RECOVERY PLAN FOR ROCKROSE (*CROCANTHEMUM CANADENSE* (L.) BRITTON) IN NOVA SCOTIA

A report prepared for the Nova Scotia Department of Lands and Forestry

April 2021
[FINAL]

Recommended Citation:

Nova Scotia Department of Lands and Forestry 2021. Recovery Plan for Rockrose (*Crocanthemum canadense* (L.) Britton) in Nova Scotia [FINAL]. *Nova Scotia Endangered Species Act Recovery Plan Series.* 62 pp.

Additional copies:

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Cover illustration: Photograph by Ruth & Reg Newell.

PREFACE

This Recovery Plan has been prepared by the responsible jurisdiction, the Nova Scotia Department of Lands and Forestry, in cooperation with the Nova Scotia Plants Recovery Team. The Recovery Plan outlines the recovery goals, objectives, and actions that are deemed necessary to protect, conserve, and recover Rockrose in Nova Scotia.

Recovery plans are not designed to provide a comprehensive summary of the biology and status of Species at Risk in Nova Scotia. For more information regarding Rockrose biology, consult the Nova Scotia Provincial Update Status Report (Nova Scotia Department of Lands and Forestry 2021).

Under the *Nova Scotia Endangered Species Act (2007)*, a Recovery Plan must be developed for species listed as Endangered or Threatened under the Act and include the following:

- Identification of the needs and threats of the species;
- The viable status needed for recovery;
- The options for recovery as well as the costs and benefits of these options;
- The recommended course of action or combination of actions to achieve recovery of the species;
- A schedule for implementation of the recovery plan including a prioritized listing of recommended actions;
- Identification of habitat; and
- Identification of areas to be considered for designation as core habitat.

The goals, objectives, and actions identified in this Recovery Plan are based upon the best available information on the species and are subject to modifications and/or revisions as new information becomes available. Recovery of Species at Risk is a shared responsibility and the collaborative approach emphasized in this document is reflective of that. Implementation of the actions and approaches identified in this plan are subject to budget constraints, appropriations, and changing priorities.

ACKNOWLEDGEMENTS

The province contracted Reg B. Newell and Ruth E. Newell to draft this Recovery Plan in consultation with members of the Nova Scotia Plants Recovery Team and the Nova Scotia Department of Lands and Forestry.

The Department would like to thank those individuals and/or organizations who have contributed to the recovery of Rockrose in Nova Scotia. In particular, the following members of the Nova Scotia Plants Recovery Team are recognized for their significant contributions to the development of this Recovery Plan:

- Alain Belliveau
- Sean Blaney
- Dr. Nick Hill
- Dr. Donna Hurlburt
- Dr. Jeremy Lundholm
- David Mazerolle

EXECUTIVE SUMMARY

Rockrose is a perennial herb with few to many ascending to erect stems, usually less than 0.5 m tall; it is distinctive when flowering with large yellow flowers. Globally, Rockrose is restricted to eastern North America with the northern edge of its range extending into Canada, in southern Ontario, southern Quebec and Nova Scotia. In Nova Scotia, Rockrose is most often associated with the dry, sandy, *Corema* barrens (heathland) of the Annapolis Valley (Kings and Annapolis Counties). However, in Queens County, plants have been found in atypical habitat along a lakeshore and cottage roads. Research has indicated that the Annapolis Valley and Queens County subpopulations are genetically distinct. Rockrose is a drought-tolerant, shade-intolerant and fire/disturbance-dependent species whose habitat has declined significantly in Nova Scotia over the last 50-100 years, due to land conversion and changes in management practices, including wildfire suppression. Biologically, Rockrose is limited by its rarity and scattered distribution, as well as by seed dispersal, competition from other species and possibly fungal associations in the soil. These factors led to its listing as "Endangered" under the *Nova Scotia Endangered Species Act* (NSESA) in 2007 and re-assessment as "Endangered" in 2019.

Primary threats to Rockrose include highway twinning, residential and commercial development, agricultural activities, sand quarries and invasive species. Other potential threats with unknown consequences include fire suppression, effects of pesticides on pollinators, problematic native species (seed predation by a predatory moth) and climate change. Although fire is understood to have played an important role in maintaining open habitats for Rockrose in the past, it is possible that other activities such as OHV use are now compensating for fire by maintaining disturbance and open habitat in some areas; more research is needed to understand this. Likewise, a predatory moth species whose larvae feed on the seeds of Rockrose was identified in 2016 and may pose a threat to the species' genetic diversity, but further study is needed. Activities provisionally considered to have a neutral or beneficial effect on Rockrose include maintenance of roads and transmission lines, OHV use and maintenance activities on the Canadian Forces Base CFB Greenwood (e.g., mowing).

The viable status for recovery of the species, intended as a long-term goal of removing Rockrose from the NSESA, requires more research on seed bank dynamics, habitat requirements and optimal disturbance and management strategies. Because Rockrose is disturbance-dependent some level of habitat manipulation will be required to maintain suitable habitat. An interim long-term recovery goal (>20 years) is to increase the population and number of sites in sand barren habitat under a variety of disturbance regimes. Projected numbers of individuals are subject to further research but should reflect an increase from current estimates. The short-term (5 year) population and distribution objective is to maintain current numbers of at least 7650-8450 plants within its known range extent in the Annapolis Valley and Queens County (i.e., no net loss of numbers of individuals or area of occupancy). An additional goal is to conduct research

to better understand the disjunct subpopulation in Queens County, including habitat studies, site history and genetics.

Broad recovery measures and actions are identified to address threats, protect and enhance habitat (including core habitat), improve communication and outreach, advance policy and guidance to support recovery, and provide a basis for surveys and assessment. In particular, protection of remaining sand barren habitat through purchase, leasing or conservation agreements, developing a conservation strategy including management of disturbance regimes, defining and designating core habitat under the NSESA, raising awareness among private landowners, partnership with CFB Greenwood, and research to address significant knowledge gaps, are important priorities.

RECOVERY FEASIBILITY SUMMARY

The recovery of Rockrose in Nova Scotia is considered technically and biologically feasible if the following four criteria can be met:

1. Individuals of the wildlife species that are capable of reproduction are available now or in the foreseeable future to sustain the population or improve its abundance.

Yes. Rockrose employs a dual reproductive system; viable seed production has been documented in Nova Scotia from both chasmogamous (open-pollinated) and cleistogamous (self-pollinated) flowers. Chasmogamous seeds germinate readily while cleistogamous seeds appear to be mostly dormant. It is possible that Rockrose forms a seedbank that must be stimulated by fire or other disturbances before germinating; however, further research is needed to determine this.

2. Sufficient suitable habitat is available to support the species or could be made available through habitat management or restoration.

Yes. Rockrose establishes primarily in dry open sandy barrens, often on the edges of areas that experience moderate levels of physical disturbance. Although these habitats are in decline in Nova Scotia, an adequate supply of habitat remains, and it is possible to restore or manage areas to become more favourable for Rockrose.

3. The primary threats to the species or its habitat (including threats outside Canada) can be avoided or mitigated.

Yes. Subject to a better understanding of the impacts of some threats (e.g., fire suppression, pesticide effects on pollinators, seed predation by a predatory moth), all of the primary threats that are currently known could be avoided or mitigated. In particular, habitat loss from ongoing development including highway twinning, urban and suburban expansion, land conversion for agriculture and sand quarrying, could be addressed through changes to land use policies and regulations.

4. Recovery techniques exist to achieve the population and distribution objectives or can be expected to be developed within a reasonable timeframe.

Yes. Rockrose can be readily propagated by seed. Seed collections are stored at Acadia University and effective seed sterilization and germination methodologies have been developed. However, long-term recovery of the species will require further research on seedbank dynamics, fire, and other disturbance regimes to ensure maintenance of suitable habitat over time.

The Recovery Team concludes that the recovery of Rockrose in Nova Scotia is technically and biologically feasible based on the criteria discussed above.

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1. NSSARWG ASSESSMENT SUMMARY*

Date of Assessment: June 2019

Common Names: Rockrose, Canada frostweed, Long-branched frostweed

Scientific Name: *Crocanthemum canadense* (L.) Britton

Status: Endangered

Reason for Designation: The Nova Scotia population[1] of Rockrose is at the northeastern limit of the species' range and is genetically distinct from the nearest populations in Quebec and New England. Furthermore, disjunct subpopulations[2] in the Annapolis Valley and Queens County are genetically distinct from each other. Population size in Nova Scotia is estimated at 7650-8450 mature individuals, which represents an increase from the 5000-5500 plants recorded in 2007 due to the discovery of several new sites. However, numbers of plants at previously known sites declined over this period or remained relatively stable. Rockrose is generally associated with the dry, sandy *Corema* barrens (heathland) of the Annapolis Valley and there has been significant historic loss of this habitat in the province; it is estimated that <3% of heathland habitat remains. Ongoing land conversion is causing gradual loss of remaining habitat and the current known distribution of Rockrose is restricted to a very few isolated sites. Primary threats include highway twinning, residential and commercial development, land conversion for agriculture, sand quarrying and invasive species. Potentially significant threats that are poorly understood include fire suppression, pesticide effects on pollinators, seed predation by a predatory moth and climate change. Rescue effect is considered unlikely with the nearest neighbouring population ~450 km away in southwestern Maine.

Nova Scotia Occurrence: Annapolis County, Kings County, Queens County.

