Middle-East Journal of Scientific Research 21 (7): 1027-1036, 2014
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2014.21.07.84225

Assessing the Conservation Status of the Sinai Primrose (*Primula boveana*)

Karim Omar

Nature Conservation Sector (NCS),
Egyptian Environmental Affairs Agency (EEAA)

Abstract: *Primula boveana* Decne. ex Duby (Primulaceae) is endemic to the St Katherine Protectorate (SKP) in southern Sinai, Egypt. This species is severely threatened by both natural (aridity of the area) and human factors (scientific research). All these factors are pushing *P. boveana* to the brink of extinction. Because of this conditions, this study is aim to assess the current conservation status of this species according to IUCN criteria in order to produce a series of recommendations for conservation action. After analyzing the collected data about species geographical range, population information, habitat and ecology, uses, threats and conservation requirements we can say that *P. boveana* qualifies as Critically Endangered (CR) because it is endemic to a tiny area (EOO 13 km², AOO <6 km²) of the high mountain area of the St. Katherine Protectorate in southern Sinai, Egypt. The total population size of mature individuals is less than 200, distributed among nine subpopulations. Because the main threat is drought and climate change, effectively there is only one location. There is a continuing decline in habitat quality for this species, with evidence of declines in subpopulation numbers as well as strong fluctuations through time. Climate change is projected to further reduce the available habitat of this high-elevation specialist. There is an urgent need to work in two directions fast to keep this species save; 1) *Ex-situ* conservation through a seed bank, genome resource bank and artificial propagation, 2) *In-situ* conservation through rehabilitation, restoration and fenced enclosures. It is important to carry out a wide range of educational and awareness activities in universities and scientific research centers about the sensitivity of this important threatened species.

Key words: IUCN Conservation Assessment · Critically Endangered · Mountain Ecosystem · Endemic Species · Saint Katherine Protectorate

INTRODUCTION

Biodiversity is an abbreviated form of biological diversity and refers to living things on the earth. Plants are an important resource and have immense impact on ecosystems and have a vital role in socioeconomic conditions of the people. Plant diversity and ecological characteristics are important in term of land degradation and erosion [1, 2]. Plants are universally recognized as a vital component of biodiversity and global sustainability. For example, plants provide food, fiber, fuel, shelter, medicine. Healthy ecosystems based on plant diversity provide the conditions and processes that sustain life and are essential to the well-being and livelihoods of all humankind [3]. It is clear that the loss of biodiversity has serious economic and social costs. The genes, species, ecosystems and human knowledge that are being lost represent a living library of options available for adapting to local and global change [4]. Environmental deterioration in arid ecosystems due to unmanaged human activities including harvesting of vegetation for fuel and medicine, overgrazing, urbanization and quarrying is evident in a decrease of plant cover, deterioration of soil productivity and aggravation of soil erosion [5]. Damage to vegetation and the soil surface and in arid lands is not easily repaired [6].

An accurate picture of the status of plants and the trends that are impacting on them is difficult to determine. Indeed, we do not yet know the exact number of plant species in the world (estimated currently at 370,000 known species). However, it is predicted that as many as two-thirds of the world's plant species are in danger of extinction in nature during the course of the 21st century [7].

Corresponding Author: Karim Omar, Nature Conservation Sector (NCS), Egyptian Environmental Affairs Agency (EEAA). E-mail: kariemomar@gmail.com.

Extinction and declines in plant diversity are due to a range of factors, including population growth, high rates of habitat modification and deforestation, over-exploitation, the spread of invasive alien species, pollution and climate change. The Millennium Ecosystem Assessment noted that approximately 60% of the ecosystem services evaluated are being degraded or used unsustainably (www.milleniumassessment.org). The degradation of ecosystem services often causes significant harm to human well-being and represents a loss of a natural asset or wealth of a country.

The IUCN Red List of Threatened Species (henceforth 'Red List'), produced by the Species Survival Commission (SSC) of the World Conservation Union (IUCN; http://www.iucn.org), highlights species that are at the greatest risk of extinction and promotes their conservation by 'concentrating minds on true priorities' [8].

The dominant method for assessment, particularly at the global level, has been the IUCN Red List process. However, it is unlikely that the target can be reached using this process alone and hence it should be stressed that it is a preliminary assessment that is called for and that this need not be a full Red List assessment [9]. In the last decade, there has been a gradual increase in the number of species included in the IUCN Red List at a global level. However, given an estimate of approximately 370,000 flowering plants, the global assessments still only include 3-4% of plant species. More encouraging progress has occurred at a national level. During the consultation on this target, 52% of countries indicated that they had completed some form of Red List assessment [9].

