028	0.0030	5	3658
60	0.0180	0.0210	6	3366
70	0.0650	0.0860	7	3122
80	0.1140	0.2000	8	2908
90	0.1468	0.3468	9	2694
100	0.1588	0.5056	10	2520
110	0.1340	0.6396	11	2352
120	0.1128	0.7524	12	2217
130	0.0776	0.8300	13	2069
140	0.0576	0.8876	14	1965
150	0.0338	0.9214	15	1837
160	0.0306	0.9520	16	1738
170	0.0164	0.9684	17	1638
180	0.0128	0.9812	18	1547
190	0.0066	0.9878	19	1466
200	0.0050	0.9928	20	1394
210	0.0030	0.9958	21	1328
220	0.0012	0.9970	22	1250
230	0.0010	0.9980	23	1185
240	0.0002	0.9982	24	1143
250	0.0008	0.9990	25	1085
260	0.0002	0.9992	26	1027
270	0.0004	0.9996	27	978
280	0.0000	0.9996	28	929
290	0.0000	0.9996	29	887
300	0.0002	0.9998	30	842

Species 2. Songbird

Birds	Songbird
Initial abundance	30 (males only, 1:1 sex ratio)
age at first reproduction	1 year
longevity	10 years
generation time	3 years
threats	dieback of habitatable areas, competition by invasives



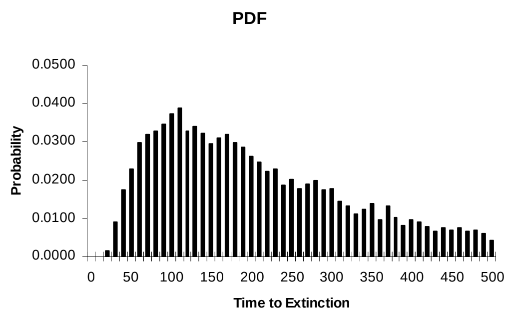


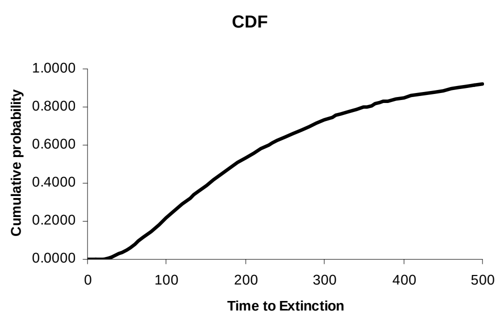


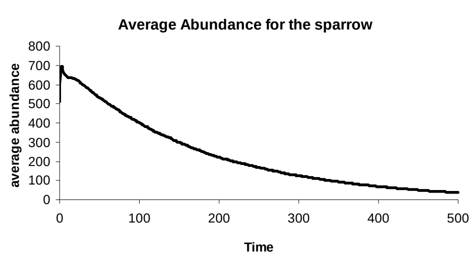
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	30
10	0.0000	0.0000	1	30
20	0.0000	0.0000	2	30
30	0.0005	0.0005	3	30
40	0.0021	0.0026	4	30
50	0.0033	0.0059	5	30
60	0.0052	0.0111	6	30
70	0.0074	0.0185	7	29
80	0.0119	0.0304	8	29
90	0.0081	0.0385	9	29
100	0.0083	0.0468	10	29
110	0.0076	0.0544	11	29
120	0.0058	0.0602	12	29
130	0.0034	0.0636	13	29
140	0.0036	0.0672	14	29
150	0.0024	0.0696	15	29
160	0.0017	0.0713	16	29
170	0.0011	0.0724	17	29
180	0.0015	0.0739	18	29
190	0.0009	0.0748	19	28
200	0.0007	0.0755	20	28
210	0.0005	0.0760	21	28
220	0.0002	0.0762	22	28
230	0.0006	0.0768	23	28
240	0.0001	0.0769	24	28
250	0.0002	0.0771	25	28
260	0.0003	0.0774	26	28
270	0.0000	0.0774	27	28
280	0.0002	0.0776	28	28
290	0.0000	0.0776	29	28
300	0.0001	0.0777	30	28

Species 3. Sparrow

Birds	**Sparrow**
Initial abundance	509 (Males only, 1:1 sex ratio)
age at first reproduction	Within the first year
longevity	6 years
generation time	3 years
threats	sea level rise



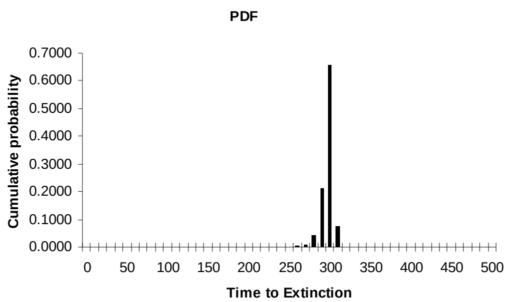


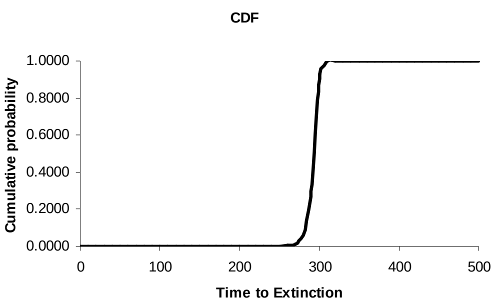


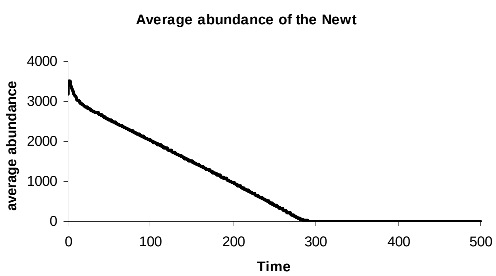
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	509
10	0.0000	0.0000	1	679
20	0.0015	0.0015	2	694
30	0.0091	0.0106	3	687
40	0.0174	0.0280	4	678
50	0.0229	0.0509	5	666
60	0.0299	0.0808	6	657
70	0.0319	0.1127	7	650
80	0.0329	0.1456	8	646
90	0.0347	0.1803	9	642
100	0.0375	0.2178	10	638
110	0.0388	0.2566	11	638
120	0.0328	0.2894	12	637
130	0.0341	0.3235	13	636
140	0.0323	0.3558	14	636
150	0.0294	0.3852	15	635
160	0.0309	0.4161	16	634
170	0.0318	0.4479	17	633
180	0.0299	0.4778	18	631
190	0.0287	0.5065	19	630
200	0.0263	0.5328	20	628
210	0.0247	0.5575	21	625
220	0.0222	0.5797	22	624
230	0.0230	0.6027	23	620
240	0.0187	0.6214	24	616
250	0.0203	0.6417	25	612
260	0.0179	0.6596	26	608
270	0.0191	0.6787	27	605
280	0.0199	0.6986	28	602
290	0.0174	0.7160	29	598
300	0.0179	0.7339	30	595

Species 4. Newt

Reptiles	**Newt**
Initial abundance	3200
age at first reproduction	1 year
longevity	7-10years
generation time	2 years
threats	habitat destruction and degradation



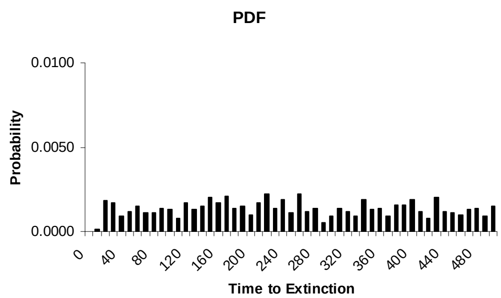


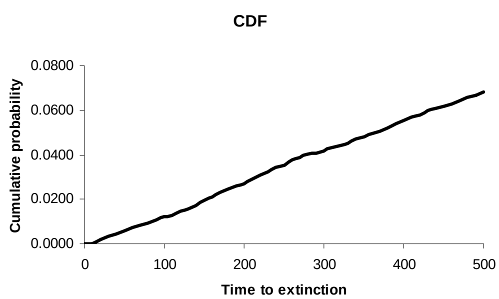


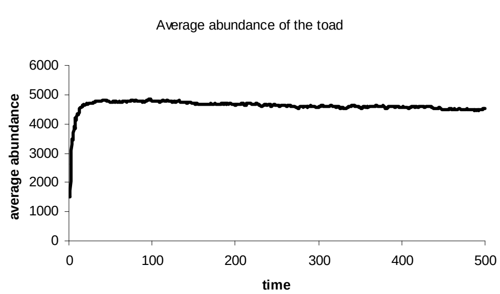
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	3200
10	0.0000	0.0000	1	3519
20	0.0000	0.0000	2	3500
30	0.0000	0.0000	3	3448
40	0.0000	0.0000	4	3370
50	0.0000	0.0000	5	3308
60	0.0000	0.0000	6	3254
70	0.0000	0.0000	7	3210
80	0.0000	0.0000	8	3169
90	0.0000	0.0000	9	3127
100	0.0000	0.0000	10	3091
110	0.0000	0.0000	11	3064
120	0.0000	0.0000	12	3036
130	0.0000	0.0000	13	3017
140	0.0000	0.0000	14	2997
150	0.0000	0.0000	15	2977
160	0.0000	0.0000	16	2952
170	0.0000	0.0000	17	2935
180	0.0000	0.0000	18	2917
190	0.0001	0.0001	19	2902
200	0.0000	0.0001	20	2888
210	0.0001	0.0002	21	2874
220	0.0000	0.0002	22	2866
230	0.0000	0.0002	23	2853
240	0.0004	0.0006	24	2842
250	0.0014	0.0020	25	2832
260	0.0034	0.0054	26	2820
270	0.0091	0.0145	27	2806
280	0.0427	0.0572	28	2797
290	0.2117	0.2689	29	2783
300	0.6575	0.9264	30	2770

Species 5. Toad

Reptiles	Toad
Initial abundance	1500 (females only, sex ratio 1:1)
age at first reproduction	within the first year
longevity	3 years
generation time	1 year
threats	habitat destruction, degradation, fragmentation, competition and hybridization



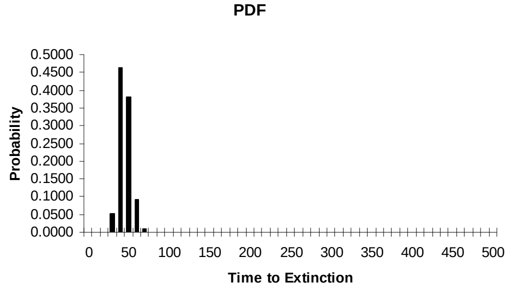


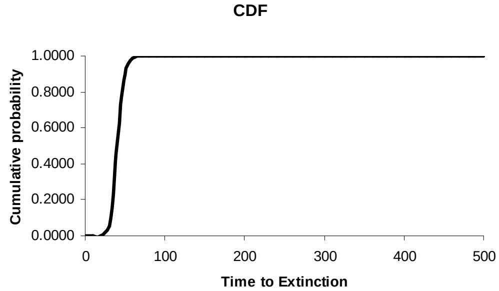


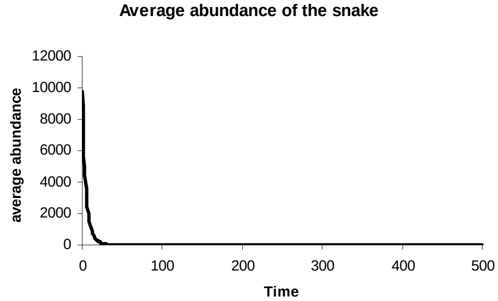
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1500
10	0.0001	0.0001	1	1515
20	0.0018	0.0019	2	2621
30	0.0017	0.0036	3	2670
40	0.0009	0.0045	4	3473
50	0.0012	0.0057	5	3436
60	0.0015	0.0072	6	3918
70	0.0011	0.0083	7	3856
80	0.0011	0.0094	8	4193
90	0.0014	0.0108	9	4134
100	0.0013	0.0121	10	4354
110	0.0008	0.0129	11	4315
120	0.0017	0.0146	12	4467
130	0.0013	0.0159	13	4460
140	0.0015	0.0174	14	4555
150	0.0020	0.0194	15	4548
160	0.0017	0.0211	16	4617
170	0.0021	0.0232	17	4616
180	0.0014	0.0246	18	4667
190	0.0015	0.0261	19	4640
200	0.0010	0.0271	20	4668
210	0.0017	0.0288	21	4664
220	0.0022	0.0310	22	4689
230	0.0014	0.0324	23	4675
240	0.0019	0.0343	24	4692
250	0.0011	0.0354	25	4714
260	0.0022	0.0376	26	4704
270	0.0012	0.0388	27	4707
280	0.0014	0.0402	28	4701
290	0.0005	0.0407	29	4712
300	0.0009	0.0416	30	4742

Species 6. Snake

Reptiles	Snake
Initial abundance	9798
age at first reproduction	3 years
longevity	15 years
generation time	7 years
threats	direct mortality from humans and habitat loss





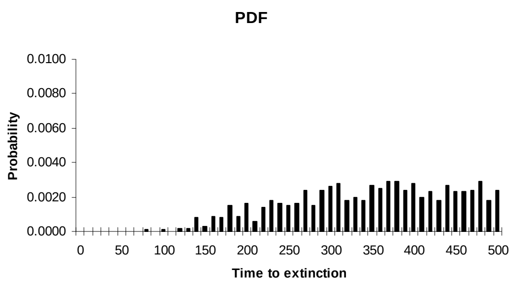


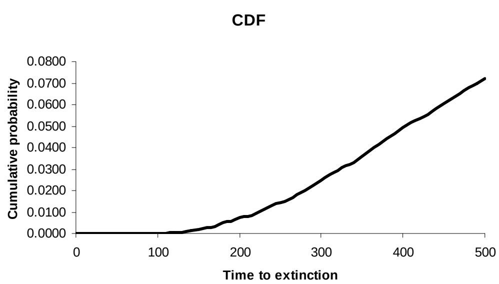
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	9798
10	0.0000	0.0000	1	8005
20	0.0000	0.0000	2	6362
30	0.0528	0.0528	3	5024
40	0.4624	0.5153	4	3989
50	0.3794	0.8947	5	3248
60	0.0933	0.9880	6	2674
70	0.0103	0.9983	7	2206
80	0.0012	0.9996	8	1808
90	0.0004	1.0000	9	1490
100	0.0000	1.0000	10	1254
110	0.0000	1.0000	11	1047
120	0.0000	1.0000	12	874
130	0.0000	1.0000	13	731
140	0.0000	1.0000	14	617
150	0.0000	1.0000	15	517
160	0.0000	1.0000	16	434
170	0.0000	1.0000	17	365
180	0.0000	1.0000	18	308
190	0.0000	1.0000	19	260
200	0.0000	1.0000	20	218
210	0.0000	1.0000	21	184
220	0.0000	1.0000	22	153
230	0.0000	1.0000	23	128
240	0.0000	1.0000	24	106
250	0.0000	1.0000	25	90
260	0.0000	1.0000	26	75
270	0.0000	1.0000	27	63
280	0.0000	1.0000	28	52
290	0.0000	1.0000	29	43
300	0.0000	1.0000	30	36

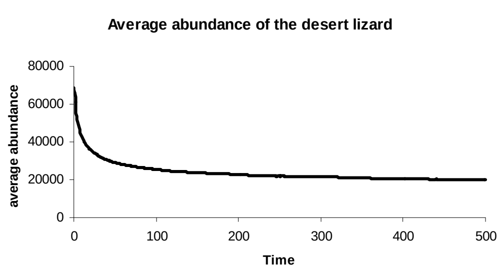
Species 7. Desert lizard

Reptiles

	Desert Lizard
Initial abundance	6891
age at first reproduction	1 year
longevity	10 - 20years
generation time	4 years
threats	fire



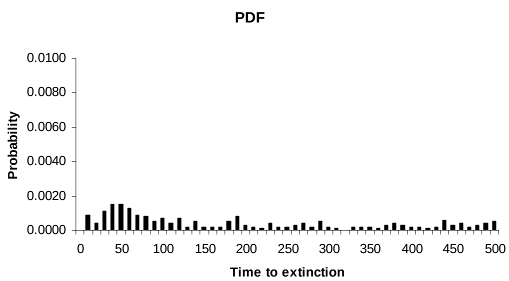


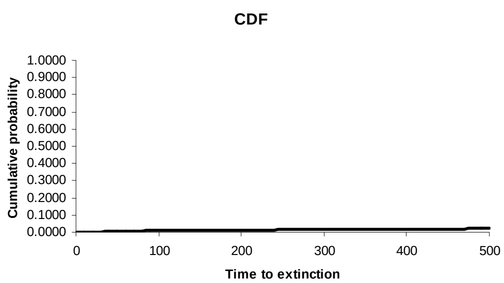


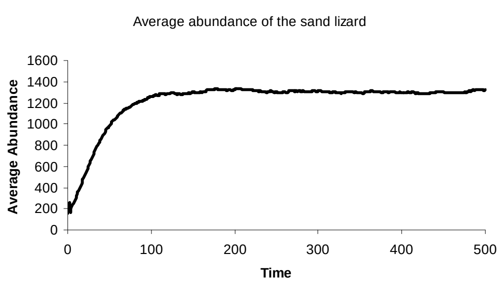
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	68914
10	0.0000	0.0000	1	65870
20	0.0000	0.0000	2	60816
30	0.0000	0.0000	3	56618
40	0.0000	0.0000	4	53254
50	0.0000	0.0000	5	50430
60	0.0000	0.0000	6	48242
70	0.0000	0.0000	7	46438
80	0.0001	0.0001	8	45036
90	0.0000	0.0001	9	43756
100	0.0001	0.0002	10	42633
110	0.0000	0.0002	11	41638
120	0.0002	0.0004	12	40809
130	0.0002	0.0006	13	39993
140	0.0008	0.0014	14	39251
150	0.0003	0.0017	15	38615
160	0.0009	0.0026	16	37997
170	0.0008	0.0034	17	37453
180	0.0015	0.0049	18	36947
190	0.0009	0.0058	19	36479
200	0.0016	0.0074	20	36050
210	0.0006	0.0080	21	35579
220	0.0014	0.0094	22	35210
230	0.0018	0.0112	23	34845
240	0.0016	0.0128	24	34558
250	0.0015	0.0143	25	34247
260	0.0016	0.0159	26	33923
270	0.0024	0.0183	27	33571
280	0.0015	0.0198	28	33286
290	0.0024	0.0222	29	33016
300	0.0026	0.0248	30	32687

Species 8. Sand lizard

Reptiles	Sand Lizard
Initial abundance	160 (females only, 1:1 sex ratio)
age at first reproduction	2 years
longevity	14 years
generation time	3 years
threats	habitat loss and fragmentation





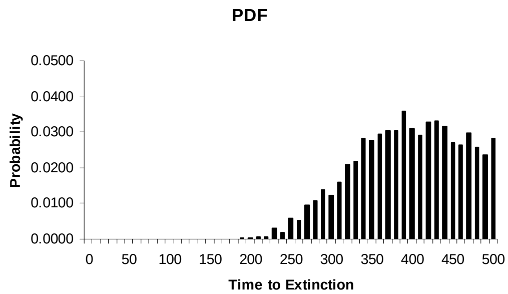


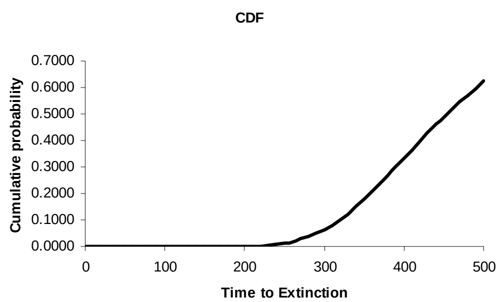
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	160
10	0.0009	0.0009	1	220
20	0.0004	0.0013	2	258
30	0.0011	0.0024	3	163
40	0.0015	0.0039	4	182
50	0.0015	0.0054	5	224
60	0.0013	0.0067	6	243
70	0.0009	0.0076	7	252
80	0.0008	0.0084	8	266
90	0.0005	0.0089	9	284
100	0.0007	0.0096	10	304
110	0.0004	0.0100	11	322
120	0.0007	0.0107	12	341
130	0.0002	0.0109	13	364
140	0.0005	0.0114	14	384
150	0.0002	0.0116	15	404
160	0.0002	0.0118	16	421
170	0.0002	0.0120	17	439
180	0.0005	0.0125	18	461
190	0.0008	0.0133	19	484
200	0.0003	0.0136	20	503
210	0.0002	0.0138	21	521
220	0.0001	0.0139	22	540
230	0.0004	0.0143	23	557
240	0.0002	0.0145	24	577
250	0.0002	0.0147	25	599
260	0.0003	0.0150	26	619
270	0.0004	0.0154	27	638
280	0.0002	0.0156	28	660
290	0.0005	0.0161	29	680
300	0.0002	0.0163	30	699

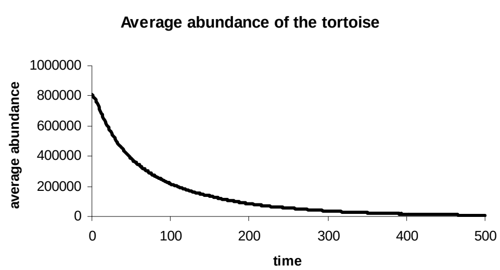
Species 9. Tortoise

Reptiles

Reptiles	Tortoise
Initial abundance	811465
age at first reproduction	12 years
longevity	60-100 years
generation time	20
threats	habitat destruction and degradation



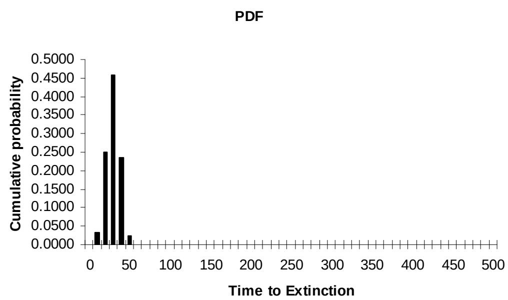


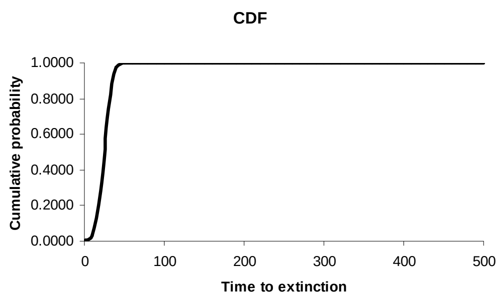


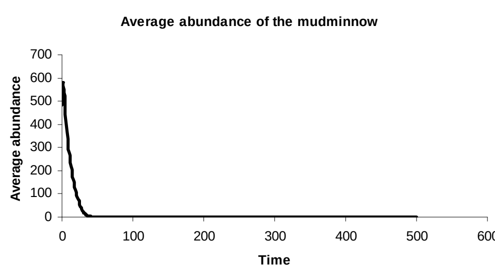
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	811465
10	0.0000	0.0000	1	802554
20	0.0000	0.0000	2	795680
30	0.0000	0.0000	3	791248
40	0.0000	0.0000	4	784144
50	0.0000	0.0000	5	774915
60	0.0000	0.0000	6	763539
70	0.0000	0.0000	7	753095
80	0.0000	0.0000	8	740276
90	0.0000	0.0000	9	727954
100	0.0000	0.0000	10	713836
110	0.0000	0.0000	11	699099
120	0.0000	0.0000	12	686600
130	0.0000	0.0000	13	674280
140	0.0000	0.0000	14	662435
150	0.0000	0.0000	15	650365
160	0.0000	0.0000	16	639369
170	0.0000	0.0000	17	626713
180	0.0000	0.0000	18	617331
190	0.0002	0.0002	19	607315
200	0.0003	0.0005	20	598051
210	0.0007	0.0012	21	588601
220	0.0005	0.0017	22	579038
230	0.0031	0.0048	23	571274
240	0.0017	0.0065	24	560582
250	0.0058	0.0124	25	551690
260	0.0053	0.0177	26	542674
270	0.0096	0.0273	27	535771
280	0.0106	0.0379	28	526745
290	0.0137	0.0516	29	519124
300	0.0122	0.0638	30	510692

Species 10. Mudminnow

Fish	Mudminnow
Initial abundance	481 (females only, 1:1 sex ratio)
age at first reproduction	within the first year
longevity	3 years
generation time	1 year
threats	restricted distribution, habitat loss



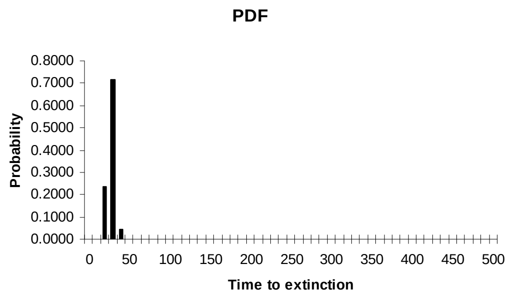


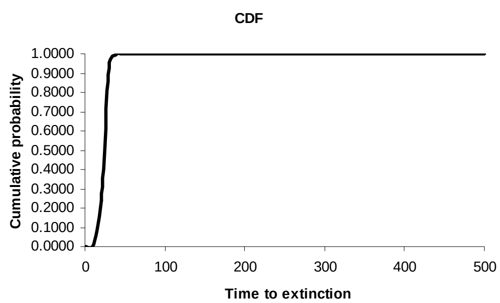


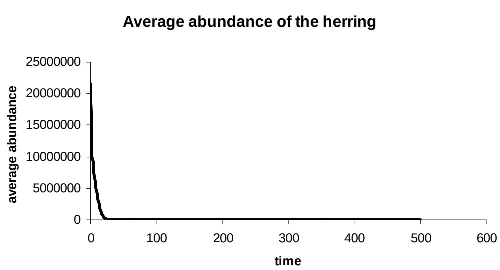
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	481
10	0.0320	0.0320	1	581
20	0.2513	0.2833	2	581
30	0.4577	0.7410	3	550
40	0.2357	0.9767	4	493
50	0.0229	0.9996	5	445
60	0.0004	1.0000	6	402
70	0.0000	1.0000	7	367
80	0.0000	1.0000	8	338
90	0.0000	1.0000	9	309
100	0.0000	1.0000	10	280
110	0.0000	1.0000	11	258
120	0.0000	1.0000	12	234
130	0.0000	1.0000	13	218
140	0.0000	1.0000	14	194
150	0.0000	1.0000	15	182
160	0.0000	1.0000	16	165
170	0.0000	1.0000	17	149
180	0.0000	1.0000	18	138
190	0.0000	1.0000	19	118
200	0.0000	1.0000	20	105
210	0.0000	1.0000	21	93
220	0.0000	1.0000	22	82
230	0.0000	1.0000	23	74
240	0.0000	1.0000	24	62
250	0.0000	1.0000	25	54
260	0.0000	1.0000	26	46
270	0.0000	1.0000	27	40
280	0.0000	1.0000	28	35
290	0.0000	1.0000	29	29
300	0.0000	1.0000	30	24

Species 11. Herring

Fish	**Herring**
Initial abundance	21546900
age at first reproduction	within the first year
longevity	9 years
generation time	4 years
threats	overharvesting



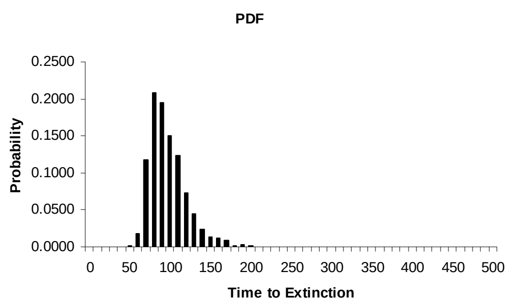


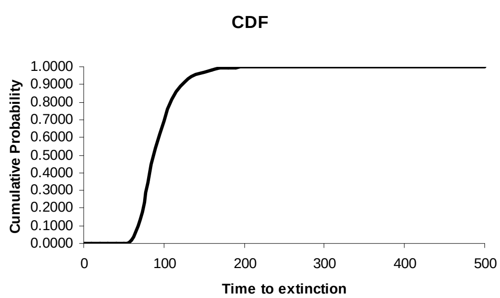


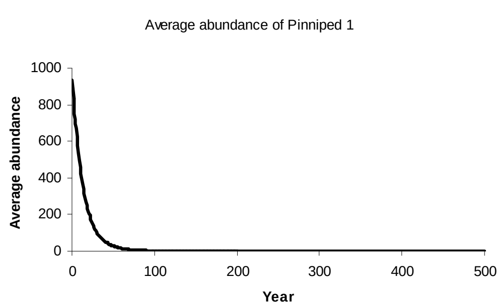
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	21546900
10	0.0000	0.0000	1	12591244
20	0.2380	0.2380	2	10834409
30	0.7154	0.9534	3	9631522
40	0.0457	0.9991	4	8672937
50	0.0009	1.0000	5	7764538
60	0.0000	1.0000	6	6899918
70	0.0000	1.0000	7	6114993
80	0.0000	1.0000	8	5376108
90	0.0000	1.0000	9	4669482
100	0.0000	1.0000	10	4021128
110	0.0000	1.0000	11	3426418
120	0.0000	1.0000	12	2898961
130	0.0000	1.0000	13	2418138
140	0.0000	1.0000	14	1989195
150	0.0000	1.0000	15	1615558
160	0.0000	1.0000	16	1281938
170	0.0000	1.0000	17	1002117
180	0.0000	1.0000	18	767515
190	0.0000	1.0000	19	578540
200	0.0000	1.0000	20	427953
210	0.0000	1.0000	21	310836
220	0.0000	1.0000	22	221389
230	0.0000	1.0000	23	155104
240	0.0000	1.0000	24	107915
250	0.0000	1.0000	25	73842
260	0.0000	1.0000	26	50058
270	0.0000	1.0000	27	34278
280	0.0000	1.0000	28	22969
290	0.0000	1.0000	29	15835
300	0.0000	1.0000	30	10826

Species 12. Pinniped1

Mammal	Pinniped1
Initial abundance	935
age at first reproduction	5-10 years
longevity	max = 30 years
generation time	~14 years
threats	foraging stress, habitat loss (islet subsidence), marine debris, shark predation; low juvenile survival (due to all factors) is largely driving the dynamics



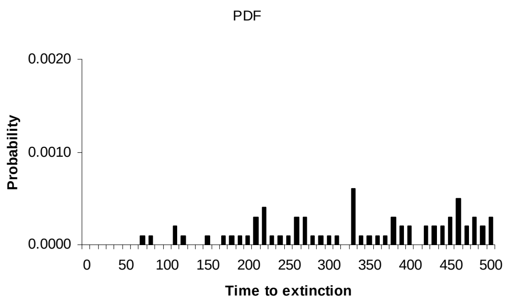


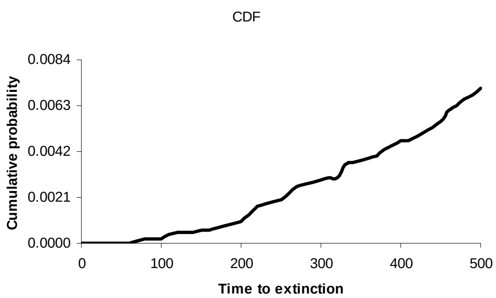


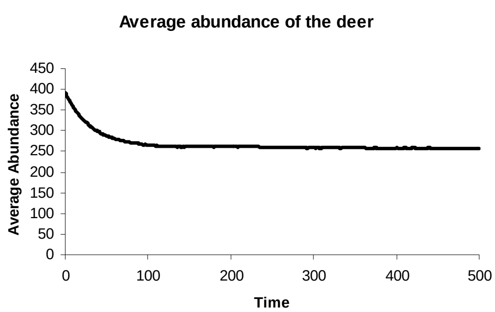
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	935
10	0.0000	0.0000	1	887
20	0.0000	0.0000	2	832
30	0.0000	0.0000	3	777
40	0.0000	0.0000	4	722
50	0.0010	0.0010	5	672
60	0.0180	0.0190	6	624
70	0.1170	0.1360	7	579
80	0.2090	0.3450	8	536
90	0.1950	0.5400	9	497
100	0.1510	0.6910	10	459
110	0.1230	0.8140	11	425
120	0.0730	0.8870	12	393
130	0.0450	0.9320	13	364
140	0.0240	0.9560	14	338
150	0.0140	0.9700	15	314
160	0.0120	0.9820	16	291
170	0.0090	0.9910	17	269
180	0.0020	0.9930	18	250
190	0.0030	0.9960	19	232
200	0.0020	0.9980	20	216
210	0.0000	1.0000	21	200
220	0.0000	1.0000	22	185
230	0.0000	1.0000	23	172
240	0.0000	1.0000	24	160
250	0.0000	1.0000	25	149
260	0.0000	1.0000	26	139
270	0.0000	1.0000	27	129
280	0.0000	1.0000	28	120
290	0.0000	1.0000	29	112
300	0.0000	1.0000	30	104