Status History: Designated Endangered under NSESA in 2007 when first status report was written. Re-assessed as Endangered by NSSARWG in 2019.

* The following definitions are applicable in this section and elsewhere: NSSARWG (Nova Scotia Species at Risk Working Group); COSEWIC (Committee on the Status of Endangered Wildlife in Canada); NSESA (Nova Scotia Endangered Species Act); SARA (Species at Risk Act).

[1] Population is defined as the total number of individuals of the taxon (COSEWIC 2019), in this case in Nova Scotia.

[2] Subpopulation is defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less) (COSEWIC 2019).

2. SPECIES STATUS INFORMATION

Rockrose is considered globally secure (G5), unranked in the U.S. (NNR), where it is of conservation concern in several states (S1-S3), and vulnerable in Canada (N3) (Table 1). It is not listed under Canada's Species At Risk Act (SARA) or by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Across its distribution in Canada it is designated as Vulnerable in Ontario (S3) and Critically Imperiled in Quebec and Nova Scotia (S1) (NatureServe 2019).

Table 1. NatureServe conservation status ranks for Rockrose in Canada* (NatureServe, 2019).

Global (G) Rank[a]	National (N) Rank[b]	Subnational (S) Rank[c]
G5	N3	S1 – Nova Scotia S3 – Ontario S1 – Quebec

[a] G-Rank – Global Conservation Status Rank, G1 = Critically Imperiled; G2 = Imperiled; G3 = Vulnerable; G4 = Apparently Secure; G5 = Secure

[b] N-Rank –National Conservation Status Rank, N1 = Critically Imperiled; N2 = Imperiled; N3 = Vulnerable; N4 = Apparently Secure; N5 = Secure

[c] S-Rank – Sub-national (provincial or territorial) ranks, S1 = Critically Imperiled; S2 = Imperiled; S3 = Vulnerable; S4 = Apparently Secure; and S5 = Secure. B = breeding; and U = Unrankable.

*A full list of definitions can be found in Definitions of NatureServe Conservation Status Rankings at http://help.natureserve.org/biotics/Content/Record_Management/Element_Files/Element_Tracking/ETRACK_Definitions_of_Heritage_Conservation_Status_Ranks.htm

3. SPECIES INFORMATION

3.1 Species Description

Rockrose is a perennial herb with few to many, ascending to erect stems usually less than 0.5 m tall. Stems are essentially unbranched at the start of the flowering period, later becoming much-branched. Most parts of the plant are stellate-pubescent, giving them a grey or silvery appearance. The simple, alternate, short-petiolate leaves are generally narrowly elliptic in shape and 18-30 mm long by 5-8 mm wide. Plants produce two types of flowers: showy, yellow chasmogamous (open-pollinated) flowers and small, non-showy, cleistogamous (closed, self-fertilizing) flowers. Open-pollinated flowers are produced first in the growing season at the top of the main stems; self-fertilizing flowers are produced later in the season on branches and branchlets. Both flower types produce capsules which bear small numbers of papillose seeds. See the Nova Scotia Provincial Update Status Report (Nova Scotia Department of Lands and Forestry 2021) for a more detailed description and references.

3.2 Population and Distribution

Globally, Rockrose is restricted to eastern North America, occurring in the U.S. from Minnesota, Iowa, and Missouri eastwards, and as far south as Georgia (Sorrie 2015) (Figure 1). Within Canada, populations occur in southern Ontario, southern Quebec and Nova Scotia.

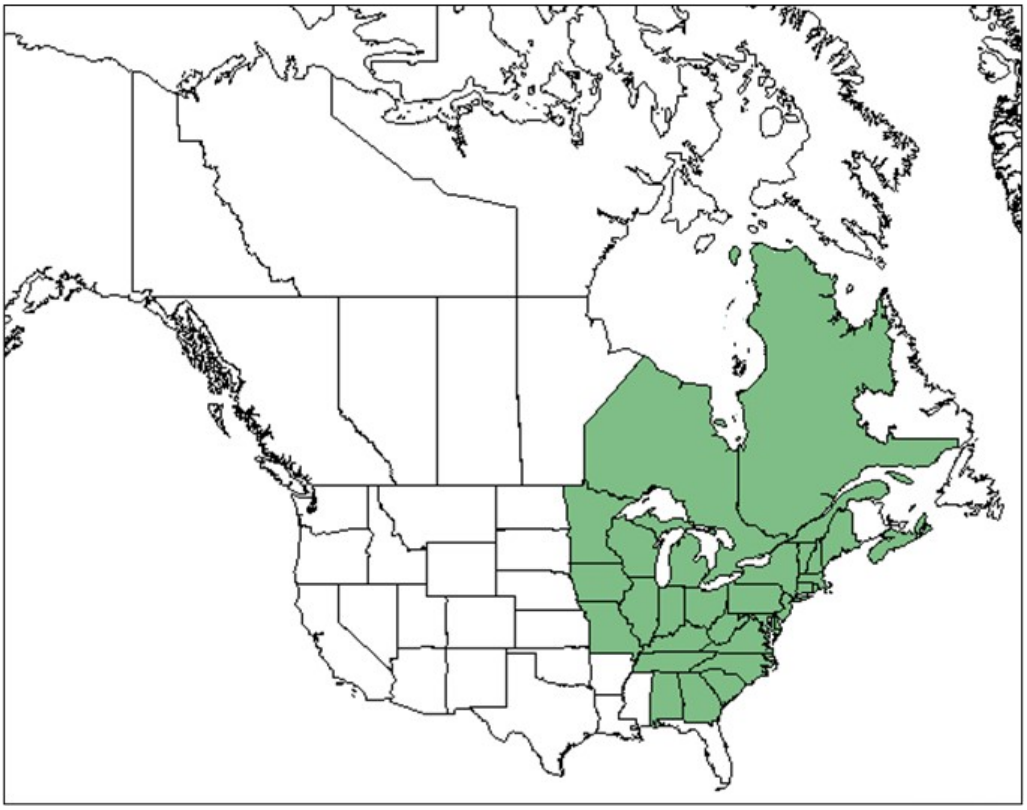

Figure 1. Distribution of Rockrose in North America, shown as presence/absence by state and province (USDA-NRCS 2020).

In Nova Scotia, Rockrose occurs primarily within a small section of the Annapolis Valley sand barrens, with a disjunct subpopulation in Queens County (Figure 2). In the Annapolis Valley, Rockrose is concentrated within the five closely associated communities of Kingston, Greenwood, Auburn, Green Acres and Aylesford in Kings County, and Meadowvale, in Annapolis County (Figure 3). In Queens County it is known from three sites: along a section of shoreline on Ponhook Lake, along the open edge of a cottage road near Molega Lake and along a dry roadside near Bang's Falls (Figure 4). There is a historic record for Five Island Lake, Halifax County, and several historic records in the Annapolis Valley and Queens County which may represent extirpated occurrences.

Research has shown the Nova Scotia population of Rockrose to be genetically unique from the nearest neighboring populations in Quebec and New England, and the Annapolis Valley and Queens County subpopulations within Nova Scotia to be genetically distinct from each other (Yorke 2007; 2011).

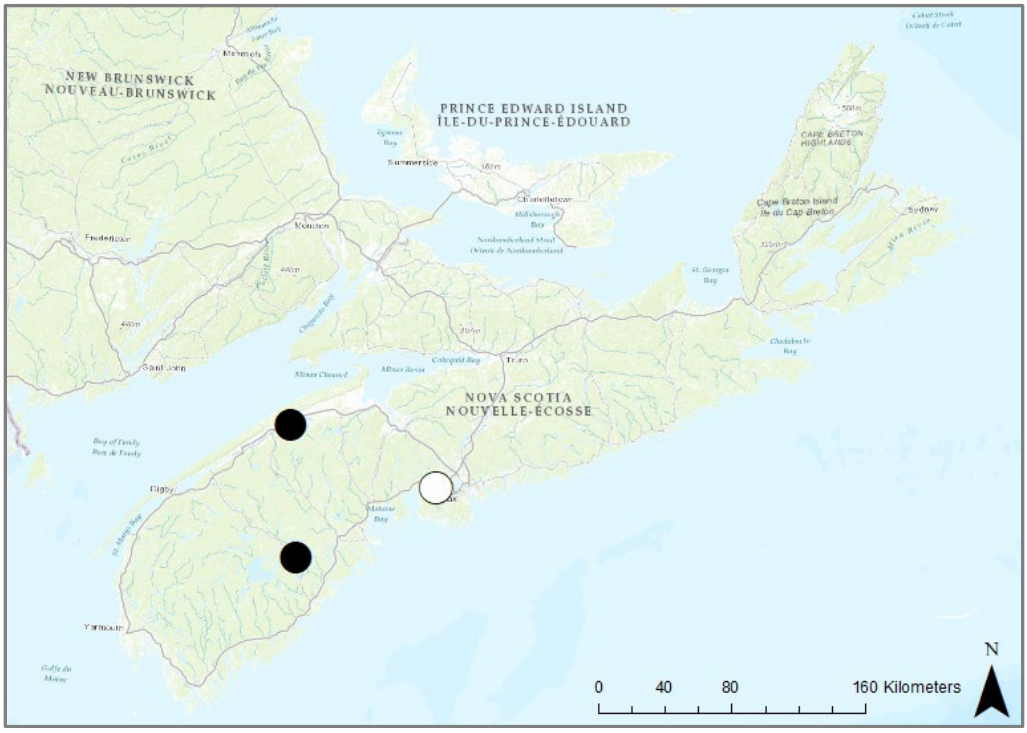

Figure 2. Distribution of Rockrose in Nova Scotia. Black dots represent sites with confirmed records; the single white dot near Halifax represents a historic record.