The utility of the Red List as a conservation tool derives not only from the classification of each species into a category of threat, but also for the wealth of data, collected to support these assessments, that are published online in a searchable format [10]. Submissions to the Red List now require the rationale for listing, supported by data on range size, population size and trend, distribution, habitat preferences, altitude, threats and conservation actions in place or needed. Many of these parameters are coded in standardized 'authority files' that enable comparative analyses across taxa [10]. The Red List data are a source of information that is essential to guide conservation efforts focused on species. Threat categorizations themselves are key to guiding priorities for conservation investment among species [11], albeit necessarily along with other information, such as cost and feasibility [12, 13]. The assessments also produce a series of recommendations for conservation action [14]

The Saint Katherine Protectorate (SKP) is one of Egypt's largest protected areas and includes the country's highest mountains. The Saint Katherine region is situated in the southern part of Sinai and is a part of the upper Sinai massif. It is located between 33° 55' to 34° 30' East and 28° 30' to 28° 35' North [15]. This arid, mountainous ecosystem supports a surprising biodiversity and a high proportion of plant endemics and rare plants. The flora of the mountains differs from the other areas, due to its unique geology, morphology and climatic aspects. The soil is formed mainly from mountains weathering, thus it is mainly granitic in origin. The soil layer is generally shallow where the bedrock is close to the surface. Annual rainfall is less than 50 mm. However, rainfall is not of annual character, rather 2 to 3 consecutive years without rainfall is common. Rain takes the form of sporadic flash floods or limited local showers, thus highly spatial heterogeneity in receiving moisture is also common. Drought, feral donkeys, over collecting, overgrazing, tourist intrusions, urbanization & settlement expansion, unmanaged scientific research and quarries had been reported as the main threats on vegetation in SKP [16, 17].

The St. Katherine Protectorate is one of the most floristically diverse spots in the Middle East with 30% of Egypt's endemic plant species. The genus *Primula* L. is the most important one in the Primulaceae family. Considering the latest evaluations, it includes 500 species, mainly located in the temperate and cold regions of the northern hemisphere and in the tropical mountains [18]. *Primula* is a complex and varied genus, with a range of habitats from alpine slopes to boggy meadows. Plants bloom mostly during the spring, with flowers often appearing in spherical umbels on stout stems arising from basal rosettes of leaves; their flowers can be purple, yellow, red, pink, blue, or white. Some species show a white mealy bloom (farina) on various parts of the plant. Many species are adapted to alpine climates.

Primula section Sphondylia (Duby) Rupr. comprises eight species with patchy distributions endemic to mountainous regions from the West Himalayas to Ethiopia, including Afghanistan, Egypt, Iran, Saudi Arabia, Turkey and Yemen [19, 20]. This section is remarkable for its intra- and inter-specific variation of floral morphologies, which is not as marked in other sections of the genus [21, 20]. *Primula boveana* Decne.

ex Duby is the only species of genus *Primula* in Egyptian flora. It is endemic to the SKP in South Sinai, Egypt and has high medical importance because of substances extracted from its roots. This species is severely threatened by both natural (aridity of the area) and human factors (scientific research). All these factors are pushing *P. boveana* to the brink of extinction. This species is restricted to Montane wadis fed by melted snow and distributed in moist ground in the vicinity of wells and sheltered mountain areas. Because of climate change, the wild population of this species could be in extreme danger in the near future.

Due to its geographic isolation, at least 1,400 km away from other species from section Sphondylia, *P. boveana* is a key element for understanding the biogeographic connections within the genus *Primula*. Population sizes are very small, although this species is known to have been more abundant in the recent past [22, 20]. Such a narrow distribution and scarcity prompted [20] to refer to *P. boveana* as ‘‘one of the rarest plant species’’. The IUCN lists it under the category deficient data [23]. Due to its extreme rarity, *P. boveana* is considered as a priority target for conservation at a national level in Egypt [24].

The alarming, recent decrease in the population sizes of *P. boveana* seemingly corresponds to the increasing aridification of its habitat, namely granitic mountains dissected by steep-sloped wadis (i.e., valleys) at high elevation (i.e., [1,700 m a.s.l.) and irrigated by springs mostly fed by melt water [25]. The climate in the Sinai is Saharan-Mediterranean, with the mountainous regions characterized by hot summers, relatively cold winters and precipitation regimes of 60 mm/ year. The highest peaks receive more water, part of it in the form of snow, which increases precipitation to up to 300 mm/year [26]. Human activities in the past few decades, especially water consumption in the local bedouin populations and a fast-developing tourist industry, have severely depleted local water reserves [26]. This human-driven aridification, together with the prediction of warmer and drier conditions due to climate change both in the mountains generally [27], forecasts a further fall in the number and extent of the populations of *P. boveana.*

This study has been carried out within the framework of "*Primula boveana* conservation Project (Assessment of the current conservation status of *Primula boveana* in St Katherine Protectorate, South Sinai, Egypt) funded by "Rufford Foundation’’. This study is aimed to assess the current conservation status of this species according to IUCN criteria in order to produce a series of recommendations for conservation action.

MATERIALS AND METHODS

The present study was carried out in the period between March to May, 2014. To determine the conservation status of this species we have to collect sufficient data about the following:

Geographic Range: Distribution of *P. boveana* within SKP during the field survey was record. A GPS fix was recorded in decimal degrees and datum WGS84 using Garmin 12 XL receiver. The fix was recorded to the fifth decimal digit. Arc View GIS 9.2 was used to plot the study sites. Number of locations where the target species occurs, Extent of Occurrence (EOO), Area of Occupancy (AOO) and its decline trend were recorded and measured according to IUCN guidelines [28]. Recorded GPS points for each location were imported into GIS 9.2 software as excel sheet, then it add on TIN map then from 3d analyst tool TIN surface was chosen to extract the topographic features (Elevation, aspect and slope) of this species [15].

Population Information: Number of *P. boveana* populations and subpopulations, number of total individuals, number of mature individuals, population structure and dynamics, population trend, fluctuations, fragmentation and decline trend were recorded and measured according to IUCN guidelines [28].

