THE APPLICATION OF POPULATION MODELLING TECHNIQUES TO THE DEVELOPMENT OF NON-DETRIMENT FINDINGS FOR *GALANTHUS ELWESII* IN TURKEY

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Summary Paragraph
The minimum criteria a population model should meet in order to aid in the making of non detriment findings (NDFs) should be a demonstrable ability to predict changes to the population size following actual harvesting regimes to a desired level of accuracy. This case study outlines how population models could be developed and used to aid in making NDFs for *G. elwesii*, the Turkish Giant Snowdrop. This taxon is particularly suited to developing such a quantitative framework because the populations are visited annually (facilitating data collection), they appear to have relatively stable abundances (suggesting relatively low stochasticity), and annual collections of relatively large quantities for international trade is likely to continue to for the foreseeable future. Furthermore, the establishment of such a quantitative framework will be a valuable example for those wishing to develop a similar system for other CITES taxa.

I. Background information on the taxa

1. BIOLOGICAL DATA

1.1 Scientific and common names

Scientific name: *Galanthus elwesii* Hook.f. var (Amaryllidaceae)
Common name: Snowdrops (English)
Kardelen, Sümbül, Nergis (Turkish)

1.2 Distribution (Specify the currently known range of the species. If possible, provide information to indicate whether or not the distribution of the species is continuous, or to what degree it is fragmented. If possible, include a map).

Galanthus elwesii has a wide natural distribution and can be found in Bulgaria, northeastern Greece, the eastern Aegean Islands, southern Ukraine and Turkey. Within Turkey this species is distributed in northwestern, western and southern Anatolia

1.3 Biological characteristics

1.3.1 Provide a summary of general biological and life history characteristics of the species (e.g. reproduction, recruitment, survival rate, migration, sex ratio, regeneration or reproductive strategies, tolerance toward humans).

Galanthus elwesii is a perennial, herbaceous geophyte which remains entirely subterranean for a large proportion of their life cycle*. G. elwesii* reproduces by seeds or vegetatively by bulbs. There is no accurate quantitative data on the life cycle for *G. elwesii*. However, for the purposes of discussing population modelling, the most plausible life history is detailed below (Fig. 1).

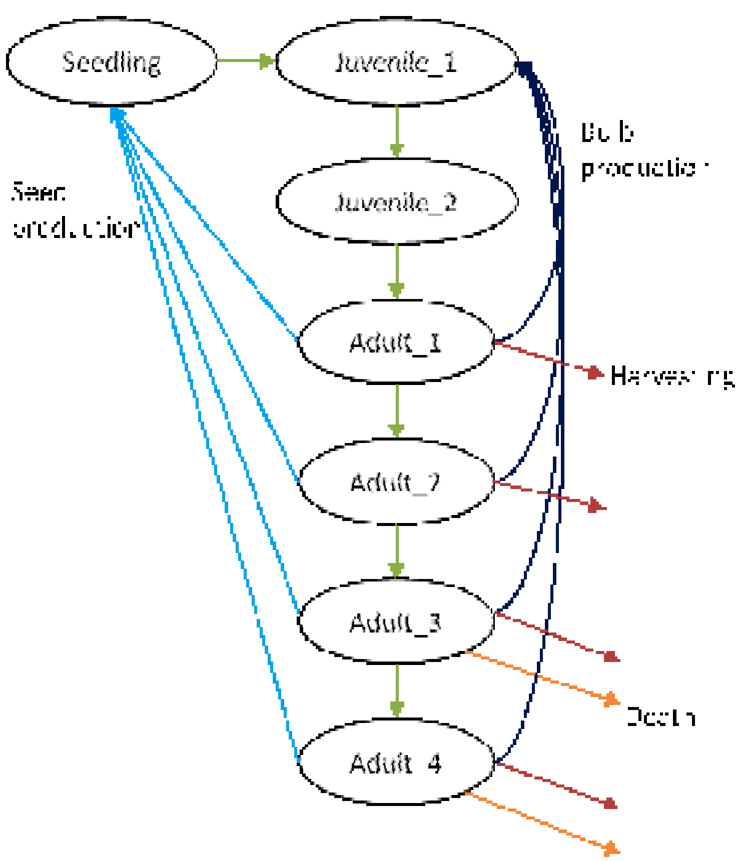

Fig. 1: Life history diagram for *G. elwesii* in optimal habitat. This model splits the population into 7 stage classes. Maturation between the stages takes one year (green arrows). Plants produced from seeds take an extra year to mature to flowering individuals. Significant mortality is only believed to occur in the two oldest adult stages. The nature of density dependence is unknown but is plausibly manifest in the rates of successful establishment of seedlings from seed production and juveniles from bulb production.