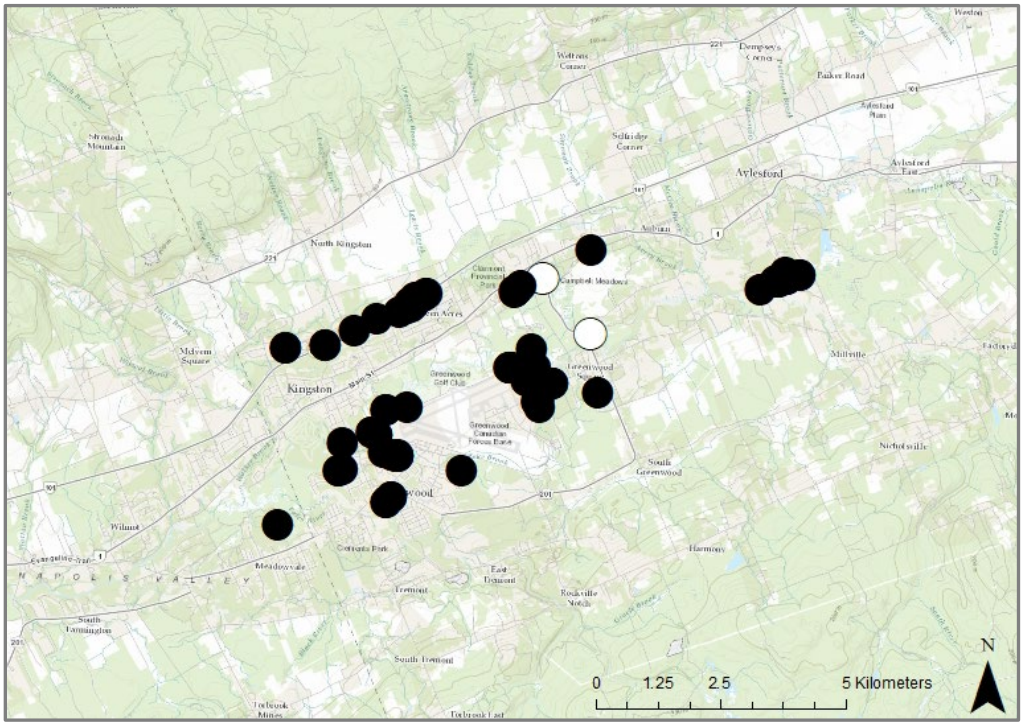

Figure 3. Distribution of Rockrose in Kings and Annapolis Counties, Nova Scotia (black dots). Also shown are historic sites where Rockrose could not be relocated in 2018 (white dots); these locations may represent recently extirpated occurrences.

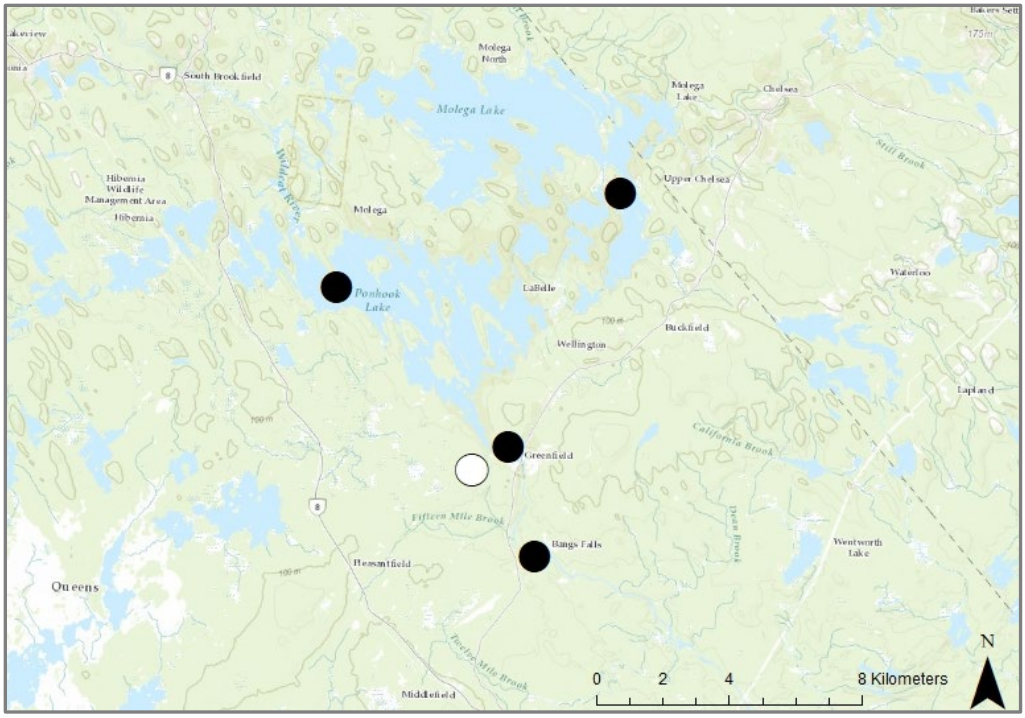

Figure 4. Distribution of Rockrose in the Greenfield area of Queens County, Nova Scotia (black dots). Also shown is an historic site along Chapel Hill Drive, where Rockrose could not be relocated in 2018 (white dot); this site appears to represent a recently extirpated occurrence.

3.2.4 Population Size and Trends

The current estimate of mature individuals of Rockrose in Nova Scotia is between 7650-8450, based on observations by R. E. Newell and R. B. Newell in 2018 and stem counts at new sites discovered in 2019 (Aylesford and Bang's Falls). This represents an overall increase from the 2007 count of 5000-5500 individuals reported in the first status report (Newell 2007; Nova Scotia Department of Lands and Forestry 2021) and is due primarily to the discovery of new sites rather than increases at previously known sites. Excluding new sites, the current number of individuals is 4800-5200 which is fairly close to the total in the first status report (2007). There were some declines at some sites in the interim period but also some increases which balanced out the total numbers.

The discovery of new sites in Queens County since the last status report in 2007 (Newell 2007) in atypical habitat (sandy, cobbly lakeshore on Ponhook Lake; sandy gravelly roadside near Molega Lake; dry roadside near Bang's Falls) suggests Rockrose should be more common in the province than it currently appears to be. However, Ponhook and Molega Lakes have been subject to extensive botanical surveys due to the presence of other Species at Risk (e.g., Redroot (*Lachnanthes caroliniana*) and Goldencrest (*Lophiola aurea*)) without resulting in additional reports of Rockrose (Nova Scotia Department of Lands and Forestry 2021). It is considered very likely that there are still a number of undocumented occurrences of Rockrose in Nova

Scotia; both in the Annapolis Valley and in Queens County. However, these are expected to be small and localized.

Most sites where Rockrose occurs in Nova Scotia represent small, localized patches that may not be self-sustaining in the long term. Rockrose in one area of Kings County (Green Acres) has declined significantly over the last 30-40 years. A site in Queens County documented in the original status report is now extirpated, possibly due to lack of disturbance which is necessary to keep its surrounding habitat open. Because of continuing habitat loss through ongoing development (e.g., road construction, urban and suburban expansion, agriculture, etc.) and disruption of natural disturbance regimes (e.g., fire suppression), it is assumed that the overall trend for Rockrose population in Nova Scotia will continue to be one of decline if no action is taken to address threats.

3.3 Species Needs

3.3.1 Habitat Needs

In Nova Scotia, Rockrose is most often associated with the dry, open, sandy, *Corema* barrens (heathlands) of the Annapolis Valley. Within the sand barren ecosystem, it is usually found in areas where competition for space and sunlight from woody and herbaceous species is limited, and where there are low to moderate levels of physical disturbance. Although the plants tend to be shade intolerant, there is a site where plants occur in partial shade. In Queens County, Rockrose occurs at one site with atypical habitat, along the upper shoreline of Ponhook Lake in sandy, cobbly substrate; it also occurs along a moderately shaded edge of a gravel-dirt road through forested woodland near Molega Lake, and along a dry roadside near Bang's Falls. Rockrose is drought- and fire-tolerant, and fire/disturbance dependent. Historically, browsing by caribou is also believed to have been part of the natural disturbance regime which kept Rockrose habitats open by preventing the establishment of woody species.

3.3.2 Biological Needs and Ecological Role

Reproductive biology

Rockrose is an herbaceous perennial with a dual reproductive system: chasmogamous (open-pollinated) flowers are produced in Nova Scotia from late June/early July to early August, and cleistogamous (self-pollinated, closed) flowers are produced from August to October. Honeybees, bumble bees and small flies have been observed pollinating the showy, large, yellow chasmogamous flowers (Newell 2007; Hillier et al. 2018). Capsules of both chasmogamous and cleistogamous flowers mature in 3-4 weeks. Seeds lack a specialized dispersal mechanism, falling close to the parent plant. Seeds developing from chasmogamous flowers germinate readily whereas seeds from cleistogamous flowers germinate poorly and may remain dormant in the seed bank until exposed to fire (further research needed). Cross-pollinated seeds are likely to be more genetically diverse, while those produced by self-pollination may provide the

plant with a mechanism to disperse in time (Newell 2007).