Habitats and Ecology: Preferable habitat and microhabitat of the target species and its decline trend within the field survey, according to IUCN Habitats Classification Scheme was recorded [28]. Climatic features (Max. Temp., Min. Temp. and Perception) and soil properties (Texture, pH, Organic Matter and moisture) were collected from former studies [15, 29) and presented in table for each site within this study. Vegetation characteristics of target species like density, cover, abundance, Size Index and associated species within each site were recorded. Life form and cycle were also recorded.

Use and Trade: We record any activities that may lead to use this species at any level beside its possibility to be traded.

Threats: During the field survey, we recorded any activities that may lead to deterioration in plant population trend. Timing, scope, severity and impact score for each threat were determined according to IUCN Threats Classification Scheme [28].

Conservation Requirements: In this part, we will collect any information about past, ongoing and future activities to protect this species in-place or outside-place. Conservation actions that will take place on land or that needed in the near future will also recorded. Researches needed according to IUCN Scheme were recommending [28].

Red List Category & Criteria: We will assess the taxon using the information and data recorded in this study and follow the IUCN Red List Categories and Criteria: version 3.1. and current version of the Guidelines for Using the IUCN Red List Categories and Criteria for guidance on applying the IUCN criteria [28].

RESULTS

Geographic Range: *Primula boveana* is endemic to SKP; it was recorded only inside the boundary of SKP; exactly, in five main very small localities (Shaq Elgragenia, Shaq Mousa, Elgabal Elahmar, Kahf Elghola and Sad Abu Hebiq). Its estimated extent of occurrence (EOO) found to be about 13 km^2 (12.7km^2) and its estimated area of occupancy (AOO) less than 1 km^2 (700m^2) and less than 6 km^2 with IUCN standers (each grid 2X2 km), See Map 1. It was observed that both EOO and AOO showed decline with time. *P. boveana* was recorded as abundant in the past by [22, 20]. SKP reports had shown also that this species record in the past at the St. Catherine Mountain and Elgalt Elazrak area.

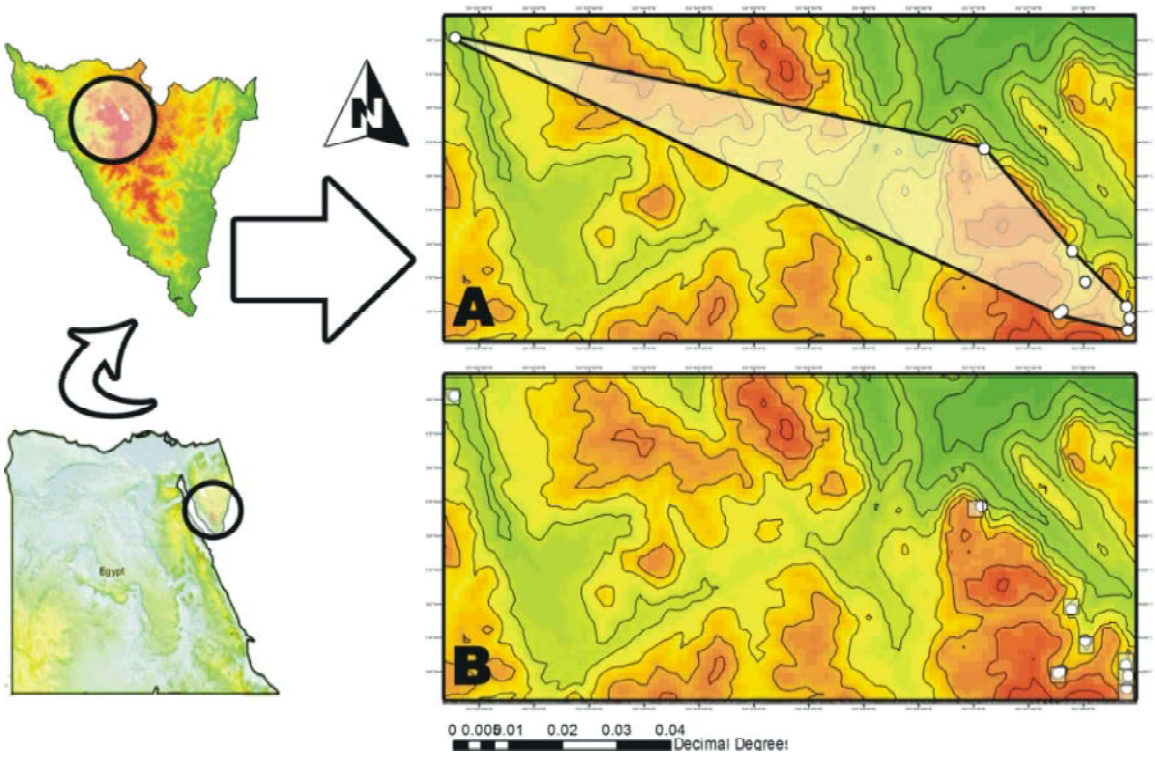
A narrow altitudinal range was recorded for this species ranging between 1745 and 2210 m. It was observed that population size positively affected by elevation. Results also shown that target species highly located in slopes that face northeast- (78%) and east aspect (22%) with slope degree ranging from 55° to 90° (Table 1).

Population Information: Most of the *P. boveana* subpopulations are small, fragmented, with individual plants occurring sporadically in space in the little groups where the soil is wet. The number of mature plants declined from 'abundant' in 1832 [20], almost 2000 in 1991 [22] and 336 in 2007 [30]: In 2014, the total global population size was recorded at about 1010 individuals during our the last survey, but only 165 individuals were mature (about 16% of the total population). Shaq Mousa was the highest in total number of individuals, it containing 733 individuals (72.6%), 74 of them are mature. Only four immature individuals were recorded at Kahf Elghola (0.3%) (Table 1).