1.3.2 *Habitat types*

Specify the types of habitats occupied by the species and, when relevant, the degree of habitat specificity.

The largest wild populations of *Galanthus elwesii* can be found within limestone areas of the Taurus Mountains, southern Turkey. Within the Taurus Mountains *G. elwesii* is mostly found in subalpine pastures between 800-1 000m (and also up to 1 600m) altitude. These habitats are covered by snow during the winter and remain cool during the summer. North western and western populations of *G. elwesii* are also associated with broad-leaved, coniferous woodland and scrub. Given this habitat variation, it is recommended that data is collected from the range of different habitat types occupied by harvested *G. elwesii* populations to identify the degree of variation in population growth rates and, therefore, the variation in sustainable harvesting rates.

1.3.3 *Role of the species in its ecosystem*

Galanthus elwesii provides an important nectar source for invertebrates whilst also providing a food source for ant species (species unknown) via a fleshy oil-bearing appendage on the seed (an elaiosome). Clumps of *G. elwesii* may offer microhabitats for invertebrates and other organisms, consequently influencing the physical and biotic composition of the soil. The role of *G. elwesii* in nutrient recycling is currently unknown and should probably be explored as knowledge of the nutrient cycle may partly explain why different habitats are characterised by different abundances of plants and, presumably, different optimum harvest rates.

1.4 Population

1.4.1 *Global Population size*

(Population size may be estimated by reference to population density, having due regard to habitat type and other methodological considerations, or simply inferred from anecdotic data)

Galanthus elwesii is native to Greece, Bulgaria, Ukraine, Yugoslavia and Turkey. Current estimates of *G. elwesii* abundance in Turkey, particularly within the Taurus Mountain range, indicate that the population is very large. The area of occupancy for individual populations extends from several square metres to 100's of hectares. Out of all CITES taxa, *G. elwesii* populations should be some of the easiest to quantify by scaling up from density estimates. We have good knowledge of the location of many populations. However we have poor knowledge as to the geographical extents of each population, and the density of bulbs within each population. It is proposed that a simple quadrat based sampling methodology is initially implemented to allow quantification of population densities and projection of population sizes.

1.4.2 *Current global population trends*
Current global population trends appear to be stable. Annual visual inspections of the harvested populations in Turkey indicate that *Galanthus elwesii* has not declined in these regions. However if the above methodology was repeated over time then more quantitative idea of the population trends could be obtained.

1.5 Conservation status

1.5.1 *Global conservation status* (according to IUCN Red List)
The IUCN Red List of Threatened Plants does not currently include *Galanthus elwesii.*

1.5.2 *National conservation status for the case study country*
Galanthus elwesii is not included in the "Red Data Book of Turkish Plants" due to its abundance and wide distribution.

1.5.3 *Main threats within the case study country*
Galanthus elwesii is collected from the wild for commercial purposes. Prior to 1995 this collection presented the greatest threat to the species. However, the current harvesting regime appears to maintain stable and sustainable populations of *G. elwesii*. Future threats to populations may arise as a result of the impacts of global warming.

2. SPECIES MANAGEMENT WITHIN THE COUNTRY FOR WHICH CASE STUDY IS BEING PRESENTED

2.1 Management measures

Export quotas for *Galanthus elwesii* are set annually by the Technical Committee, following field inspections (of wild habitat and cultivation fields) by scientific teams. Monitoring of collection and storage volume of *G. elwesii* has also been utilised to provide information to determine annual export quotas. This process of Committees, quota setting based on scientific advice, field monitoring and monitoring of harvested material in the processing warehouses prior to export forms a management plan for the species.

2.2 Monitoring system

Inspections are conducted in the field and the Interim Warehouse by scientific experts with more than 20 years research experience with populations of *Galanthus elwesii*. These inspections have a very important role in setting harvesting quotas. Information recorded from the wild plants at the Interim Warehouse provides important data for the conservation status of *G. elwesii* habitats and populations from which they have been collected. This information can be obtained through assessing the bulbs (species, size classes, numbers etc…) and analysing warehouse records (for example, assessing changing harvest effort based on records held over several years), without going into the field. It is proposed here that the methods used to monitor the populations could be improved to provide more quantitative evidence as to the effects of harvesting on the population trends. While this will have no effect on whether current harvesting levels are deemed to be detrimental (they are not), it would allow quantities to be given as to how much could be harvested before the trade does become detrimental. It is recommended below that a simple sampling methodology is implemented to allow efficient estimation of stock levels and monitoring of these levels through time.