Recent research at Acadia University (Hillier et al., 2018) has discovered a previously, undocumented type of insect-plant interaction in the form of florivory-initiated autogamy (self-fertilization resulting from the ingestion of floral tissue by an organism) within the chasmogamous flowers of Rockrose.

Fungal Associations

Ongoing mycological research at Acadia University (Allison Walker Laboratory) indicates that there are several fungal associates of Rockrose***.*** A limited occurrence of mutualistic fungal associations in the soils may or may not also be a limiting factor in the distribution of Rockrose. The identification of mutualistic fungal partners has the potential to enhance the success of future conservation efforts (P. Byers, Acadia University, pers. comm., 2018)**.**

3.3.3 Limiting Factors

Natural Disturbance

Rockrose appears to be an edge species that does not grow well under shady conditions. Wildfire suppression has had a significant impact on the quality of the sand barren ecosystem in the Annapolis Valley. Fires have served through time to maintain a variety of successional stages, thereby maximizing biodiversity. The persistence of an open landscape by eliminating or discouraging woody species is particularly critical for the continuing existence of Rockrose. In the absence of fire, succession to woodland habitat is currently steadily replacing open barren, especially on more mesic sites (Catling et al. 2004). Fire suppression and the role of other disturbances will be discussed in more detail under the “Threats” section of this report.

Seed Dispersal

Seed dispersal in Rockrose appears to be somewhat limited. Short-distance seed dispersal is considered characteristic of the Rockrose family as there is no specialized mode of dispersal found within the family (Thanos et al. 1992).

Seeds appear to be too heavy for wind dispersal and the sandy soils in which Rockrose grows restricts dispersal via water. There does not appear to be any fauna that transport the seeds either through ingestion or accidentally on their bodies. Historically, it is possible that grazing animals such as the extirpated Woodland Caribou (*Rangifer tarandus caribou*) may have provided a dispersal mechanism. Currently, seeds appear to drop very near the parent plants, leading to localized clumping. Anthropogenic activities (e.g. hiking, trail riding) may help spread seeds and seeds may possibly be caught on OHV tires and machinery but, unlike in muddy substrates, seeds in dry sand

do not attach well. Therefore, even when viable seeds and suitable habitat are present, the ability of seeds to disperse to new sites appears to be extremely limited.

Species Competition

Rockrose is a poor competitor and is easily displaced by dense, mat-forming plants such as Broom crowberry (*Corema conradii*), a dominant component of sand barrens. Growth of Rockrose is generally restricted to the disturbed soils along the edges of mat-forming plants, along moderately used OHV trails, hiking trails and roadsides, as well as in other open areas where competition is limited by disturbance.

4. THREATS

4.1 Threat Assessment

The Rockrose threat assessment (Table 2) is based on the IUCN-CMP (World Conservation Union–Conservation Measures Partnership) unified threats classification system (IUCN 2012). Threats are defined as the proximate activities or processes that have caused, are causing, or may cause in the future the destruction, degradation, and/or impairment of the entity being assessed (population, species, community, or ecosystem) in the area of interest (in this case, the province of Nova Scotia). Limiting factors are not considered during this assessment process. For purposes of the threat assessment, only present and future threats are considered. Historical threats, indirect or cumulative effects of the threats, or any other relevant information that would help understand the nature of nature of the threats are presented in Section 4.2 *Description of Threats*.

Table 2. Threat calculator assessment

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
1	Residential & commercial development	Low	Small	Extreme	High	
1.1	Housing & urban areas	Low	Small	Extreme	High	The Annapolis Valley sand barren ecosystem has been reduced to an estimated 3% of its original extent due to commercial, housing and road development, sand extraction and land conversion for agriculture (Catling et al. 2004; Catling and Carbyn 2005). There continues to be a significant amount of subdivision development in the Kingston and Greenwood areas. Scope is rated 'small' to reflect the ongoing threat to existing (extant) occurrences from urban, suburban and rural development (does not include historical losses or threats to potential habitat).
1.2	Commercial & industrial areas	Low	Small	Extreme	High	As above, ongoing commercial development associated with urban sprawl is estimated to threaten a small proportion of the Rockrose sites in the Annapolis Valley; impacts from greenhouse developments are also captured here. Military base considerations are captured in 6.2.
1.3	Tourism & recreation areas	Negligible	Negligible	Extreme-moderate	High	Development of trails, golf courses, etc. may pose a threat to some sites.
2	Agriculture & aquaculture	Low	Small	Extreme	High	
2.1	Annual & perennial non-timber crops	Low	Small	Extreme	High	Rockrose occurs adjacent to active croplands (e.g., corn fields) in several areas, particularly along Hwy 101 near Kingston. Although not all forms of agriculture may threaten Rockrose (e.g., there is some evidence that mowing or plowing may benefit growth or regeneration in some cases; see

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						McCormick and Buell 1957; Neher et al. 2003) the current trend towards increased cultivation of intensive crops like corn in the Valley suggest a potential threat from land conversion.
2.2	Wood & pulp plantations					Not applicable.
2.3	Livestock farming & ranching	Negligible	Negligible	Unknown	High	There is a significant amount of farming in the Annapolis Valley sand barren area (Catling et al. 2004); it is unclear how much consists of grazing and whether moderate grazing could be beneficial for Rockrose.
2.4	Marine & freshwater aquaculture					Not applicable.
3	Energy production & mining	Low	Small	Extreme - serious	High	
3.1	Oil & gas drilling					Not applicable.
3.2	Mining & quarrying	Low	Small	Extreme - serious	High	Heath sand barrens in Nova Scotia continue to be disrupted by the creation and expansion of sand quarries. Rock/sand pits and quarries contribute to habitat losses and degradation for the species. Note that the size of the pit may be significant as smaller scale activities could result in beneficial disturbance.
3.3	Renewable energy					Not currently applicable. Development of wind and solar farms or biofuel production are possible in future (e.g., the open, level exposed characteristics of sandy heath barrens may be conducive for establishing wind or solar fields) but there is no current evidence for this.
4	Transportation & service corridors	High-low	Large	Serious-slight	High	
4.1	Roads & railroads	High-low	Large	Serious-slight	High	Roadside maintenance (e.g., vegetation management) is beneficial for Rockrose

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						along road edges. However, new road construction projects have potential for serious impacts and highway twinning along Hwy 101 in the Kingston-Greenwood area is real threat within the next 10 years.
4.2	Utility & service lines	Not a threat	Negligible	Neutral or potential benefit	High	Rockrose is known to occur along transmission corridors, and OHV trails often occur in the same areas. The opening of habitat for power/service lines and some OHV activity can be beneficial for the species; it is difficult to disentangle threats from beneficial disturbance. Note that management of these areas could represent some of the best habitat for planting in future, to augment existing population.
4.3	Shipping lanes					Not applicable.
4.4	Flight paths					Not applicable.
5	Biological resource use	Negligible	Negligible	Slight	High	
5.1	Hunting & collecting terrestrial animals					Not applicable.
5.2	Gathering terrestrial plants	Negligible	Negligible	Slight	High	Wildcraft and botanical collecting may pose a minor threat; collection for herbal remedies has harmed some populations in the U.S. (Greenwood Kinsley 2005).
5.3	Logging & wood harvesting					Not currently applicable. Some forest plantations exist in sand barren areas (e.g., Hwy 101, Exit 17w) but have not yet been harvested and do not overlap with Rockrose at present. These areas could represent good potential for positive management in future.
5.4	Fishing & harvesting aquatic resources					Not applicable.
6	Human intrusions & disturbance	Negligible	Negligible	Negligible	Insignificant/neg	

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
					ligible or past	
6.1	Recreational activities	Not a threat	Large	Neutral or potential benefit	High	OHVs are the primary activity of consequence in this category, although disturbance may result to a lesser degree from cyclists, hikers, bird watchers, waterfront use, dog walkers, etc. Disturbance from OHV use is currently believed to have a positive impact by maintaining open habitat for Rockrose, in the absence of natural fires and browsing by the (now extirpated) Woodland caribou. However, heavy OHV use could be detrimental to Rockrose and this should be monitored in future.
6.2	War, civil unrest, & military exercises	Not a threat	Large	Neutral or potential benefit	High	A significant portion of the Nova Scotia Rockrose population (~60%) occurs on the CFB Greenwood military air base. Current sites are protected as much as base operations will allow, including mowing which maintains open habitat and reduces competition from taller vegetation. Base personnel are supportive of efforts to protect existing plants and habitat; collaboration with the base presents good potential for positive management. Note that major infrastructure expansion or changes in landscape management in future (e.g., pesticide use) could have serious negative impacts on the species.
6.3	Work & other activities	Negligible	Negligible	Negligible	Insignificant/negligible or past	Over-collecting for scientific research may have caused the decline of Rockrose at one site in Nova Scotia.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
7	Natural system modifications	Unknown	Pervasive	Unknown	High	
7.1	Fire & fire suppression	Unknown	Pervasive	Unknown	High	Wildfire suppression has had a significant impact on the quality of the sand barren ecosystem in the Annapolis Valley; the absence of fire has led to encroachment of woody vegetation and succession to woodland replacing open barren habitat (Catling et al. 2004; Newell 2007). The persistence of an open landscape is critical for Rockrose. OHV activity may be compensating for fire in maintaining disturbance and open habitat in some areas; however, Rockrose is still being lost to succession. More research is needed to understand the role of fire and fire suppression relative to other activities in maintaining Rockrose habitat, as well as potential effects on biology (e.g., reproductive changes, inbreeding depression, etc.).
7.2	Dams & water management/use					Not applicable
7.3	Other ecosystem modifications	Unknown	Unknown	Unknown	High	Honeybees, bumble bees and small flies have been observed pollinating Rockrose (e.g., Newell 2007; Hiller et al. 2018); pesticide use in surrounding agricultural and residential areas may have an indirect effect on Rockrose habitat and pollinator availability.
8	Invasive & other problematic species, & genes	Medium	Large	Moderate	High	
8.1	Invasive non-native/alien species	Low	Small	Moderate	High	Scots pine (*Pinus sylvestris*) is an aggressive invader of the Corema-dominated sand plains of the Annapolis Valley and dense stands reduce native