There are nine very small but clearly separate subpopulations, but only seven of them contain between 3 and 65 mature individuals. There are no records for mature individuals in Kahf Elghola and Sad Abu Hebiq. The largest Number of mature plants was recorded in one of the three subpopulation recorded in Shaq Mousa and was 65 with percentage reach to 46% of the total individuals recorded in this subpopulation (Map 1). In 1991, the target species was distributed in more than 12 subpopulations including Gabal St. Katherine, Elgalt Elazrak that not recorded in this study. These studies disappeared in period between 2001 to 2007. ElgaltElazrak subpopulation appered from 2007 to 2012 and then disappeared again. Area like Shaq Elgragenia that recorded in this study as one of the main sites for *P. boveana* was not found in the past (2005 to 2008). KahfElghola subpopulation was the main site for *P. boveana* in the past but in this study, we did not record any mature individuals in it. *Pimulaboveana* distribution and size depending on the presence of water (rainfall) that is mean that species is undergoes extreme fluctuations in past, ongoing, and future resulting from irregular precipitation. These fluctuations in subpopulations number led to fluctuations in both EOO and AOO.

During the last 10 years, these subpopulations showed large changes in the total number of individuals, cover and density. There was a peak observed between 2008 to 2010 (345 to 360 mature individuals) but now (2012-2014) the population is at its lowest observed number: it may be that the species undergoes severe fluctuations. The population decline was also recorded, thirty individuals were recorded at the Kahf Elghoula subpopulation in 2009, but only four immature seedlings in 2014. Forty-one individuals were recorded in Sad Abu Hebiq subpopulation in 2007 [30], but only six immature seedlings in 2014. Drought is the main limiting factor for this species and because the plant is distributed within such a very small-restricted area, the entire population will feel the effect of this threat: thus, they are all effectively in one location.

Habitats and Ecology: According to IUCN Habitats Classification Scheme, this species belong to rocky habitat (mountain peaks), is restricted to Montane wadis fed by melted snow and distributed in moist ground in the



Map 1: Automated preliminary GIS analysis of *Primula boveana* geographical distribution. A- Extent Of Occurrence (EOO) and B- Area Of occupancy (AOO)

Table 1: Environmental variation among different *P. boveana* subpopulation

	Population			Topographic feathers			Climatic variable			Edaphic Factors		
Subpopulation	No. of Indv.	Mature	Micro- habitat	Altitude (m)	Aspect	Slope	TMIN	TMAX	PREC	pH	Water content	Organic matter%
S.G.1	23	3	Cliff	1886	NE	70	7.5	18.6	7.8	8.5	0.59	3.28
S.G.2	141	65	Slope	2170	NE	55	7.5	18.6	7.8	8.7	0.55	3.05
S.G.3	98	16	Cliff	2202	NE	90	7.5	18.6	7.8	8.6	0.53	0.45
S.M.1	535	24	Cliff	2067	NE	90	8.83	20.13	7.92	7.7	0.31	2.76
S.M.2	103	37	Cliff	2065	NE	85	8.83	20.13	7.92	7.9	0.41	3.45
S.M.3	80	12	Cliff	1939	NE	79	8.83	20.13	7.92	7.2	1.13	4.14
A.	20	8	Gorge	1914	E	80	8.09	19.46	9.25	8.7	0.98	8.03
K.E.	4	0	Cave	1850	E	82	9.93	21.19	5.67	7.8	0.95	4.83
A.H.	6	0	Cliff	1740	NE	90	10.5	21.78	4.75	8.1	1.01	2.07

Note: S.G=Shaq Elgragenia, S.M=Shaq Mousa, A= Elgabal Elahmar, K.E= Kahf Elghola and A.H.= Sad Abu Hebik.

Table 2: Vegetation characteristics of *P. boveana* within SKP

Subpopulation	D.	A.	C.	S.I	Dominant Sp.	Associated Species
S.G.1	0.92	23	0.09	6	*Primula boveana*	*Mentha longifolia, Juncus rigidus, Hypericum sinaicum, Scrophularia libanotica*
S.G.2	5.04	141	0.99	10	*Primula boveana*	*Nepeta septemcrenata, Mentha longifolia, Juncus rigidus, Origanum syriacum*
S.G.3	3.92	98	1.11	11.5	*Primula boveana*	*Mentha longifolia, Juncus rigidus, Origanum syriacum*
S.M.1	22	535	1.6	5	*Primula boveana*	*Mentha longifolia, Crataegus x sinaica*
S.M.2	4.12	103	1.8	15.5	*Primula boveana*	*Scrophularia libanotica*
S.M.3	3.2	80	0.6	8.5	*Primula boveana*	*Hypericum sinaicum, Mentha longifolia, Juncus rigidus, Scrophularia libanotica*
A.	0.8	20	1.4	28	*Juncus rigidus*	*Adiantum capillus-veneris, Hypericum sinaicum, Phlomis aurea, Mentha longifolia*
K.E.	0.16	4	0.01	4.5	*Adiantum capillus-veneris*	*Hypericum sinaicum, Mentha longifolia, Juncus rigidus*
A.H.	0.24	6	0.01	6	*Adiantum capillus-veneris*	*Mentha longifolia, Juncus rigidus*