Species 13. Deer

Mammals	**Deer**
Initial abundance	392 (only females, 1:1 sex ratio)
age at first reproduction	1 year
longevity	9 years
generation time	4 years
threats	habitat loss and fragmentation



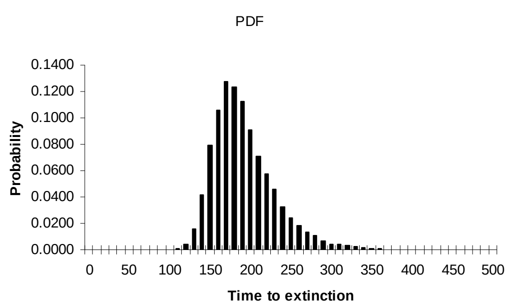


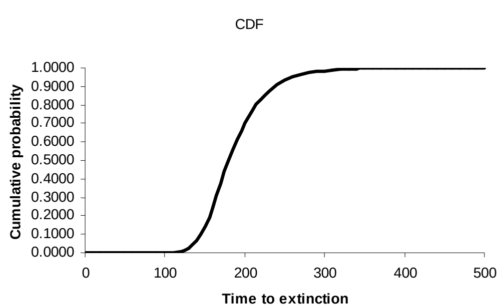


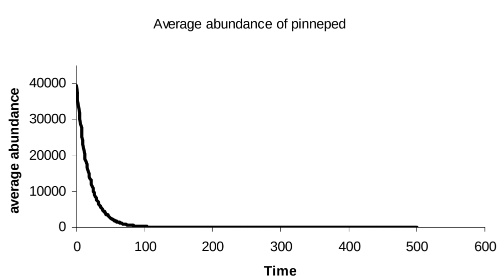
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	392
10	0.0000	0.0000	1	388
20	0.0000	0.0000	2	384
30	0.0000	0.0000	3	380
40	0.0000	0.0000	4	376
50	0.0000	0.0000	5	372
60	0.0000	0.0000	6	369
70	0.0001	0.0001	7	366
80	0.0001	0.0002	8	363
90	0.0000	0.0002	9	360
100	0.0000	0.0002	10	356
110	0.0002	0.0004	11	354
120	0.0001	0.0005	12	350
130	0.0000	0.0005	13	347
140	0.0000	0.0005	14	345
150	0.0001	0.0006	15	342
160	0.0000	0.0006	16	340
170	0.0001	0.0007	17	337
180	0.0001	0.0008	18	335
190	0.0001	0.0009	19	333
200	0.0001	0.0010	20	330
210	0.0003	0.0013	21	329
220	0.0004	0.0017	22	327
230	0.0001	0.0018	23	324
240	0.0001	0.0019	24	322
250	0.0001	0.0020	25	321
260	0.0003	0.0023	26	319
270	0.0003	0.0026	27	317
280	0.0001	0.0027	28	315
290	0.0001	0.0028	29	313
300	0.0001	0.0029	30	311

Species 14. Pinniped2

Mammals	Pinniped2
Initial abundance	39500
age at first reproduction	3 years
longevity	20 years
generation time	8 years
threats	unknown but could be bycatch, disease, predation, environmental change, entanglement in nets, pollution



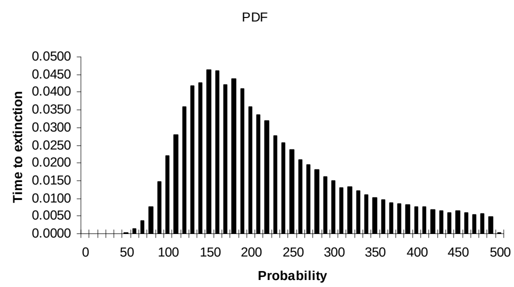


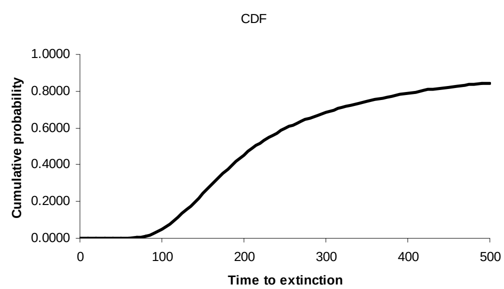


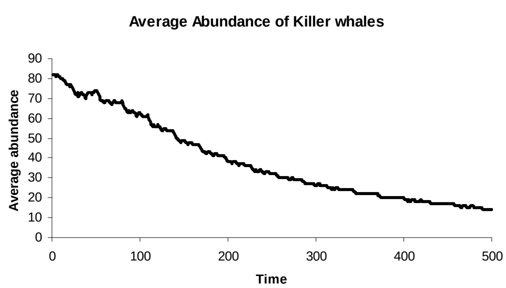
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	39500
10	0.0000	0.0000	1	37406
20	0.0000	0.0000	2	35408
30	0.0000	0.0000	3	33536
40	0.0000	0.0000	4	31753
50	0.0000	0.0000	5	30083
60	0.0000	0.0000	6	28492
70	0.0000	0.0000	7	26984
80	0.0000	0.0000	8	25577
90	0.0000	0.0000	9	24250
100	0.0000	0.0000	10	22973
110	0.0009	0.0009	11	21758
120	0.0042	0.0051	12	20598
130	0.0160	0.0211	13	19493
140	0.0417	0.0628	14	18450
150	0.0793	0.1421	15	17451
160	0.1056	0.2477	16	16537
170	0.1276	0.3753	17	15673
180	0.1233	0.4986	18	14854
190	0.1126	0.6112	19	14089
200	0.0906	0.7018	20	13339
210	0.0705	0.7723	21	12629
220	0.0574	0.8297	22	11954
230	0.0462	0.8759	23	11315
240	0.0322	0.9081	24	10714
250	0.0239	0.9320	25	10133
260	0.0185	0.9505	26	9595
270	0.0131	0.9636	27	9080
280	0.0105	0.9741	28	8596
290	0.0066	0.9807	29	8144
300	0.0042	0.9849	30	7719

Species 15. Killer whale

Mammals	**Killer whale**
Initial abundance	82
age at first reproduction	15
longevity	80-90
generation time	30 years
threats	habitat destruction and degradation (loss of prey), contaminants



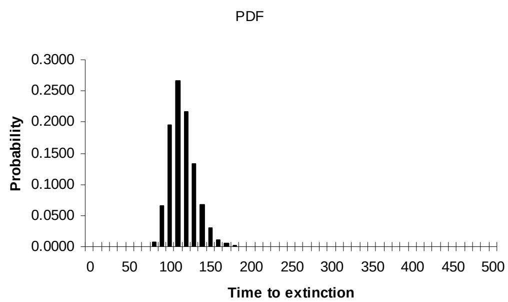


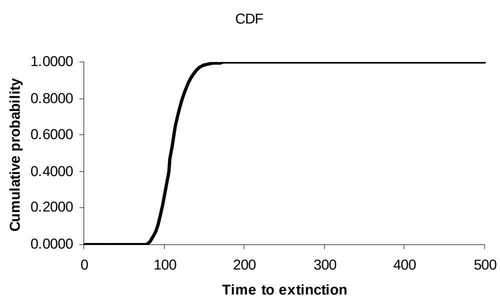


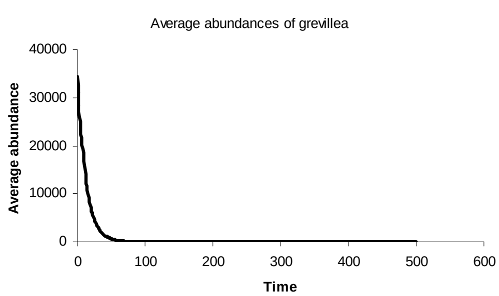
Year	**PDF**	**CDF**	**Year**	**Abund**
0	0.0000	0.0000	1	82
10	0.0000	0.0000	2	82
20	0.0000	0.0000	3	82
30	0.0000	0.0000	4	81
40	0.0000	0.0000	5	82
50	0.0004	0.0004	6	82
60	0.0014	0.0018	7	82
70	0.0037	0.0055	8	81
80	0.0076	0.0131	9	81
90	0.0147	0.0278	10	80
100	0.0219	0.0497	11	80
110	0.0281	0.0778	12	80
120	0.0358	0.1136	13	80
130	0.0417	0.1553	14	79
140	0.0426	0.1979	15	79
150	0.0462	0.2441	16	78
160	0.0461	0.2902	17	77
170	0.0422	0.3324	18	77
180	0.0438	0.3762	19	77
190	0.0410	0.4172	20	76
200	0.0359	0.4531	21	77
210	0.0336	0.4867	22	77
220	0.0318	0.5185	23	76
230	0.0277	0.5462	24	75
240	0.0258	0.5720	25	74
250	0.0237	0.5957	26	73
260	0.0208	0.6165	27	72
270	0.0195	0.6360	28	72
280	0.0181	0.6541	29	73
290	0.0162	0.6703	30	71
300	0.0151	0.6854	31	71

Species 16. Grevillea

Plants	Grevillea
Initial abundance	34472 (only females including seeds)
age at first reproduction	4 years
longevity	16-30 years
generation time	10 years
threats	habitat loss, fire, fragmentation



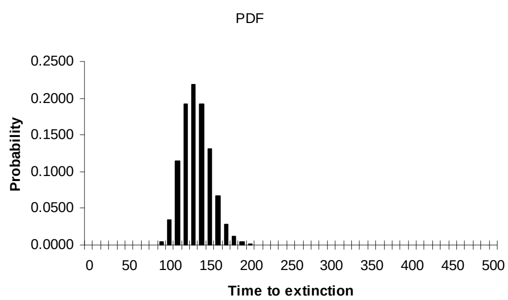


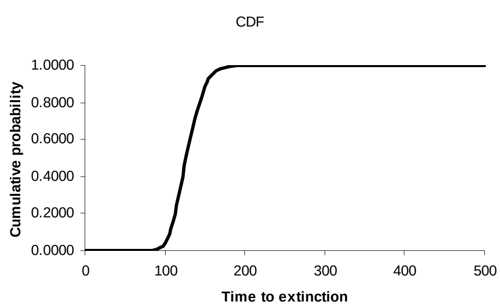


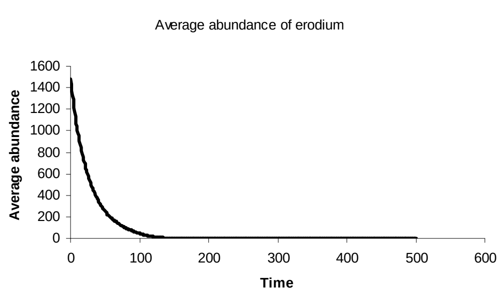
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	34472
10	0.0000	0.0000	1	31064
20	0.0000	0.0000	2	28275
30	0.0000	0.0000	3	25885
40	0.0000	0.0000	4	24240
50	0.0000	0.0000	5	22951
60	0.0000	0.0000	6	21743
70	0.0000	0.0000	7	20737
80	0.0069	0.0069	8	19388
90	0.0665	0.0734	9	17958
100	0.1945	0.2679	10	16758
110	0.2668	0.5347	11	15389
120	0.2174	0.7521	12	14040
130	0.1327	0.8848	13	12807
140	0.0669	0.9517	14	11708
150	0.0301	0.9818	15	10729
160	0.0100	0.9918	16	9858
170	0.0049	0.9967	17	9063
180	0.0024	0.9991	18	8350
190	0.0006	0.9997	19	7688
200	0.0001	0.9998	20	7088
210	0.0002	1.0000	21	6532
220	0.0000	1.0000	22	6014
230	0.0000	1.0000	23	5534
240	0.0000	1.0000	24	5089
250	0.0000	1.0000	25	4681
260	0.0000	1.0000	26	4303
270	0.0000	1.0000	27	3953
280	0.0000	1.0000	28	3633
290	0.0000	1.0000	29	3339
300	0.0000	1.0000	30	3064

Species 17. Erodium

Plant	Erodium
Initial abundance	1483
age at first reproduction	within the first year
longevity	15 years
generation time	3-4 years
threats	restricted range, small population size, low recruitment, seed predation



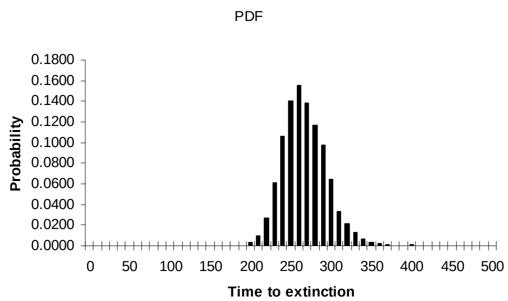


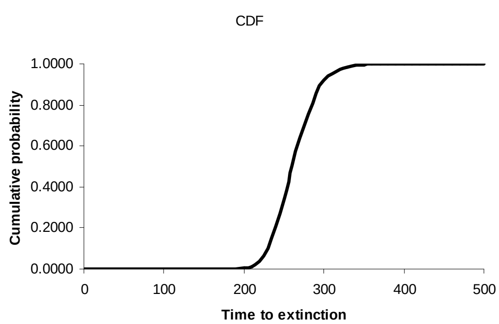


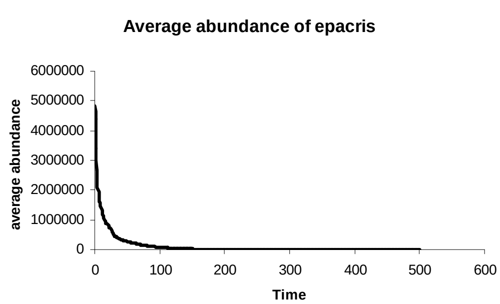
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1483
10	0.0000	0.0000	1	1433
20	0.0000	0.0000	2	1375
30	0.0000	0.0000	3	1319
40	0.0000	0.0000	4	1266
50	0.0000	0.0000	5	1217
60	0.0000	0.0000	6	1171
70	0.0000	0.0000	7	1128
80	0.0006	0.0006	8	1086
90	0.0045	0.0051	9	1046
100	0.0349	0.0400	10	1008
110	0.1141	0.1541	11	972
120	0.1925	0.3466	12	937
130	0.2181	0.5647	13	905
140	0.1916	0.7563	14	873
150	0.1309	0.8872	15	841
160	0.0665	0.9537	16	812
170	0.0285	0.9822	17	784
180	0.0115	0.9937	18	756
190	0.0045	0.9982	19	730
200	0.0016	0.9998	20	705
210	0.0002	1.0000	21	681
220	0.0000	1.0000	22	657
230	0.0000	1.0000	23	634
240	0.0000	1.0000	24	613
250	0.0000	1.0000	25	592
260	0.0000	1.0000	26	572
270	0.0000	1.0000	27	552
280	0.0000	1.0000	28	534
290	0.0000	1.0000	29	515
300	0.0000	1.0000	30	498

Species 18. Epacris

Plants	**Epacris**
Initial abundance	4818722 (only females and including seeds)
age at first reproduction	10 years
longevity	60+ years (senescence at 60)
generation time	30 years
threats	narrow range, disease and fire



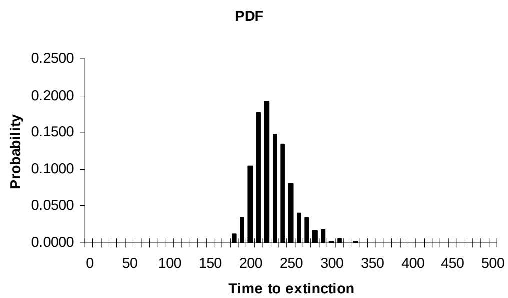


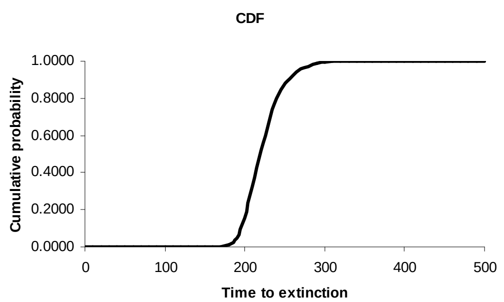


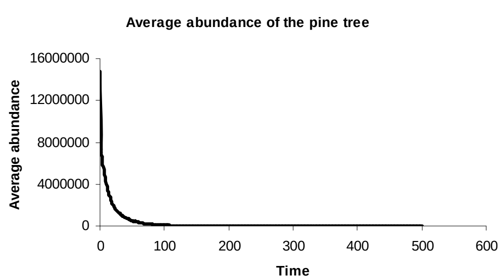
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	4818722
10	0.0000	0.0000	1	4378809
20	0.0000	0.0000	2	3394224
30	0.0000	0.0000	3	2667656
40	0.0000	0.0000	4	2245248
50	0.0000	0.0000	5	2019335
60	0.0000	0.0000	6	1851761
70	0.0000	0.0000	7	1685326
80	0.0000	0.0000	8	1579730
90	0.0000	0.0000	9	1473439
100	0.0000	0.0000	10	1378079
110	0.0000	0.0000	11	1308330
120	0.0000	0.0000	12	1208082
130	0.0000	0.0000	13	1116457
140	0.0000	0.0000	14	1048517
150	0.0000	0.0000	15	993071
160	0.0000	0.0000	16	954526
170	0.0000	0.0000	17	923727
180	0.0000	0.0000	18	887974
190	0.0000	0.0000	19	860882
200	0.0031	0.0031	20	832621
210	0.0092	0.0123	21	803331
220	0.0273	0.0396	22	769050
230	0.0610	0.1006	23	749251
240	0.1064	0.2070	24	721418
250	0.1405	0.3475	25	679000
260	0.1552	0.5028	26	629293
270	0.1379	0.6407	27	603503
280	0.1168	0.7575	28	553559
290	0.0971	0.8545	29	515232
300	0.0645	0.9190	30	482663

Species 19. Pine tree

Plants	**Pine tree**
Initial abundance	14770437 (including seed)
age at first reproduction	46
longevity	100 years +
generation time	60 years
threats	disease, fire exclusion, insect outbreaks



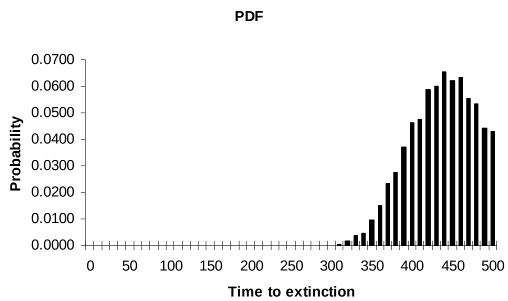


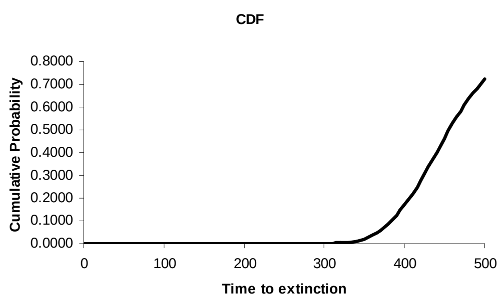


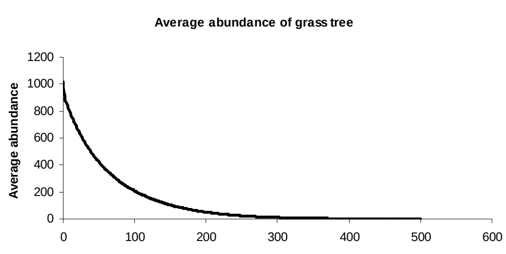
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	14770437
10	0.0000	0.0000	1	7378460
20	0.0000	0.0000	2	6996921
30	0.0000	0.0000	3	6615261
40	0.0000	0.0000	4	6033592
50	0.0000	0.0000	5	5747420
60	0.0000	0.0000	6	5353959
70	0.0000	0.0000	7	4960015
80	0.0000	0.0000	8	4664665
90	0.0000	0.0000	9	4291330
100	0.0000	0.0000	10	3961638
110	0.0000	0.0000	11	3809575
120	0.0000	0.0000	12	3465812
130	0.0000	0.0000	13	3239312
140	0.0000	0.0000	14	2906824
150	0.0000	0.0000	15	2898420
160	0.0000	0.0000	16	2543875
170	0.0000	0.0000	17	2447089
180	0.0126	0.0126	18	2317564
190	0.0346	0.0472	19	2136203
200	0.1038	0.1509	20	2029485
210	0.1771	0.3281	21	1854386
220	0.1918	0.5199	22	1869414
230	0.1468	0.6667	23	1701529
240	0.1342	0.8008	24	1611067
250	0.0797	0.8805	25	1522462
260	0.0409	0.9214	26	1466569
270	0.0346	0.9560	27	1379724
280	0.0168	0.9727	28	1321431
290	0.0178	0.9906	29	1279640
300	0.0021	0.9927	30	1194189

Species 20. Grass tree

Plants	**Grass tree**
Initial abundance	1017 (Seed included in summation but they are only produced after a fire. Initial abundance has no seeds included)
age at first reproduction	30 years
longevity	200 years +
generation time	100 years
threats	disease, fire







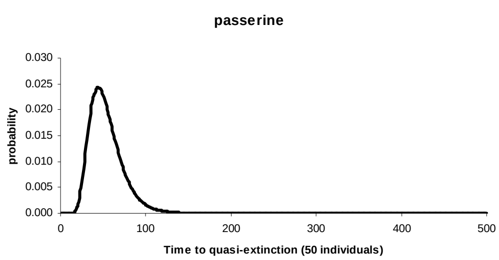
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1017
10	0.0000	0.0000	1	938
20	0.0000	0.0000	2	889
30	0.0000	0.0000	3	875
40	0.0000	0.0000	4	870
50	0.0000	0.0000	5	857
60	0.0000	0.0000	6	842
70	0.0000	0.0000	7	827
80	0.0000	0.0000	8	811
90	0.0000	0.0000	9	795
100	0.0000	0.0000	10	783
110	0.0000	0.0000	11	772
120	0.0000	0.0000	12	759
130	0.0000	0.0000	13	745
140	0.0000	0.0000	14	732
150	0.0000	0.0000	15	721
160	0.0000	0.0000	16	711
170	0.0000	0.0000	17	699
180	0.0000	0.0000	18	688
190	0.0000	0.0000	19	677
200	0.0000	0.0000	20	666
210	0.0000	0.0000	21	656
220	0.0000	0.0000	22	646
230	0.0000	0.0000	23	636
240	0.0000	0.0000	24	626
250	0.0000	0.0000	25	616
260	0.0000	0.0000	26	607
270	0.0000	0.0000	27	598
280	0.0000	0.0000	28	589
290	0.0002	0.0002	29	580
300	0.0002	0.0004	30	571

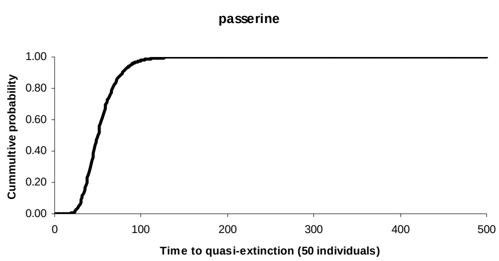
Section 6.2 Near-extinction of 50 mature individuals

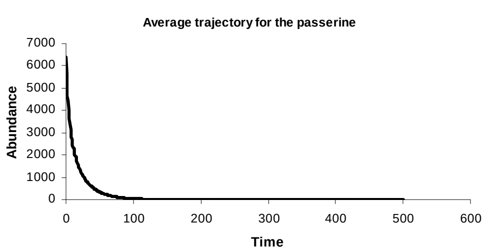
Species 1. Passerine

Birds	Passerine
Initial abundance	6400
age at first reproduction	5 years
longevity	16 years
generation time	10 years
threats	habitat destruction and degradation

Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	6400
10	0.0000	0.0000	1	5625
20	0.0015	0.0037	2	4966
30	0.0129	0.0734	3	4443
40	0.0233	0.2676	4	4005
50	0.0228	0.5056	5	3658
60	0.0167	0.7024	6	3366
70	0.0105	0.8342	7	3122
80	0.0059	0.9123	8	2908
90	0.0032	0.9553	9	2694
100	0.0016	0.9778	10	2520
110	0.0008	0.9891	11	2352
120	0.0004	0.9948	12	2217
130	0.0002	0.9975	13	2069
140	0.0001	0.9988	14	1965
150	0.0000	0.9994	15	1837
160	0.0000	0.9997	16	1738
170	0.0000	0.9999	17	1638
180	0.0000	0.9999	18	1547
190	0.0000	1.0000	19	1466
200	0.0000	1.0000	20	1394
210	0.0000	1.0000	21	1328
220	0.0000	1.0000	22	1250
230	0.0000	1.0000	23	1185
240	0.0000	1.0000	24	1143
250	0.0000	1.0000	25	1085
260	0.0000	1.0000	26	1027
270	0.0000	1.0000	27	978
280	0.0000	1.0000	28	929
290	0.0000	1.0000	29	887
300	0.0000	1.0000	30	842

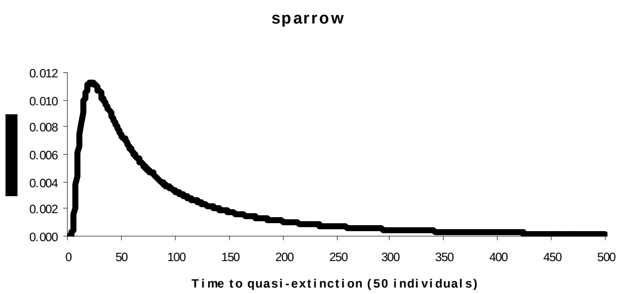


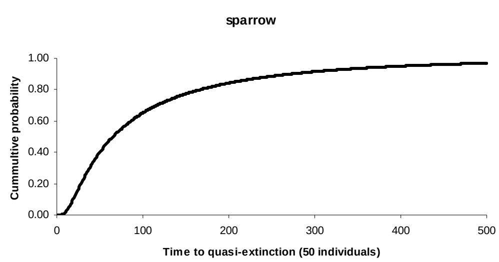


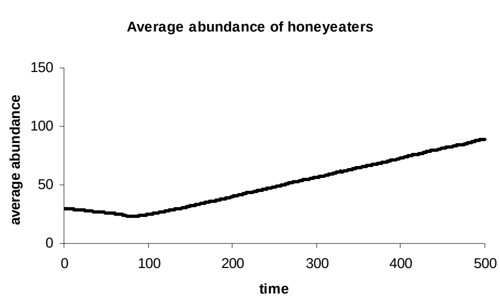


Species 2. Sparrow

Birds	**Sparrow**
Initial abundance	509 (Males only, 1:1 sex ratio)
age at first reproduction	Within the first year
longevity	6 years
generation time	3 years
threats	sea level rise



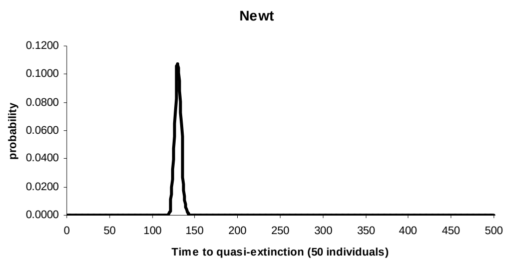


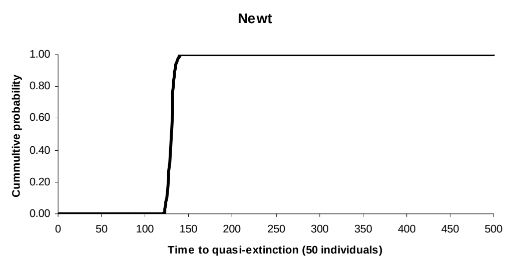


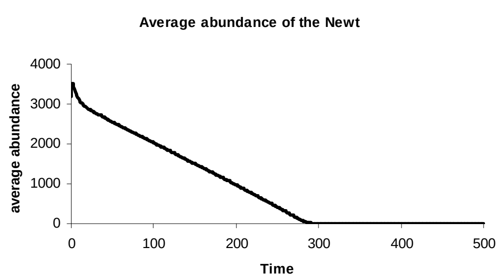
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	30
10	0.0055	0.0169	1	30
20	0.0111	0.1112	2	30
30	0.0106	0.2216	3	30
40	0.0090	0.3191	4	30
50	0.0075	0.4008	5	30
60	0.0063	0.4688	6	30
70	0.0053	0.5258	7	29
80	0.0045	0.5740	8	29
90	0.0038	0.6151	9	29
100	0.0033	0.6506	10	29
110	0.0029	0.6815	11	29
120	0.0026	0.7085	12	29
130	0.0023	0.7324	13	29
140	0.0020	0.7535	14	29
150	0.0018	0.7724	15	29
160	0.0016	0.7893	16	29
170	0.0015	0.8045	17	29
180	0.0013	0.8182	18	29
190	0.0012	0.8307	19	28
200	0.0011	0.8421	20	28
210	0.0010	0.8524	21	28
220	0.0009	0.8619	22	28
230	0.0008	0.8706	23	28
240	0.0008	0.8786	24	28
250	0.0007	0.8859	25	28
260	0.0007	0.8927	26	28
270	0.0006	0.8990	27	28
280	0.0006	0.9048	28	28
290	0.0005	0.9102	29	28
300	0.0005	0.9153	30	28

Species 3. Newt

Reptiles	Newt
Initial abundance	3200
age at first reproduction	1 year
longevity	7-10years
generation time	2 years
threats	habitat destruction and degradation



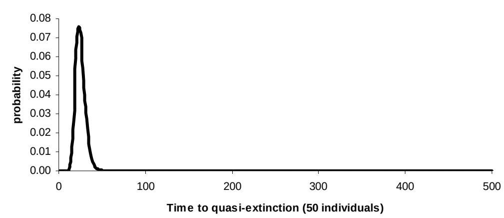


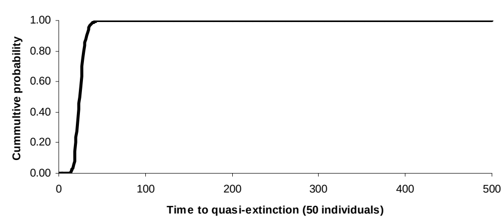


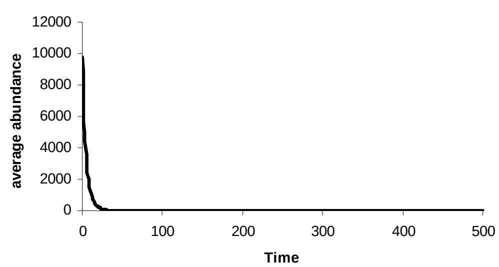
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	3200
10	0.0000	0.0000	1	3519
20	0.0000	0.0000	2	3500
30	0.0000	0.0000	3	3448
40	0.0000	0.0000	4	3370
50	0.0000	0.0000	5	3308
60	0.0000	0.0000	6	3254
70	0.0000	0.0000	7	3210
80	0.0000	0.0000	8	3169
90	0.0000	0.0000	9	3127
100	0.0000	0.0000	10	3091
110	0.0000	0.0000	11	3064
120	0.0019	0.0031	12	3036
130	0.1071	0.5244	13	3017
140	0.0042	0.9960	14	2997
150	0.0000	1.0000	15	2977
160	0.0000	1.0000	16	2952
170	0.0000	1.0000	17	2935
180	0.0000	1.0000	18	2917
190	0.0000	1.0000	19	2902
200	0.0000	1.0000	20	2888
210	0.0000	1.0000	21	2874
220	0.0000	1.0000	22	2866
230	0.0000	1.0000	23	2853
240	0.0000	1.0000	24	2842
250	0.0000	1.0000	25	2832
260	0.0000	1.0000	26	2820
270	0.0000	1.0000	27	2806
280	0.0000	1.0000	28	2797
290	0.0000	1.0000	29	2783
300	0.0000	1.0000	30	2770

Species 4. Snake

Reptiles	Snake
Initial abundance	9798
age at first reproduction	3 years
longevity	15 years
generation time	7 years
threats	direct mortality from humans and habitat loss