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						vegetation cover and biodiversity (Catling and Carbyn 2005). Similar trends are emerging with Black locust (*Robinia pseudoacacia*) (Porter et al. 2020). A number of other alien species may become dominant in sand barren habitat following disturbance (e.g., see Catling et al. 2004; Porter et al. 2020) and other potentially invasive species becoming more common in the area include Autumn olive (*Elaeagnus umbellata*) and Common milkweed (*Asclepias syriaca*)[3]. Direct impacts of these species on Rockrose are poorly understood. Where Rockrose occurs currently along OHV edges it does not appear to overlap with introduced species; however, roadsides and trails are pathways of spread for many invasive species and these may pose a threat in future.
8.2	Problematic native species	Unknown	Large	Unknown	High	Recent discovery and identification of a predatory moth (*Mompha capella*) in two of the largest patches of Rockrose in Nova Scotia suggests genetic diversity may be significantly affected by seed predation (White et al. 2016; Hillier et al. 2018). Research and observations indicate that approximately 50% of chasmogamous flowers are infected by the moth in sites studied, resulting in increased levels of self-fertilization; effects on reproductive success and genetic diversity require further study.
8.3	Introduced genetic material					Not applicable.

[3] Note that Common milkweed is considered a weed in Nova Scotia but it is unclear whether it is introduced or native; see further detail below.

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
8.4	Problematic species/diseases of unknown origin					Not applicable.
8.5	Viral/prion-induced diseases					Not applicable.
8.6	Diseases of unknown cause					Not applicable.
9	Pollution	Negligible	Negligible	Unknown	High	
9.1	Domestic & urban waste water	Negligible	Negligible	Unknown	High	Several sites where Rockrose occurs in Nova Scotia are adjacent to residential developments, where they could be affected by septic fields, fertilizer use and road run-off / snow removal (e.g., salts, contaminants, sediments).
9.2	Industrial & military effluents					Not applicable.
9.3	Agricultural & forestry effluents	Negligible	Negligible	Unknown	High	Several sites where Rockrose occurs in Nova Scotia are adjacent to agricultural fields, where they could be affected by fertilizer and pesticide runoff. Dry, sandy soils are often nutrient-poor and fertilizer runoff could promote growth of more competitive species that could crowd out Rockrose. Herbicides could impact soil fungi necessary to Rockrose.
9.4	Garbage & solid waste					Not applicable.
9.5	Air-borne pollutants					Not applicable.
9.6	Excess energy					Not applicable.
10	Geological events					Not applicable
10.1	Volcanoes					Not applicable.
10.2	Earthquakes/tsunamis					Not applicable.
10.3	Avalanches/landslides					Not applicable.
11	Climate change & severe weather	Unknown	Pervasive	Unknown	High	
11.1	Habitat shifting & alteration	Unknown	Pervasive	Unknown	High	The effects of climate change are uncertain and difficult to predict at the local scale. Rockrose is a poor competitor adapted to dry conditions; a shift to wetter

Threat #	Threat description	Impact[a]	Scope[b]	Severity[c]	Timing[d]	Comments
						conditions could increase competition from other plant species that are less adapted to dry soils. Conversely, an alteration of climate to prolonged drier conditions could favour Rockrose.
11.2	Droughts	Not a threat	Pervasive	Neutral or Potential Benefit	High	Rockrose is a southern, warm weather species, adapted to dry conditions and a fire-driven disturbance regime. An alteration of climate to prolonged drier conditions could be beneficial for Rockrose depending on the exact nature of the changes.
11.3	Temperature extremes					Not applicable.
11.4	Storms & flooding	Negligible	Pervasive	Negligible	High	Rockrose could be negatively affected by extreme wind and storm events – wind erosion, physical damage, excessive moisture.

[a] **Impact** – The degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on Severity and Scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment timeframe (e.g., timing is insignificant/negligible or low as threat is only considered to be in the past); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[b] **Scope** – Proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[c] **Severity** – Within the scope, the level of damage to the species from the threat that can reasonably be expected to be affected by the threat within a 10-year or three-generation timeframe. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit ≥ 0%).

[d] **Timing** – High = continuing; Moderate = only in the future (could happen in the short term [< 10 years or 3 generations]) or now suspended (could come back in the short term); Low = only in the future (could happen in the long term) or now suspended (could come back in the long term); Insignificant/Negligible = only in the past and unlikely to return, or no direct effect but limiting.

4.2 Description of Threats

The largest numbers of Rockrose plants in Nova Scotia occur in the Annapolis Valley sand barrens (heathlands). Catling et al. (2004) indicated that the original extent of the Annapolis Valley sand barren ecosystem was believed to be approximately 200 km². Today it is estimated that less than 3% remains (Catling et al. 2004; Catling and Carbyn 2005). The loss of this amount of sand barren habitat has undoubtedly had a negative impact on Rockrose. Within the last 50-100 years, Rockrose habitat in the Annapolis Valley has declined significantly because of wildfire suppression, steadily increasing agriculture and housing and commercial developments and the establishment of at least one aggressive invasive tree species i.e., Scots pine (*Pinus sylvestris*). The extirpation of caribou in Nova Scotia has also been linked to habitat decline. Browsing by caribou is believed to have been part of the natural disturbance regime which kept Rockrose habitats open by preventing the establishment of woody species.

The remaining Rockrose population continues to face many of these same threats today, although the species' dependence on natural disturbance makes it difficult to distinguish positive and negative impacts in some cases. Primary threats to Rockrose in Nova Scotia in the next 10 years include large-scale road construction (e.g., highway twinning), ongoing housing and commercial development, agricultural activities, sand quarries and invasive species. Additional minor threats include tourism and recreation development (e.g., trails, golf courses), livestock grazing, plant collecting, pollution from residential areas, and storms and flooding due to climate change. Potentially significant threats with unknown consequences include fire suppression, effects of pesticides on pollinators, problematic native species (seed predation by a predatory moth), and droughts due to climate change. Although fire is understood to have played an important role in maintaining open habitats for Rockrose in the past, it is possible that other activities such as OHV use are now compensating for fire by maintaining disturbance and open habitat in some areas; more research is needed to understand the impacts of wildfire suppression on Rockrose. Likewise, a predatory moth species whose larvae feed on the seeds of Rockrose was identified in 2016 and may pose a threat to the species' genetic diversity, but further study is needed. Activities provisionally considered to have a neutral or beneficial effect on Rockrose include maintenance of roads and transmission lines, OHV use and military activities.

The overall threat impact to Rockrose is High. The overall threat impact considers the cumulative impacts of multiple threats. A description of each threat is provided below, in order of decreasing level of concern.

Transportation & Service Corridors – Roads & Railroads (High-Low)

Many Rockrose sites currently occur along roadsides. Rockrose is a poor competitor and is generally restricted, or at least located, primarily in the disturbed soils associated with the open edges of moderately used trails and roadsides as well as other open

areas where competition from other plant species is limited by disturbance. As such, some roads and highways appear to be providing a small amount of suitable open habitat for Rockrose along their edges. Generally, Rockrose will grow along the edges between the more active/heavily used parts of the trail and the surrounding woodland. Roadside maintenance activities along edges (e.g., vegetation management) are also beneficial for Rockrose. However, new road construction and large-scale twinning projects that could damage or eliminate these edge communities pose a significant threat to Rockrose. In particular, highway twinning along Hwy 101 in the Kingston-Greenwood area may pose a threat to Rockrose in the next 10 years.

Residential & Commercial Development – Housing & Urban Areas (Low)

Housing and urban development, in particular subdivision development in the Kingston and Greenwood area, continues to pose a threat to Rockrose plants and habitat. From 2011-2016, Greenwood had the highest percent population increase (19%) of all growth centers in Kings County, with Aylesford, Waterville and Kingston having the next highest at 8%, 5% and 2%, respectively (Municipality of the County of Kings 2021). At least one Rockrose site occurs adjacent to a residential subdivision in Greenwood and additional urban/suburban growth has the potential to impact other Rockrose sites in the Annapolis Valley.

Residential & Commercial Development – Commercial & Industrial Areas (Low)

As above, ongoing commercial development associated with urban/suburban sprawl could affect Rockrose in the Annapolis Valley. Infrastructure development including stores, restaurants, parking lots, etc., are associated with the residential developments discussed above. Consideration of large-scale greenhouse operations is also included here; greenhouse, nursery and floriculture production represented 8.2% of farms by farm type in Kings County in 2011 (Nova Scotia Federation of Agriculture 2017). Military base considerations are captured under *Human Intrusions & Disturbance – War, Civil & Military Exercises*.