Note: S. G=Shaq Elgragenia, S. M=Shaq Mousa, A= Elgabal Elahmar, K. E= Kahf Elghola, A. H. = Sad Abu Hebik, D. = Density, A. = Abundant, C. = Cover and S. I= Size Index.

vicinity of wells and sheltered mountain areas, especially cliffs and caves with steep granite slopes. The cold winter climate (minimum temperature can reach -10°C) and cool summers (maximum about 29°C) of the high elevations of Mt. St. Katherine is the coolest on the peninsula [15]. The arid climate has a mean annual rainfall of about 37.5 mm (between 1971-2014), some in the form of snow, but there is great inter-annual variation with up to 300 mm in any one year, usually between October and May. Relative humidity is low, ranging from 10-35% (data for 2005-2014) and potential evaporation rates are very high, in excess of 20 mm/day during August. *P. boveana* grows in loamy sandy soil with average pH 8.2, water content 0.7 and organic matter 3.5% [31, 29], See Table 1.

Vegetation parameters showed variation among different subpopulation; Density varied and ranged from 0.16 (Kahf Elghola) to 22 (subpopulation 1 in Shaq Mousa). Abundant ranged also from 4 (Kahf Elghola) to 535 (subpopulation 1 in Shaq Mousa). Cover ranged from 0.01 (Kahf Elghola) to 1.8 (subpopulation 2 in Shaq Mousa). Size Index ranged from 4.5 (Kahf Elghola) to 26 (Elgabal Elahmar). Because of its restricted micro-habitat, *P. boveana* is the dominant species in most sites, but its associated species are *Adiantum capillus-veneris* L., *Mentha longifolia* (L.) Huds., *Hypericum sinaicum* Boiss. and *Juncus rigidus* Desf. [31]. *Primula boveana* is a perennial herb with stems up to 50 cm long. The grayish-green leaves are spear-shaped, up to 20 cm long in a rosette. It bears several whorls of long-tubed, golden-yellow, scented flowers in late spring and reproduction is by seed in late summer. Field observation showed that *P. boveana* starting the flowering season from the early of March and finish at the end of July when the fruiting season started in July and finish at the end of September and this agrees with [29], Table 2.

It was observed that Shaq Mousa contains the highest values in most variables (Population size, mature individuals, density, abundance and cover); this may be explained as this site owning the best preferable suitable conditions for species to grow and distribute.

Use and Trade: The species is not commercially or traditionally used in Sinai, but it has been collected for pharmacological testing by various scientific research centers.

Threats: Because of climate change, the wild population of this species could be in extreme danger in the relatively near future. The most important natural threats are the long-lasting droughts, the very scarce irregular precipitation during the year, the fragmentation inherent to its habitat and the possibility that rare floods may cause harm such as uprooting (5% loss observed). Apart from climate change, the most important human impacts are reductions in water availability caused by collection for human consumption from the nearby areas, possible sheep and goat grazing, insect pests that eat the vegetative parts and may cause reductions in plant vigor (observed) and a species of ant that collects the seeds, perhaps causing reductions in the reproductive rate (Table 3).

About 4 million people from 51 nationalities visited SKP from 2003 to 2014 with an average 335.000 people per year. Most of them focused on the northern part of SKP, a world heritage site. Many of the tourists do safari and camp in remote areas; usually safaris extend for many days using different camping sites; the most camping sites are in Sad Abu Hebik, Shaq Mousa, GabalMousa, WadiTenia, and WadiGebal. Five of the nine subpopulations recorded within this study are minor influence by the presence of tourism. Some of the negative impacts associated with tourists include collecting plants as souvenirs from the SKP. Soil compactions due to trespassing leads to poor vegetation cover and results from trampling. Garbage also may lead to deterioration in species growth. Camping takes place in sheltered sites which provide water sources for tourists. Because of its importance and rarity, it's a target for collecting. The unmanaged collecting for this species will lead to deterioration in population size (observed). Human activities like climbing and trespassing in areas Like Shaq Mousa, Shaq Elgragenia lead individual destruction through mashing lead to deterioration in species population size (observed). Human modification was the extent of water cannons relocating water from elevated wadies rich in water supply to low wadies. This activity leads to consume and loss of water from wells which directly affect the plant population size resulting from consuming the water around Primula habitat and lead to extreme deterioration.

Former studies found that species subpopulations have very low genetic variation among individuals within them and gene flow between them must be extremely low or actually zero: conversely, genetic differentiation among the subpopulations is high [30]. It may self-fertilize most of the time, apparently with little or no detrimental effects [21, 30]. Probably deleterious alleles have been purged a long time ago, making inbreeding depression, possibly not a major problem today, although possibly restricting its ability to evolve in response to environmental change [30].