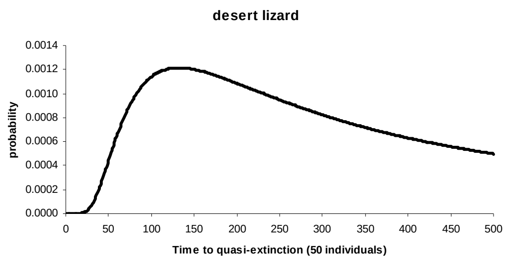


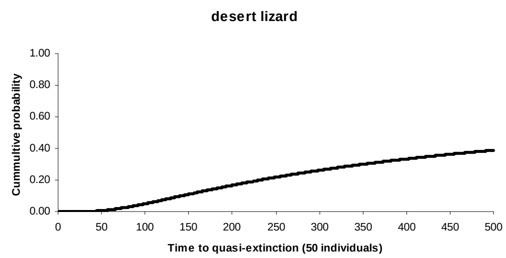
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	9798
10	0.0000	0.0000	1	8005
20	0.0590	0.2046	2	6362
30	0.0401	0.8391	3	5024
40	0.0038	0.9893	4	3989
50	0.0002	0.9996	5	3248
60	0.0000	1.0000	6	2674
70	0.0000	1.0000	7	2206
80	0.0000	1.0000	8	1808
90	0.0000	1.0000	9	1490
100	0.0000	1.0000	10	1254
110	0.0000	1.0000	11	1047
120	0.0000	1.0000	12	874
130	0.0000	1.0000	13	731
140	0.0000	1.0000	14	617
150	0.0000	1.0000	15	517
160	0.0000	1.0000	16	434
170	0.0000	1.0000	17	365
180	0.0000	1.0000	18	308
190	0.0000	1.0000	19	260
200	0.0000	1.0000	20	218
210	0.0000	1.0000	21	184
220	0.0000	1.0000	22	153
230	0.0000	1.0000	23	128
240	0.0000	1.0000	24	106
250	0.0000	1.0000	25	90
260	0.0000	1.0000	26	75
270	0.0000	1.0000	27	63
280	0.0000	1.0000	28	52
290	0.0000	1.0000	29	43
300	0.0000	1.0000	30	36

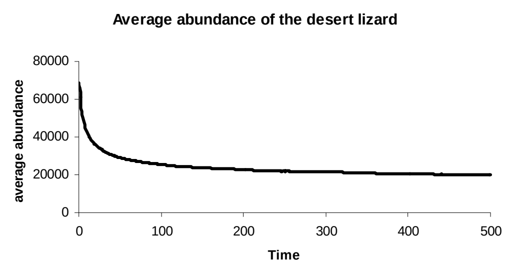
Species 5. Desert lizard

Reptiles

Desert Lizard	
Initial abundance	6891
age at first reproduction	1 year
longevity	10 - 20years
generation time	4 years
threats	fire







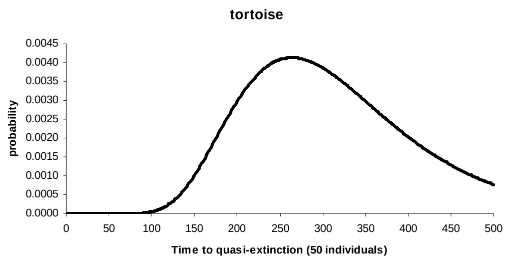
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	68914
10	0.0000	0.0000	1	65870
20	0.0000	0.0000	2	60816
30	0.0001	0.0003	3	56618
40	0.0002	0.0018	4	53254
50	0.0004	0.0053	5	50430
60	0.0007	0.0109	6	48242
70	0.0008	0.0184	7	46438
80	0.0010	0.0275	8	45036
90	0.0011	0.0378	9	43756
100	0.0011	0.0489	10	42633
110	0.0012	0.0605	11	41638
120	0.0012	0.0725	12	40809
130	0.0012	0.0846	13	39993
140	0.0012	0.0967	14	39251
150	0.0012	0.1088	15	38615
160	0.0012	0.1207	16	37997
170	0.0012	0.1324	17	37453
180	0.0011	0.1439	18	36947
190	0.0011	0.1552	19	36479
200	0.0011	0.1662	20	36050
210	0.0011	0.1769	21	35579
220	0.0010	0.1873	22	35210
230	0.0010	0.1974	23	34845
240	0.0010	0.2073	24	34558
250	0.0009	0.2169	25	34247
260	0.0009	0.2262	26	33923
270	0.0009	0.2353	27	33571
280	0.0009	0.2441	28	33286
290	0.0008	0.2527	29	33016
300	0.0008	0.2610	30	32687

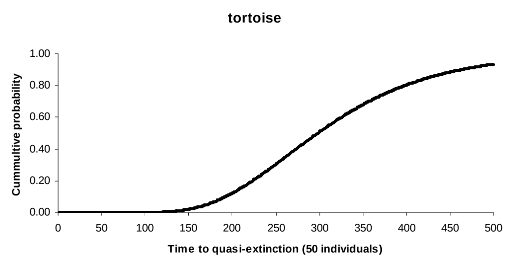
Species 6. Tortoise

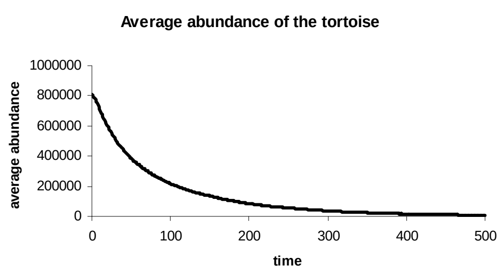
Reptiles

Tortoise	
Initial abundance	811465
age at first reproduction	12 years
longevity	60-100 years
generation time	20
threats	habitat destruction and degradation

Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	811465
10	0.0000	0.0000	1	802554
20	0.0755	0.2079	2	795680
30	0.0273	0.9416	3	791248
40	0.0004	0.9995	4	784144
50	0.0000	1.0000	5	774915
60	0.0000	1.0000	6	763539
70	0.0000	1.0000	7	753095
80	0.0000	1.0000	8	740276
90	0.0000	1.0000	9	727954
100	0.0000	1.0000	10	713836
110	0.0000	1.0000	11	699099
120	0.0000	1.0000	12	686600
130	0.0000	1.0000	13	674280
140	0.0000	1.0000	14	662435
150	0.0000	1.0000	15	650365
160	0.0000	1.0000	16	639369
170	0.0000	1.0000	17	626713
180	0.0000	1.0000	18	617331
190	0.0000	1.0000	19	607315
200	0.0000	1.0000	20	598051
210	0.0000	1.0000	21	588601
220	0.0000	1.0000	22	579038
230	0.0000	1.0000	23	571274
240	0.0000	1.0000	24	560582
250	0.0000	1.0000	25	551690
260	0.0000	1.0000	26	542674
270	0.0000	1.0000	27	535771
280	0.0000	1.0000	28	526745
290	0.0000	1.0000	29	519124
300	0.0000	1.0000	30	510692

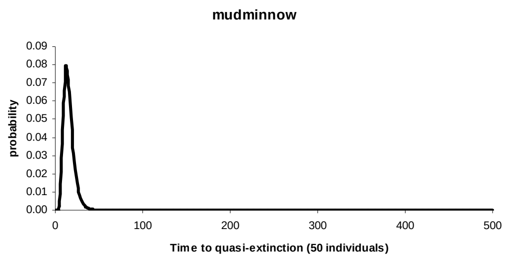


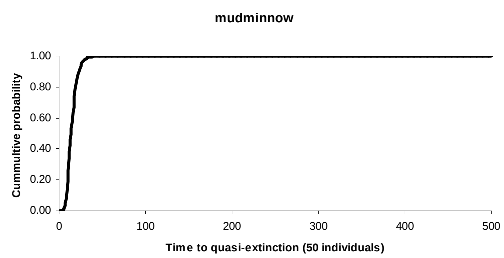


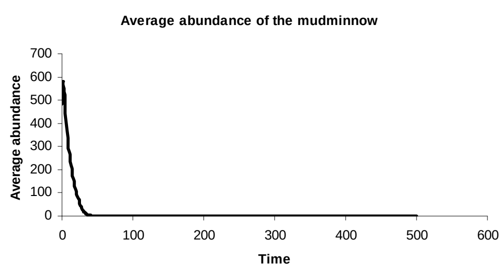


Species 7. Mudminnow

Fish	Mudminnow
Initial abundance	481 (females only, 1:1 sex ratio)
age at first reproduction	within the first year
longevity	3 years
generation time	1 year
threats	restricted distribution, habitat loss



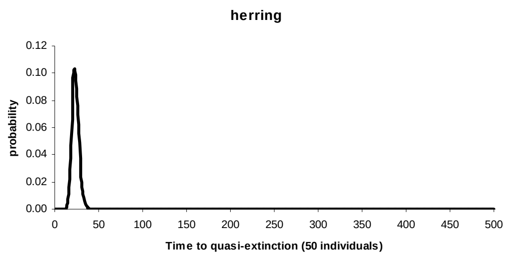


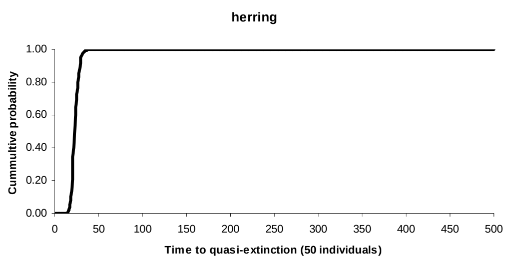


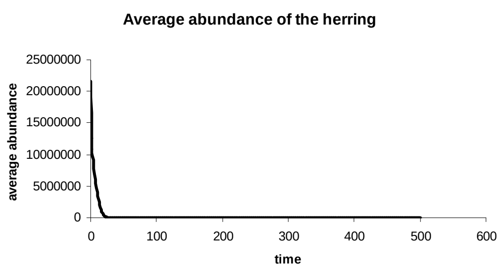
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	481
10	0.0655	0.1862	1	581
20	0.0375	0.8240	2	581
30	0.0052	0.9790	3	550
40	0.0006	0.9979	4	493
50	0.0001	0.9998	5	445
60	0.0000	1.0000	6	402
70	0.0000	1.0000	7	367
80	0.0000	1.0000	8	338
90	0.0000	1.0000	9	309
100	0.0000	1.0000	10	280
110	0.0000	1.0000	11	258
120	0.0000	1.0000	12	234
130	0.0000	1.0000	13	218
140	0.0000	1.0000	14	194
150	0.0000	1.0000	15	182
160	0.0000	1.0000	16	165
170	0.0000	1.0000	17	149
180	0.0000	1.0000	18	138
190	0.0000	1.0000	19	118
200	0.0000	1.0000	20	105
210	0.0000	1.0000	21	93
220	0.0000	1.0000	22	82
230	0.0000	1.0000	23	74
240	0.0000	1.0000	24	62
250	0.0000	1.0000	25	54
260	0.0000	1.0000	26	46
270	0.0000	1.0000	27	40
280	0.0000	1.0000	28	35
290	0.0000	1.0000	29	29
300	0.0000	1.0000	30	24

Species 8. Herring

Fish	Herring
Initial abundance	21546900
age at first reproduction	within the first year
longevity	9 years
generation time	4 years
threats	overharvesting



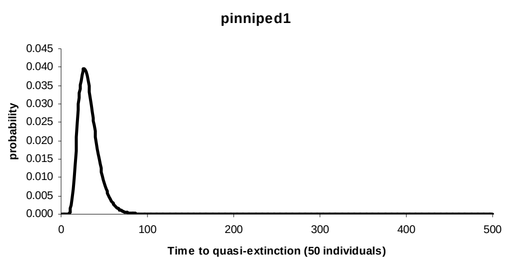


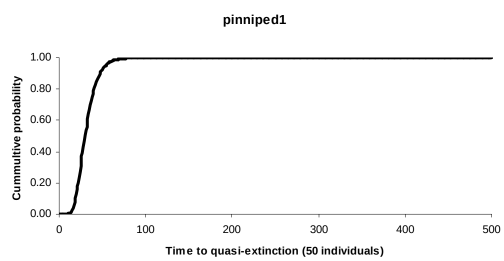


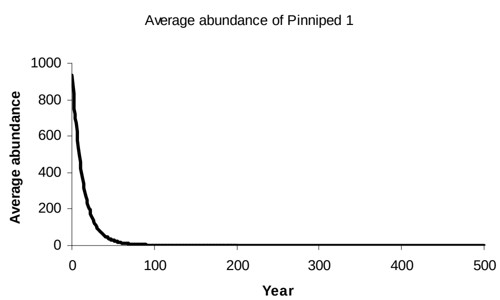
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	21546900
10	0.0000	0.0000	1	12591244
20	0.2380	0.2380	2	10834409
30	0.7154	0.9534	3	9631522
40	0.0457	0.9991	4	8672937
50	0.0009	1.0000	5	7764538
60	0.0000	1.0000	6	6899918
70	0.0000	1.0000	7	6114993
80	0.0000	1.0000	8	5376108
90	0.0000	1.0000	9	4669482
100	0.0000	1.0000	10	4021128
110	0.0000	1.0000	11	3426418
120	0.0000	1.0000	12	2898961
130	0.0000	1.0000	13	2418138
140	0.0000	1.0000	14	1989195
150	0.0000	1.0000	15	1615558
160	0.0000	1.0000	16	1281938
170	0.0000	1.0000	17	1002117
180	0.0000	1.0000	18	767515
190	0.0000	1.0000	19	578540
200	0.0000	1.0000	20	427953
210	0.0000	1.0000	21	310836
220	0.0000	1.0000	22	221389
230	0.0000	1.0000	23	155104
240	0.0000	1.0000	24	107915
250	0.0000	1.0000	25	73842
260	0.0000	1.0000	26	50058
270	0.0000	1.0000	27	34278
280	0.0000	1.0000	28	22969
290	0.0000	1.0000	29	15835
300	0.0000	1.0000	30	10826

Species 9. Pinniped1

Mammal	Pinniped1
Initial abundance	935
age at first reproduction	5-10 years
longevity	max = 30 years
generation time	~14 years
threats	foraging stress, habitat loss (islet subsidence), marine debris, shark predation; low juvenile survival (due to all factors) is largely driving the dynamics



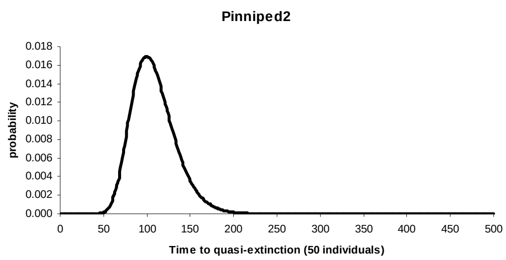


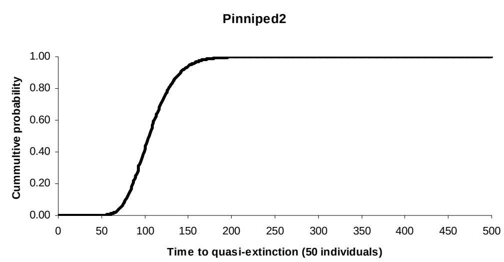


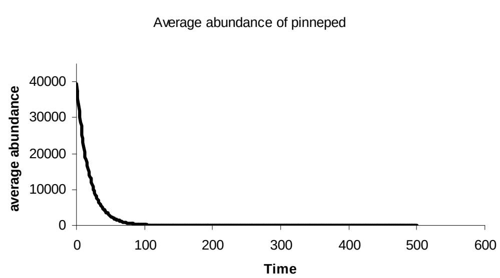
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	935
10	0.0005	0.0007	1	887
20	0.0284	0.1302	2	832
30	0.0376	0.5038	3	777
40	0.0209	0.7915	4	722
50	0.0085	0.9254	5	672
60	0.0030	0.9756	6	624
70	0.0010	0.9924	7	579
80	0.0003	0.9977	8	536
90	0.0001	0.9993	9	497
100	0.0000	0.9998	10	459
110	0.0000	0.9999	11	425
120	0.0000	1.0000	12	393
130	0.0000	1.0000	13	364
140	0.0000	1.0000	14	338
150	0.0000	1.0000	15	314
160	0.0000	1.0000	16	291
170	0.0000	1.0000	17	269
180	0.0000	1.0000	18	250
190	0.0000	1.0000	19	232
200	0.0000	1.0000	20	216
210	0.0000	1.0000	21	200
220	0.0000	1.0000	22	185
230	0.0000	1.0000	23	172
240	0.0000	1.0000	24	160
250	0.0000	1.0000	25	149
260	0.0000	1.0000	26	139
270	0.0000	1.0000	27	129
280	0.0000	1.0000	28	120
290	0.0000	1.0000	29	112
300	0.0000	1.0000	30	104

Species 10. Pinniped2

Mammals	Pinniped2
Initial abundance	39500
age at first reproduction	3 years
longevity	20 years
generation time	8 years
threats	unknown but could be bycatch, disease, predation, environmental change, entanglement in nets, pollution



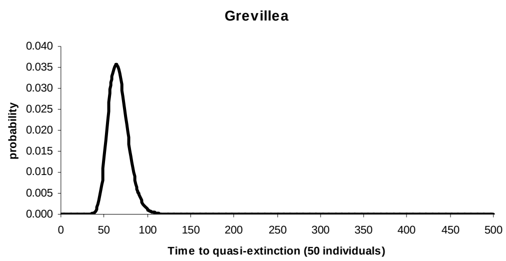


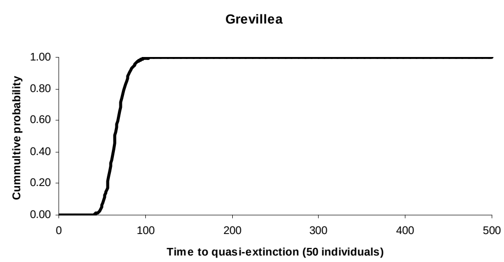


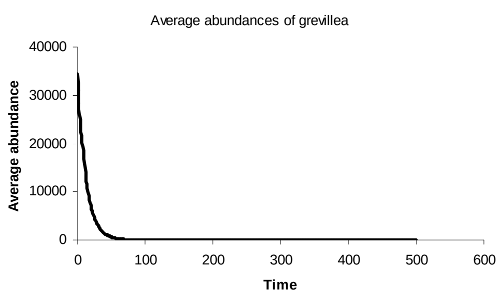
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	39500
10	0.0000	0.0000	1	37406
20	0.0000	0.0000	2	35408
30	0.0000	0.0000	3	33536
40	0.0000	0.0000	4	31753
50	0.0001	0.0005	5	30083
60	0.0014	0.0071	6	28492
70	0.0051	0.0388	7	26984
80	0.0106	0.1196	8	25577
90	0.0153	0.2535	9	24250
100	0.0169	0.4183	10	22973
110	0.0155	0.5819	11	21758
120	0.0123	0.7204	12	20598
130	0.0088	0.8243	13	19493
140	0.0058	0.8953	14	18450
150	0.0036	0.9403	15	17451
160	0.0021	0.9673	16	16537
170	0.0012	0.9826	17	15673
180	0.0006	0.9910	18	14854
190	0.0003	0.9955	19	14089
200	0.0002	0.9977	20	13339
210	0.0001	0.9989	21	12629
220	0.0000	0.9995	22	11954
230	0.0000	0.9998	23	11315
240	0.0000	0.9999	24	10714
250	0.0000	0.9999	25	10133
260	0.0000	1.0000	26	9595
270	0.0000	1.0000	27	9080
280	0.0000	1.0000	28	8596
290	0.0000	1.0000	29	8144
300	0.0000	1.0000	30	7719

Species 16. Grevillea

Plants	Grevillea
Initial abundance	34472 (only females including seeds)
age at first reproduction	4 years
longevity	16-30 years
generation time	10 years
threats	habitat loss, fire, fragmentation



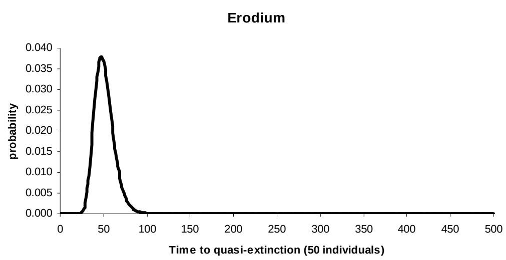


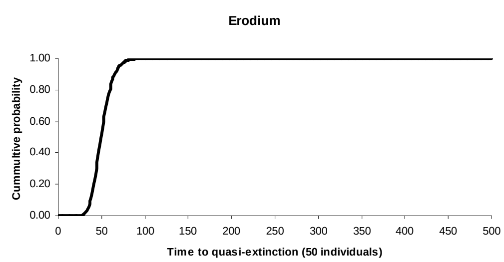


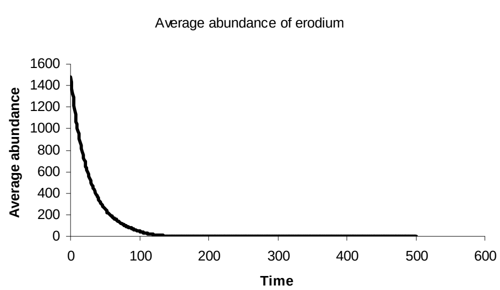
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	34472
10	0.0000	0.0000	1	31064
20	0.0000	0.0000	2	28275
30	0.0000	0.0000	3	25885
40	0.0008	0.0022	4	24240
50	0.0130	0.0613	5	22951
60	0.0335	0.3128	6	21743
70	0.0311	0.6561	7	20737
80	0.0152	0.8799	8	19388
90	0.0049	0.9686	9	17958
100	0.0012	0.9934	10	16758
110	0.0002	0.9988	11	15389
120	0.0000	0.9998	12	14040
130	0.0000	1.0000	13	12807
140	0.0000	1.0000	14	11708
150	0.0000	1.0000	15	10729
160	0.0000	1.0000	16	9858
170	0.0000	1.0000	17	9063
180	0.0000	1.0000	18	8350
190	0.0000	1.0000	19	7688
200	0.0000	1.0000	20	7088
210	0.0000	1.0000	21	6532
220	0.0000	1.0000	22	6014
230	0.0000	1.0000	23	5534
240	0.0000	1.0000	24	5089
250	0.0000	1.0000	25	4681
260	0.0000	1.0000	26	4303
270	0.0000	1.0000	27	3953
280	0.0000	1.0000	28	3633
290	0.0000	1.0000	29	3339
300	0.0000	1.0000	30	3064

Species 12. Erodium

Plant	Erodium
Initial abundance	1483
age at first reproduction	within the first year
longevity	15 years
generation time	3-4 years
threats	restricted range, small population size, low recruitment, seed predation



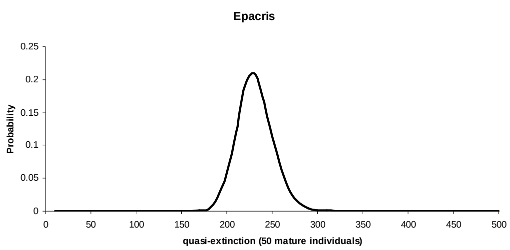


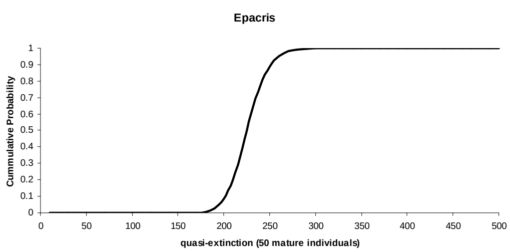


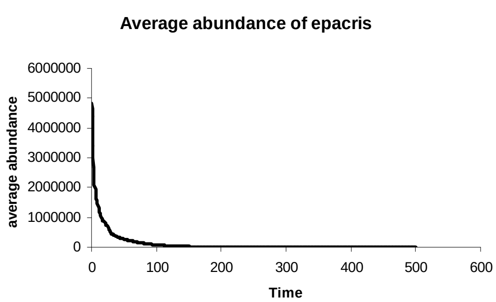
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1483
10	0.0000	0.0000	1	1433
20	0.0000	0.0000	2	1375
30	0.0038	0.0109	3	1319
40	0.0277	0.1687	4	1266
50	0.0368	0.5248	5	1217
60	0.0213	0.8153	6	1171
70	0.0077	0.9462	7	1128
80	0.0021	0.9872	8	1086
90	0.0005	0.9974	9	1046
100	0.0001	0.9995	10	1008
110	0.0000	0.9999	11	972
120	0.0000	1.0000	12	937
130	0.0000	1.0000	13	905
140	0.0000	1.0000	14	873
150	0.0000	1.0000	15	841
160	0.0000	1.0000	16	812
170	0.0000	1.0000	17	784
180	0.0000	1.0000	18	756
190	0.0000	1.0000	19	730
200	0.0000	1.0000	20	705
210	0.0000	1.0000	21	681
220	0.0000	1.0000	22	657
230	0.0000	1.0000	23	634
240	0.0000	1.0000	24	613
250	0.0000	1.0000	25	592
260	0.0000	1.0000	26	572
270	0.0000	1.0000	27	552
280	0.0000	1.0000	28	534
290	0.0000	1.0000	29	515
300	0.0000	1.0000	30	498

Species 13. Epacris

Plants	Epacris
Initial abundance	4818722 (only females and including seeds)
age at first reproduction	10 years
longevity	60+ years (senescence at 60)
generation time	30 years
threats	narrow range, disease and fire



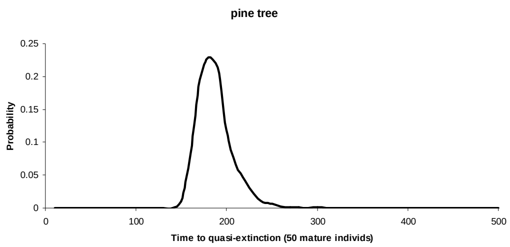


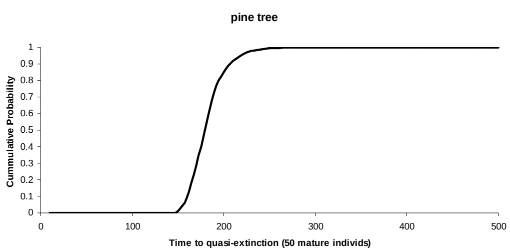


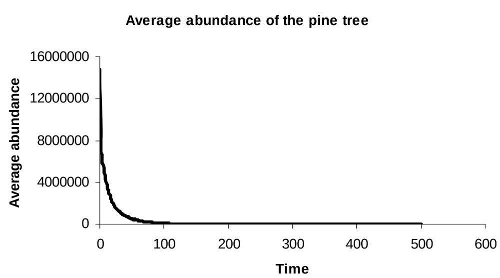
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	4818722
10	0.0000	0.0000	1	4378809
20	0.0000	0.0000	2	3394224
30	0.0000	0.0000	3	2667656
40	0.0000	0.0000	4	2245248
50	0.0000	0.0000	5	2019335
60	0.0000	0.0000	6	1851761
70	0.0000	0.0000	7	1685326
80	0.0000	0.0000	8	1579730
90	0.0000	0.0000	9	1473439
100	0.0000	0.0000	10	1378079
110	0.0000	0.0000	11	1308330
120	0.0000	0.0000	12	1208082
130	0.0000	0.0000	13	1116457
140	0.0000	0.0000	14	1048517
150	0.0000	0.0000	15	993071
160	0.0001	0.0001	16	954526
170	0.0007	0.0008	17	923727
180	0.0028	0.0036	18	887974
190	0.0205	0.0241	19	860882
200	0.0575	0.0816	20	832621
210	0.1204	0.2020	21	803331
220	0.1897	0.3917	22	769050
230	0.2093	0.6010	23	749251
240	0.1727	0.7737	24	721418
250	0.1139	0.8876	25	679000
260	0.0631	0.9507	26	629293
270	0.0298	0.9805	27	603503
280	0.0123	0.9928	28	553559
290	0.0048	0.9976	29	515232
300	0.0014	0.9990	30	482663

Species 14. Pine tree

Plants	Pine tree
Initial abundance	14770437 (including seed)
age at first reproduction	46
longevity	100 years +
generation time	60 years
threats	disease, fire exclusion, insect outbreaks



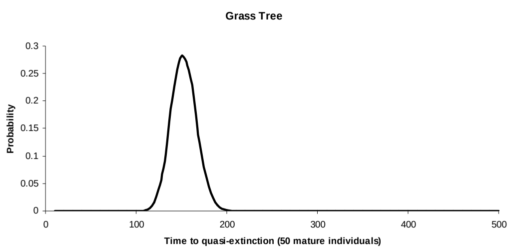


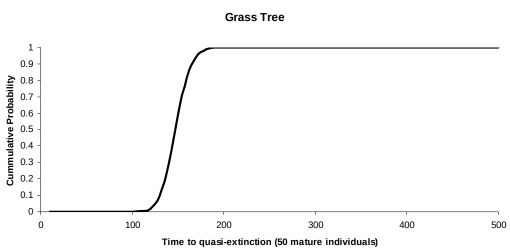


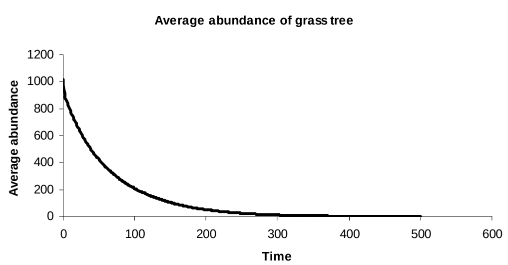
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	14770437
10	0.0000	0.0000	1	7378460
20	0.0000	0.0000	2	6996921
30	0.0000	0.0000	3	6615261
40	0.0000	0.0000	4	6033592
50	0.0000	0.0000	5	5747420
60	0.0000	0.0000	6	5353959
70	0.0000	0.0000	7	4960015
80	0.0000	0.0000	8	4664665
90	0.0000	0.0000	9	4291330
100	0.0000	0.0000	10	3961638
110	0.0000	0.0000	11	3809575
120	0.0000	0.0000	12	3465812
130	0.0000	0.0000	13	3239312
140	0.0000	0.0000	14	2906824
150	0.0102	0.0102	15	2898420
160	0.0817	0.0919	16	2543875
170	0.1949	0.2868	17	2447089
180	0.2294	0.5162	18	2317564
190	0.2143	0.7305	19	2136203
200	0.1191	0.8496	20	2029485
210	0.0671	0.9167	21	1854386
220	0.0412	0.9579	22	1869414
230	0.0213	0.9792	23	1701529
240	0.0088	0.9880	24	1611067
250	0.0062	0.9942	25	1522462
260	0.0024	0.9966	26	1466569
270	0.0013	0.9979	27	1379724
280	0.0009	0.9988	28	1321431
290	0.0003	0.9991	29	1279640
300	0.0009	1.0000	30	1194189

Species 15. Grass tree

Plants	Grass tree
Initial abundance	1017 (Seed included in summation but they are only produced after a fire. Initial abundance has no seeds included)
age at first reproduction	30 years
longevity	200 years +
generation time	100 years
threats	disease, fire



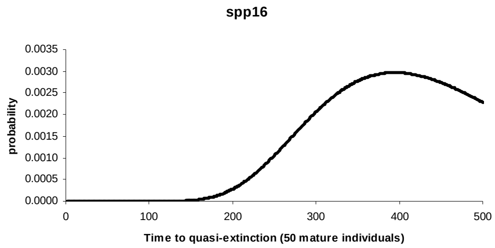


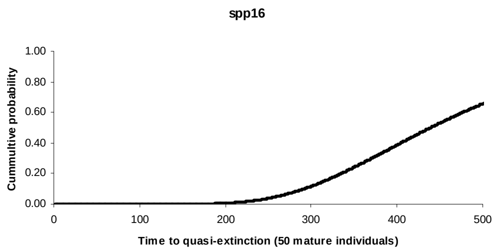


Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1017
10	0.0000	0.0000	1	938
20	0.0000	0.0000	2	889
30	0.0000	0.0000	3	875
40	0.0000	0.0000	4	870
50	0.0000	0.0000	5	857
60	0.0000	0.0000	6	842
70	0.0000	0.0000	7	827
80	0.0000	0.0000	8	811
90	0.0000	0.0000	9	795
100	0.0004	0.0004	10	783
110	0.0019	0.0023	11	772
120	0.0160	0.0183	12	759
130	0.0776	0.0959	13	745
140	0.2004	0.2963	14	732
150	0.2818	0.5781	15	721
160	0.2393	0.8174	16	711
170	0.1262	0.9436	17	699
180	0.0444	0.9880	18	688
190	0.0102	0.9982	19	677
200	0.0013	0.9995	20	666
210	0.0005	1.0000	21	656
220	0.0000	1.0000	22	646
230	0.0000	1.0000	23	636
240	0.0000	1.0000	24	626
250	0.0000	1.0000	25	616
260	0.0000	1.0000	26	607
270	0.0000	1.0000	27	598
280	0.0000	1.0000	28	589
290	0.0000	1.0000	29	580
300	0.0000	1.0000	30	571

Species 16.