Agriculture & Aquaculture – Annual & Perennial Non-Timber Crops (Low)

Rockrose occurs adjacent to active croplands (e.g., corn fields) in several areas, particularly along Hwy 101 near Kingston. Some of the literature suggests that not all forms of agriculture may present an absolute threat to Rockrose, particularly when farmed land is left to regenerate. For example, a study of the natural revegetation of a recently plowed field in the New Jersey pine barrens revealed an abundance of herbaceous perennials within a few months after plowing including Rockrose (McCormick & Buell 1957). This may indicate that many of these herbaceous perennials were relics from the old orchard present on the site prior to plowing. In another situation, Rockrose was one of several herbaceous species which re-established in a sand barren (Badger Barren) located in northwestern Ohio. This area was farmed intensively from about 1840-1951 at which point it was allowed to revert to natural vegetation. Today,

Rockrose occurs there at densities considered typical for the geographic region. The barren is almost completely surrounded by second-growth forest which may have limited revegetation to those species which maintain a seed bank (Neher et al. 2003).

However, in both studies mentioned above, active farming ceased in the 1950s. Today, the presence of Rockrose near farmlands in the Annapolis Valley and the trend towards increased cultivation of intensive crops like corn suggest a potential threat from land conversion. The land area used for farming purposes continues to increase in Kings County and in 2011, crops represented 45% of agricultural land use type. During the period 2006-2011, oilseed and grain farming increased from 1.3–3.9% of total number of farms by farm type, and 'other crop farming' increased from 10.4–12.5% (Nova Scotia Federation of Agriculture 2017). In addition to land conversion, decades of herbicide and pesticide applications may have potentially reduced the ability of certain species to rejuvenate from a seed bank so that Rockrose and other species may not be able re-establish themselves if land is left to revert to a natural state.

Energy Production & Mining – Mining & Quarrying (Low)

Heath sand barrens in Nova Scotia continue to be disrupted by the creation and expansion of sand quarries. Rock/sand pits and quarries established in existing heathland habitats contribute to ongoing habitat losses and degradation (e.g. fragmentation and elimination) for the species. Quarry development under a certain size does not require an environmental assessment and even on sites that have identified Rockrose (or other endangered species), roles and responsibilities for monitoring and reporting are not always clear. This situation was observed in 2018 where a portion of a Rockrose site is currently critically imperiled by the on-going expansion of a sand quarry. Note that the size of the pit may be significant as smaller scale activities could result in beneficial disturbance; working with quarry owners/operators could present opportunities for positive management.

Invasive & Other Problematic Species, Genes & Diseases – Invasive Non-Native/Alien Species (Low)

Scots pine is an aggressive invader of the *Corema* dominated sand plains of the Annapolis Valley (Catling et al. 2004; Catling and Carbyn, 2005). Scots pine displaces native vegetation and quickly colonizes sand barrens, converting endemic shrubland to exotic forest (Porter et al. 2020). Dense stands of Scots pine have been shown to reduce native cover to 12%, vascular plant biodiversity to less than 42% and the cover of the heathland dominant, broom crowberry from 100% to less than 2% (Catling and Carbyn 2005). Similar trends are emerging with Black locust (*Robinia pseudoacacia*) (Porter et al. 2020). Rockrose is shade intolerant and would not be able to survive in dense stands of species such as Scots pine. For that matter, it is also unlikely that Rockrose would be able to survive in dense stands of any of the native pines i.e., Red

pine (*Pinus resinosa*), White pine (*Pinus strobus*) and Jack pine (*Pinus banksiana*) which occur on the Annapolis Valley sand plains.

There are several non-native herbaceous species that quickly become dominant in sand barren habitat following a disturbance. These include Mouse-ear hawkweed (*Pilosella officinarum*), Sheep sorrel (*Rumex acetosella*), Canada bluegrass (*Poa compressa*) and Hair fescue (*Festuca filiformis*) (Catling et al., 2004; Porter et al. 2020). Open habitats in the Five Island Lake area of Halifax County where Rockrose appears to be extirpated, were noted by R.E. Newell (pers. obs., 2006) to have abundant Knapweed (*Centaurea nigra*). It is not known if these aggressive alien species negatively impact Rockrose.

A relatively new invasive species to Nova Scotia, Autumn olive (*Elaeagnus umbellata*), first documented in Nova Scotia near Amherst in 2008, has now been found as far west as Middleton (R.E. Newell, pers. obs., 2018). This is an invasive shrub that grows well in open areas (similar to Rockrose) and has the potential to create a canopy over the shade intolerant Rockrose negatively impacting Rockrose habitat. Autumn olive is a prolific fruit producer/bearer. Fruit dispersal is by birds enabling this species to spread rapidly. Furthermore, Autumn olive, like Black locust (mentioned above), has root nodules that fix nitrogen, a characteristic that could potentially negatively impact native plant communities that occur in sand barrens and are adapted to low nutrient levels. The resulting increase in nitrogen levels in the soil promotes the growth and spread of weedy species at the expense of native species, particularly marginal native species such as Rockrose (Michigan Department of Natural Resources 2012).

Finally, the distribution of Common milkweed (*Asclepis syriaca*) in the Annapolis Valley has increased dramatically in recent years especially along Highway 101 verges in areas of sandy soil in the Coldbrook area. During recent field work (R.E. Newell, 2018), a small patch of approximately 20 stems of this species was observed in the general vicinity of three Rockrose sites in the Kingston area, along the south shoulder of Highway 101 east of Exit 17E. In addition to the sites directly associated with Rockrose along the highway, several areas of Common milkweed were observed on open barren habitat in which Rockrose was not observed. It appears to be well established in the Kingston/Greenwood area. Common milkweed is considered a weed in Nova Scotia and is regulated under the *Nova Scotia Agricultural Weed Control Act – Noxious Weed Regulations*, however it is unclear whether it is introduced or native in Nova Scotia (e.g., Bhowmik and Bandeen 1976; Munro et al. 2014); if it is determined to be native in future it should be treated under *Problematic Native Species* (see below).

Direct impacts of these species on Rockrose are poorly understood, and most do not currently overlap with known Rockrose sites; however, impacts on potential habitat, and the fact that roadsides and trails are pathways of spread for many invasive species, suggest they pose a threat in future.

Residential & Commercial Development – Tourism & Recreation Areas (Negligible)

The development of recreational areas such as trails and golf courses associated with urban/suburban development could pose a minor threat to Rockrose at some sites. Small urban parks with trail systems, natural areas, park playgrounds and recreational fields as well as larger developments such as golf courses all have potential to damage plants or habitat.

Agriculture & Aquaculture – Livestock Farming & Ranching (Negligible)

There is a significant amount of farming in the Annapolis Valley sand barren area (Catling et al. 2004). In 2011, a total of 49,630 ha in Kings County were used for farming purposes, with cattle ranching representing 15.5% of number of farms by farm type (Nova Scotia Federation of Agriculture 2017). However, it is unclear how much grazing overlaps with Rockrose habitat and what its impacts are. Moderate grazing could be beneficial for Rockrose.

Biological Resource Use – Gathering Terrestrial Plants (Negligible)

Wildcraft and botanical collecting may pose a minor threat to Rockrose. One reference to over-harvesting by unrestrained collectors for herbal remedies in the U.S. was noted in the literature (Greenwood Kinsley 2005).

Human Intrusions & Disturbance – Work & Other Activities (Negligible)

Similarly, over collecting by researchers and student botanists in Nova Scotia may have been the cause of the drastic decline at one Rockrose site over a thirty-year period up to about the year 2000, which was prior to the listing of Rockrose (Newell 2007; Nova Scotia Department of Lands and Forestry 2021).

Pollution – Domestic & Urban Wastewater (Negligible)

Several sites where Rockrose occurs, especially within the Annapolis Valley, are adjacent to residential developments. Artificially elevated levels of soil nutrification caused by runoff from managed residential properties and associated septic fields, combined with chemical contaminants, fertilizer use and road run-off / snow removal (e.g., salts, contaminants, sediments), all have the potential to decrease habitat suitability of any adjacent sand barren areas.

Pollution – Agricultural & forestry effluents (Negligible)

Several sites where Rockrose occurs in Nova Scotia are adjacent to agricultural fields, where they could be affected by fertilizer and pesticide runoff, with associated soil nutrification and contamination potentially affecting habitat suitability, as above. Dry

sandy soils are often nutrient poor and any fertilizer runoff could promote growth of vegetation not typically able to thrive in these sites, crowding out Rockrose. Herbicides like Roundup can have a significant impact on soil fungi (which could impact Rockrose mycorrhizal fungi).

Climate Change & Severe Weather – Storms & Flooding (Negligible)

Rockrose could be negatively affected by extreme wind and storm events resulting from climate change, including wind erosion, physical damage, and excessive moisture.