Table 3: Threats Classification Scheme for *P. boveana* within SKP

Threat	Timing	Scope	Severity	Impact Score
Tourism & recreation areas	Ongoing	Minority (< 50%)	Causing/Could cause fluctuations	Low Impact
Gathering terrestrial plants -Intentional use (species is the target)	Ongoing	Minority (< 50%)	Slow, Significant Declines	Low Impact
Gathering terrestrial plants -Persecution/control	Ongoing	Minority (< 50%)	Slow, Significant Declines	Low Impact
Human intrusions & disturbance - Work & other activities	Ongoing	Minority (< 50%)	Slow, Significant Declines	Low Impact
Dams & water management/use -Abstraction of ground water (domestic use)	Ongoing	Minority (< 50%)	Slow, Significant Declines	Low Impact
Droughts	Ongoing	Whole (> 9 0%)	Very Rapid Declines	High Impact
Temperature extremes	Ongoing	Whole (> 9 0%)	Very Rapid Declines	High Impact
Storms & flooding	Ongoing	Whole (> 9 0%)	Very Rapid Declines	High Impact

Conservation Requirements: The entire world distribution of *P. boveana* is inside the St. Katherine Protectorate. Six from the nine subpopulations are already protected by fenced enclosures and regular monitoring by SKP rangers takes place every two years to detect the effect of this protection on population trends. On average 48 checks are made every year to keep a watch on the current situation for the plant and its habitat and to record any detrimental activities. Funded by UNEP, the Medicinal Plants Conservation Project tried to conserve some important species, *P. boveana* among them, using cultivation inside greenhouses as well as storing its seeds for future use. Studies were initiated of its ecological, morphological and reproductive ecology and the threats to its existence [31]. Much more is needed, however.

Red List Category & Criteria: After analyzing the data above, we can say that *P. boveana* qualifies as Critically Endangered (CR) because it is endemic to a tiny area (EOO 13 km^2, AOO <1 km^2- <6 km^2 IUCN) of the high mountain area of the St. Katherine Protectorate in South Sinai, Egypt. The total population size of mature individuals is less than 200, distributed among nine subpopulations. Because the main threat is drought and climate change, effectively there is only one location. There is a continuing decline in habitat quality for this species, with evidence of declines in subpopulation numbers as well as strong fluctuations through time. Climate change is projected to further reduce the available habitat of this high-elevation specialist.

DISCUSSION

From this study, we found that *P. boveana* is in extreme danger and by time, it will tend to be in extinct cycle. The sharp decline in population size, number of total individuals, number of mature individuals and habitat may came from the changing in the world climate, which increase the effect of the main threat to this species (drought), Fig. 1. Many explanations found that global warming represents perhaps the most pervasive of the various threats to the planet's biodiversity, given its potential to affect even areas far from human habitation. Despite this and recent reports outlining the extensive biological changes that are ongoing because of the warming [32], few efforts have been made to assess the potential effects of greenhouse warming on terrestrial biodiversity at a global scale [33].

A recent exception is [34], who used a climate-envelope modeling approach to look at the potential future distributions of 1103 species in six regions. Their work suggests that restricted-range endemic species may be especially vulnerable, which is not able given recent efforts to prioritize conservation at the global scale by identifying biodiversity hotspots that are of particular value based on their high species richness and endemism [35]. Extensive impacts due to global warming within these high-value ecosystems would constitute a key threat to the planet's biodiversity. Indeed, threats to these ecosystems would presumably constitute the unnatural adaptation of ecosystems that is to be avoided under the United Nations Framework Convention on Climate Change.

It's recognized that, many rare and/or endemic species like *P. boveana* have one or more of the following characteristics: (1) They have a narrow (or single) geographical range, (2) they have only one or a few populations remaining, (3) they show small population size and little genetic variability, (4) they are usually over-exploited (overhunted and over-harvested) by people, (5) they exhibit declining population sizes, (6) they have low reproductive ability, (7) they show specialized niche demands, (8) they grow in stable and nearly constant environments. All of these attributes, either alone or in combination, make a species prone to extinction at an increased rate. When habitats of a rare and/or endemic

Fig. 1: Deterioration of *Primula boveana* population in the last ten years.

species are damaged and/or fragmented by mismanagement and various other human activities, the distribution ranges, population sizes and genetic variability of the species will be reduced and its members will become vulnerable to extinction at a faster rate than other species. Species with any one or more of the above attributes must be carefully monitored and managed in an effort to maintain biodiversity [36].

Consequently, it is necessary to carry out regular monitoring to keep updated on the population size, distribution & its trends. Researches and workshops must establish rabidly to start in Species Action/Recovery Plan. This dramatic demographic decline observed in *P. boveana* is likely caused by environmental changes in the past few decades. Habitat deterioration as a consequence of global warming trends is a general threat for the survival not only of *P. boveana,* but also of other species endemic to the Sinai mountains [37, 30]. Both temperatures and aridification are expected to increase in the Mediterranean region in the next decades [38-40] and predictive models forecast a high extirpation risk for species in the mountains, especially in arid areas [41]. Less precipitation throughout the year would unavoidably reduce the volume of the water flows to which *P. boveana* is intimately linked, therefore reducing the number and size of habitat patches suitable for this species [30]. Furthermore, rising human demands on the environment would aggravate the problem of water availability. Besides the direct effect of low water availability on plant survival, an increase in temperatures could definitely affect the flowering phenology of the species and further disrupt the already irregular pollination services [42, 30].

Finally, One of the natural strategies that may buffer *P. boveana* against the risk of extinction is the build-up of seed banks [25, 43, 30], a strategy previously reported for other primroses [44, 45]. Seed banks in arid habitats allow seeds to stay dormant in dry years and germinate when conditions are more favorable to growth and reproduction [30]. In addition, seed banks can also act as reservoirs of genetic variation, thus delaying the loss of genetic variation and maintaining the evolutionary potential of populations [43, 30]. Therefore, as long as dry periods are interspersed with moister intervals, seed banks could buffer the genetic and demographic erosion of *P. boveana*. However, as explained above, both temperatures and aridification are expected to increase in the Sinai mountains in the very near future. These measures, mainly focused on habitat preservation, should include a careful management of water resources in the region, restoration of the habitats potentially suitable for *P. boveana* and, if necessary, occasional artificial irrigation of the populations. In addition, the fenced subpopulations protect the plants from threats of lesser concern currently affecting *P. boveana,* such as sporadic collections for medicinal uses [46] and grazing (H. Mansour, personal observation), however Kahf Elghola enclosure needs for rapid maintenance. This location showed fast deterioration in the last 5 years resulted from drought and unmanaged collecting for scientific research, its urgent need for closing this site for any visits for at least two years and keep monitoring on the population trend.