2.3 Legal framework and law enforcement

Provide details of national and international legislation relating to the conservation of the species.

Current legislation, produced by the Ministry of Agriculture and Rural Affairs (MARA) (effective since August 1995), aims to control the harvesting and export of bulbs through the regulation of collection, propagation and export of wild bulbs. *Galanthus elwesii* exports are permitted subject to the publication of an annual quota of bulbs by the Technical Committee of MARA.

3. UTILIZATION AND TRADE FOR RANGE STATE FOR WHICH CASE STUDY IS BEING PRESENTED

3.1 **Type of use** (origin) **and destinations** (purposes) (e.g. commercial, medicinal, subsistence hunting, sport hunting, trophies, pet, food).

Specify the types and extent of all known uses of the species. Indicate the extent to which utilization is from captive-bred, artificially propagated, or wild specimens

Galanthus elwesii in Turkey is predominantly exported to the Netherlands for commercial horticultural trade.

3.2 Harvest

3.2.1 *Harvesting regime* (extractive versus non extractive harvesting, demographic segment harvested, harvesting effort, harvesting method, harvest season)

Bulb collection is conducted by local villagers, by hand with small hand-picks. The collection period starts in mid May, lasting approximately 2 weeks. During collection, export size bulbs are harvested and smaller bulbs are left remaining in the ground. The bulbs are then gathered at the Interim Warehouse at Serik and mixed before being sent to companies according to the quota allocated to each company. Populations are generally harvested every 3 years. The harvesting methodology is likely to be a feature that determines the effects of harvesting *G. elwesii* on the long term dynamics of its populations. For example different bulb sieves may be more appropriate in different sites and populations may recover faster from harvesting if the spatial harvesting strategy is different.

3.2.2 *Harvest management/ control* (quotas, seasons, permits, etc.)

In October of each year, the Ministry of Agriculture and Rural Affairs (MARA) determines the quota for Galanthus elwesii bulb harvest on the advice of the Technical Committee. This figure is published annually in the Official Gazette. The quota is divided among the relevant companies. Allocation of the overall quota to export companies is conducted according to a scoring system. This takes account of the quality and conditions of the storage facilities, past performance per company over the past five years, and whether individual companies have previously managed to sell all or only part of their quota. It is recommended that abundance is monitored in the harvest and non-harvest years to give a clearer understanding of the population dynamics of the harvested populations.

3.3 Legal and illegal trade levels: To the extent possible, quantify the level of legal and illegal use nationally and export and describe its nature.

National export levels of *Galanthus elwesii* are determined and controlled by the Ministry of Agriculture and Rural Affairs. The current export quota for *G. elwesii* is 8 million bulbs per year. There is no evidence of illegal trade in *Galanthus* to or from Turkey.

II. Non-detriment finding procedure (NDFs)

Provide detailed information on the procedure used to make the non-detriment finding for the species evaluated.

International trade in *Galanthus elwesii* (the Turkish Giant Snowdrop) is dominated by annual exports of large numbers of plants, relative to other CITES Appendix II plant taxa, collected annually from wild populations in Turkey. These exports are widely regarded as sustainable because the populations are assessed annually by experts, and precautionary harvest levels are set (summarised above).

What is currently lacking from the Turkish NDF making process is a quantitative understanding of why this harvesting regime ensures that annual harvest rates of bulbs are offset by the reproduction of the wild populations. As a result it is difficult to define the optimal harvest levels more precisely (e.g. why not 5 or 10 million bulbs a year and not the current 6 million?) and it is unclear how much this system will work for different taxa with different biological characteristics. For example the natural dynamics of some orchid populations, the other major group in this session, are much more variable on a year-to-year basis than the seemingly stable *G. elwesii* populations. It therefore seems likely that the best population monitoring system, and NDF making process, for such populations may be quite different to that which works for *G. elwesii*.

Population modelling allows the formal quantitative assessment of sustainable harvest levels based on the known biological details of the taxon concerned. Current methods allow for uncertainty in the biological parameters and environmental conditions to be incorporated into the model to obtain probabilistic estimates of sustainable harvest levels. Having a sufficiently accurate model for *G. elwesii* would not only allow NDFs to be made with more understanding about what is sustainable, but would also facilitate other parties in learning which aspects of the *G. elwesii* may be usefully adopted to make NDFs for other systems. This case study presents our thoughts on how population models could be developed and used to aid in making NDFs for *G. elwesii*.