Natural System Modifications – Fire & Fire Suppression (Unknown)

Wildfire suppression has had a significant impact on the quality of the sand barren ecosystem in the Annapolis Valley. The absence of fire has led to encroachment of woody vegetation and succession to woodland replacing open barren habitat (Catling et al. 2004; Newell 2007). Fires have served through time to maintain a variety of successional stages, thereby maximizing biodiversity. The persistence of an open landscape by eliminating or keeping at bay woody species is particularly critical for the continuing existence of Rockrose. Drier barrens are generally less susceptible to the establishment of native woody species, but the invasive woody species *Pinus sylvestris* is more able to quickly establish in these areas (Catling and Carbyn, 2005). Although succession is a natural phenomenon, suppression of natural disturbance regimes (i.e. wildfires, grazing from caribou) has accelerated the loss of open sand barrens in the Annapolis Valley (primarily through the encroachment of red and white pine). Establishment of tall shrubs and eventual tree canopy closures lead to local extirpations of the shade-intolerant Rockrose.

Currently, OHV activity may be compensating for fire in maintaining disturbance and open habitat in some areas; however, Rockrose is still being lost to succession. More research is needed to understand the role of fire and fire suppression relative to other activities in maintaining Rockrose habitat, as well as potential effects on biology (e.g., reproductive changes, more inbred population, etc.).

Natural system modifications – Other ecosystem modifications (Unknown)

Honeybees, bumble bees and small flies have been observed pollinating Rockrose (Newell 2007; Hiller et al. 2018). Pesticide use in surrounding agricultural and residential areas may suppress populations of insect pollinators and have an indirect effect on Rockrose habitat and pollinator availability (e.g., see Hladik et al. 2018).

Invasive & Other Problematic Species & Genes – Problematic Native Species (Unknown)

The recent discovery and identification of a predatory moth (*Mompha capella*) at sites with two of the largest concentrations of Rockrose in Nova Scotia is significant (White et

al. 2016). *Mompha* larvae appear to consistently target ~50% of the showy, open-pollinated (chasmogamous) flowers thereby significantly impacting the number of seeds generated by cross-pollination. Cross-pollination increases genetic variation in a population which is of benefit to the overall survival of the species. It has been shown that interactions reducing genetic diversity decrease survivability and adaptability of a species and will increase extinction risk in populations of species which are already at risk (Hillier et al. 2018; McCall et al. 2006; Ancheta et al. 2011). Because Rockrose sites in Nova Scotia are generally very small and localized, they are highly vulnerable to extirpation through small scale, stochastic events. Further research is needed to determine effects on reproductive success and genetic diversity.

Climate Change & Severe Weather – Habitat shifting & alteration (Unknown)

The effects of climate change are uncertain and difficult to predict at the local scale. Rockrose is a poor competitor adapted to dry conditions; a shift to wetter conditions could increase competition from other plant species that are less adapted to dry soils. Conversely, an alteration of climate to prolonged drier conditions could favour Rockrose, depending on the exact nature of the changes (e.g., rate and magnitude of change, indirect effects on other species including pollinators, etc.).

Transportation & Service Corridors – Utility & service lines (Not a Threat)

Not all habitat alterations are having a negative impact on Rockrose. Rockrose is known to occur along transmission corridors, and OHV trails often occur in the same areas. The opening of habitat for power/service lines, along with vegetation management and some OHV activity can be beneficial for the species; see discussion of OHV activity below. Note that management of these areas could represent some of the best habitat for outplanting in future, to augment the existing population.

Human Intrusions & Disturbance – Recreational Activities (Not a Threat)

Historic natural disturbance regimes in the Annapolis Valley sand barren habitat have been replaced to some extent by hiking trails (rail trails), horse paths and moderately used OHV trails that have all created open habitat. Activities in these areas have reduced vegetative competition allowing Rockrose to establish itself along the edges, generally between active trails and adjacent woodland. Without these activities the areas would probably be covered in woodland/shrubs or continuous mats of *Corema* reducing the habitat for the shade-intolerant and poorly competing Rockrose.

However, OHV activity is currently very high in remaining pockets of open *Corema* barren in the Annapolis Valley. Although moderate OHV use can provide a level of disturbance which may fill some of the void left by suppression of natural fires and extirpation of Woodland caribou, heavy use can be detrimental to Rockrose. At best, it is a precarious existence for any Rockrose plant that establishes along the edge of an

OHV trail. Levels of OHV use and location of trails should be monitored in future, for any changes that might threaten Rockrose. Working with the OHV community may also present opportunities for positive management.

Human Intrusions & Disturbance – War, Civil & Military Exercises (Not a Threat)

The largest concentration of Rockrose plants in Nova Scotia occurs on federal land at CFB Greenwood, a military air base (the 'base'). Although there was undoubtedly some loss of Rockrose habitat on the base during past development of infrastructure (e.g., runways, hangars and housing), the plants currently occurring there are documented and protected as much as operations will allow. As well, activities associated with runway development and maintenance and the maintenance of railroad and highway corridors create limited suitable disturbance.

Without the presence of the base, it is unlikely that Rockrose would inhabit the area. In part, habitat is being maintained by the mowing activities on the base. Although the number of Rockrose plants in the more heavily mowed areas have decreased somewhat, the plants in the less frequently mowed areas have increased. As with the trail activities mentioned above, mowing reduces competition from taller vegetation and shrubs, allowing Rockrose to become established. Base personnel are aware of Rockrose and supportive in protecting the plant and habitat unless it impedes safety or becomes too great of an expense. The base is also engaged with Acadia University on several research projects involving Rockrose. Working cooperatively with the base on Rockrose conservation is another opportunity for positive management.

Climate Change & Severe Weather – Droughts (Not a Threat)

Rockrose is a southern, warm weather species, adapted to dry conditions and a fire-driven disturbance regime. Rockrose in Kings, Annapolis and Queens Counties exists in sandy, well-drained soils. These factors suggest that an alteration of the climate to prolonged drier conditions in either one, or all, of these counties may favour Rockrose.

5. POPULATION AND DISTRIBUTION OBJECTIVES

5.1 Viable Status for Recovery

Declines in Rockrose abundances and distribution are presumed to be tied to land conversion and changes in land management practices. In particular, the steady conversion of Annapolis Valley heathlands to agricultural and residential use has resulted in significant habitat loss, while fire suppression on the landscape has prevented the natural episodic restoration and creation of sand barrens, allowing non-barren plant species to encroach, establish, and ultimately displace many specialist plants from the area (Catling et al. 2004; Carbyn et al. 2006). The currently documented distribution of Rockrose in Nova Scotia likely represents a very limited extent of the

actual range a century ago; however, historical data on population size and distribution are lacking. Likewise, the relationship between genetically distinct subpopulations in Kings and Queens Counties, and associated habitat requirements, are poorly understood. To determine viable status for recovery, intended as a long-term goal of removing the species from the NSESA, more research is needed on seed banks, ecology, habitat requirements and optimal disturbance and management strategies.

In the interim, a long-term recovery goal (>20 years) for Rockrose is to increase the population and number of sites in sand barren habitat under a variety of disturbance regimes. Projected numbers of individuals are not determined at this time but should reflect an increase from current estimates of 7650-8450 plants, subject to further research. An additional goal is to conduct research to better understand the disjunct subpopulation in Queens County, including habitat studies, site history and genetics.

5.2 Short-term population and distribution objective

The short-term population and distribution objective for the recovery of Rockrose is to maintain the province-wide population at its current level of 7650-8450 plants within its known range extent in the Annapolis Valley and Queens County (i.e., no net loss of numbers of individuals or area of occupancy) over five years. Experimental planting in adjacent or nearby habitat that might be able to support the species should also be considered, to support the long-term goals, above.

5.3 Rationale

Population and distribution objectives assist with the identification of activities needed for recovery, and for Rockrose are based on the best available information in this document as well as the most recent Update Status Report (Nova Scotia Department of Lands and Forestry 2021). Surveys performed for the Update Status Report in 2018 with the addition of two new sites discovered in 2019 offer the most accurate population estimate to date of 7650-8450 individuals which represents an increase over 2007 numbers (5000-5500) (Newell 2007). This increase is primarily due to the discovery of several additional sites between 2007-2019; numbers of plants at previously known sites declined over this period or remained relatively stable. Prior to 2007, there are no detailed historical data on which to base population trends.

The short-term population and distribution objective of maintaining current numbers of plants as well as range extent in the Annapolis Valley and Queens County areas (i.e., no net loss of # individuals or area of occupancy) over five years aims to prevent further population decline, while allowing for some landscape-wide natural fluctuation. An additional goal is to initiate research on seedbank dynamics, fire ecology and other disturbance regimes. As stated above, the long-term goal of increasing the population and number of sites in sand barren habitat under a variety of disturbance regimes will require development of optimal management strategies for maintaining a dynamic

matrix of Rockrose habitat over time. A better understanding of the disjunct subpopulation in Queens County is also necessary to further refine recovery goals.

6. BROAD STRATEGIES AND GENERAL APPROACHES TO RECOVERY

6.1 Actions Completed or Underway

Since the first status report for Rockrose was completed in 2007 (Newell 2007), no formal action plan has guided the recovery of the species. However, Rockrose has been the focus of significant amount of work. Most of the work completed has been coordinated by the province of Nova Scotia (Department of Lands and Forestry) and researchers at Acadia University.