Elgabal Elahmar subpopulation located inside a fenced enclosure that condensed by plants, this makes this place is like a closed room and will lead to negative impact on species reproduction by time. Number of individuals in this subpopulation is 8 from 2006 to date this number is constant; I think it will be useful if we cut some parts from unranked plant species that surround *Primula* like *Juncus rigidus* to increase the size for reproductive success and will decrease the pressure. Suitable habitat for optimum growth, including climatic, edaphic, topographic and preferable microhabitat should be followed when *in-situ* conservation by rehabilitation or

restoration takes place as listed in this study. It found that places like Elmesirdi, Shaq Itlah, Abu Tweita, Abu Hamman, Wadi Eltebq and Wadi Eltalaa are the best places for this process. There are urgent needs to work fast in two directions to keep this species save; 1) *Ex-situ* conservation through a seed bank, genome resource bank and artificial propagation, 2) *In-situ* conservation through rehabilitation and restoration and fenced enclosures. It's important to carry out a wide range of educational and awareness activities in universities and scientific research centers about the sensitivity of this important threatened species.

ACKNOWLEDGEMENT

I would like to extend my thanks to all those who contributed time, suggestions and support during the planning, research and writing of this study. I am personally indebted to Eng. M. Kotb, General Manager of Saint Katherine Protectorate for honest support.

REFERENCES

1. Ahmad, I., M.S.A. Ahmad, M. Hussain, M. Ashraf, M.Y. Ashraf and M. Hameed, 2010. Spatiotemporal aspects of plant community structure in open scrub rangelands of submountainous Himalayan plateaus. Pak. J. Bot., 42(5): 3431-3440.
2. Bocuk, H., C. Ture and O. Ketenoglu, 2009. Plant diversity and conservation of the northeast Phrygia region under the impact of land degradation and desertification (Central Anatolia, Turkey). Pak. J. Bot., 41(5): 2305-2321.
3. Wilson, E.O., 1992. The Diversity of Life. Penguin, London, UK., pp: 432.
4. United Nations Environment Programme (UNEP)., 1995. Global Biodiversity Assessment. Cambridge University Press. New York, NY.
5. Batanouny, K.H., 1983. Human impact on desert vegetation. In: Man's Impact on Vegetation", W. Holzner, M.J.A. Werger and I. Ikusima, (eds.), Dr. W. Junk Publishers, London, pp: 380.
6. Milton, S.J., W.R.J. Dea, M.A. Du Plessis and W.R. Siegfried, 1994. A conceptual model of arid rangeland degradation", Bio Science, 44: 70-76.
7. The Gran Canaria Declaration, 1999. Calling for a Global Program for Plant Conservation.
8. Collar, N.J. and P. Andrew, 1988. Birds to Watch – The ICBP World Check-list of Threatened Birds, International Council for Bird Preservation.
9. Secretariat of the Convention on Biological Diversity, 2009. The Convention on Biological Diversity Plant Conservation Report: A Review of Progress in Implementing the Global Strategy of Plant Conservation (GSPC), pp: 48.
10. IUCN, 2004. 2004 IUCN Red List of Threatened Species, IUCN-SSC (http://www.iucnredlist.org).
11. Collar, N.J., 1996. The reasons for Red Data Books. Oryx, 30: 121-130.
12. Possingham, H.P., 2002. Limits to the use of threatened species lists. Trends Ecol. Evol., 17: 503-507.
13. Mace, G.M. and R. Lande, 1991. Assessing extinction threats toward a reevaluation of IUCN Threatened Species Categories. Conserv. Biol., 5: 148-157.
14. BirdLife International, 2004. Threatened Birds of the World 2004, CDROM BirdLife International (http://www.birdlife.org/datazone/species/index.html).
15. Omar, K., O. Khafaga and M.A. Elkholy, 2013. Geomatics and plant conservation: GIS for best conservation planning, LAP LAMBERT Academic Publishing, pp: 312.
16. Assi, R., 2007. MP Threat Analysis and Threat Reduction Assessment Report, Conservation and sustainable use of medicinal plants in arid and semi-arid Ecosystems Project, pp: 61.
17. Khafaga, O., E.E. Hatab and K. Omar, 2013. Challenges towards Hypericum sinaicum conservation in south Sinai, Egypt. Jordan Journal of Biological Sciences, 6(2): 116-126.
18. Hao G., C.M. Hu and N.S. Lee, 2002. Circumscriptions and phylogenetic relationships of Primula Sects. Auganthus and Ranunculoides: evidence from nrDNA ITS sequences. Acta Bot Sin., 44: 72-75.
19. Wendelbo, P., 1961. Studies in Primulaceae. II. An account of Primula subgenus Sphondylia with review of the sections of the genus. Aarbok for Universitet I Bergen. Mat- Naturv Serie, 11: 1-49.
20. Richards, A.J., 2003. Primula, 2nd ed. Timber Press, Portland, Oregon, USA.
21. Al Wadi H. and A.J. Richards, 1993. Primary homostyly in Primula L. subgenus Sphondylia (Duby) Rupr. and the evolution of distyly in Primula. New Phytol., 124: 329-338.
22. Al Wadi, H., 1993. Primula boveana and Jebel Katarina. Bull Alp. Gar. Soc., 61: 68-70.
23. Garcı´a N., A. Cuttelod and D. Abdul Malak, 2010. The status and distribution of freshwater biodiversity in northern Africa. IUCN, Gland, Switzerland, Cambridge, UK and Malaga, Spain.