General	Spp 16
Initial abundance	10000
Mean growth (r)	-0.01
Variance in r	0.0005

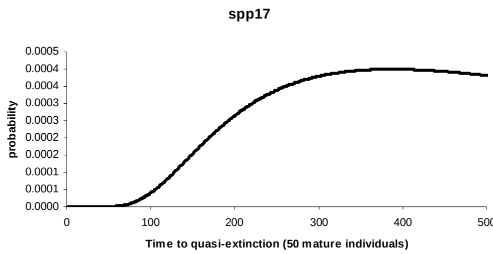


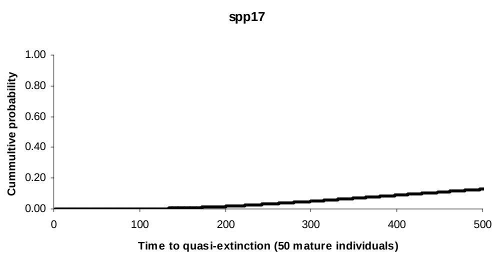


Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0000
30	0.0000	0.0000
40	0.0000	0.0000
50	0.0000	0.0000
60	0.0000	0.0000
70	0.0000	0.0000
80	0.0000	0.0000
90	0.0000	0.0000
100	0.0000	0.0000
110	0.0000	0.0000
120	0.0000	0.0000
130	0.0000	0.0000
140	0.0000	0.0001
150	0.0000	0.0003
160	0.0000	0.0006
170	0.0001	0.0013
180	0.0001	0.0024
190	0.0002	0.0041
200	0.0003	0.0067
210	0.0004	0.0105
220	0.0006	0.0155
230	0.0007	0.0222
240	0.0009	0.0306
250	0.0011	0.0408
260	0.0013	0.0531
270	0.0015	0.0675
280	0.0017	0.0838
290	0.0019	0.1023
300	0.0021	0.1226

Species 17.

General	Spp 17
Initial abundance	3000
Mean growth (r)	0.0
Variance in r	0.01

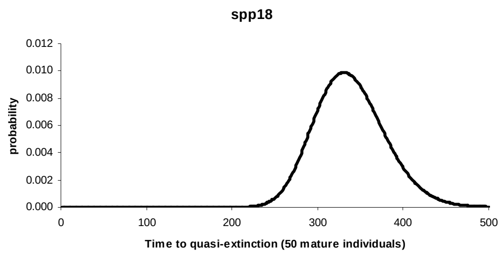


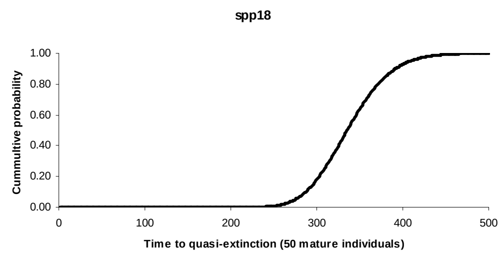


Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0000
30	0.0000	0.0000
40	0.0000	0.0000
50	0.0000	0.0000
60	0.0000	0.0000
70	0.0000	0.0001
80	0.0000	0.0002
90	0.0000	0.0003
100	0.0000	0.0007
110	0.0001	0.0012
120	0.0001	0.0019
130	0.0001	0.0029
140	0.0001	0.0041
150	0.0002	0.0056
160	0.0002	0.0073
170	0.0002	0.0092
180	0.0002	0.0114
190	0.0002	0.0137
200	0.0003	0.0163
210	0.0003	0.0191
220	0.0003	0.0220
230	0.0003	0.0251
240	0.0003	0.0283
250	0.0003	0.0316
260	0.0003	0.0351
270	0.0004	0.0386
280	0.0004	0.0423
290	0.0004	0.0460
300	0.0004	0.0498

Species 18.

General	Spp 18
Initial abundance	85000
Mean growth (r)	-0.02
Variance in r	0.002

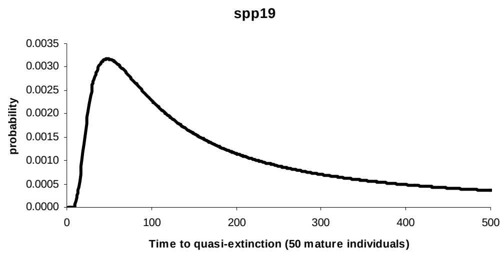


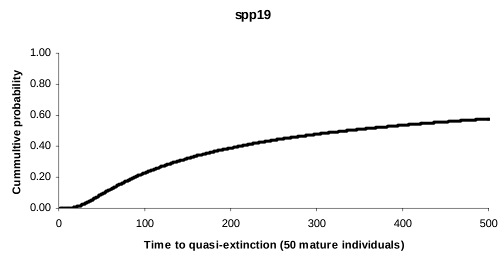


Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0000
30	0.0000	0.0000
40	0.0000	0.0000
50	0.0000	0.0000
60	0.0000	0.0000
70	0.0000	0.0000
80	0.0000	0.0000
90	0.0000	0.0000
100	0.0000	0.0000
110	0.0000	0.0000
120	0.0000	0.0000
130	0.0000	0.0000
140	0.0000	0.0000
150	0.0000	0.0000
160	0.0000	0.0000
170	0.0000	0.0000
180	0.0000	0.0000
190	0.0000	0.0000
200	0.0000	0.0000
210	0.0000	0.0001
220	0.0000	0.0003
230	0.0001	0.0010
240	0.0003	0.0031
250	0.0007	0.0083
260	0.0014	0.0192
270	0.0025	0.0394
280	0.0040	0.0724
290	0.0056	0.1213
300	0.0073	0.1869

Species 19.

General	Spp 19
Initial abundance	10000
Mean growth (r)	0.001
Variance in r	0.15

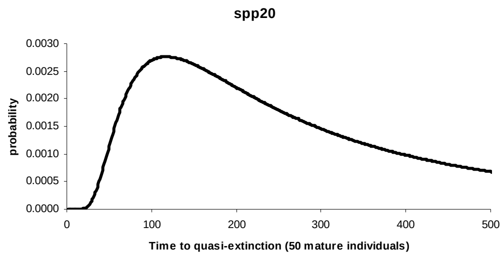


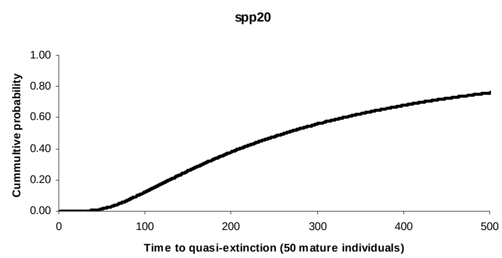


Year	PDF	CDF
0	0.0000	0.0000
10	0.0001	0.0002
20	0.0015	0.0084
30	0.0027	0.0304
40	0.0031	0.0598
50	0.0032	0.0914
60	0.0030	0.1225
70	0.0029	0.1520
80	0.0027	0.1795
90	0.0025	0.2049
100	0.0023	0.2284
110	0.0021	0.2501
120	0.0019	0.2702
130	0.0018	0.2889
140	0.0017	0.3062
150	0.0016	0.3223
160	0.0015	0.3373
170	0.0014	0.3514
180	0.0013	0.3647
190	0.0012	0.3771
200	0.0011	0.3888
210	0.0011	0.3999
220	0.0010	0.4103
230	0.0010	0.4203
240	0.0009	0.4297
250	0.0009	0.4387
260	0.0008	0.4472
270	0.0008	0.4553
280	0.0008	0.4631
290	0.0007	0.4705
300	0.0007	0.4777

Species 20.

General	Spp 20
Initial abundance	5000
Mean growth (r)	-0.01
Variance in r	0.04



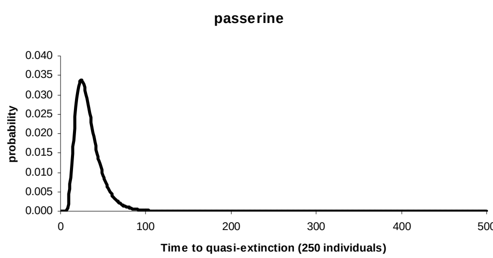


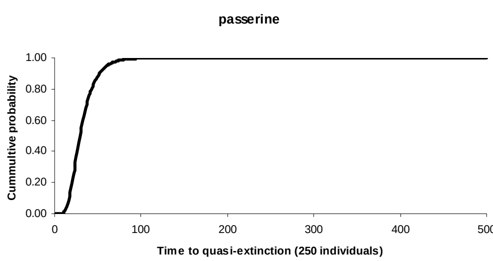
Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0000
30	0.0002	0.0010
40	0.0007	0.0054
50	0.0012	0.0149
60	0.0017	0.0298
70	0.0021	0.0492
80	0.0024	0.0720
90	0.0026	0.0971
100	0.0027	0.1237
110	0.0028	0.1511
120	0.0028	0.1787
130	0.0027	0.2061
140	0.0027	0.2332
150	0.0026	0.2597
160	0.0025	0.2854
170	0.0025	0.3103
180	0.0024	0.3344
190	0.0023	0.3577
200	0.0022	0.3800
210	0.0021	0.4015
220	0.0020	0.4221
230	0.0019	0.4419
240	0.0019	0.4609
250	0.0018	0.4791
260	0.0017	0.4966
270	0.0016	0.5133
280	0.0016	0.5294
290	0.0015	0.5448
300	0.0015	0.5596

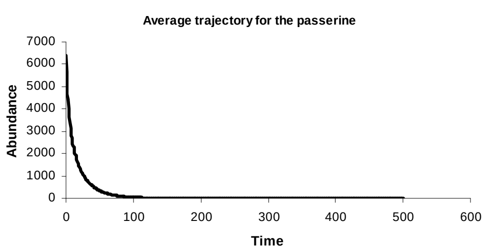
Section 6.3 Near-extinction of 250 mature individuals

Species 1. Passerine

Birds	**Passerine**
Initial abundance	6400
age at first reproduction	5 years
longevity	16 years
generation time	10 years
threats	habitat destruction and degradation



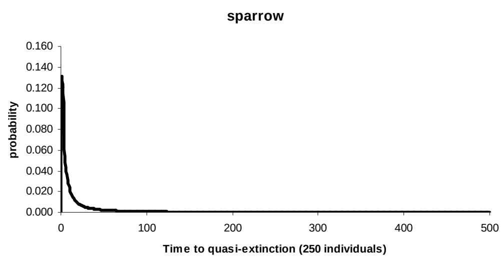


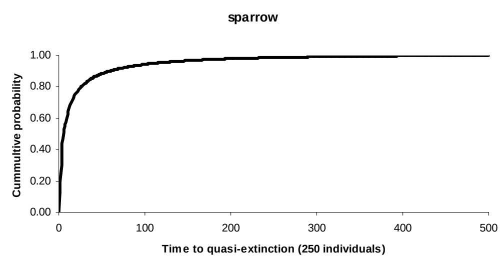


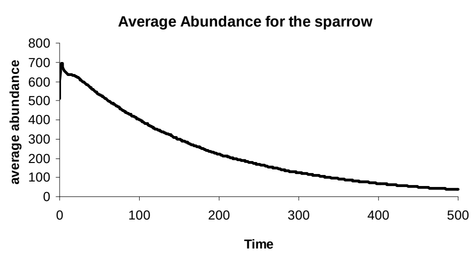
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	6400
10	0.0034	0.0062	1	5625
20	0.0308	0.1977	2	4966
30	0.0301	0.5235	3	4443
40	0.0180	0.7582	4	4005
50	0.0091	0.8858	5	3658
60	0.0043	0.9479	6	3366
70	0.0020	0.9766	7	3122
80	0.0009	0.9896	8	2908
90	0.0004	0.9954	9	2694
100	0.0002	0.9980	10	2520
110	0.0001	0.9991	11	2352
120	0.0000	0.9996	12	2217
130	0.0000	0.9998	13	2069
140	0.0000	0.9999	14	1965
150	0.0000	1.0000	15	1837
160	0.0000	1.0000	16	1738
170	0.0000	1.0000	17	1638
180	0.0000	1.0000	18	1547
190	0.0000	1.0000	19	1466
200	0.0000	1.0000	20	1394
210	0.0000	1.0000	21	1328
220	0.0000	1.0000	22	1250
230	0.0000	1.0000	23	1185
240	0.0000	1.0000	24	1143
250	0.0000	1.0000	25	1085
260	0.0000	1.0000	26	1027
270	0.0000	1.0000	27	978
280	0.0000	1.0000	28	929
290	0.0000	1.0000	29	887
300	0.0000	1.0000	30	842

Species 2. Sparrow

Birds	Sparrow
Initial abundance	509 (Males only, 1:1 sex ratio)
age at first reproduction	Within the first year
longevity	6 years
generation time	3 years
threats	sea level rise



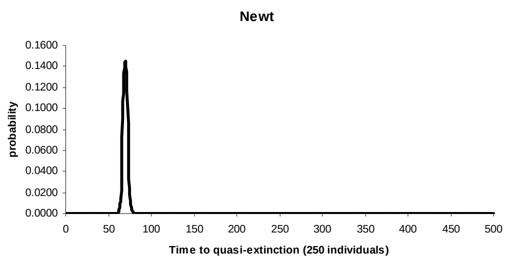


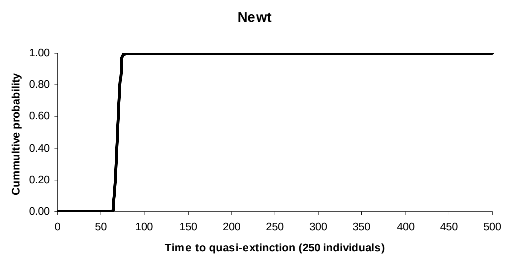


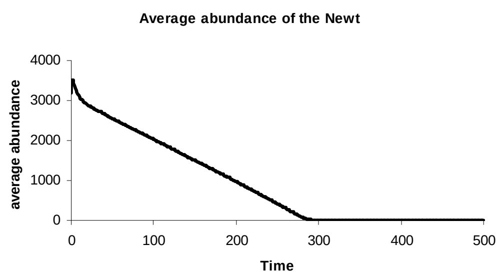
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	509
10	0.0229	0.6248	1	679
20	0.0087	0.7578	2	694
30	0.0048	0.8201	3	687
40	0.0031	0.8574	4	678
50	0.0022	0.8827	5	666
60	0.0016	0.9011	6	657
70	0.0013	0.9152	7	650
80	0.0010	0.9263	8	646
90	0.0008	0.9353	9	642
100	0.0007	0.9427	10	638
110	0.0006	0.9490	11	638
120	0.0005	0.9543	12	637
130	0.0004	0.9589	13	636
140	0.0004	0.9629	14	636
150	0.0003	0.9664	15	635
160	0.0003	0.9695	16	634
170	0.0003	0.9723	17	633
180	0.0002	0.9747	18	631
190	0.0002	0.9769	19	630
200	0.0002	0.9789	20	628
210	0.0002	0.9807	21	625
220	0.0002	0.9824	22	624
230	0.0001	0.9838	23	620
240	0.0001	0.9852	24	616
250	0.0001	0.9864	25	612
260	0.0001	0.9876	26	608
270	0.0001	0.9886	27	605
280	0.0001	0.9896	28	602
290	0.0001	0.9905	29	598
300	0.0001	0.9913	30	595

Species 3. Newt

Reptiles	**Newt**
Initial abundance	3200
age at first reproduction	1 year
longevity	7-10years
generation time	2 years
threats	habitat destruction and degradation



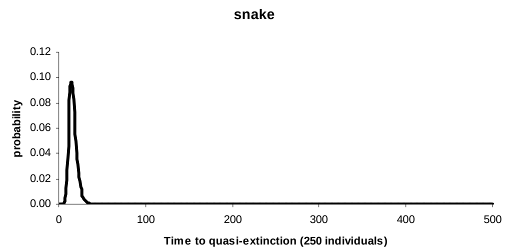


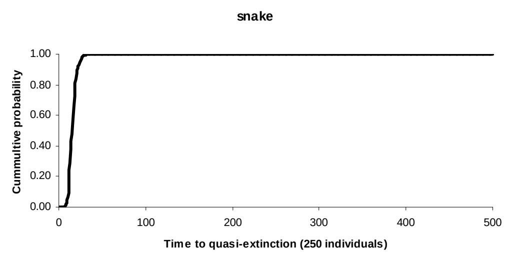


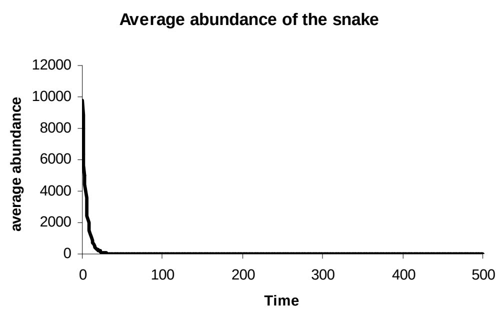
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	3200
10	0.0000	0.0000	1	3519
20	0.0000	0.0000	2	3500
30	0.0000	0.0000	3	3448
40	0.0000	0.0000	4	3370
50	0.0000	0.0000	5	3308
60	0.0001	0.0001	6	3254
70	0.1454	0.6084	7	3210
80	0.0003	0.9999	8	3169
90	0.0000	1.0000	9	3127
100	0.0000	1.0000	10	3091
110	0.0000	1.0000	11	3064
120	0.0000	1.0000	12	3036
130	0.0000	1.0000	13	3017
140	0.0000	1.0000	14	2997
150	0.0000	1.0000	15	2977
160	0.0000	1.0000	16	2952
170	0.0000	1.0000	17	2935
180	0.0000	1.0000	18	2917
190	0.0000	1.0000	19	2902
200	0.0000	1.0000	20	2888
210	0.0000	1.0000	21	2874
220	0.0000	1.0000	22	2866
230	0.0000	1.0000	23	2853
240	0.0000	1.0000	24	2842
250	0.0000	1.0000	25	2832
260	0.0000	1.0000	26	2820
270	0.0000	1.0000	27	2806
280	0.0000	1.0000	28	2797
290	0.0000	1.0000	29	2783
300	0.0000	1.0000	30	2770

Species 4. Snake

Reptiles	**Snake**
Initial abundance	9798
age at first reproduction	3 years
longevity	15 years
generation time	7 years
threats	direct mortality from humans and habitat loss



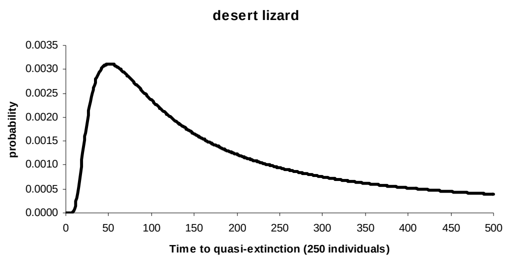


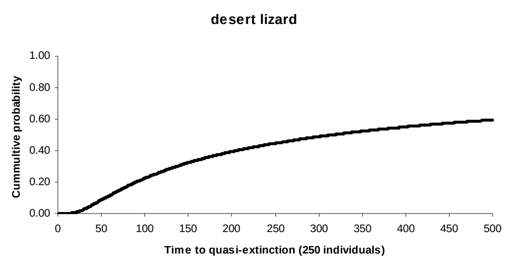


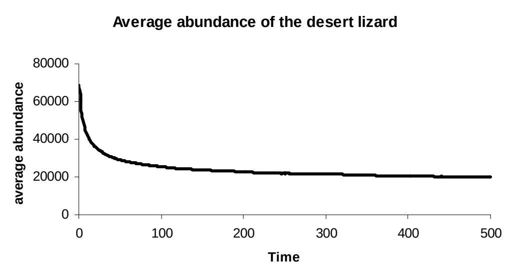
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	9798
10	0.0364	0.0655	1	8005
20	0.0499	0.8359	2	6362
30	0.0028	0.9933	3	5024
40	0.0001	0.9998	4	3989
50	0.0000	1.0000	5	3248
60	0.0000	1.0000	6	2674
70	0.0000	1.0000	7	2206
80	0.0000	1.0000	8	1808
90	0.0000	1.0000	9	1490
100	0.0000	1.0000	10	1254
110	0.0000	1.0000	11	1047
120	0.0000	1.0000	12	874
130	0.0000	1.0000	13	731
140	0.0000	1.0000	14	617
150	0.0000	1.0000	15	517
160	0.0000	1.0000	16	434
170	0.0000	1.0000	17	365
180	0.0000	1.0000	18	308
190	0.0000	1.0000	19	260
200	0.0000	1.0000	20	218
210	0.0000	1.0000	21	184
220	0.0000	1.0000	22	153
230	0.0000	1.0000	23	128
240	0.0000	1.0000	24	106
250	0.0000	1.0000	25	90
260	0.0000	1.0000	26	75
270	0.0000	1.0000	27	63
280	0.0000	1.0000	28	52
290	0.0000	1.0000	29	43
300	0.0000	1.0000	30	36

Species 5. Desert lizard

Reptiles	Desert Lizard
Initial abundance	6891
age at first reproduction	1 year
longevity	10 - 20years
generation time	4 years
threats	fire



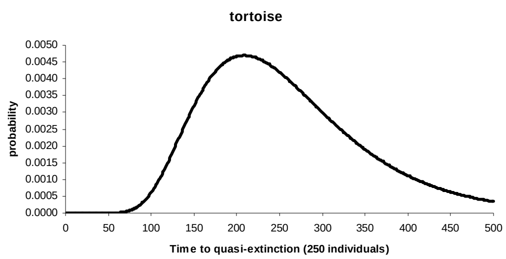


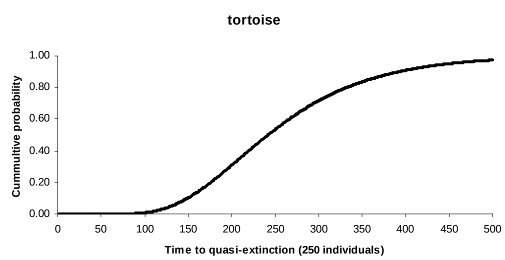


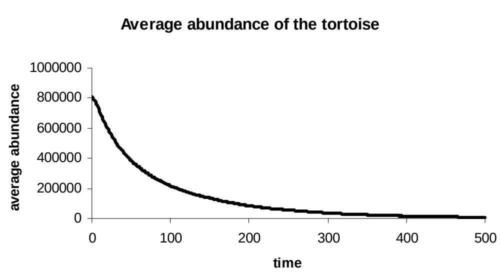
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	68914
10	0.0001	0.0001	1	65870
20	0.0013	0.0066	2	60816
30	0.0024	0.0260	3	56618
40	0.0030	0.0537	4	53254
50	0.0031	0.0845	5	50430
60	0.0031	0.1154	6	48242
70	0.0029	0.1451	7	46438
80	0.0027	0.1732	8	45036
90	0.0025	0.1994	9	43756
100	0.0024	0.2238	10	42633
110	0.0022	0.2464	11	41638
120	0.0020	0.2674	12	40809
130	0.0019	0.2870	13	39993
140	0.0018	0.3053	14	39251
150	0.0017	0.3223	15	38615
160	0.0016	0.3383	16	37997
170	0.0015	0.3533	17	37453
180	0.0014	0.3674	18	36947
190	0.0013	0.3806	19	36479
200	0.0012	0.3931	20	36050
210	0.0012	0.4050	21	35579
220	0.0011	0.4162	22	35210
230	0.0010	0.4268	23	34845
240	0.0010	0.4369	24	34558
250	0.0009	0.4466	25	34247
260	0.0009	0.4557	26	33923
270	0.0009	0.4645	27	33571
280	0.0008	0.4729	28	33286
290	0.0008	0.4809	29	33016
300	0.0008	0.4886	30	32687

Species 6. Tortoise

Reptiles	**Tortoise**
Initial abundance	811465
age at first reproduction	12 years
longevity	60-100 years
generation time	20
threats	habitat destruction and degradation



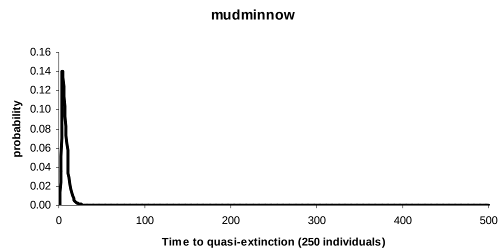


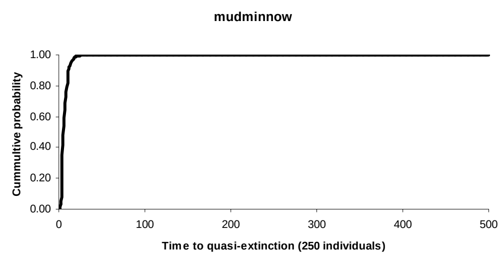


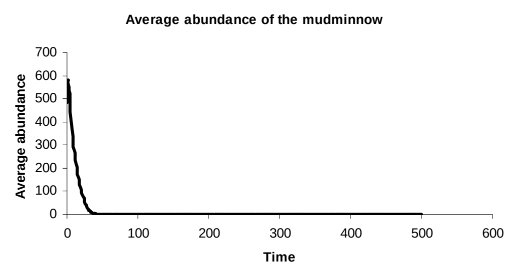
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	811465
10	0.0000	0.0000	1	802554
20	0.0000	0.0000	2	795680
30	0.0000	0.0000	3	791248
40	0.0000	0.0000	4	784144
50	0.0000	0.0000	5	774915
60	0.0000	0.0000	6	763539
70	0.0000	0.0002	7	753095
80	0.0001	0.0010	8	740276
90	0.0003	0.0032	9	727954
100	0.0006	0.0078	10	713836
110	0.0010	0.0161	11	699099
120	0.0015	0.0291	12	686600
130	0.0021	0.0475	13	674280
140	0.0027	0.0716	14	662435
150	0.0032	0.1012	15	650365
160	0.0037	0.1358	16	639369
170	0.0041	0.1747	17	626713
180	0.0044	0.2170	18	617331
190	0.0046	0.2617	19	607315
200	0.0047	0.3080	20	598051
210	0.0047	0.3548	21	588601
220	0.0046	0.4016	22	579038
230	0.0045	0.4475	23	571274
240	0.0044	0.4921	24	560582
250	0.0042	0.5349	25	551690
260	0.0040	0.5757	26	542674
270	0.0037	0.6142	27	535771
280	0.0035	0.6502	28	526745
290	0.0032	0.6838	29	519124
300	0.0030	0.7149	30	510692

Species 7. Mudminnow

Fish	Mudminnow
Initial abundance	481 (females only, 1:1 sex ratio)
age at first reproduction	within the first year
longevity	3 years
generation time	1 year
threats	restricted distribution, habitat loss



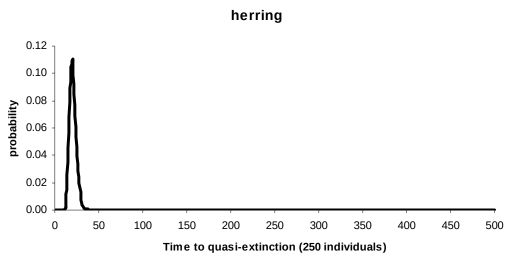


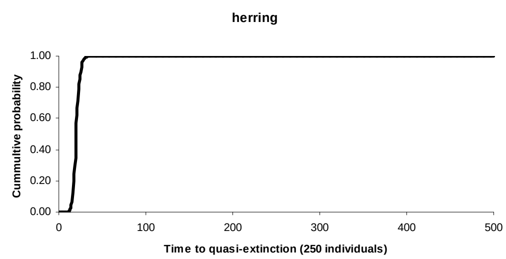


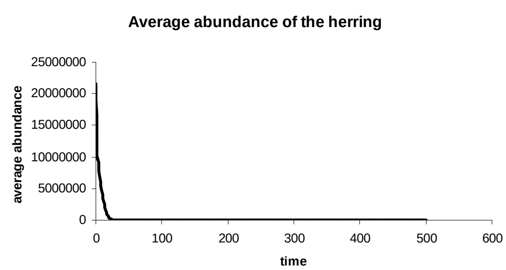
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	481
10	0.0498	0.8410	1	581
20	0.0032	0.9898	2	581
30	0.0002	0.9995	3	550
40	0.0000	1.0000	4	493
50	0.0000	1.0000	5	445
60	0.0000	1.0000	6	402
70	0.0000	1.0000	7	367
80	0.0000	1.0000	8	338
90	0.0000	1.0000	9	309
100	0.0000	1.0000	10	280
110	0.0000	1.0000	11	258
120	0.0000	1.0000	12	234
130	0.0000	1.0000	13	218
140	0.0000	1.0000	14	194
150	0.0000	1.0000	15	182
160	0.0000	1.0000	16	165
170	0.0000	1.0000	17	149
180	0.0000	1.0000	18	138
190	0.0000	1.0000	19	118
200	0.0000	1.0000	20	105
210	0.0000	1.0000	21	93
220	0.0000	1.0000	22	82
230	0.0000	1.0000	23	74
240	0.0000	1.0000	24	62
250	0.0000	1.0000	25	54
260	0.0000	1.0000	26	46
270	0.0000	1.0000	27	40
280	0.0000	1.0000	28	35
290	0.0000	1.0000	29	29
300	0.0000	1.0000	30	24

Species 8. Herring

Fish	Herring
Initial abundance	21546900
age at first reproduction	within the first year
longevity	9 years
generation time	4 years
threats	overharvesting



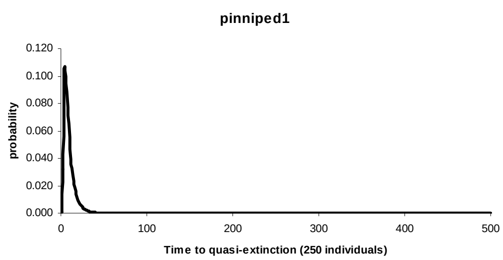


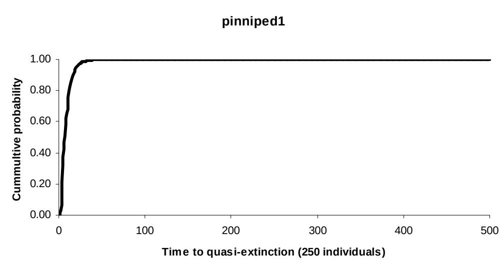


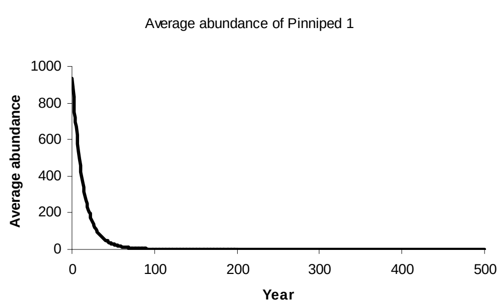
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	21546900
10	0.0001	0.0001	1	12591244
20	0.1106	0.5154	2	10834409
30	0.0071	0.9883	3	9631522
40	0.0000	1.0000	4	8672937
50	0.0000	1.0000	5	7764538
60	0.0000	1.0000	6	6899918
70	0.0000	1.0000	7	6114993
80	0.0000	1.0000	8	5376108
90	0.0000	1.0000	9	4669482
100	0.0000	1.0000	10	4021128
110	0.0000	1.0000	11	3426418
120	0.0000	1.0000	12	2898961
130	0.0000	1.0000	13	2418138
140	0.0000	1.0000	14	1989195
150	0.0000	1.0000	15	1615558
160	0.0000	1.0000	16	1281938
170	0.0000	1.0000	17	1002117
180	0.0000	1.0000	18	767515
190	0.0000	1.0000	19	578540
200	0.0000	1.0000	20	427953
210	0.0000	1.0000	21	310836
220	0.0000	1.0000	22	221389
230	0.0000	1.0000	23	155104
240	0.0000	1.0000	24	107915
250	0.0000	1.0000	25	73842
260	0.0000	1.0000	26	50058
270	0.0000	1.0000	27	34278
280	0.0000	1.0000	28	22969
290	0.0000	1.0000	29	15835
300	0.0000	1.0000	30	10826