The minimum criteria a population model should meet in order to properly advise the NDF making process should be a demonstrable ability to predict changes to the population size following actual harvesting regimes to a desired level of accuracy.

Obtaining sufficient accuracy requires the incorporation of sufficient relevant realism in a model. Modelling studies of other harvested plant populations highlight that key features of the biology of the taxon concerned are important in determining the population growth rate of the population, and thus the sustainable harvest levels (e.g. Lamont *et al.* 2001; Freckleton *et al*. 2003; Ling & Millner-Gulland, 2008). Therefore a population model for *G. elwesii* should capture the key elements of the biology of the taxon that determine its population growth rate.

What we know already about the harvested *G. elwesii* populations is that they are relatively isolated (i.e. not connected by dispersal) from each other but that plants are relatively abundant within each population (around 40 plants m^2). The precise rates at which individuals grow and mature seems to be site dependent but in the most productive habitats individuals produced asexually take around 3 years to mature to reproductive adults, with plants produced sexually taking around a year longer. This information alone can be used to formulate a provisional population model for *G. elwesii* such as that illustrated schematically in Fig. 1.

Such structured population models have been shown to successfully predict sustainable harvest levels in other plant populations (e.g. Lamont *et al*. 2001; Freckleton *et al*. 2003; Ghimire *et al*. 2008; Rock *et al*. 2003). However our ability to identify such a model for *G. elwesii* is hampered by the lack of quantitative data on the populations that could be used to parameterise and test such a model. At present we can bring together unconnected data sources to infer likely population dynamics and this study is currently being undertaken. However a directed data collection effort would allow more accurate parameterisation of the model.

Given that the populations are visited and sampled (harvested) every year it may be relatively straightforward to gather the necessary data to develop a predictive population model. Below I outline the data that could be collected, and the sampling methodologies that could be used, to obtain sufficient data to parameterise models in order to make quantitative NDF findings for *G. elwesii*

1) Basic static population data for harvested and non-harvested populations
   a. The distribution of density of flowering bulbs. This could be assessed using random quadrat sampling of measured areas and should be relatively easy to collect.
   b. The distribution of size/age classes in the soil. This could be obtained by randomly sampling 1m2 areas of soil for the presence of bulbs of different ages/stages. Such measurements could be made while the harvest is being conducted but is likely to be more resource and time intensive
2) Dynamic population data for harvested and non-harvested populations
   a. Birth rates could be estimated by looking at the distribution of bulbs of different sizes/ages in the soil, but could more accurately by repeatedly monitoring the same plants over several

years. Similarly death rates could be estimated by monitoring marked individuals over several years. Obtaining this data is crucially important to estimating the generation capacity of the population

   b. Measuring the population size over time is also important to assess the degree over which harvested and unharvested populations vary over time. Populations for long term monitoring could be GPS marked simply marked out with fence posts and assessed annually.

3) Biotic and abiotic conditions associated with harvested and non-harvested populations.
   a. Such information (e.g. altitude and aspect) can be used to explain differences in abundances and population dynamics between sites and is usually straightforward to obtain.

4) Population dynamics under different harvesting regimes
   a. An extremely powerful way to estimate sustainable harvest levels more accurately, and to identify the reproductive potential of the population for population models, is to harvest similar populations with differing intensities and monitor the effect on the overall population and on key biological features of the population that may determine the population growth rate (such as those detailed in 1-2 above). Given that the same sites are visited every year it would be relatively straightforward to mark out plots that are harvested according to different levels, including populations that are not harvested at all.

If the data detailed above were available then it would be possible to assess the ability of models to accurately predict sustainable harvest levels for the wild G. elwesii populations and, crucially, pick the best model to assist in making NDFs. There are various approaches to developing models based on sufficient data and usually a number of models are plausible. One of the key questions that is usually addressed is "what level of biological detail is sufficient to capture the desired level of accuracy in predicting the population dynamics?". For example, the spatial extent over which individuals limit each other birth and death rates (density-dependence) in G. elwesii populations is currently unknown and it is plausible that spatial processes, ignored in the proposed modelling framework outlined in Fig.1, may be a key determinant of the population dynamics (Ling & Millner-Gulland, 2008). However there are now a wide range of techniques available to asses the ability of a model to predict the data and formal methods to identify the appropriate level of abstraction.

In summary, there is good justification for developing population models to aid in making NDFs for G. elwesii harvesting in Turkey. Such a model would not only assist the Scientific Authority in setting annual harvest quotas but would also be useful to other parties by illustrating clearly why the harvesting regime in place works for this taxon and whether elements that will differ for their system may be important.

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