24. Radford, E.A., G. Catullo and B. De Montmollin, 2011. Important plant areas of the south and east Mediterranean region: priority sites for conservation. IUCN, Gland, Switzerland and Malaga, Spain.
25. Moustafa, A.A., A.A. Ramadan, M.S. Zaghloul and M.A. Helmy, 2001. Characteristics of two endemic and endangered species (Primula boveana and Kickxia macilenta) growing in South Sinai. Egypt J. Bot., 41: 17-39.
26. Grainger, J., 2003. 'People are living in the park'. Linking biodiversity conservation to community development in the Middle East region: a case study from the Saint Katherine Protectorate, Southern Sinai. J. Arid Environ., 54: 29-38.
27. Nogue´s-Bravo, D., M.B. Arau´jo, M.P. Errea and J.P. Martý´nez-Rica, 2007. Exposure of global systems to climate warming during the 21st Century. Global Environ Chang, 17: 420-428.
28. IUCN Standards and Petitions Subcommittee, 2014. Guidelines for Using the IUCN Red List Categories and Criteria. Version 3.1. Prepared by the Standards and Petitions Subcommittee. Downloadable from http://www.iucnredlist.org/documents/RedListGuidelines.pdf.
29. Omar, K. and I. Elgamal, 2014. Reproductive and germination ecology of Sinai primrose, Primula boveana Decne. ex Duby. Journal of Global Biosciences., 3(3): 695-708.
30. Jime´nez, A., H. Mansour, B. Keller and E. Conti 2014. Low genetic diversity and high levels of inbreeding in the Sinai primrose (Primula boveana), a species on the brink of extinction. Plant Syst Evol. (2014) 300: 1199-1208.
31. Omar, K., 2013b. *Primulaboveana* conservation (assessment of the current conservation status of *Primulaboveana* in St Katherine Protectorate, South Sinai, Egypt). Rufford Small Grants Foundation.
32. Parmesan, C. and G. Yohe, 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature, 421: 37-42.
33. Noss, R.F., 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology, 15: 578-590.
34. Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F.D. Siqueira, A. Grainger and L. Hannah, 2004. "Extinction risk from climate change" (PDF). Nature 427(6970): 145-148.
35. Mayers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca and J. Kent, 2000. Biodiversity hotspots for conservation priorities. Nature, 403: 853-858.
36. Kani, I.Ş.I.K., 2011. Rare and endemic species: why are they prone to extinction? Turk J. Bot., 35: 411-417.
37. Hoyle, M. and M. James, 2005. Global warming, human population pressure and viability of the world's smallest butterfly. Conserv. Biol., 19: 1113-1124.
38. Alpert, P., S.O. Krichak, H. Shafir, D. Haim and I. Osetinsky, 2008. Climatic trends to extremes employing regional modeling and statistical interpretation over the E. Mediterranean. Global Planet Change, 63: 163-170.
39. Giorgi, F. and P. Lionello, 2008. Climate change projections for the Mediterranean region. Global Planet Change, 63: 90-104.
40. Issar, A.S., 2008. The impact of global warming on the water resources of the Middle East: past, present and future. In: F. Zereini and H. Ho¨tzl, (eds) Climate changes and water resources in the Middle East and North Africa. Springer, Heidelberg, pp: 145-164.
41. McCain, C.M. and R.K. Colwell, 2011. Assessing the threat to montane biodiversity from discordant shifts in temperature and precipitation in a changing climate. Ecol. Lett., 14: 1236-1245.
42. Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig and J.A. Pounds, 2003. Fingerprints of global warming on wild animals and plants. Nature, 421: 57-60.
43. Zaghloul, M.S., 2008. Diversity in soil seed bank of Sinai and implications for conservation and restoration. Afr. J. Environ. Sci. Technol., 2: 172-184.
44. Milberg, P., 1994. Germination ecology of the polycarpic grassland perennials Primula veris and Trollius europaeus. Ecography, 17: 3-8.
45. Shimono, A., S. Ueno, Y. Tsumura and I. Washitani 2006. Spatial genetic structure links between soil seed banks and above-ground populations of Primula modesta in subalpine grassland. J. Ecol., 94: 77-86.
46. Gonza´lez-Tejero, M.R., M. Casares-Porcel, C.P. Sa´nchez-Rojas, J.M. Ramiro-Gutie´rrez, J. Molero-Mesa, A. Pieroni, M.E. Giusti, E. Censorii, C. de Pascale, A. Della, D. Paraskeva-Hadijchambi, A. Hadjichambis, Z. Houmani, M. El-Demerdash, M. El-Zayat, M. Hmamouchi and S. ElJohring, 2008. Medicinal plants in the Mediterranean area: synthesis of the results of the project Rubia. J. Ethnopharmacol., 116: 341-357.