Species 9. Pinniped1

Mammal	Pinniped1
Initial abundance	935
age at first reproduction	5-10 years
longevity	max = 30 years
generation time	~14 years
threats	foraging stress, habitat loss (islet subsidence), marine debris, shark predation; low juvenile survival (due to all factors) is largely driving the dynamics



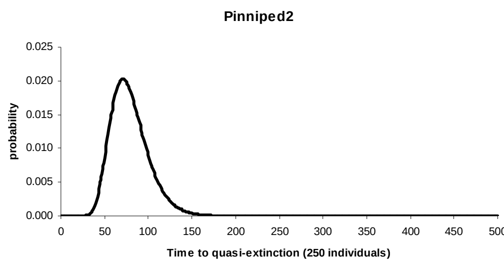


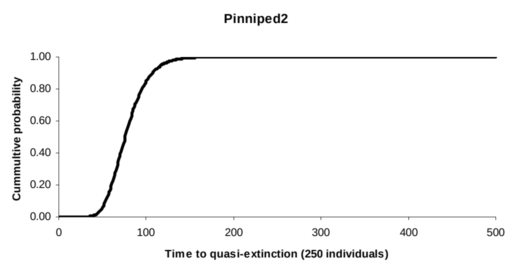


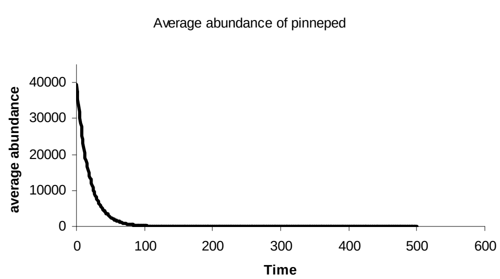
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	935
10	0.0553	0.7069	1	887
20	0.0097	0.9455	2	832
30	0.0019	0.9887	3	777
40	0.0004	0.9975	4	722
50	0.0001	0.9994	5	672
60	0.0000	0.9999	6	624
70	0.0000	1.0000	7	579
80	0.0000	1.0000	8	536
90	0.0000	1.0000	9	497
100	0.0000	1.0000	10	459
110	0.0000	1.0000	11	425
120	0.0000	1.0000	12	393
130	0.0000	1.0000	13	364
140	0.0000	1.0000	14	338
150	0.0000	1.0000	15	314
160	0.0000	1.0000	16	291
170	0.0000	1.0000	17	269
180	0.0000	1.0000	18	250
190	0.0000	1.0000	19	232
200	0.0000	1.0000	20	216
210	0.0000	1.0000	21	200
220	0.0000	1.0000	22	185
230	0.0000	1.0000	23	172
240	0.0000	1.0000	24	160
250	0.0000	1.0000	25	149
260	0.0000	1.0000	26	139
270	0.0000	1.0000	27	129
280	0.0000	1.0000	28	120
290	0.0000	1.0000	29	112
300	0.0000	1.0000	30	104

Species 10. Pinniped2

Mammals	Pinniped2
Initial abundance	39500
age at first reproduction	3 years
longevity	20 years
generation time	8 years
threats	unknown but could be bycatch, disease, predation, environmental change, entanglement in nets, pollution



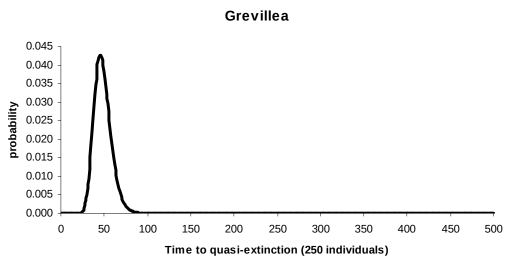


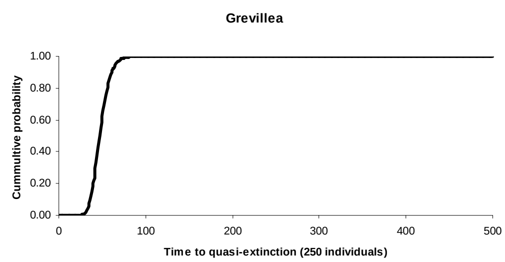


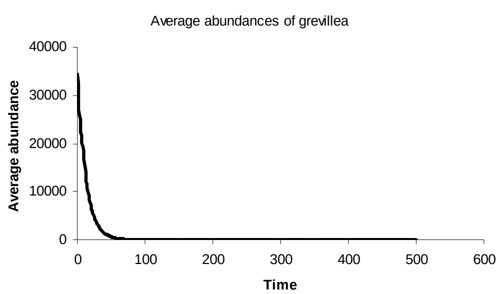
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	39500
10	0.0000	0.0000	1	37406
20	0.0000	0.0000	2	35408
30	0.0001	0.0002	3	33536
40	0.0019	0.0080	4	31753
50	0.0086	0.0602	5	30083
60	0.0167	0.1927	6	28492
70	0.0202	0.3843	7	26984
80	0.0183	0.5796	8	25577
90	0.0137	0.7382	9	24250
100	0.0090	0.8486	10	22973
110	0.0054	0.9173	11	21758
120	0.0030	0.9569	12	20598
130	0.0016	0.9783	13	19493
140	0.0008	0.9894	14	18450
150	0.0004	0.9950	15	17451
160	0.0002	0.9976	16	16537
170	0.0001	0.9989	17	15673
180	0.0000	0.9995	18	14854
190	0.0000	0.9998	19	14089
200	0.0000	0.9999	20	13339
210	0.0000	1.0000	21	12629
220	0.0000	1.0000	22	11954
230	0.0000	1.0000	23	11315
240	0.0000	1.0000	24	10714
250	0.0000	1.0000	25	10133
260	0.0000	1.0000	26	9595
270	0.0000	1.0000	27	9080
280	0.0000	1.0000	28	8596
290	0.0000	1.0000	29	8144
300	0.0000	1.0000	30	7719

Species 11. Grevillea

Plants	Grevillea
Initial abundance	34472 (only females including seeds)
age at first reproduction	4 years
longevity	16-30 years
generation time	10 years
threats	habitat loss, fire, fragmentation



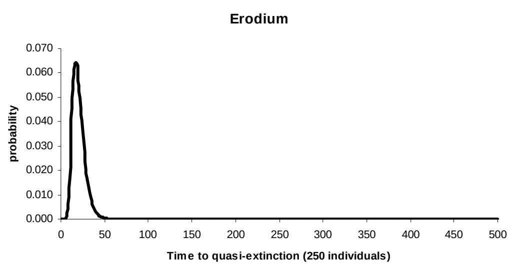


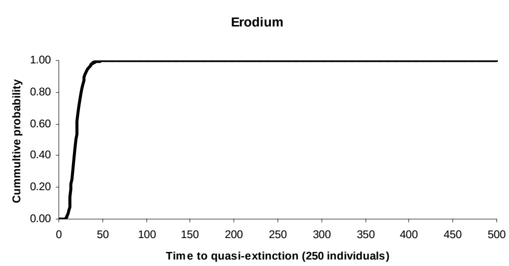


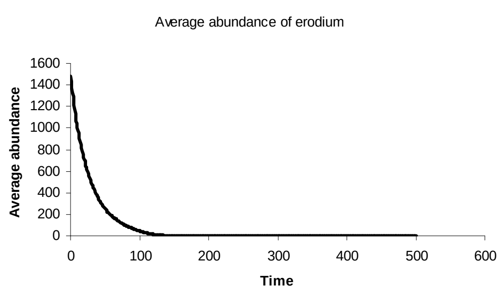
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	34472
10	0.0000	0.0000	1	31064
20	0.0000	0.0000	2	28275
30	0.0049	0.0136	3	25885
40	0.0348	0.2171	4	24240
50	0.0382	0.6230	5	22951
60	0.0167	0.8871	6	21743
70	0.0044	0.9760	7	20737
80	0.0008	0.9960	8	19388
90	0.0001	0.9994	9	17958
100	0.0000	0.9999	10	16758
110	0.0000	1.0000	11	15389
120	0.0000	1.0000	12	14040
130	0.0000	1.0000	13	12807
140	0.0000	1.0000	14	11708
150	0.0000	1.0000	15	10729
160	0.0000	1.0000	16	9858
170	0.0000	1.0000	17	9063
180	0.0000	1.0000	18	8350
190	0.0000	1.0000	19	7688
200	0.0000	1.0000	20	7088
210	0.0000	1.0000	21	6532
220	0.0000	1.0000	22	6014
230	0.0000	1.0000	23	5534
240	0.0000	1.0000	24	5089
250	0.0000	1.0000	25	4681
260	0.0000	1.0000	26	4303
270	0.0000	1.0000	27	3953
280	0.0000	1.0000	28	3633
290	0.0000	1.0000	29	3339
300	0.0000	1.0000	30	3064

Species 12. Erodium

Plant	**Erodium**
Initial abundance	1483
age at first reproduction	within the first year
longevity	15 years
generation time	3-4 years
threats	restricted range, small population size, low recruitment, seed predation



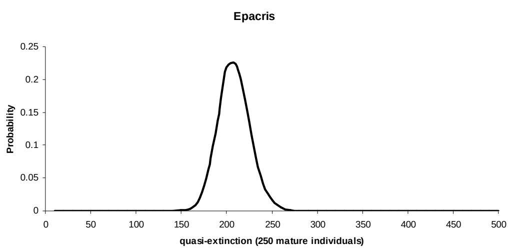


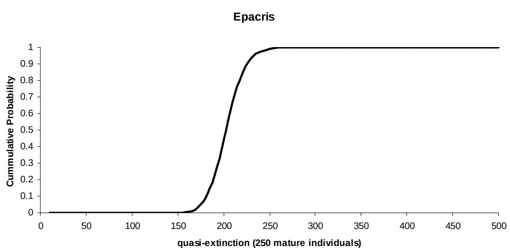


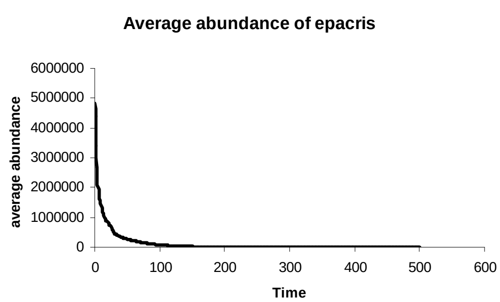
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1483
10	0.0166	0.0312	1	1433
20	0.0588	0.5632	2	1375
30	0.0174	0.9099	3	1319
40	0.0030	0.9863	4	1266
50	0.0004	0.9982	5	1217
60	0.0001	0.9998	6	1171
70	0.0000	1.0000	7	1128
80	0.0000	1.0000	8	1086
90	0.0000	1.0000	9	1046
100	0.0000	1.0000	10	1008
110	0.0000	1.0000	11	972
120	0.0000	1.0000	12	937
130	0.0000	1.0000	13	905
140	0.0000	1.0000	14	873
150	0.0000	1.0000	15	841
160	0.0000	1.0000	16	812
170	0.0000	1.0000	17	784
180	0.0000	1.0000	18	756
190	0.0000	1.0000	19	730
200	0.0000	1.0000	20	705
210	0.0000	1.0000	21	681
220	0.0000	1.0000	22	657
230	0.0000	1.0000	23	634
240	0.0000	1.0000	24	613
250	0.0000	1.0000	25	592
260	0.0000	1.0000	26	572
270	0.0000	1.0000	27	552
280	0.0000	1.0000	28	534
290	0.0000	1.0000	29	515
300	0.0000	1.0000	30	498

Species 13. Epacris

Plants	**Epacris**
Initial abundance	4818722 (only females and including seeds)
age at first reproduction	10 years
longevity	60+ years (senescence at 60)
generation time	30 years
threats	narrow range, disease and fire



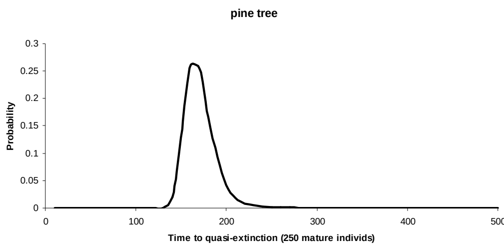


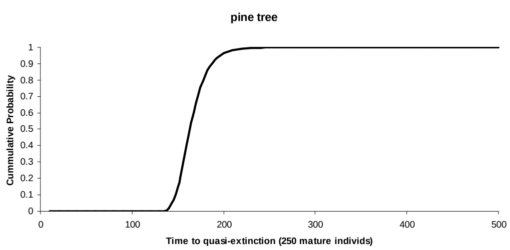


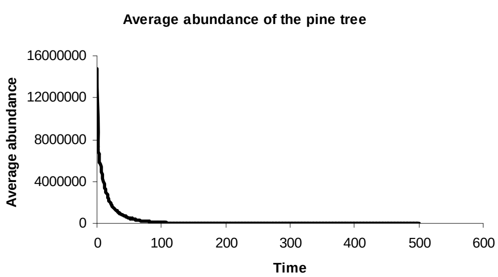
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	4818722
10	0.0000	0.0000	1	4378809
20	0.0000	0.0000	2	3394224
30	0.0000	0.0000	3	2667656
40	0.0000	0.0000	4	2245248
50	0.0000	0.0000	5	2019335
60	0.0000	0.0000	6	1851761
70	0.0000	0.0000	7	1685326
80	0.0000	0.0000	8	1579730
90	0.0000	0.0000	9	1473439
100	0.0000	0.0000	10	1378079
110	0.0000	0.0000	11	1308330
120	0.0000	0.0000	12	1208082
130	0.0000	0.0000	13	1116457
140	0.0002	0.0002	14	1048517
150	0.0008	0.0010	15	993071
160	0.0035	0.0045	16	954526
170	0.0192	0.0237	17	923727
180	0.0632	0.0869	18	887974
190	0.1378	0.2247	19	860882
200	0.2187	0.4434	20	832621
210	0.2241	0.6675	21	803331
220	0.1688	0.8363	22	769050
230	0.0980	0.9343	23	749251
240	0.0414	0.9757	24	721418
250	0.0167	0.9924	25	679000
260	0.0057	0.9981	26	629293
270	0.0014	0.9995	27	603503
280	0.0004	0.9999	28	553559
290	0.0001	1.0000	29	515232
300	0.0000	1.0000	30	482663

Species 14. Pine tree

Plants	Pine tree
Initial abundance	14770437 (including seed)
age at first reproduction	46
longevity	100 years +
generation time	60 years
threats	disease, fire exclusion, insect outbreaks



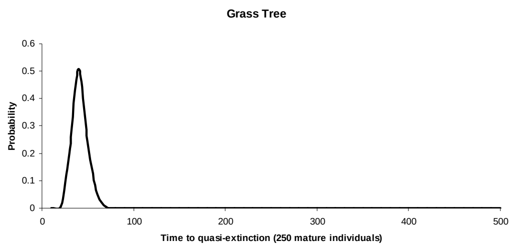


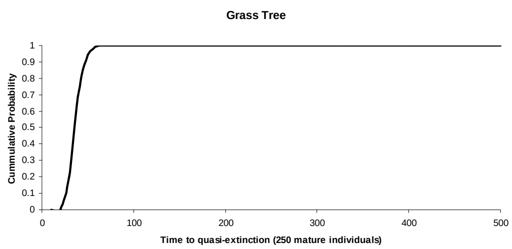


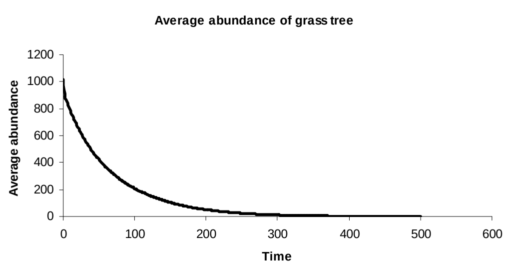
Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	14770437
10	0.0000	0.0000	1	7378460
20	0.0000	0.0000	2	6996921
30	0.0000	0.0000	3	6615261
40	0.0000	0.0000	4	6033592
50	0.0000	0.0000	5	5747420
60	0.0000	0.0000	6	5353959
70	0.0000	0.0000	7	4960015
80	0.0000	0.0000	8	4664665
90	0.0000	0.0000	9	4291330
100	0.0000	0.0000	10	3961638
110	0.0000	0.0000	11	3809575
120	0.0000	0.0000	12	3465812
130	0.0006	0.0006	13	3239312
140	0.0190	0.0196	14	2906824
150	0.1280	0.1476	15	2898420
160	0.2593	0.4069	16	2543875
170	0.2545	0.6614	17	2447089
180	0.1664	0.8278	18	2317564
190	0.0927	0.9205	19	2136203
200	0.0425	0.9630	20	2029485
210	0.0188	0.9818	21	1854386
220	0.0085	0.9903	22	1869414
230	0.0048	0.9951	23	1701529
240	0.0022	0.9973	24	1611067
250	0.0011	0.9984	25	1522462
260	0.0007	0.9991	26	1466569
270	0.0007	0.9998	27	1379724
280	0.0001	0.9999	28	1321431
290	0.0001	1.0000	29	1279640
300	0.0000	1.0000	30	1194189

Species 15. Grass tree

Plants	**Grass tree**
Initial abundance	1017 (Seed included in summation but they are only produced after a fire. Initial abundance has no seeds included)
age at first reproduction	30 years
longevity	200 years +
generation time	100 years
threats	disease, fire



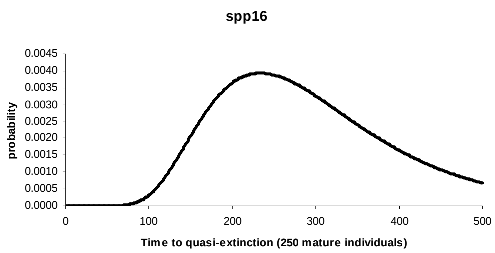


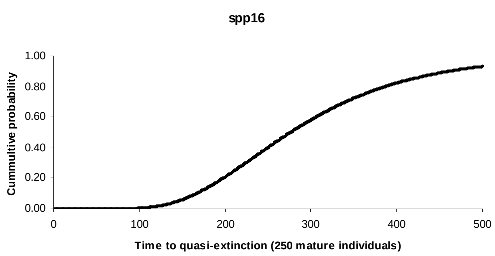


Year	PDF	CDF	Year	Abund
0	0.0000	0.0000	0	1017
10	0.0000	0.0000	1	938
20	0.0052	0.0052	2	889
30	0.1993	0.2045	3	875
40	0.5090	0.7135	4	870
50	0.2318	0.9453	5	857
60	0.0485	0.9938	6	842
70	0.0056	0.9994	7	827
80	0.0006	1.0000	8	811
90	0.0000	1.0000	9	795
100	0.0000	1.0000	10	783
110	0.0000	1.0000	11	772
120	0.0000	1.0000	12	759
130	0.0000	1.0000	13	745
140	0.0000	1.0000	14	732
150	0.0000	1.0000	15	721
160	0.0000	1.0000	16	711
170	0.0000	1.0000	17	699
180	0.0000	1.0000	18	688
190	0.0000	1.0000	19	677
200	0.0000	1.0000	20	666
210	0.0000	1.0000	21	656
220	0.0000	1.0000	22	646
230	0.0000	1.0000	23	636
240	0.0000	1.0000	24	626
250	0.0000	1.0000	25	616
260	0.0000	1.0000	26	607
270	0.0000	1.0000	27	598
280	0.0000	1.0000	28	589
290	0.0000	1.0000	29	580
300	0.0000	1.0000	30	571

Species 16.

General	Spp 16
Initial abundance	10000
Mean growth (r)	-0.01
Variance in r	0.0005

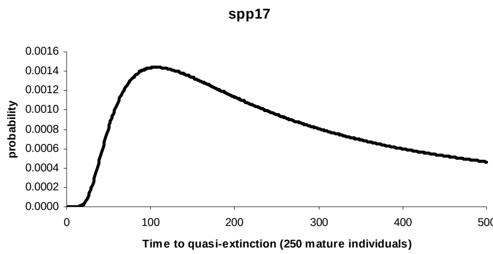


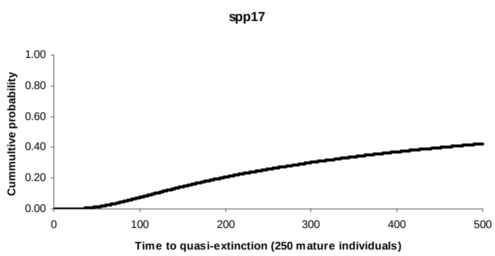


Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0000
30	0.0000	0.0000
40	0.0000	0.0000
50	0.0000	0.0000
60	0.0000	0.0000
70	0.0000	0.0001
80	0.0001	0.0004
90	0.0002	0.0015
100	0.0003	0.0038
110	0.0006	0.0082
120	0.0009	0.0155
130	0.0012	0.0263
140	0.0017	0.0410
150	0.0021	0.0598
160	0.0025	0.0828
170	0.0028	0.1095
180	0.0032	0.1397
190	0.0034	0.1729
200	0.0036	0.2084
210	0.0038	0.2457
220	0.0039	0.2841
230	0.0039	0.3233
240	0.0039	0.3625
250	0.0039	0.4015
260	0.0038	0.4399
270	0.0037	0.4772
280	0.0036	0.5134
290	0.0034	0.5482
300	0.0033	0.5815

Species 17.

General	Spp 17
Initial abundance	3000
Mean growth (r)	0.0
Variance in r	0.01

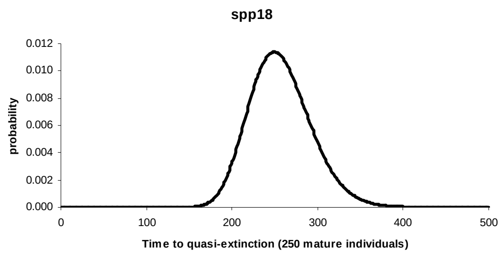


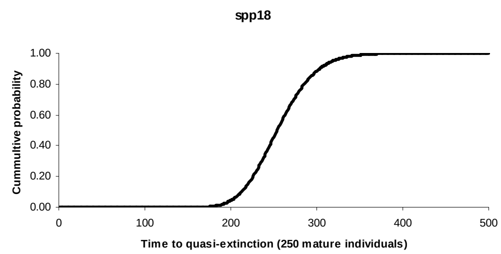


Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0001
30	0.0002	0.0012
40	0.0005	0.0049
50	0.0008	0.0117
60	0.0011	0.0212
70	0.0012	0.0328
80	0.0013	0.0458
90	0.0014	0.0596
100	0.0014	0.0739
110	0.0014	0.0883
120	0.0014	0.1026
130	0.0014	0.1168
140	0.0014	0.1306
150	0.0013	0.1441
160	0.0013	0.1573
170	0.0013	0.1700
180	0.0012	0.1823
190	0.0012	0.1942
200	0.0011	0.2057
210	0.0011	0.2168
220	0.0011	0.2276
230	0.0010	0.2379
240	0.0010	0.2479
250	0.0010	0.2576
260	0.0009	0.2669
270	0.0009	0.2760
280	0.0009	0.2847
290	0.0008	0.2931
300	0.0008	0.3013

Species 18.

General	**Spp 18**
Initial abundance	85000
Mean growth (r)	-0.02
Variance in r	0.002

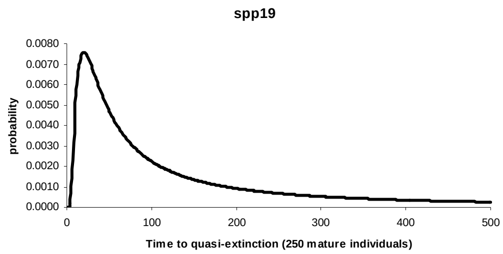


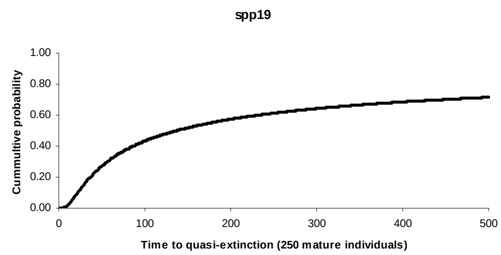


Year	PDF	CDF
0	0.0000	0.0000
10	0.0000	0.0000
20	0.0000	0.0000
30	0.0000	0.0000
40	0.0000	0.0000
50	0.0000	0.0000
60	0.0000	0.0000
70	0.0000	0.0000
80	0.0000	0.0000
90	0.0000	0.0000
100	0.0000	0.0000
110	0.0000	0.0000
120	0.0000	0.0000
130	0.0000	0.0000
140	0.0000	0.0000
150	0.0000	0.0001
160	0.0001	0.0004
170	0.0002	0.0019
180	0.0007	0.0066
190	0.0017	0.0186
200	0.0032	0.0434
210	0.0053	0.0868
220	0.0076	0.1524
230	0.0096	0.2398
240	0.0110	0.3441
250	0.0114	0.4567
260	0.0109	0.5685
270	0.0097	0.6712
280	0.0081	0.7593
290	0.0063	0.8305
300	0.0047	0.8849

Species 19.

General	**Spp 19**
Initial abundance	10000
Mean growth (r)	0.001
Variance in r	0.15

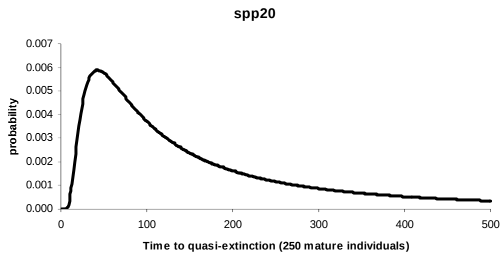


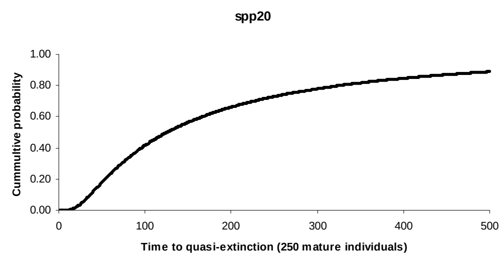


Year	PDF	CDF
0	0.0000	0.0000
10	0.0048	0.0166
20	0.0076	0.0858
30	0.0068	0.1581
40	0.0057	0.2198
50	0.0047	0.2709
60	0.0040	0.3136
70	0.0034	0.3498
80	0.0029	0.3809
90	0.0025	0.4079
100	0.0022	0.4316
110	0.0020	0.4526
120	0.0018	0.4714
130	0.0016	0.4884
140	0.0015	0.5038
150	0.0013	0.5178
160	0.0012	0.5307
170	0.0011	0.5425
180	0.0011	0.5535
190	0.0010	0.5637
200	0.0009	0.5732
210	0.0009	0.5821
220	0.0008	0.5904
230	0.0008	0.5982
240	0.0007	0.6056
250	0.0007	0.6125
260	0.0006	0.6191
270	0.0006	0.6254
280	0.0006	0.6313
290	0.0006	0.6369
300	0.0005	0.6423

Species 20.

General	**Spp 20**
Initial abundance	5000
Mean growth (r)	-0.01
Variance in r	0.04





Year	PDF	CDF
0	0.0000	0.0000
10	0.0003	0.0007
20	0.0032	0.0191
30	0.0053	0.0641
40	0.0059	0.1208
50	0.0058	0.1792
60	0.0054	0.2350
70	0.0050	0.2866
80	0.0045	0.3337
90	0.0041	0.3765
100	0.0037	0.4153
110	0.0034	0.4506
120	0.0031	0.4827
130	0.0028	0.5120
140	0.0026	0.5388
150	0.0024	0.5634
160	0.0022	0.5861
170	0.0020	0.6070
180	0.0019	0.6263
190	0.0017	0.6443
200	0.0016	0.6609
210	0.0015	0.6765
220	0.0014	0.6910
230	0.0013	0.7045
240	0.0012	0.7172
250	0.0012	0.7292
260	0.0011	0.7404
270	0.0010	0.7509
280	0.0010	0.7609
290	0.0009	0.7703
300	0.0009	0.7792

Appendix 6. Elicitation of the value of extinction through time

PTWG members Cochrane, Maguire, Thompson, and Regan did a separate study to elicit policy parameters that could be used in developing quantitative listing criteria using performance testing. We studied biologists' assessments of species "endangerment" based on quantitative depictions of extinction risk, mostly graphs of extinction probability by time and expressions of concern about extinction based on its timing. This appendix summarizes the exercises conducted to elicit extinction time loss functions for performance testing and explains how the elicitation was used in Phase 1. The complete study and much more detailed discussion are presented in a separate report (Cochrane et al. in prep).

Selection of Subjects for Interviews

When requesting this study, the Performance Testing Working Group (PTWG; successor to the Quantitative Working Group) determined that "participants should be people who are familiar with graphs of time to extinction, extinction dynamics generally, and the purpose and practices of the ESA (e.g., PTWG members, other experienced agency staff, and other ecological modelers)" (December 2006 meeting notes). Thus we sought to conduct interviews with a sample of biologists (hereafter referred to as "subjects") meeting these criteria, drawn from both NOAA and the Department of the Interior (both FWS and the agency's research partner, the USGS Biological Research Division), and a few biologists from outside these agencies. We also attempted to diversify the sample to biologists who work in different roles, both research and management, and with different life history groups—beyond the marine and vertebrate biologists who predominate in the PTWG, to include at least some professionals with primary experience in botany or invertebrate biology. Otherwise, selection of subjects was determined primarily by availability for interviews during travels arranged on a limited budget.

Interview Protocol

Interviews were conducted one-on-one between the interviewer (JC or TR) and each subject. We began each interview with a brief introduction to the project, emphasizing the purpose of the study and methodology. Then structured techniques were used to elicit directly the subject's value and utility functions[2] (Keeney and Raiffa 1976) for extinction risk without reference to actual species case examples.

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[2] Value functions quantify a person's relative degree of concern or caring associated with a variable, in our case with species extinction occurring with certainty at a particular future time. Utility functions are similar to value functions, but describe level of concern under uncertainty, in this case extinction occurring at some uncertain time in the future. Both values and utilities are typically expressed on 0-1 scales (representing the lowest to highest or 0-100% potential value or utility). The endpoints of the scale

We elicited each subject's value function for extinction time (task 3; tasks 1-2 are described in Cochrane et al. and do not pertain to the loss function elicitation) by asking directly for the time from present when the subject would be most and least "upset" about extinction, then for the time the subject would value "nearly" as much or little as those extreme times (5% and 95% values) and finally bisection of the endpoints to elicit three intermediate values (50%, then 27.5% and 72.5% values) (Goodwin and Wright 2004:37-38). To help the subject express his or her values or "degree of satisfaction" in this context, we described the time of highest value as far enough out where concern about extinction at that distant time is low enough, whether it is 500 or 100 or more than 100,000 years from now, that if we changed the time of extinction to an even later time—say 10 or 50 or even 100 years later—the response would be that the later time of extinction really doesn't seem any different or better. So the 100% value time was the point in the future where concern is about as low as it will go (conversely, "satisfaction" or value is about as high as it will go or 100%), such that adding additional years doesn't improve the reaction. Task 3 was completed without any references to particular species, graphs, or predetermined timelines; the subjects chose their extinction year answers "out of their heads." The key assumption in this task is that extinction is <u>certain</u> at the year given.

In task 4, we elicited each subject's utility functions for extinction time, or how the subject's relative reaction to hypothetical future extinction events improves with increasing time from the present under the assumption that extinction timing is <u>uncertain</u>. Utility functions describe subjects' risk attitudes, reflecting subjects' aversion to the possibility that an uncertain extinction time could be very short or, conversely, subjects' attraction to the possibility that an uncertain extinction time could be very far in the future. We employed standard utility elicitation or "lottery" methods that ask questions as choices involving gambles. Subjects were asked to choose which of two options was more acceptable (less concern) to them ("preference comparison" Farquhar 1984:1288): either a 50:50 gamble between two extinction times or a certain time of extinction in between the other two. We began by using the subject's 5% and 95% value extinction times from task 3 for the 50:50 gamble and a time approximately midway between those anchors for the choice of a certain extinction time. For example, a subject with 10 and 200 years as their 5% and 95% values would be asked, "Would you prefer a 50:50 (equal probability) gamble of extinction at 10 years or 200 years, or certain extinction at 100 years? In other words, if you chose the gamble, the species has a 50% chance it will go extinct in 10 years otherwise it will persist all the way to 200 years, the time you have said your concern about extinction becomes minimal. Alternately, you may prefer the certainty, where the species is 'for sure' extinct at 100 years."

After the subject stated a preference, we followed with a new lottery question that moved the certain time until the subject could not express a preference between the

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refer to most and least satisfaction felt by the respondent, for the array of possible outcomes they are considering. Thus the 0-1 ratings are relative to the particular outcomes and may not transfer to different situations.

gamble and the certain time.[3] This "indifference point" (Farquhar 1984:1289) represents the extinction time for the utility or relative degree of concern/satisfaction being elicited. After finding the indifference point between the 5% and 95% utility extinction times, which represents 50% utility, we repeated the exercise to elicit two approximately quartile utilities with bisection between the 50% and 5%/95% extinction times.[4] Thus, the experimental design used a "chained" sequence of 50:50 lottery questions with the set of times offered in each lottery based on the response to the previous question, as follows: 1) extinction time at 5% utility, 2) extinction time at 95% utility, 3) extinction time at 50% utility, 4) extinction time at 72.5 % utility, and 5) extinction time at 27.5% utility.

Analytical methods

Thompson developed the analytical methods to put results of the elicitation exercise into a decision theory framework. A new method (Theory of Extinction Risk, Thompson et al. in prep.) frames the loss function with two parameters: the time discount rate and the risk aversion rate. Responses to task 3 were used to estimate these two parameters in a hierarchical Bayesian analysis. Assumptions in the analysis were: 1) discount function parameters were log transformed ($\chi \equiv$ (ln(discount rate), $\gamma \equiv$ -ln(1 – relative risk aversion), 2) parameters of individual discount functions were drawn from bivariate normal priors, 3) "hyperparameters" of the joint distribution were drawn from normal "hyperpriors" (means were not transformed, variances were log transformed, and correlation was logit transformed).

Results

Results from tasks 3 and 4 are illustrated as extinction time value and utility curves, respectively, in Figure 10 and Figure 11. The complete report of this elicitation documents that some of the variation in answers provided by the subjects likely reflect true differences in reactions to extinction, while some may be due to subjects interpreting the tasks differently. Of the responses to task 4, Thompson used 12 that were complete and collected under the same protocol to estimate the candidate loss function for performance testing.

[3] If they chose the gamble, we moved the certain time higher; if they chose the certain time, we moved it lower.

[4] In a few interviews we used the 0-100% value times for anchors in task 4, but for most of the interviews we anchored the bisection questions on the 5%-95% values to avoid issues about the exact meaning of 0 and 100% value or utility. Thus in most interviews, the quartiles were 22.5-72.5% utilities, rather than 25-75%, while the central value was always 50%.

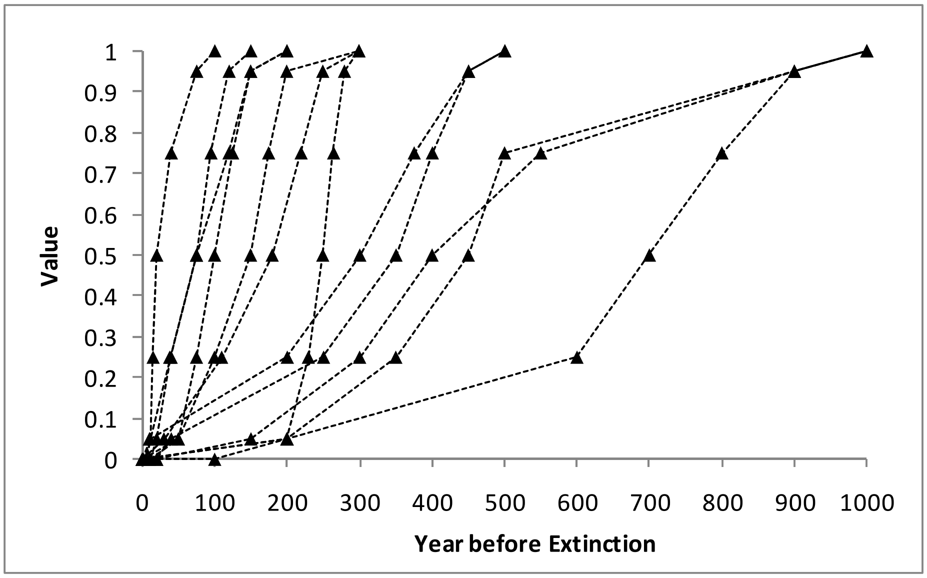

Figure 10. Value of time before extinction when extinction time is certain from task 3, for the 12 interview subjects used for the candidate loss function calculation. Data points are shown for the 0, 5, 25, 50, 75, 95, and 100% values, connected by dashed lines for each subject.

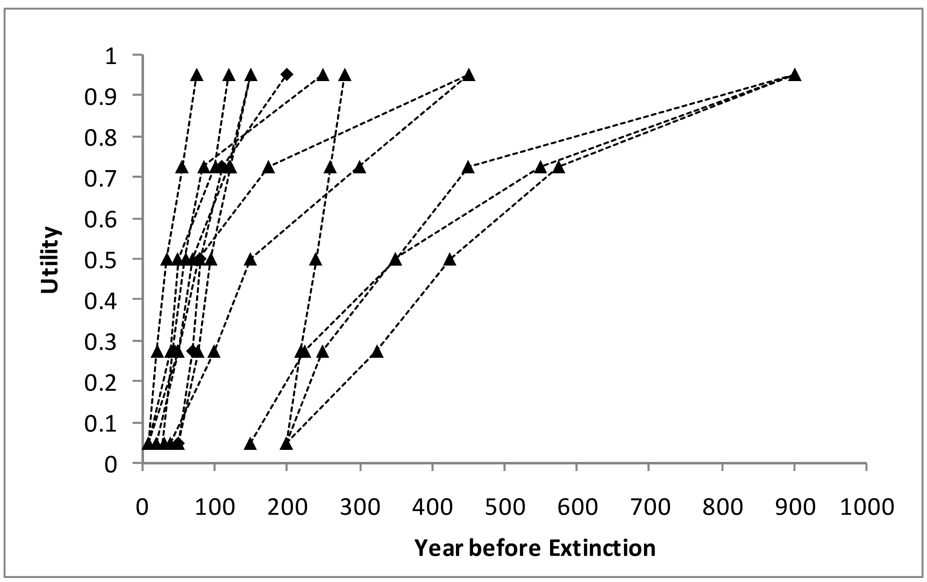

Figure 11. Utility of time before extinction when extinction time is uncertain, for the 12 interview subjects used for the candidate loss function calculation. Data points are shown for the 5 and 95% values (from task 3) and the 27.5, 50, and 72.5% utilities (from task 4), connected by dashed lines for each subject.

Goodness of fit for the 5 points and the 12 respondents was very good (R^2 = 0.95, Figure 12Figure 12). Discount rate ranged from 0.0053 to 0.356 and risk aversion ranged from -8.62 to -0.293. Parameters of the joint distribution were: mean discount rate = 0.0178, standard deviation of discount rate = 0.0147, mean relative risk aversion = -4.25, standard deviation of relative risk aversion = 3.97, and correlation between discount rate and relative risk aversion = -0.223. Mean rates were used in the shoulder function in performance testing.

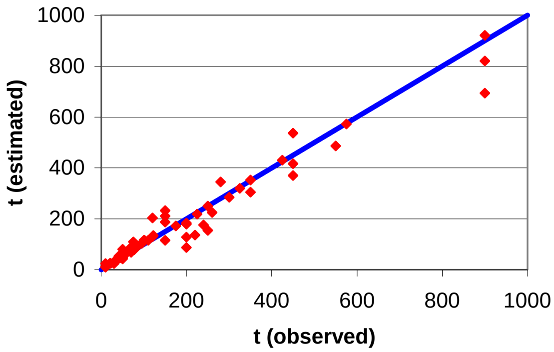

Figure 12. Goodness of fit for the 12 subjects used in analysis of task 4.

Discussion

One of the purposes of this study was to identify one or more candidate loss functions to use in performance testing of quantitative listing criteria, in combination with the threatened and endangered species classification cutoff values elicited in a separate exercise (see main report). We found the extinction time value and utility elicitations to be sensitive to question framing and assumptions. Lack of familiarity with the experimental presentation, combined with minimal feedback or time for serious analysis and reflection, likely contributed to part of the variation in quantitative results. Some of the variation among answers could be reduced by adjusting the methodology, allowing more preparation and learning in repeated elicitations, and also by clarifying the decision context, policy constraints, and definitions involved. Yet some differences in valuing among even similarly-employed biologists are real; science does not tell us how protective to be. Scientists hold distinct preferences, based only in part on their biological training and experience.

Appendix 7. Technical documentation of simulations.

The three alternative decision criteria are evaluated using a procedure that we refer to as performance testing, cached within a decision theory context. This framework allows the investigation of the impact of different levels of uncertainties inherent in the decision making process by quantifying their affect on the performance of alternative decision options (Harwood & Stokes 2003). This type of framework has been used in evaluating alternative management strategies in fisheries management (Cooke 1999; Punt & Smith 1999), for developing management procedures for marine mammals (Cooke 1995; Taylor et al. 2000), for evaluating model uncertainty when classifying species at risk (Taylor 1995) and for testing the impact of observation errors on extinction risk estimates (Taylor et al. 2002; Meir & Fagan 2000).

The framework involves simulating the underlying biological processes of interest. In this instance our challenge simulations form our reality (i.e. the perfect world) and the time to extinction is the biological quantity of interest. We employ a virtual ecologist who lives in an uncertain world where she does not know the true fate of the species (i.e., the true extinction time) but instead collects and analyzes data and makes an inference on the fate of the species. This allows a comparison between the true fate of the species and the estimated fate[5], and the level of protection each decision alternative would assign in these two situations. Performance evaluation can be done by analyzing the proportion of correct and incorrect decisions for each of the OADs and by the weighting of the different types of misclassifications (i.e. over-protection errors versus under-protection errors (Figure 13)), where a decision is defined to be "correct" if it matches the decision that would be made in the special case where process uncertainty is the only form of uncertainty present and "incorrect" otherwise.

[5] There is actually only one true fate for each species, in this case one true time that it goes extinct. What is compared here is not that one true fate, but the distribution of possible fates given uncertainty about random birth and death events and random changes in the environment in the future as represented by the process error in the model. Thus, when we refer to the "true future fate" we mean the suite of fates given known and statistically described uncertainties in the species' future (random processes of birth, death and changes in the biotic and abiotic environments).

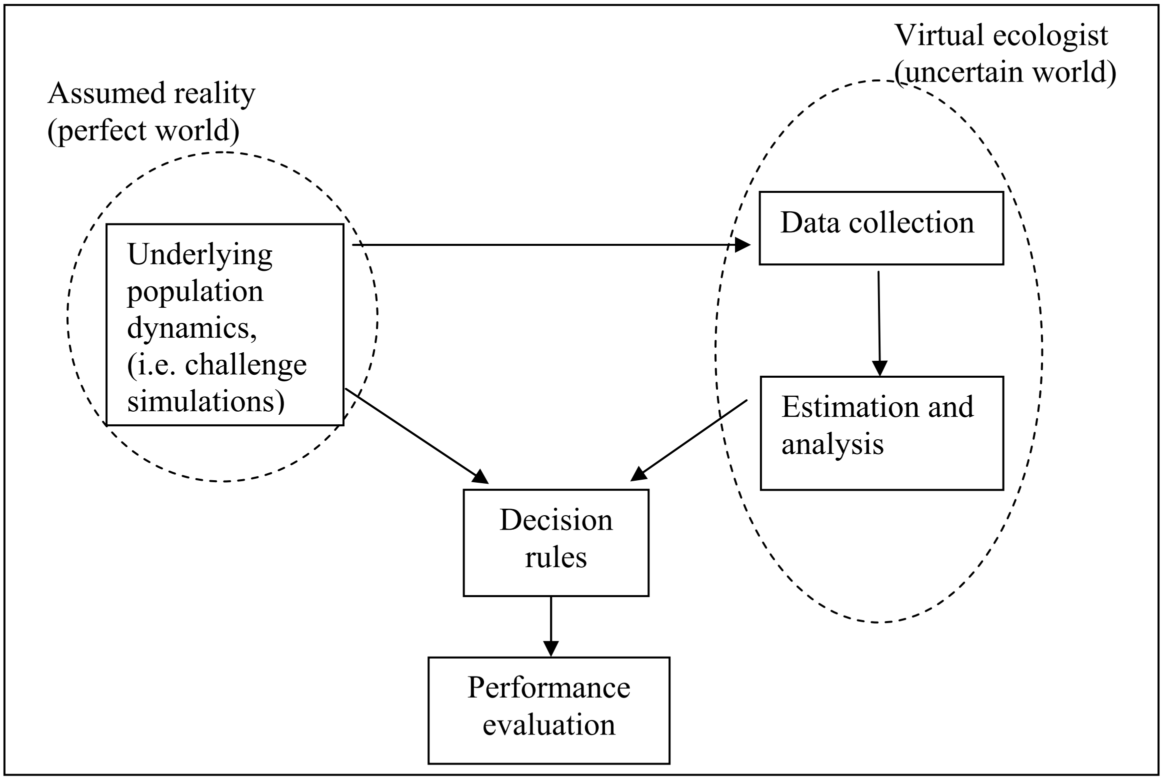

Figure 13: Schematic of the performance testing framework including the assumed reality, the virtual ecologist, the decision rules and the performance evaluation.

The specific steps involved in the performance testing of the challenge simulations are outlined below through a simple example.

Step 1: Define Universe of challenge simulations.

This involved defining probability distributions that make up the challenge cases for the three parameters of interest; growth rate, standard deviation of the growth rate due to process error, and the population size (Figure 14). These challenge cases were chosen within the range of plausible petitions to list but in a narrower challenging range to emphasize performance differences between the OADs. A random sample from each of these distributions represents a species within our universe of challenge cases. These parameters are combined in a simple stochastic population model that simulates population dynamics of species and results in a probability density function of the time to extinction (Eq 2).

$$N_{t+1} = N_t e^{(r+z)}, \quad \textit{where } z \sim N(0, \sigma_p) \qquad (2)$$

Where N_t is the population size at time t; r is the intrinsic rate of population growth, and σ_p is the standard deviation of the process error term, z.

When combined with the alternative listing criteria these distributions result in classifications that range from endangered (EN) to not warranted (NW). The proportion of cases in each threat category under each of the OADs is outlined in Table 21. Not all cases result in identical listings across the alternative OAD's. Table 22,Table 23, and Table 24 compare listings under each of the different OADs and for the different definitions of extinction (absolute, NE = 50 and NE = 250). For example, according to Table 22, of the cases that were listed as EN using the threshold rule and assuming absolute extinction, 98% were listed as EN and 2% were listed as TH when the shoulder rule was used.

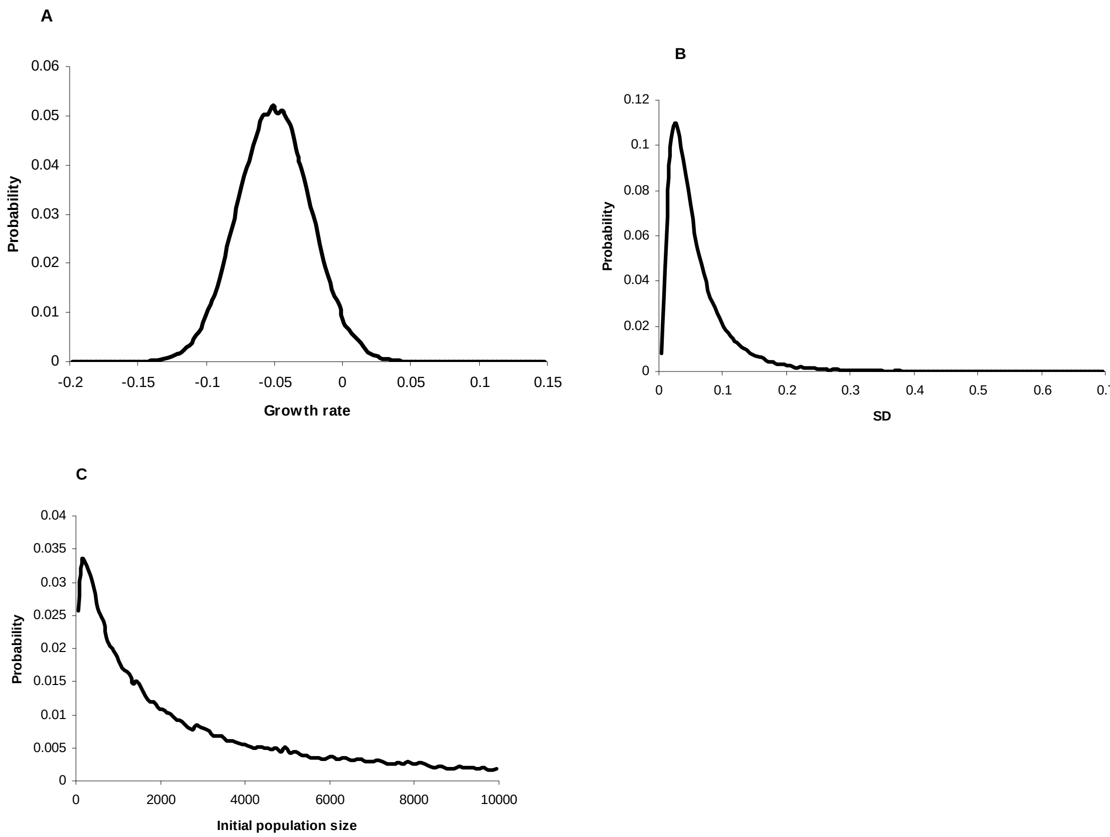

Figure 14: Probability distributions that form the challenge cases for performance testing: a) growth rate, b) standard deviation of the growth rate due to process error, and c) Initial population size.

Table 21: The proportion of challenge cases in each of the threat categories for each of the functional forms and for the different extinction definition types.

Type		EN	TH	NW
E = 0	Step	0.20	0.35	0.45
	Shoulder	0.24	0.37	0.40
	Concave	0.27	0.37	0.36
NE = 50	Step	0.25	0.32	0.43
	Shoulder	0.39	0.29	0.32
	Concave	0.22	0.38	0.40
NE = 250	Step	0.34	0.20	0.46
	Shoulder	0.27	0.31	0.43
	Concave	0.33	0.26	0.42

Table 22: Comparison of OAD listings for the Universe of challenge cases using absolute extinction.

		Threshold		
Shoulder		EN	TH	NW
	EN	0.98	0.54	0.00
	TH	0.02	0.44	0.35
	NW	0.00	0.02	0.65
		Threshold		
Concave		EN	TH	NW
	EN	0.98	0.25	0.00
	TH	0.02	0.72	0.29
	NW	0.00	0.03	0.71
		Shoulder		
Concave		EN	TH	NW
	EN	0.82	0.01	0.01
	TH	0.18	0.92	0.00
	NW	0.00	0.06	0.99

Table 23: Comparison of OAD listings for the Universe of challenge cases using near-extinction of 50 mature individuals.

Threshold				
Shoulder		EN	TH	NW
	EN	0.96	0.47	0.00
	TH	0.03	0.51	0.28
	NW	0.00	0.02	0.72
Threshold				
Concave		EN	TH	NW
	EN	0.87	0.01	0.00
	TH	0.13	0.95	0.10
	NW	0.00	0.04	0.90
Shoulder				
Concave		EN	TH	NW
	EN	0.56	0.01	0.00
	TH	0.44	0.70	0.01
	NW	0.00	0.29	0.99

Table 24. Comparison of OAD listings for the Universe of challenge cases using near-extinction of 250 mature individuals.

Threshold				
Shoulder		EN	TH	NW
	EN	0.82	0.07	0.00
	TH	0.18	0.78	0.13
	NW	0.00	0.15	0.87
Threshold				
Concave		EN	TH	NW
	EN	0.99	0.14	0.00
	TH	0.01	0.78	0.10
	NW	0.00	0.08	0.90
Shoulder				
Concave		EN	TH	NW
	EN	1.00	0.22	0.00
	TH	0.00	0.74	0.05
	NW	0.00	0.04	0.95

Step 2: Select a species from the universe:
A random variable is selected from each of the three probability distributions. This three parameter combination represents a species within our challenge cases. For our example: we randomly select the following values from our Universe:
$N_0 = 1405$, $r = -0.047$, $\sigma = 0.084$.

Step 3: Perfect world: Population viability analysis.

In the perfect world the values of the parameters selected from the universe are known without any error. These parameters are used in a population viability analysis model with the underlying structure of Eq 2. The model is iterated 10,000 times over a 500 year period to produce a probability density function for the time to extinction. This probability density function represents the true future fate of the species (Figure 15, see comments in footnote 5 to see the context of "true future fate").

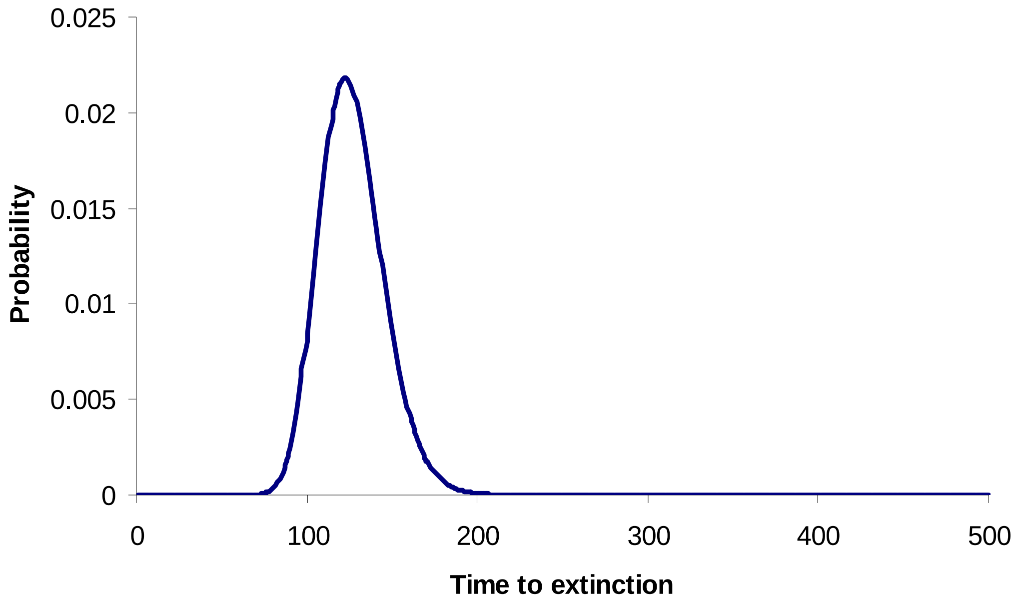

Figure 15: Probability density function for the true fate of the species when the true parameter values are known. Underlying parameters: N_0 = 2000, *r* =-0.06, σ = 0.1

Step 4: Uncertain world, Data Collection:

Unlike the perfect world, in the uncertain world the same set of parameters values selected from the universe are not known with any certainty. Instead the virtual ecologist collects data over time. This is done by generating time series data of population sizes of different quantities and qualities. One trajectory is generated that is conditional on the true parameter values and that would result in an ending population size that matches the true population size (which then becomes the initial population size for the PVA simulation). Lognormally distributed observation error is then applied to the time series data. The distribution from which individual observation errors are drawn is assumed to have a known CV (estimated from abundance surveys). Four scenarios for data collection were used in the performance testing with varying data quantity and quality.

High quantity /high precision: 20 years of time series of population sizes with CV=0.1
Low quantity/high precision: 4 observations at year 11, 14, 17 and 20 with CV=0.1
High quantity/low precision: 20 years of time series of population sizes with CV=0.8
Low quantity/low precision: 4 observations at year 11, 14, 17 and 20 with CV=0.1

Sample trajectories for each are shown in Figure 16Figure 17 and Figure 17.

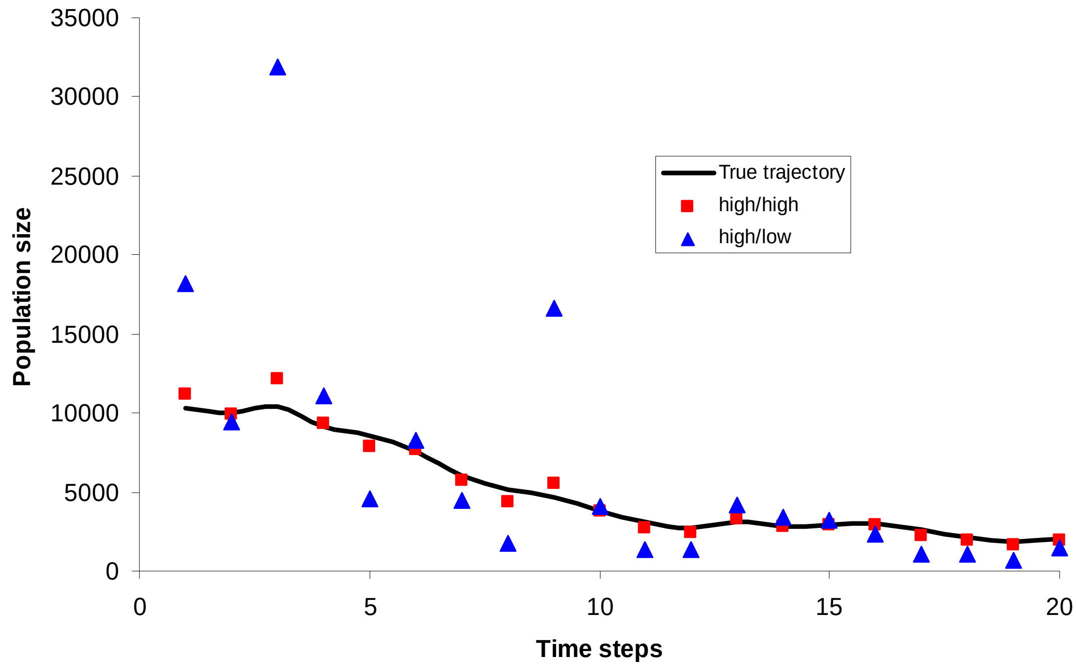

Figure 16. Example of data generation for the high/high case (red squares) and the high/low case (blue triangles). Black line is the true trajectory.

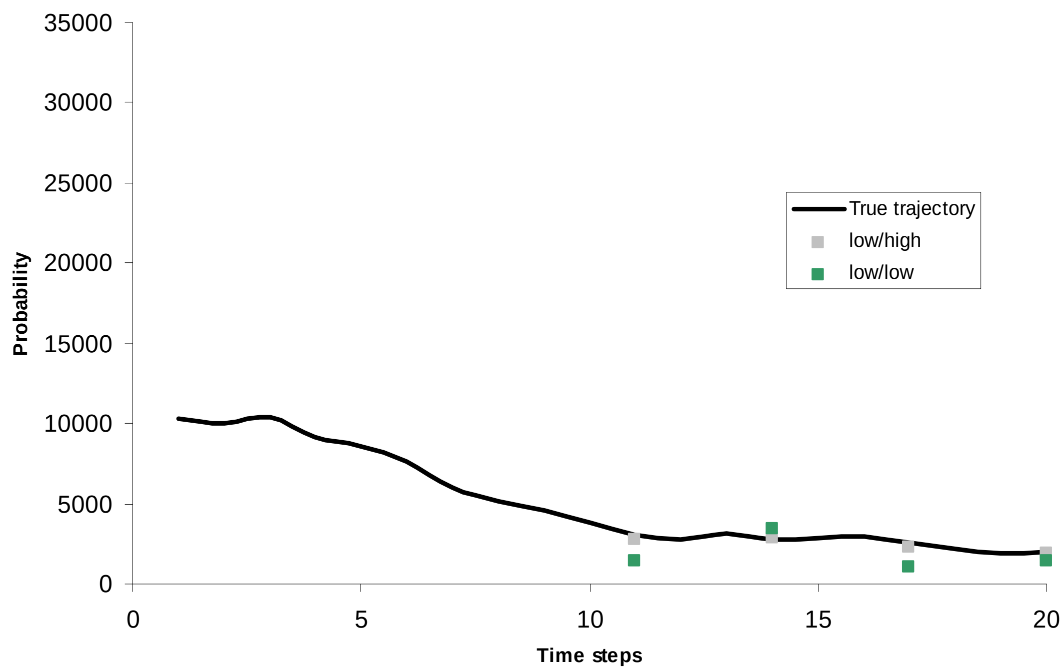

Figure 17. Example of data generation for the low/high case (gray squares) and the low/low case (green squares). Black line is the true trajectory.

Step 5: Uncertain world: Parameter Estimation:

In the uncertain world we only have data to estimate the parameters of interest. Mean growth rate, standard deviation of the process error and the current population size are estimated using Bayesian analysis. The parameter estimation is done using software created by D. Goodman (http://www.esg.montana.edu/). We use the SWLB program shell that is the SWL shell but for batches. The program shell manages Bayesian inference for a small number of parameters using an algorithm that samples the prior by direct simulation with calls to random number generators, and then weights each sampled set of values of parameters by their likelihood, cumulating histograms and posterior summaries of the sampled parameter values weighted accordingly.. This analysis requires determination of a prior for each of the parameters and a likelihood function. The priors used for each of the parameters are the same as the universe (Figure 14). The data have two types of error incorporated, process error (i.e. random natural variation or environmental stochasticity) and observation error (i.e. error due to random sampling strategy). To account for both process error and observation error we use a Kalman filter (described in detail in Appendix 8). This procedure, while not a full state space model, approximates a full state space model and works within the limitations of the software.

Figure 198, Figure 209, Figure 21 and Figure 21 illustrate the posterior distributions of the growth rate, standard deviation of the growth rate due to process error, and the current population size under the four different sampling strategies.

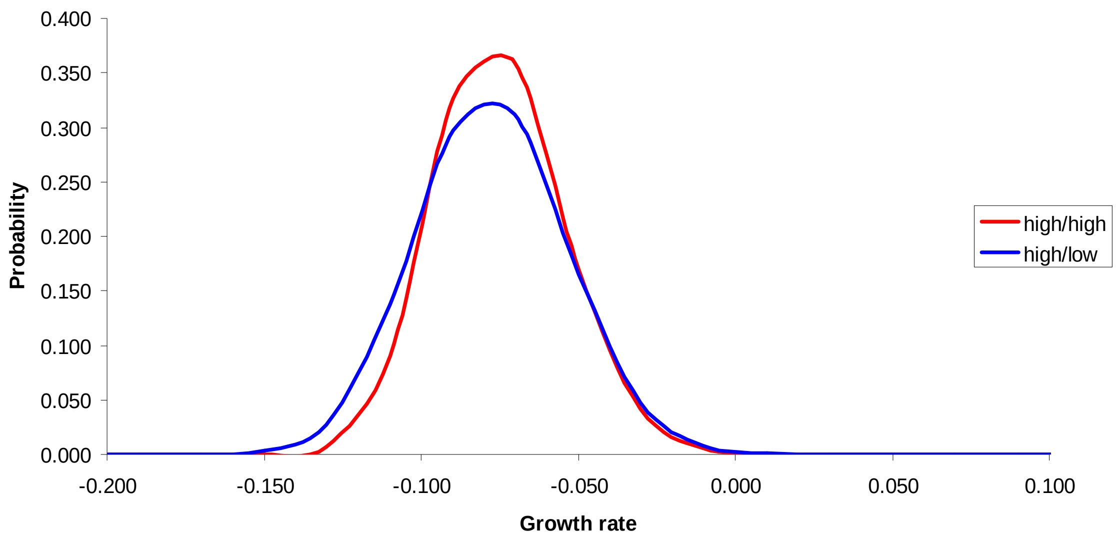

Figure 18. Posterior distributions of the mean growth rate for the high/high and high/low data cases.

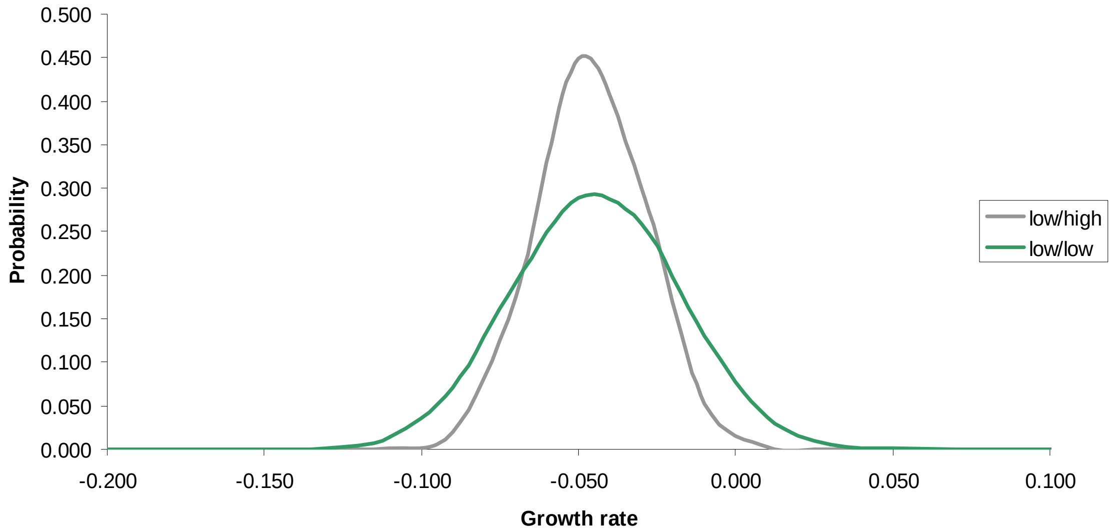

Figure 19. Posterior distributions of the mean growth rate for the low/high and low/low data cases.

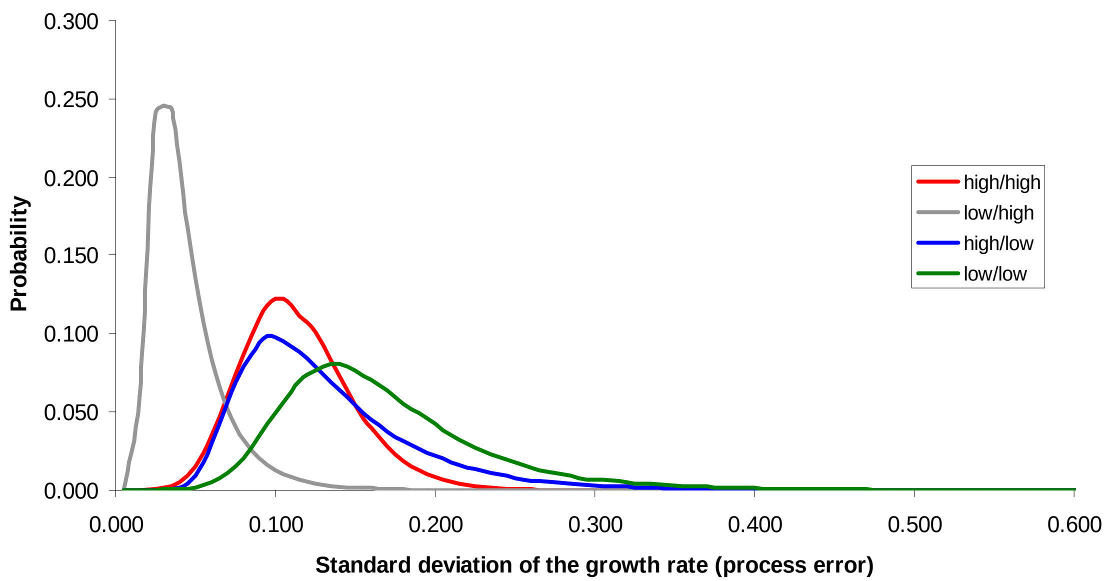

Figure 20. The posterior distributions of the standard deviation of the growth rate (i.e. process error) for each of the different sampling strategies.

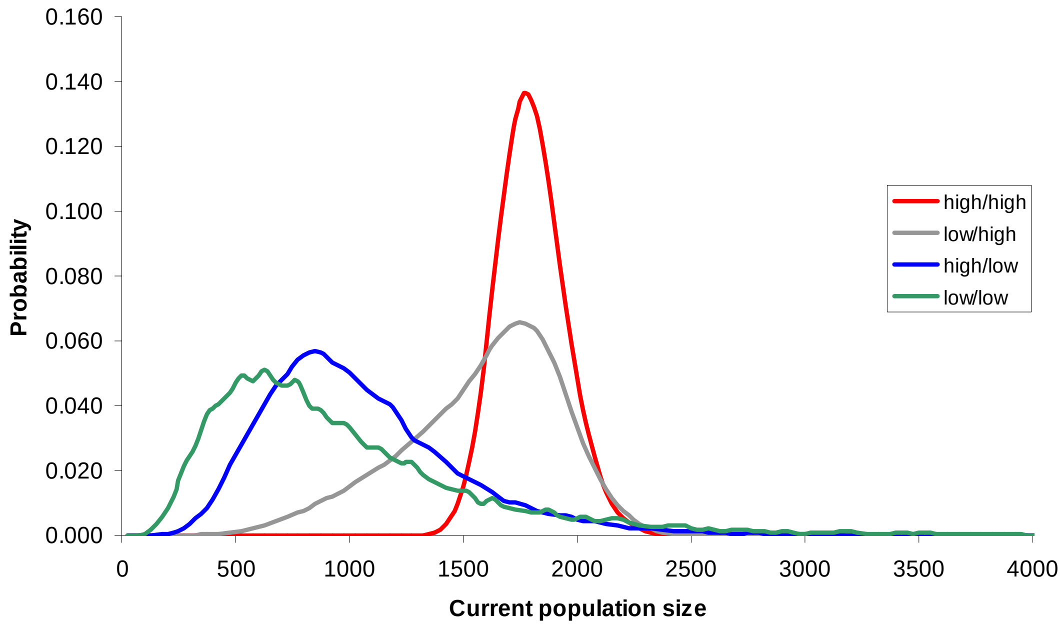

Figure 21. The posterior distributions of the current population size for each of the different sampling strategies.

Step 6: Population Viability Analysis:

We employ a Bayesian population viability analysis assuming the same model structure as Eq 2 . This is easily done in the software by calculating a derived parameter from the weighted set of sampled values: r and σ_p and N_0. The derived parameter in this case is the time to extinction where extinction is defined when the population is $N_t \leq 1$. Results are summarized in a probability distribution of time to extinction and incorporate all the parameter uncertainty reflected in the data. This type of PVA, is not common in the PVA literature but has been advocated by several authors when using PVAs for classifying species as it incorporates the parameter uncertainty directly into the probability distribution of time to extinction rather than using point estimates and performing sensitivity analysis (Taylor 1995; Taylor *et al.* 1996; Taylor *et al.* 2002; Wade 2002; Goodman 2002).

The distributions of time to extinction based on the inferences for growth rate, process error, and population size for the four sampling strategies are illustrated in Figure 22.

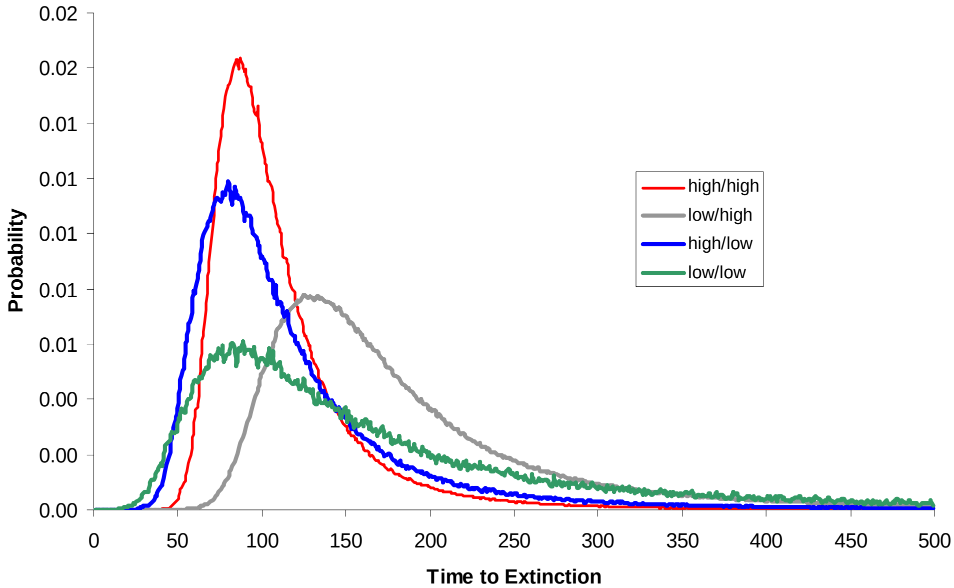

Figure 22. Time to extinction curves based on the inferences for each of the data sampling strategies.

Step 7: Apply Decision Criteria; Compare decision under the perfect world with decision in the uncertain world:

The risk of extinction under the alternative OADs (called Risk) is calculated by multiplying the time to extinction pdf with the loss functions and summing over time (Figure 23Figure 23). The decision rules are then applied to determine the threat category (Table 25). This is done for the perfect world and then compared to the threat categories corresponding to the different sampling strategies in the uncertain world (Table 26). For our example, in the perfect world the species would be listed as threatened (TH) under all the OAD decision rules. In the uncertain world the species is correctly listed in the high/low and low/low data cases for the step and the shoulder decision rules. For all other sampling strategies and for the concave function the species is listed as EN.

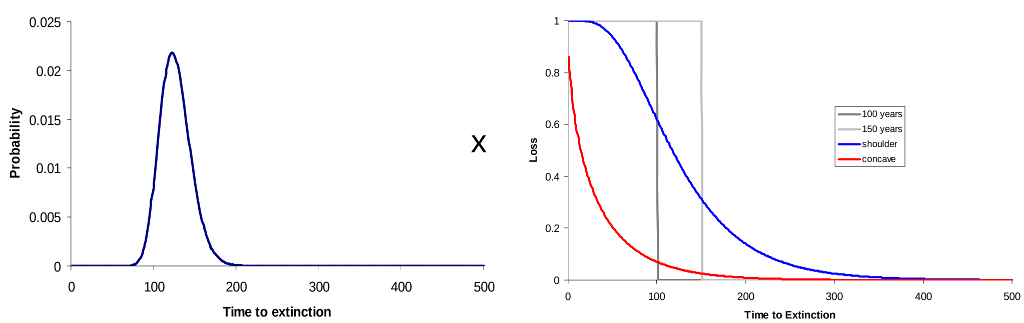

Figure 23. Risk is calculated by multiplying the pdf of time to extinction with the loss functions associated with each of the OADs.

Table 25. Decision rules for the alternative OADs and types of extinction where E = Extinction and NE = near-extinction expressed in units of mature individuals.

Category	Type	Step function (OAD1)	Shoulder function (OAD3)	Concave function (OAD3)
EN	E = 0	0.30 in 100 yrs (0.18-0.37)	0.54 (0.50-0.54)	0.05 (0.05-0.06)
TH	E = 0	0.08 in 150 yrs (0.001-0.010)	0.18 (0.02-0.18)	0.01 (0.001-0.010)
EN	NE = 50	0.10 in 50 years (0.1-0.4)	0.68 (0.58-0.68)	0.17 (0.08-0.17)
TH	NE = 50	0.05 in 100 years (0.01-0.12)	0.20 (0.1-0.2)	0.03 (0.02-0.03)
EN	NE = 250	0.28 in 50 years (0.28-0.62)	0.86 (0.83-0.94)	0.14 (0.13-0.22)
TH	NE = 250	0.02 in 100 years (0.02-0.42)	0.21 (0.17-0.44)	0.02 (0.02-0.08)

Table 26. Comparison of risk categories for the different sampling strategies with the truth (see definition in footnote 5). The true category using the decision rules (listing criteria) in Table 25 is TH for the Step, Shoulder and Concave criteria and is shown in bold. Data scenarios the got the correct estimated category are similarly listed in bold.

	Step 100yrs	Step 150 yrs	Shoulder	Concave
True Risk	0.07	**0.89 (TH)**	**0.45 (TH)**	**0.04 (TH)**
high/high	0.52 (EN)	0.87	0.58 (EN)	0.07 (EN)
low/high	0.07	**0.42 (TH)**	**0.28 (TH)**	**0.03 (TH)**
high/low	0.51 (EN)	0.80	0.56 (EN)	0.08 (EN)
low/low	0.29	**0.52 (TH)**	**0.38 (TH)**	0.05 (EN)

Step 8: Tabulate decisions:

The example outlined here is for one possible situation from the universe and one scenario for each of the data sampling strategies. In this case, the high/high data scenario decision table would tally a misclassification error (EN instead of TH) for each listing criterion (Step, Shoulder and Concave). The low/high data scenario decision table would tally correct classifications for the Step and Shoulder criteria (TH), but a misclassification error for the Concave criterion (EN instead of TH). We repeat steps 2 – 7 at least 5000 times to get a comprehensive sample of the universe and the data generation possibilities. The correct and incorrect decisions are then tabulated (See Appendix 9).

Performance testing of each of the consensus species was done in a similar fashion, although we did not use the same priors. Instead we used broad vague priors where the likelihood was non-negligible (Figure 7body of this Report).

Appendix 8. Explanation of the Kalman filter

Introduction

The dynamics of natural populations pose daunting statistical problems. One of these is that both process error and measurement error are almost always present. That is, equations of population dynamics at best describe some sort of central tendency around which the true population fluctuates stochastically (process error), and true population abundance is inevitably measured with some degree of imprecision (measurement error). In principle, both process error and measurement error can be incorporated into a "state space" model of population dynamics, but such representations tend to be of high dimension and therefore computationally expensive, with the state of the system (population abundance) at each point in time represented by a parameter in the model. Moreover, in applications such as the one described in this report, all states except the terminal one end up being integrated out of the joint distribution numerically, adding to the computational overhead. Because a large number of simulated population assessments were required in this report, the computational requirements of a full state space model, even a relatively simple one, were prohibitive. Fortunately, the properties of the simple model examined in this report were amenable to the Kalman filter, a technique that preserves the statistical rigor of the full state space model while vastly reducing computational overhead by eliminating the need for numerical integration with respect to the states. The following is an explanation of how the Kalman filter accomplishes this, using a worked example based on the model described in Appendix 7.

Assumptions

Notation here follows that of Appendix 7.

Consider the simple linear-normal system with transition equation

$$x_t = x_{t-1} + r + z_{t-1} \quad ,$$

where x is a scalar state variable representing log population size (where population size, labeled N in Appendix 7, is measured in units of individual organisms), t is time, r is the constant intrinsic rate of population growth, and z is a normally distributed process error term with mean zero and standard deviation σ_p; and observation equation

$$y_t = x_t + w_t \quad ,$$

where y is the observed value of x and w is a normally distributed measurement error term with mean zero and standard deviation σ_m.

To develop a simple example, let t range from 0 to 3, and let $r=-0.15$, $\sigma_p=1$, $\sigma_m=0.5$, and $x_0=10$. Possible realizations for the error vectors are $z=\{0.390,0.418,-1.822\}$ for $t=\{0,1,2\}$ (no z value is needed for $t=3$) and $w=\{-0.754,-0.128,-0.358,0.347\}$ for $t=\{0,1,2,3\}$.

By the above equations, these values give x={10.000,10.240,10.508,8.536} and y={9.246,10.112,10.150,8.883}, respectively.

For simplicity, assume that the value of σ_m is known, and assume "guess" values for the other parameters and states equal to 90% of their respective true values, giving r=−0.135, σ_p=0.9, and x={9.000,9.216,9.457,7.682}.

Full state space log likelihood

The observation error pdf may be written

$$f\left(y_t, x_t \mid \sigma_m\right) = \sqrt{\frac{1}{2\pi}} \cdot \left(\frac{1}{\sigma_m}\right) \cdot \exp\left(-\frac{1}{2} \cdot \left(\frac{y_t - x_t}{\sigma_m}\right)^2\right) \quad ,$$

and the transition error pdf may be written

$$g\left(x_t, x_{t-1} \mid r, \sigma_p\right) = \sqrt{\frac{1}{2\pi}} \cdot \left(\frac{1}{\sigma_p}\right) \cdot \exp\left(-\frac{1}{2} \cdot \left(\frac{x_t - \left(x_{t-1} + r\right)}{\sigma_p}\right)^2\right) \quad .$$

The log likelihood for the full state space model at time t=1,2,3 may thus be written as

$$\begin{aligned} L_1\left(r, \sigma_p, \sigma_m, x_0, x_1\right) = {} & \ln\left(f\left(y_0, x_0 \mid \sigma_m\right)\right) + \\ & \ln\left(f\left(y_1, x_1 \mid \sigma_m\right)\right) + \ln\left(g\left(x_1, x_0 \mid r, \sigma_p, \sigma_m\right)\right) \quad , \\ L_2\left(r, \sigma_p, \sigma_m, x_0, x_1, x_2\right) = {} & \ln\left(f\left(y_0, x_0 \mid \sigma_m\right)\right) + \\ & \ln\left(f\left(y_1, x_1 \mid \sigma_m\right)\right) + \ln\left(g\left(x_1, x_0 \mid r, \sigma_p, \sigma_m\right)\right) + \\ & \ln\left(f\left(y_2, x_2 \mid \sigma_m\right)\right) + \ln\left(g\left(x_2, x_1 \mid r, \sigma_p, \sigma_m\right)\right) \quad , \quad \text{and} \\ L_3\left(r, \sigma_p, \sigma_m, x_0, x_1, x_2, x_3\right) = {} & \ln\left(f\left(y_0, x_0 \mid \sigma_m\right)\right) + \\ & \ln\left(f\left(y_1, x_1 \mid \sigma_m\right)\right) + \ln\left(g\left(x_1, x_0 \mid r, \sigma_p, \sigma_m\right)\right) + \\ & \ln\left(f\left(y_2, x_2 \mid \sigma_m\right)\right) + \ln\left(g\left(x_2, x_1 \mid r, \sigma_p, \sigma_m\right)\right) + \\ & \ln\left(f\left(y_3, x_3 \mid \sigma_m\right)\right) + \ln\left(g\left(x_3, x_2 \mid r, \sigma_p, \sigma_m\right)\right) \quad . \end{aligned}$$

Note that the likelihood for the full state space model is a function of both parameters and states. Given the guess values of the parameters and states listed above, the values of the log likelihood at t=1,2,3 are −3.068, −5.155, and −10.737, respectively.

Kalman filter log likelihood

The log likelihood for the Kalman filter is built up from the Kalman filter recursions, which are described below.

Initialization of the recursion at t=0 depends on the way the initial state x_0 is interpreted, for which several possibilities exist. In this report, the initial state is interpreted as a parameter. Given this interpretation, the recursion is initialized by evaluating the following equations in the order listed ($\sigma xpri$ and $\mu xpri$ can be thought of as the standard deviation and mean of a normal prior distribution for the state x, σy can be thought of as the standard deviation of a normal distribution for the observation y, and $\sigma xpos$ and $\mu xpos$ can be thought of as the standard deviation and mean of a normal posterior distribution for the state x):

$$\sigma xpri_0 = 0$$

$$\mu xpri_0 = x_0$$

$$\sigma y_0 = \sqrt{\sigma xpri_0^{\,2} + \sigma_m^{\,2}}$$

$$\sigma xpos_0 = \sigma xpri_0 \cdot \sqrt{1 - \left(\frac{\sigma xpri_0}{\sigma y_0}\right)^2}$$

$$\mu xpos_0 = \mu xpri_0 + \left(\frac{\sigma xpri_0}{\sigma y_0}\right)^2 \cdot \left(y_0 - \mu xpri_0\right) \quad .$$

For the remaining time periods t=1,2,3, the recursion proceeds by evaluating the following equations for each time period in the order listed:

$$\sigma xpri_t = \sqrt{\sigma xpos_{t-1}^{\,2} + \sigma_p^{\,2}}$$

$$\mu xpri_t = \mu xpos_{t-1} + r$$

$$\sigma y_t = \sqrt{\sigma xpri_t^{\,2} + \sigma_m^{\,2}}$$

$$\sigma xpos_t = \sigma xpri_t \cdot \sqrt{1 - \left(\frac{\sigma xpri_t}{\sigma y_t}\right)^2}$$

$$\mu xpos_t = \mu xpri_t + \left(\frac{\sigma xpri_t}{\sigma y_t}\right)^2 \cdot \left(y_t - \mu xpri_t\right) \quad .$$

To emphasize the sets of parameters on which $\mu xpri$ and σy depend, these coefficients will be written as functions $\mu xpri(r,\sigma_p,\sigma_m,x_0)$ and $\sigma y(\sigma_p,\sigma_m)$, respectively.

The guess values listed above result in $\mu xpri(r,\sigma_p,\sigma_m,x_0)$={9.000,8.865,9.683,9.922} and $\sigma y(\sigma_p,\sigma_m)$={0.500,1.030,1.118,1.123} for t={0,1,2,3}.

From the above recursions, the log likelihood for the Kalman filter can be written for arbitrary time t=1,2,3 as

$$L_{KF}\left(t \middle| r,\sigma_p,\sigma_m,x_0\right) = -\left(\frac{1}{2}\right)\cdot\sum_{j=0}^{t}\left(\begin{array}{l}\ln(2\pi)+2\cdot\ln\left(\sigma y\left(\sigma_p,\sigma_m\right)_j\right)+\\ \left(\dfrac{y_j-\mu xpri\left(r,\sigma_p,\sigma_m,x_0\right)_j}{\sigma y\left(\sigma_p,\sigma_m\right)_j}\right)^2\end{array}\right) \quad .$$

Comparing the two log likelihoods

The full state space model and the Kalman filter have a simple correspondence, so long as both methods use the same interpretation of the initial state. The central equivalence between the two methods is this: *The Kalman filter likelihood is the same as the marginal likelihood from the full state space model after the states have been integrated out of the joint distribution of parameters and states.*

For t=1, integrating x_1 out of the joint distribution from the full state space model gives a marginal log likelihood equal to the Kalman filter log likelihood evaluated at t=1:

$$\ln\left(\int_{-\infty}^{\infty}\exp\left(L_1\left(r,\sigma_p,\sigma_m,x_0,x_1\right)\right)dx_1\right) = L_{KF}\left(1\middle| r,\sigma_p,\sigma_m,x_0\right) = -2.028 \quad .$$

For t=2, integrating x_1 and x_2 out of the joint distribution from the full state space model gives a marginal log likelihood equal to the Kalman filter log likelihood evaluated at t=2:

$$\ln\left(\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\exp\left(L_2\left(r,\sigma_p,\sigma_m,x_0,x_1,x_2\right)\right)dx_1\,dx_2\right) = L_{KF}\left(2\middle| r,\sigma_p,\sigma_m,x_0\right) = -3.147 \quad .$$

For t=3, integrating x_1, x_2, and x_3 out of the joint distribution from the full state space model gives a marginal log likelihood equal to the Kalman filter log likelihood evaluated at t=3:

$$\ln\left(\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\exp\left(L_3\left(r,\sigma_p,\sigma_m,x_0,x_1,x_2\right)\right)dx_1\,dx_2\,dx_3\right) = L_{KF}\left(3\middle| r,\sigma_p,\sigma_m,x_0\right) = -4.609 \quad .$$

Conclusion

By providing closed-form (i.e., analytic) solutions to the integrations with respect to the states, the Kalman filter provides an efficient alternative to the full state space representation of the model described in Appendix 7.

Appendix 9. Results of Challenge Simulation Performance testing

Decision tables for the challenge simulations. The proportion of correct listings are in bold. The data scenarios have the following data quantity/data quality: high/high—20 annual surveys/CV = 0.1, low/high—4 surveys over 10 years/CV = 0.1, high/low—20 annual surveys/CV = 0.8, low/low 4 surveys over 10 years/CV = 0.8. This is followed by a summary table for the weighted results for the challenge simulations for the 4 weighting tables.

Section 9.1 Results for absolute extinction

Table 27. Decision table for absolute extinction High/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.82**	0.19	0.01
	TH	0.18	**0.77**	0.43
	NW	0.00	0.04	**0.56**
Shoulder function (OAD3)	EN	**0.73**	0.11	0.01
	TH	0.26	**0.78**	0.25
	NW	0.01	0.11	**0.74**
Concave function (OAD3)	EN	**0.81**	0.16	0.01
	TH	0.19	**0.76**	0.29
	NW	0.01	0.08	**0.70**

Table 28. Decision table for absolute extinction Low/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.80**	0.39	0.08
	TH	0.20	**0.59**	0.69
	NW	0.00	0.03	**0.24**
Shoulder function (OAD3)	EN	**0.64**	0.20	0.04
	TH	0.35	**0.69**	0.45
	NW	0.01	0.11	**0.51**
Concave function (OAD3)	EN	**0.78**	0.34	0.07
	TH	0.21	**0.59**	0.53
	NW	0.01	0.07	**0.39**

Table 29. Decision table for absolute extinction High/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.80**	0.39	0.08
	TH	0.20	**0.59**	0.69
	NW	0.00	0.03	**0.24**
Shoulder function (OAD3)	EN	**0.64**	0.20	0.04
	TH	0.35	**0.69**	0.45
	NW	0.01	0.11	**0.51**
Concave function (OAD3)	EN	**0.78**	0.34	0.07
	TH	0.21	**0.59**	0.53
	NW	0.01	0.07	**0.39**

Table 30. Decision table for absolute extinction Low/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.91**	0.78	0.61
	TH	0.09	**0.22**	0.39
	NW	0.00	0.00	**0.00**
Shoulder function (OAD3)	EN	**0.38**	0.15	0.09
	TH	0.62	**0.85**	0.91
	NW	0.00	0.00	**0.00**
Concave function (OAD3)	EN	**0.92**	0.80	0.68
	TH	0.08	**0.20**	0.32
	NW	0.00	0.00	**0.00**

Table 31. Weighted results assuming absolute extinction for the different weighting tables. Best value/listing criteria in bold.

Weighting table type	Listing criteria	High/high	low/high	high/low	low/low
Equal	Step (OAD1)	0.85	1.37	1.72	1.87
	Shoulder (OAD3)	0.74	**1.16**	**1.46**	**1.77**
	Concave (OAD3)	**0.73**	1.24	1.63	1.88
Symmetrical	Step (OAD1)	0.86	1.45	1.84	2.48
	Shoulder (OAD3)	0.76	**1.21**	**1.52**	**1.86**
	Concave (OAD3)	**0.75**	1.31	1.84	2.56
Precautionary	Step (OAD1)	0.54	0.84	1.05	1.29
	Shoulder (OAD3)	0.57	0.85	**1.00**	**1.24**
	Concave (OAD3)	**0.51**	**0.81**	**1.00**	1.32
List v not list	Step (OAD1)	0.51	0.82	0.99	**1.00**
	Shoulder (OAD3)	0.49	**0.74**	**0.88**	**1.00**
	Concave (OAD3)	**0.47**	0.75	0.95	**1.00**

Section 9.2 Results for near-extinction of 50 mature individuals

Table 32. Decision table for NE = 50 and the High/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.90**	0.22	0.01
	TH	0.10	**0.75**	0.38
	NW	0.00	0.03	**0.61**
Shoulder function (OAD3)	EN	**0.78**	0.10	0.01
	TH	0.21	**0.78**	0.22
	NW	0.01	0.13	**0.78**
Concave function (OAD3)	EN	**0.82**	0.07	0.00
	TH	0.17	**0.83**	0.24
	NW	0.00	0.10	**0.76**

Table 33. Decision table for NE = 50 and the Low/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.90**	0.37	0.11
	TH	0.10	**0.61**	0.65
	NW	0.00	0.02	**0.24**
Shoulder function (OAD3)	EN	**0.63**	0.11	0.02
	TH	0.35	**0.78**	0.48
	NW	0.01	0.10	**0.50**
Concave function (OAD3)	EN	**0.71**	0.09	0.03
	TH	0.28	**0.81**	0.42
	NW	0.01	0.10	**0.55**

Table 34. Decision table for NE = 50 and the High/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.94**	0.60	0.37
	TH	0.06	**0.40**	0.62
	NW	0.00	0.00	**0.01**
Shoulder function (OAD3)	EN	**0.47**	0.10	0.06
	TH	0.52	**0.84**	0.81
	NW	0.01	0.05	**0.13**
Concave function (OAD3)	EN	**0.71**	0.16	0.08
	TH	0.29	**0.79**	0.72
	NW	0.00	0.05	**0.19**

Table 35. Decision table for NE = 50 and the Low/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**1.00**	0.88	0.77
	TH	0.00	**0.12**	0.23
	NW	0.00	0.00	**0.00**
Shoulder function (OAD3)	EN	**0.49**	0.16	0.16
	TH	0.51	**0.84**	0.83
	NW	0.00	0.00	**0.00**
Concave function (OAD3)	EN	**0.83**	0.28	0.23
	TH	0.17	**0.72**	0.76
	NW	0.00	0.00	**0.01**

Table 36. Weighted results using NE = 50 for the different weighting tables. Best value/listing criteria in bold.

Weighting table type	Listing criteria	High/high	low/high	high/low	low/low
Equal	Step (OAD1)	0.74	1.24	1.64	1.89
	Shoulder (OAD3)	0.67	1.08	1.55	1.67
	Concave (OAD3)	**0.59**	**0.93**	**1.30**	**1.45**
Symmetrical	Step (OAD1)	0.75	1.36	2.01	2.66
	Shoulder (OAD3)	0.68	1.11	1.62	1.84
	Concave (OAD3)	**0.60**	**0.97**	**1.39**	**1.68**
Precautionary	Step (OAD1)	**0.44**	0.74	1.03	1.33
	Shoulder (OAD3)	0.52	0.80	1.10	1.18
	Concave (OAD3)	**0.44**	**0.68**	**0.86**	**0.93**
List v not list	Step (OAD1)	**0.46**	0.79	0.99	**1.00**
	Shoulder (OAD3)	0.49	0.72	0.99	**1.00**
	Concave (OAD3)	**0.46**	**0.67**	**0.91**	**1.00**

Section 9.3 Results for near-extinction of 250 mature individuals

Table 37. Decision table for NE = 250 and the High/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.88**	0.20	0.01
	TH	0.12	**0.79**	0.54
	NW	0.00	0.01	**0.45**
Shoulder function (OAD3)	EN	**0.68**	0.10	0.01
	TH	0.31	**0.79**	0.25
	NW	0.01	0.11	**0.74**
Concave function (OAD3)	EN	**0.85**	0.18	0.02
	TH	0.14	**0.73**	0.28
	NW	0.00	0.10	**0.71**

Table 38. Decision table for NE = 250 and the Low/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.85**	0.25	0.08
	TH	0.15	**0.74**	0.82
	NW	0.00	0.01	**0.10**
Shoulder function (OAD3)	EN	**0.39**	0.09	0.02
	TH	0.61	**0.80**	0.44
	NW	0.00	0.12	**0.54**
Concave function (OAD3)	EN	**0.78**	0.22	0.08
	TH	0.22	**0.70**	0.49
	NW	0.00	0.09	**0.43**

Table 39. Decision table for NE = 250 and the High/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.90**	0.40	0.25
	TH	0.10	**0.60**	0.75
	NW	0.00	0.00	**0.00**
Shoulder function (OAD3)	EN	**0.28**	0.10	0.03
	TH	0.72	**0.83**	0.77
	NW	0.00	0.07	**0.20**
Concave function (OAD3)	EN	**0.84**	0.31	0.26
	TH	0.16	**0.67**	0.65
	NW	0.00	0.01	**0.09**

Table 40. Decision table for NE = 250 and the Low/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.97**	0.67	0.58
	TH	0.03	**0.33**	0.42
	NW	0.00	0.00	**0.00**
Shoulder function (OAD3)	EN	**0.32**	0.13	0.07
	TH	0.68	**0.86**	0.92
	NW	0.00	0.01	**0.01**
Concave function (OAD3)	EN	**0.94**	0.56	0.56
	TH	0.06	**0.44**	0.44
	NW	0.00	0.00	**0.00**

Table 41. Weighted results using NE = 250 for the different weighting tables. Best value/listing criteria in bold.

Weighting table type	Listing criteria	High/high	low/high	high/low	low/low
Equal	Step (OAD1)	0.88	1.30	1.50	1.70
	Shoulder (OAD3)	0.79	1.28	1.69	1.81
	Concave (OAD3)	**0.71**	**1.09**	**1.40**	**1.62**
Symmetrical	Step (OAD1)	0.89	1.38	1.75	2.28
	Shoulder (OAD3)	0.81	1.30	1.73	**1.88**
	Concave (OAD3)	**0.73**	**1.18**	**1.65**	2.18
Precautionary	Step (OAD1)	0.51	0.77	0.92	1.15
	Shoulder (OAD3)	0.63	1.02	1.26	1.28
	Concave (OAD3)	**0.49**	**0.74**	**0.91**	**1.12**
List v not list	Step (OAD1)	0.57	0.91	1.00	**1.00**
	Shoulder (OAD3)	0.50	**0.70**	**0.93**	1.01
	Concave (OAD3)	**0.49**	0.74	0.94	1.01

Appendix 10. Results of Consensus Species Performance Testing

Decision tables for the consensus species follow. The correct listing category is put in bold. For all the columns for the data scenarios have the data quantity/data quality: high/high—20 annual surveys/CV = 0.1, low/high—4 surveys over 10 years/CV = 0.1, high/low—20 annual surveys/CV = 0.8, low/low 4 surveys over 10 years/CV = 0.8. The species specific results are then followed by a summary table for the weighted results for the 4 weighting tables.

Section 10.1 Results for absolute extinction

Table 42. Species—Herring (EN**) using absolute extinction.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**0.94** 0.06 0.00
Shoulder function (OAD3)	**1.00** 0.00 0.00	**0.97** 0.03 0.00	**0.99** 0.01 0.00	**0.82** 0.18 0.00
Concave function (OAD3)	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**0.96** 0.04 0.00

Table 43. Species—Mudminnow (EN**) using absolute extinction.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.98** 0.02 0.00	**0.96** 0.04 0.00	**0.95** 0.05 0.00	**0.81** 0.19 0.00
Shoulder function (OAD3)	**0.94** 0.05 0.01	**0.87** 0.11 0.02	**0.87** 0.12 0.01	**0.48** 0.46 0.06
Concave function (OAD3)	**0.98** 0.02 0.00	**0.97** 0.03 0.00	**0.97** 0.03 0.00	**0.92** 0.08 0.00

Table 44. Species—Snake (EN) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.98** 0.02 0.00	**0.96** 0.04 0.00	**0.95** 0.05 0.00	**0.75** 0.25 0.00
Shoulder function (OAD3)	**0.94** 0.06 0.00	**0.85** 0.13 0.02	**0.84** 0.15 0.01	**0.42** 0.52 0.06
Concave function (OAD3)	**0.98** 0.02 0.00	**0.96** 0.04 0.00	**0.97** 0.03 0.00	**0.86** 0.14 0.00

Table 45. Species—Pinniped1 (EN) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.65** 0.32 0.03	**0.60** 0.37 0.03	**0.65** 0.35 0.00	**0.54** 0.44 0.02
Shoulder function (OAD3)	**0.51** 0.41 0.08	**0.39** 0.47 0.14	**0.39** 0.46 0.15	**0.20** 0.60 0.20
Concave function (OAD3)	**0.67** 0.27 0.06	**0.65** 0.32 0.03	**0.73** 0.27 0.00	**0.71** 0.29 0.00

Table 46. Species—Passerine (EN) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.58** 0.46 0.06	**0.48** 0.45 0.07	**0.59** 0.39 0.02	**0.48** 0.50 0.02
Shoulder function (OAD3)	**0.43** 0.38 0.19	**0.34** 0.45 0.21	**0.32** 0.47 0.21	**0.18** 0.57 0.25
Concave function (OAD3)	**0.59** 0.35 0.06	**0.54** 0.40 0.06	**0.61** 0.37 0.02	**0.66** 0.34 0.00

Table 47. Species—Grevillea(TH) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.00 **0.34** 0.66	0.08 **0.43** 0.49	0.06 **0.66** 0.28	0.25 **0.69** 0.06
Shoulder function (OAD3)	0.00 **0.06** 0.94	0.00 **0.21** 0.76	0.01 **0.33** 0.66	0.04 **0.49** 0.47
Concave function (OAD3)	0.00 **0.23** 0.77	0.09 **0.36** 0.55	0.08 **0.57** 0.35	0.37 **0.62** 0.01

Table 48. Species—Sparrow (TH) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.53 **0.37** 0.10	0.40 **0.42** 0.18	0.24 **0.37** 0.39	0.17 **0.42** 0.41
Shoulder function (OAD3)	0.27 **0.45** 0.28	0.30 **0.32** 0.38	0.24 **0.37** 0.39	0.17 **0.42** 0.41
Concave function (OAD3)	0.58 **0.31** 0.11	0.48 **0.37** 0.14	0.53 **0.36** 0.11	0.54 **0.44** 0.02

Table 49. Species—killer whale (TH) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.46 **0.40** 0.14	0.38 **0.53** 0.09	0.57 **0.39** 0.04	0.45 **0.49** 0.06
Shoulder function (OAD3)	0.22 **0.37** 0.41	0.26 **0.36** 0.38	0.18 **0.54** 0.28	0.18 **0.48** 0.34
Concave function (OAD3)	0.47 **0.36** 0.17	0.49 **0.45** 0.06	0.62 **0.38** 0.00	0.69 **0.31** 0.00

Table 50. Species—Erodium (TH) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.34 **0.60** 0.06	0.42 **0.57** 0.01	0.57 **0.43** 0.00	0.45 **0.54** 0.01
Shoulder function (OAD3)	0.19 **0.61** 0.20	0.23 **0.63** 0.14	0.12 **0.68** 0.20	0.14 **0.66** 0.20
Concave function (OAD3)	0.39 **0.52** 0.09	0.43 **0.55** 0.02	0.63 **0.37** 0.00	0.67 **0.33** 0.00

Table 51. Species—Pinniped2 (TH) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.13 **0.64** 0.23	0.25 **0.64** 0.11	0.29 **0.67** 0.04	0.36 **0.62** 0.02
Shoulder function (OAD3)	0.04 **0.51** 0.45	0.14 **0.39** 0.47	0.06 **0.59** 0.35	0.09 **0.57** 0.34
Concave function (OAD3)	0.13 **0.53** 0.34	0.27 **0.57** 0.16	0.34 **0.58** 0.08	0.49 **0.50** 0.01

Table 52. Species—Newt (NW) using absolute extinction.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.00 0.19 **0.81**	0.01 0.95 **0.04**	0.14 0.84 **0.02**	0.39 0.58 **0.03**
Shoulder function (OAD3)	0.00 0.00 **1.00**	0.00 0.45 **0.55**	0.02 0.64 **0.34**	0.07 0.65 **0.28**
Concave function (OAD3)	0.00 0.06 **0.94**	0.02 0.94 **0.04**	0.23 0.75 **0.02**	0.58 0.42 **0.00**

Table 53. Species—Tortoise (NW) using absolute extinction.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.01 0.48 **0.51**	0.11 0.42 **0.47**	0.07 0.62 **0.31**	0.21 0.73 **0.06**
Shoulder function (OAD3)	0.00 0.21 **0.79**	0.07 0.21 **0.72**	0.01 0.35 **0.64**	0.03 0.44 **0.53**
Concave function (OAD3)	0.02 0.37 **0.61**	0.11 0.35 **0.54**	0.07 0.53 **0.40**	0.27 0.69 **0.04**

Table 54. Species—Lizard (NW) using absolute extinction.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.08 0.48 **0.44**	0.19 0.48 **0.33**	0.14 0.58 **0.28**	0.29 0.62 **0.00**
Shoulder function (OAD3)	0.03 0.034 **0.63**	0.11 0.24 **0.65**	0.05 0.37 **0.58**	0.09 0.44 **0.47**
Concave function (OAD3)	0.08 0.43 **0.49**	0.22 0.42 **0.36**	0.23 0.49 **0.28**	0.42 0.56 **0.02**

Table 55. Results for all consensus species combined using absolute extinction for the High/High data scenario using absolute extinction.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.84**	0.29	0.03
	TH	0.14	**0.47**	0.38
	NW	0.02	0.24	**0.59**
Shoulder function (OAD3)	EN	**0.76**	0.14	0.01
	TH	0.18	**0.40**	0.18
	NW	0.06	0.46	**0.81**
Concave function (OAD3)	EN	**0.84**	0.31	0.03
	TH	0.13	**0.39**	0.29
	NW	0.02	0.30	**0.68**

Table 56. Results for all consensus species combined using absolute extinction for the Low/High data scenario using absolute extinction.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.80**	0.31	0.10
	TH	0.18	**0.52**	0.62
	NW	0.02	0.18	**0.28**
Shoulder function (OAD3)	EN	**0.68**	0.19	0.06
	TH	0.24	**0.38**	0.30
	NW	0.08	0.43	**0.64**
Concave function (OAD3)	EN	**0.82**	0.35	0.12
	TH	0.16	**0.46**	0.57
	NW	0.02	0.19	**0.31**

Table 57. Results for all consensus species combined using absolute extinction for the High/Low data scenario using absolute extinction.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.83**	0.39	0.12
	TH	0.17	**0.51**	0.68
	NW	0.00	0.11	**0.20**
Shoulder function (OAD3)	EN	**0.68**	0.12	0.03
	TH	0.24	**0.50**	0.45
	NW	0.08	0.38	**0.52**
Concave function (OAD3)	EN	**0.86**	0.44	0.18
	TH	0.14	**0.45**	0.59
	NW	0.00	0.11	**0.23**

Table 58. Results for all consensus species combined using absolute extinction for the Low/Low data scenario using absolute extinction.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.70**	0.38	0.30
	TH	0.29	**0.57**	0.64
	NW	0.01	0.05	**0.06**
Shoulder function (OAD3)	EN	**0.42**	0.12	0.06
	TH	0.47	**0.52**	0.51
	NW	0.11	0.35	**0.43**
Concave function (OAD3)	EN	**0.82**	0.55	0.42
	TH	0.18	**0.44**	0.56
	NW	0.00	0.01	**0.02**

Table 59. Weighted results assuming absolute extinction for the different weighting tables. Best value/listing criteria in bold.

Weighting table type	Listing criteria	High/high	low/high	high/low	low/low
Equal	Step (OAD1)	1.11	1.40	1.46	1.66
	Shoulder (OAD3)	**1.03**	**1.29**	**1.30**	**1.63**
	Concave (OAD3)	1.09	1.40	1.46	1.72
Symmetrical	Step (OAD1)	1.15	1.53	1.58	1.97
	Shoulder (OAD3)	**1.10**	**1.43**	**1.40**	**1.81**
	Concave (OAD3)	1.14	1.40	1.64	2.14
Precautionary	**Step (OAD1)**	**0.79**	**0.96**	**0.93**	**1.16**
	Shoulder (OAD3)	0.92	1.13	1.08	1.43
	Concave (OAD3)	0.81	**0.96**	0.95	**1.16**
List v not list	Step (OAD1)	**0.93**	1.11	1.02	1.05
	Shoulder (OAD3)	1.22	1.37	1.38	1.51
	Concave (OAD3)	0.96	**1.10**	**0.99**	**1.00**

Section 10.2 Results for near-extinction of 50 mature individuals

Table 60. Species—Herring (EN**) using NE = 50.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**0.98** 0.02 0.00
Shoulder function (OAD3)	**1.00** 0.00 0.00	**0.97** 0.03 0.00	**0.99** 0.01 0.00	**0.74** 0.26 0.00
Concave function (OAD3)	**0.99** 0.01 0.00	**0.95** 0.05 0.00	**0.98** 0.02 0.00	**0.68** 0.32 0.00

Table 61. Species—Mudminnow (EN**) using NE = 50.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00
Shoulder function (OAD3)	**0.96** 0.04 0.00	**0.89** 0.11 0.00	**0.73** 0.27 0.00	**0.48** 0.48 0.04
Concave function (OAD3)	**0.98** 0.02 0.00	**0.95** 0.05 0.00	**0.93** 0.07 0.00	**0.78** 0.22 0.00

Table 62. Species—Snake (EN**) using NE = 50.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00	**1.00** 0.00 0.00
Shoulder function (OAD3)	**0.97** 0.03 0.00	**0.92** 0.08 0.00	**0.92** 0.08 0.00	**0.40** 0.56 0.04
Concave function (OAD3)	**0.96** 0.04 0.00	**0.92** 0.08 0.00	**0.91** 0.09 0.00	**0.63** 0.37 0.00

Table 63. Species—Pinniped1 (EN) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.96** 0.04 0.00	**0.97** 0.03 0.00	**1.00** 0.00 0.00	**0.98** 0.02 0.00
Shoulder function (OAD3)	**0.81** 0.16 0.03	**0.66** 0.30 0.04	**0.56** 0.42 0.02	**0.25** 0.67 0.08
Concave function (OAD3)	**0.82** 0.16 0.02	**0.73** 0.27 0.00	**0.77** 0.23 0.00	**0.68** 0.32 0.00

Table 64. Species—Passerine (EN) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.89** 0.08 0.03	**0.85** 0.14 0.01	**0.92** 0.08 0.00	**0.94** 0.06 0.00
Shoulder function (OAD3)	**0.64** 0.31 0.05	**0.47** 0.43 0.10	**0.41** 0.54 0.05	**0.18** 0.70 0.12
Concave function (OAD3)	**0.56** 0.38 0.06	**0.44** 0.49 0.07	**0.52** 0.46 0.02	**0.45** 0.54 0.01

Table 65. Species—Erodium (EN) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.92** 0.08 0.00	**0.95** 0.05 0.00	**1.00** 0.00 0.00	**0.97** 0.03 0.00
Shoulder function (OAD3)	**0.76** 0.23 0.01	**0.48** 0.49 0.03	**0.42** 0.57 0.01	**0.18** 0.72 0.10
Concave function (OAD3)	**0.58** 0.41 0.01	**0.49** 0.51 0.00	**0.65** 0.35 0.00	**0.56** 0.44 0.00

Table 66. Species—Sparrow (EN) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.88** 0.08 0.04	**0.76** 0.16 0.08	**0.82** 0.11 0.07	**0.89** 0.10 0.01
Shoulder function (OAD3)	**0.40** 0.44 0.16	**0.33** 0.41 0.26	**0.32** 0.44 0.24	**0.17** 0.56 0.27
Concave function (OAD3)	**0.52** 0.40 0.08	**0.41** 0.43 0.16	**0.47** 0.45 0.08	**0.44** 0.53 0.03

Table 67. Species—pinniped2 (TH) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.31 **0.62** 0.07	0.42 **0.55** 0.03	0.67 **0.33** 0.00	0.89 **0.11** 0.00
Shoulder function (OAD3)	0.19 **0.63** 0.18	0.25 **0.57** 0.18	0.10 **0.72** 0.18	0.09 **0.75** 0.16
Concave function (OAD3)	0.04 **0.72** 0.24	0.13 **0.71** 0.16	0.08 **0.82** 0.10	0.21 **0.76** 0.03

Table 68. Species—spp19 (TH) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.72 **0.20** 0.08	0.63 **0.23** 0.14	0.63 **0.28** 0.09	0.83 **0.15** 0.02
Shoulder function (OAD3)	0.16 **0.55** 0.29	0.23 **0.40** 0.37	0.16 **0.43** 0.41	0.15 **0.44** 0.41
Concave function (OAD3)	0.23 **0.56** 0.21	0.26 **0.49** 0.25	0.24 **0.49** 0.27	0.27 **0.66** 0.07

Table 69. Species—spp 20 (TH) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.51 **0.38** 0.11	0.54 **0.34** 0.12	0.68 **0.29** 0.03	0.90 **0.10** 0.00
Shoulder function (OAD3)	0.11 **0.49** 0.40	0.18 **0.38** 0.44	0.08 **0.59** 0.33	0.13 **0.57** 0.30
Concave function (OAD3)	0.08 **0.56** 0.36	0.18 **0.56** 0.26	0.16 **0.63** 0.21	0.30 **0.68** 0.02

Table 70. Species—Epacris (NW) using NE = 50.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.00 0.06 **0.94**	0.00 0.75 **0.25**	0.03 0.94 **0.03**	0.48 0.52 **0.00**
Shoulder function (OAD3)	0.00 0.24 **0.76**	0.00 0.40 **0.60**	0.00 0.61 **0.39**	0.01 0.62 **0.37**
Concave function (OAD3)	0.00 0.04 **0.96**	0.00 0.29 **0.71**	0.00 0.59 **0.41**	0.01 0.82 **0.17**

Table 71. Species—Tortoise (NW) using NE = 50.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.02 0.52 **0.46**	0.13 0.61 **0.26**	0.19 0.66 **0.15**	0.57 0.43 **0.00**
Shoulder function (OAD3)	0.01 0.47 **0.52**	0.08 0.34 **0.58**	0.02 0.54 **0.44**	0.02 0.60 **0.38**
Concave function (OAD3)	0.00 0.39 **0.61**	0.00 0.40 **0.60**	0.01 0.56 **0.43**	0.05 0.79 **0.16**

Table 72. Species—16 (NW) using NE = 50.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.00 0.51 **0.49**	0.22 0.73 **0.05**	0.65 0.35 **0.00**	0.90 0.10 **0.00**
Shoulder function (OAD3)	0.00 0.35 **0.65**	0.04 0.47 **0.49**	0.02 0.66 **0.32**	0.05 0.75 **0.20**
Concave function (OAD3)	0.00 0.24 **0.76**	0.01 0.53 **0.46**	0.03 0.78 **0.19**	0.22 0.75 **0.03**

Table 73. Species—17 (NW) using NE = 50.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.14 0.43 **0.43**	0.42 0.52 **0.06**	0.71 0.29 **0.00**	0.92 0.08 **0.00**
Shoulder function (OAD3)	0.02 0.43 **0.55**	0.09 0.39 **0.52**	0.03 0.66 **0.31**	0.08 0.71 **0.21**
Concave function (OAD3)	0.00 0.44 **0.56**	0.09 0.54 **0.37**	0.09 0.79 **0.12**	0.36 0.62 **0.02**

Table 74. Species—18 (NW) using NE = 50.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.00 0.19 **0.81**	0.01 0.92 **0.07**	0.32 0.67 **0.01**	0.81 0.19 **0.00**
Shoulder function (OAD3)	0.00 0.10 **0.90**	0.00 0.38 **0.62**	0.01 0.66 **0.33**	0.02 0.71 **0.27**
Concave function (OAD3)	0.00 0.03 **0.97**	0.00 0.36 **0.64**	0.00 0.70 **0.30**	0.07 0.87 **0.06**

Table 75. Results for all consensus species combined using NE = 50 for the High/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.95**	0.51	0.03
	TH	0.04	**0.40**	0.34
	NW	0.01	0.09	**0.63**
Shoulder function (OAD3)	EN	**0.79**	0.15	0.01
	TH	0.17	**0.56**	0.32
	NW	0.04	0.29	**0.68**
Concave function (OAD3)	EN	**0.77**	0.12	0.00
	TH	0.20	**0.61**	0.23
	NW	0.02	0.27	**0.77**

Table 76. Results for all consensus species combined using NE = 50 for the Low/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.93**	0.53	0.16
	TH	0.05	**0.37**	0.71
	NW	0.01	0.10	**0.14**
Shoulder function (OAD3)	EN	**0.67**	0.22	0.04
	TH	0.26	**0.45**	0.40
	NW	0.06	0.33	**0.56**
Concave function (OAD3)	EN	**0.70**	0.19	0.02
	TH	0.27	**0.59**	0.42
	NW	0.03	0.22	**0.56**

Table 77. Results for all consensus species combined using NE = 50 for the High/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.96**	0.66	0.38
	TH	0.03	**0.30**	0.58
	NW	0.01	0.04	**0.04**
Shoulder function (OAD3)	EN	**0.62**	0.11	0.02
	TH	0.33	**0.58**	0.63
	NW	0.05	0.31	**0.36**
Concave function (OAD3)	EN	**0.75**	0.16	0.03
	TH	0.24	**0.65**	0.68
	NW	0.01	0.19	**0.29**

Table 78. Results for all consensus species combined using NE = 50 for the Low/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.97**	0.87	0.74
	TH	0.03	**0.12**	0.26
	NW	0.00	0.01	**0.00**
Shoulder function (OAD3)	EN	**0.34**	0.12	0.04
	TH	0.56	**0.59**	0.68
	NW	0.09	0.29	**0.29**
Concave function (OAD3)	EN	**0.60**	0.26	0.14
	TH	0.39	**0.70**	0.77
	NW	0.01	0.04	**0.09**

Table 79. Weighted results using NE = 50 for the different weighting tables. Best value/listing criteria in bold.

Weighting table type	Listing criteria	High/high	low/high	high/low	low/low
Equal	Step (OAD1)	1.02	1.56	1.70	1.91
	Shoulder (OAD3)	0.98	1.31	1.44	1.78
	Concave (OAD3)	**0.84**	**1.16**	**1.32**	**1.61**
Symmetrical	Step (OAD1)	1.07	1.72	2.09	2.65
	Shoulder (OAD3)	1.02	1.42	1.50	1.91
	Concave (OAD3)	**0.87**	**1.21**	**1.36**	**1.76**
Precautionary	**Step (OAD1)**	**0.61**	0.95	1.09	1.35
	Shoulder (OAD3)	0.78	1.07	1.12	1.48
	Concave (OAD3)	0.69	**0.88**	**0.91**	**1.10**
List v not list	Step (OAD1)	**0.57**	1.08	**1.06**	1.02
	Shoulder (OAD3)	0.98	1.22	1.35	1.48
	Concave (OAD3)	0.82	**0.96**	1.13	**1.00**

Section 10.3 Results for near-extinction of 250 mature individuals

Table 80. Species—Herring (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**0.98** 0.02 0.00	**1.00** 0.00 0.00	**0.93** 0.07 0.00
Shoulder function (OAD3)	**0.98** 0.02 0.00	**0.89** 0.11 0.00	**0.96** 0.04 0.00	**0.39** 0.61 0.00
Concave function (OAD3)	**1.00** 0.00 0.00	**0.98** 0.02 0.00	**1.00** 0.00 0.00	**0.89** 0.11 0.00

Table 81. Species—Mudminnow (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**0.99** 0.01 0.00	**1.00** 0.00 0.00	**0.95** 0.05 0.00
Shoulder function (OAD3)	**0.95** 0.05 0.00	**0.81** 0.19 0.00	**0.86** 0.14 0.00	**0.35** 0.63 0.02
Concave function (OAD3)	**1.00** 0.00 0.00	**0.99** 0.01 0.00	**1.00** 0.00 0.00	**0.95** 0.05 0.00

Table 82. Species—Snake (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**1.00** 0.00 0.00	**0.98** 0.02 0.00	**0.99** 0.01 0.00	**0.92** 0.08 0.00
Shoulder function (OAD3)	**0.96** 0.04 0.00	**0.80** 0.20 0.00	**0.76** 0.24 0.00	**0.20** 0.77 0.03
Concave function (OAD3)	**1.00** 0.00 0.00	**0.98** 0.02 0.00	**0.99** 0.01 0.00	**0.89** 0.11 0.00

Table 83. Species—Pinniped1 (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.99** 0.01 0.00	**0.97** 0.03 0.00	**0.99** 0.01 0.00	**0.91** 0.09 0.00
Shoulder function (OAD3)	**0.84** 0.16 0.00	**0.63** 0.37 0.00	**0.52** 0.48 0.00	**0.19** 0.78 0.03
Concave function (OAD3)	**0.98** 0.02 0.00	**0.97** 0.03 0.00	**1.00** 0.00 0.00	**0.94** 0.06 0.00

Table 84. Species—Passerine (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.88** 0.12 0.00	**0.81** 0.19 0.00	**0.83** 0.17 0.00	**0.74** 0.26 0.00
Shoulder function (OAD3)	**0.50** 0.46 0.04	**0.34** 0.60 0.06	**0.27** 0.69 0.04	**0.08** 0.85 0.07
Concave function (OAD3)	**0.82** 0.15 0.03	**0.78** 0.22 0.00	**0.81** 0.19 0.00	**0.73** 0.27 0.00

Table 85. Species—Erodium (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.97** 0.03 0.00	**0.95** 0.05 0.00	**0.97** 0.03 0.00	**0.88** 0.12 0.00
Shoulder function (OAD3)	**0.81** 0.19 0.00	**0.41** 0.59 0.00	**0.26** 0.74 0.00	**0.11** 0.83 0.06
Concave function (OAD3)	**0.96** 0.04 0.00	**0.94** 0.06 0.00	**0.98** 0.02 0.00	**0.92** 0.08 0.00

Table 86. Species—Sparrow (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.94** 0.06 0.00	**0.79** 0.20 0.01	**0.87** 0.13 0.00	**0.85** 0.15 0.00
Shoulder function (OAD3)	**0.37** 0.59 0.04	**0.33** 0.53 0.14	**0.32** 0.61 0.07	**0.19** 0.74 0.07
Concave function (OAD3)	**0.95** 0.04 0.01	**0.81** 0.17 0.02	**0.90** 0.10 0.00	**0.92** 0.08 0.00

Table 87: Species—Grevillea (EN) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	**0.68**	**0.67**	**0.75**	**0.63**
	0.32	0.33	0.25	0.37
	0.00	0.00	0.00	0.00
Shoulder function (OAD3)	**0.47**	**0.31**	**0.10**	**0.03**
	0.52	0.67	0.88	0.89
	0.01	0.02	0.02	0.08
Concave function (OAD3)	**0.75**	**0.68**	**0.71**	**0.58**
	0.24	0.32	0.29	0.42
	0.01	0.00	0.00	0.00

Table 88. Species—Newt (TH) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.43	0.83	0.82	0.78
	0.57	**0.17**	**0.18**	**0.22**
	0.00	0.00	0.00	0.00
Shoulder function (OAD3)	0.01	0.02	0.04	0.03
	0.99	**0.98**	**0.94**	**0.90**
	0.00	0.00	0.02	0.07
Concave function (OAD3)	0.50	0.72	0.77	0.80
	0.50	**0.28**	**0.23**	**0.20**
	0.00	0.00	0.00	0.00

Table 89. Species—sp 19 (TH) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.56	0.43	0.50	0.47
	0.40	**0.53**	**0.48**	**0.53**
	0.04	0.04	0.02	0.00
Shoulder function (OAD3)	0.05	0.16	0.06	0.08
	0.71	**0.53**	**0.60**	**0.61**
	0.24	0.31	0.34	0.31
Concave function (OAD3)	0.52	0.41	0.48	0.46
	0.41	**0.47**	**0.44**	**0.54**
	0.07	0.12	0.08	0.00

Table 90. Species—pinniped2 (TH) using NE = 250.

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.37	0.37	0.56	0.54
	0.61	**0.63**	**0.44**	**0.46**
	0.02	0.00	0.00	0.00
Shoulder function (OAD3)	0.12	0.14	0.03	0.02
	0.80	**0.74**	**0.86**	**0.84**
	0.08	0.12	0.11	0.14
Concave function (OAD3)	0.40	0.37	0.46	0.48
	0.54	**0.60**	**0.54**	**0.52**
	0.06	0.03	0.00	0.00

Table 91. Species—sp 20 (TH**) using NE = 250.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.50	0.44	0.56	0.62
	0.45	**0.55**	**0.44**	**0.38**
	0.05	0.01	0.00	0.00
Shoulder function (OAD3)	0.07	0.13	0.03	0.05
	0.68	**0.59**	**0.75**	**0.79**
	0.25	0.28	0.22	0.16
Concave function (OAD3)	0.47	0.40	0.53	0.64
	0.42	**0.53**	**0.45**	**0.36**
	0.11	0.07	0.02	0.00

Table 92. Species—Tortoise (NW**) using NE = 250.**

Listing criterion	high/high	low/high	high/low	low/low
Step function (OAD1)	0.00	0.09	0.07	0.24
	0.87	0.89	0.93	0.76
	0.13	**0.02**	**0.00**	**0.00**
Shoulder function (OAD3)	0.00	0.00	0.01	0.00
	0.51	0.48	0.58	0.66
	0.49	**0.52**	**0.41**	**0.34**
Concave function (OAD3)	0.01	0.09	0.06	0.18
	0.54	0.59	0.72	0.81
	0.45	**0.32**	**0.22**	**0.01**

Table 93. Species—Epacris (NW**) using NE = 250.**

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.00	0.00	0.00	0.13
	0.51	1.00	1.00	0.87
	0.49	**0.00**	**0.00**	**0.00**
Shoulder function (OAD3)	0.00	0.00	0.00	0.00
	0.43	0.50	0.69	0.69
	0.57	**0.50**	**0.31**	**0.31**
Concave function (OAD3)	0.00	0.00	0.00	0.07
	0.40	0.69	0.81	0.90
	0.60	**0.31**	**0.19**	**0.03**

Table 94. Species—sp 16 (NW**) using NE = 250.**

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.03	0.20	0.45	0.54
	0.88	0.80	0.55	0.46
	0.09	**0.00**	**0.00**	**0.00**
Shoulder function (OAD3)	0.01	0.00	0.02	0.01
	0.51	0.66	0.76	0.83
	0.48	**0.34**	**0.22**	**0.16**
Concave function (OAD3)	0.03	0.18	0.34	0.54
	0.55	0.77	0.66	0.46
	0.42	**0.05**	**0.00**	**0.00**

Table 95. Species—sp 18 (NW) using NE = 250.

Listing criterion	High/high	low/high	high/low	low/low
Step function (OAD1)	0.00 0.68 **0.32**	0.00 1.00 **0.00**	0.08 0.92 **0.00**	0.43 0.57 **0.00**
Shoulder function (OAD3)	0.00 0.37 **0.63**	0.00 0.60 **0.40**	0.00 0.71 **0.29**	0.00 0.81 **0.19**
Concave function (OAD3)	0.00 0.38 **0.62**	0.01 0.89 **0.10**	0.04 0.94 **0.02**	0.33 0.67 **0.00**

Table 96. Results for all consensus species combined using NE = 250 for the High/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.93**	0.47	0.01
	TH	0.07	**0.51**	0.74
	NW	0.00	0.03	**0.26**
Shoulder function (OAD3)	EN	**0.74**	0.06	0.00
	TH	0.25	**0.80**	0.46
	NW	0.01	0.14	**0.54**
Concave function (OAD3)	EN	**0.93**	0.47	0.01
	TH	0.06	**0.47**	0.47
	NW	0.01	0.06	**0.52**

Table 97. Results for all consensus species combined using NE = 250 for the Low/High data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.89**	0.52	0.07
	TH	0.11	**0.47**	0.92
	NW	0.00	0.01	**0.01**
Shoulder function (OAD3)	EN	**0.57**	0.11	0.00
	TH	0.41	**0.71**	0.56
	NW	0.03	0.18	**0.44**
Concave function (OAD3)	EN	**0.89**	0.48	0.07
	TH	0.11	**0.47**	0.74
	NW	0.00	0.06	**0.20**

Table 98. Results for all consensus species combined using NE = 250 for the High/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.93**	0.61	0.15
	TH	0.08	**0.39**	0.85
	NW	0.00	0.01	**0.00**
Shoulder function (OAD3)	EN	**0.51**	0.04	0.01
	TH	0.48	**0.79**	0.69
	NW	0.02	0.17	**0.31**
Concave function (OAD3)	EN	**0.92**	0.56	0.11
	TH	0.08	**0.42**	0.78
	NW	0.00	0.03	**0.11**

Table 99. Results for all consensus species combined using NE = 250 for the Low/Low data scenario.

Listing criterion		EN	TH	NW
Step function (OAD1)	EN	**0.85**	0.60	0.34
	TH	0.15	**0.40**	0.67
	NW	0.00	0.00	**0.00**
Shoulder function (OAD3)	EN	**0.19**	0.05	0.00
	TH	0.76	**0.79**	0.75
	NW	0.05	0.17	**0.25**
Concave function (OAD3)	EN	**0.85**	0.60	0.28
	TH	0.15	**0.41**	0.71
	NW	0.00	0.00	**0.01**

Table 100. Weighted results using NE = 250 for the different weighting tables. Best value/listing criteria in bold.

Weighting table type	Listing criteria	High/high	low/high	high/low	low/low
Equal	Step (OAD1)	1.30	1.63	1.69	1.75
	Shoulder (OAD3)	**0.93**	**1.29**	**1.40**	1.77
	Concave (OAD3)	1.08	1.44	1.55	**1.73**
Symmetrical	Step (OAD1)	1.31	1.71	1.84	2.09
	Shoulder (OAD3)	**0.94**	**1.31**	**1.42**	**1.82**
	Concave (OAD3)	1.09	1.52	1.66	2.01
Precautionary	**Step (OAD1)**	0.70	0.91	0.96	1.12
	Shoulder (OAD3)	0.68	0.98	1.05	1.42
	Concave (OAD3)	**0.61**	**0.84**	**0.88**	**1.08**
List v not list	Step (OAD1)	0.80	1.02	1.01	1.00
	Shoulder (OAD3)	0.77	0.97	1.07	1.18
	Concave (OAD3)	**0.61**	**0.92**	**0.94**	**0.99**

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