- Research on Rockrose biology, ecology and sand barren habitat has been conducted, as follows:
    - Dr. S. P. Vander Kloet of Acadia University examined seeds and seed banks of heathlands in Nova Scotia in 2004 and evaluated the reproductive capacity of a Rockrose site in Annapolis Valley (unpublished, see Newell 2007).
    - Dr. S. P. Vander Kloet of Acadia University and Steve Javorek of Agri-Food Canada in Kentville, NS, made observations on pollinators of Rockrose in 2004-2005 (unpublished, see Newell 2007).
    - A. Yorke studied the genetic structure of Nova Scotia and other northeastern Rockrose populations (Yorke 2007; Yorke et al. 2011) and E.L. Gillis conducted a comparative genetic analysis of chasmogamous and cleistogamous-derived seeds (Gillis 2017), both at Acadia University under the supervision of Dr. R. Evans.
    - Seed collection, seed banking, germination trials and *ex-situ* propagation of plants have been completed for Rockrose at Acadia University. Seeds sourced from the wild and reared plants are stored at the K.C. Irving Environmental Science Centre (see Nova Scotia Department of Lands and Forestry 2021).
    - Studies of predation on Rockrose seeds (White et al., 2016) and floral development ecology (Hillier et al., 2018) have been completed at Acadia University. Additionally, the research team of Dr. R. Evans at Acadia University is investigating how the macro development of Rockrose is affected following being predated by the moth, *Mompha capella*.

  - Work is underway by Dr. A. Walker's research team at Acadia University to describe mutualistic fungal partners, both above and below-ground, associated with Rockrose. Describing the fungal community in symbioses with Rockrose will provide a better understanding of the microbial relationships shaping the Nova Scotia Rockrose population.

  - Dr. Ponomarenko, a soil scientist at University of Ottawa specializing in the interpretation of soil profiles, examined heath sand barrens in the Annapolis Valley in 2019, specifically assessing the charcoal and pollen record to describe fire history (in progress; unpublished).

  - An analysis of land cover and land use from 1955 to present is underway at the Nova Scotia Community College (NSCC) (David Colville). Digital mappings based on historical aerial photography are being developed to examine historical changes in sand barren distribution over time across the sand barren region of the Annapolis Valley (in progress).

  - A classification of barrens ecosystems in Nova Scotia was published in 2020 by St. Mary's University and Nova Scotia Department of Lands and Forestry (Porter et al. 2020).

- Targeted fieldwork has included sporadic small-scale monitoring and surveys of individual Rockrose sites by the Nova Scotia Department of Lands and Forestry, CFB Greenwood and environmental consultants. These efforts have been focused mainly on the Annapolis Valley. Fieldwork for status reports included:

  - 2 days by R.E. Newell and A. Yorke in 2006 to try to re-locate sites in Queens and Halifax Counties

  - 2 days x 3 people in 2006 in Kings County and 2 days by R.E. Newell at CFB Greenwood

  - 11 days by R.E. Newell in 2018 with assistance from several others (R.B. Newell, D. Sam, Dr. R. Evans, A. Ng, A. Deutsch).

- A provincial status report was prepared for Rockrose in 2007 (Newell 2007) and an Update Status Report in 2018-19 (Nova Scotia Department of Lands and Forestry 2021).

- In 2019, the Annapolis Sandplain heathlands were recognized as a conservation target within the Southwest Nova Scotia Priority Place (see Canada Nature Fund / Pan-Canadian approach to transforming species at risk conservation in Canada: https://www.canada.ca/en/services/environment/wildlife-plants-species/species-risk/pan-canadian-approach/species-at-risk-conservation.html),

facilitating a number of conservation initiatives that address Rockrose. Examples include:

- A strategic planning workshop of stakeholders including scientific experts, resource managers, conservation organizations, municipal, provincial and federal government staff, and local naturalists hosted in 2019 by Fernhill Institute for Plant Conservation (Nick Hill) to develop a conservation action plan for the province's sand barrens habitats.

- Development of a landowner field guide to the Annapolis sandplain heathlands highlighting information about the significance of the ecosystem and the rare species that depend on it (Clean Annapolis River Project (CARP), draft, in prep.)

- Development of educational modules linked to the Nova Scotia public school curriculum outcomes and delivery of conservation messaging about rare species and rare habitats associated with sand barrens to municipal and village planners and leaders (CARP, ongoing)

- Workshops to teach environmental educators about heathlands and to outreach to private landowners, municipal leaders, and environmental planners about heath habitat and the environmental services provided by them (CARP, ongoing).

6.2 Options for Recovery

The following table (Table 3) summarizes recovery actions and specific steps recommended to address threats and achieve successful recovery Rockrose in Nova Scotia, along with their priority and approximate costs.

Table 3. Recovery options planning table

Recovery Measures	Threats Addressed*	Actions	Priority**	Cost***	Benefit
Habitat Protection, Management and Stewardship					
Protect Rockrose habitat through land purchase and conservation easements.	1.1,1.2, 1.3 2.1, 2.3, 3.2, 4.1, 5.2, 6.2, 6.3, 9.1	• Identify high priority lands for protection and potential purchase. Although several Rockrose sites are currently owned and protected Crown Lands (both provincial and federal), opportunities to purchase additional lands should be considered (e.g. land purchase/leasing, land donation, conservation easements, etc). • Incentivize the protection of private land • Partner with conservation groups to inform landowners about stewardship and ecological land donation opportunities • Develop stewardship agreements with private landowners in Rockrose habitat.	H	$$$$	Habitat protection and enhancement; threat reduction; stakeholder investment in SAR recovery.
Develop a long-term conservation strategy to increase the Rockrose population through habitat manipulation and expansion.	All threats	• Manage known sites to maintain existing disturbance regimes, e.g., forest harvest activities, trimming trail/road edges including the cottage road in Queens County and mowing (interim). • Conduct a pilot project for land disturbance management to determine best practices (see Research, below). • Develop a long-term conservation strategy including consideration of habitat manipulation and disturbance management for population expansion.	M	$$	Habitat protection and expansion; increase in population size; long-term storage of genetic material.

		• Collect and preserve Rockrose seeds and/or material in order to support future restoration efforts. • Increase the Rockrose population by dispersing seeds in unoccupied sand barren areas between known Rockrose occurrence sites.			
Develop a multi-year invasive species management plan to remove species that may impact Rockrose.	8.1	• Develop a plan for managing invasive species on sand barren habitat including monitoring, control and removal of problematic species. • Consider removal or harvest Scots pine and some areas of native pines on Crown lands in the Annapolis Valley to open up barrens. • Encourage landowners to remove (or allow the removal of) Scots pine from their property through an active stewardship program (potentially including incentives). • Consider removal of Autumn olive and other problematic plant species from the sand barrens in the Kingston/Greenwood area (within the known Rockrose corridor) to slow the rate of colonization in the area.	H	$$$	Habitat protection and enhancement; threat reduction; increase awareness of Rockrose and impacts of invasive species.
Surveys and Monitoring					
Conduct ongoing monitoring of known Rockrose sites.	All threats	• Develop a monitoring plan with standardized survey approaches and timelines. • Conduct ongoing monitoring of known Rockrose sites and gather baseline data to assess population dynamics. • Record and monitor changes in site and habitat parameters and the impacts of threats, including invasive species.	H	$	Population and distribution knowledge to support recovery actions.
Conduct surveys of potential sites to identify possible new occurrences of Rockrose.	All threats	• Conduct botanical surveys of high-potential sites where Rockrose may occur but has not been documented.	H	$	Population and distribution knowledge to inform recovery planning process.
Communication, Outreach and Education					

Increase landowner awareness about the presence and status of Rockrose on private land.	1.1,1.2, 1.3 2.1, 2.3, 3.2, 4.1, 5.2, 6.3, 7.3, 8.1, 9.1	• Develop information resources (e.g., factsheets, handouts, best management practices) summarising information about the ecology of Rockrose and what activities are beneficial or harmful. • Provide information to landowners in relevant areas to inform them about species present on their lands and their responsibilities as landowners with SAR. • Notify real estate agencies and developers that there could be an endangered species in the general area of the properties they are marketing and encourage them to pass this information along to their clients. • Attach informative statement and relevant contact information to transactional processes such as property deeds and permit applications. • Partner with community conservation groups in the areas where Rockrose occurs as this may be the most efficient way to inform landowners and the general public.	H	$	Habitat protection and enhancement; increased awareness and public engagement; stakeholder investment in SAR recovery.
Define/clarify responsibilities of various agencies to aid in the protection of Rockrose.	1.1,1.2, 1.3 2.1, 2.3, 3.2, 4.1, 5.2, 6.3, 7.3, 8.1, 9.1	• Define responsibilities and communication pathways between federal, provincial, municipal and non-governmental organizations responsible for the management of land on which core habitat occurs. • Provide detailed information to relevant agencies about Rockrose distribution, ecology and conservation.	M	$	Habitat protection and enhancement; increased cooperation and efficiencies.
Provide information to Municipalities about their responsibility to assist in the protection of Rockrose.	1.1, 1.2, 1.3, 2.1, 2.3, 4.1, 8.1, 9.1	• Provide detailed information to municipal governments in the three counties where Rockrose occurs, as well as other provincial and federal agencies regarding Rockrose locations and conservation.	M	$	Habitat protection and enhancement; increased awareness and public engagement; stakeholder investment in SAR recovery.

		• Coordinate with municipalities to promote awareness and protection of Rockrose on private lands. • Encourage incorporation of SAR restrictions into municipal development plans. • Work with municipal officers who review development projects and home construction to inform them of legal obligations regarding endangered species on site and any necessary restrictions that are required.			
Law, Policy and Enforcement					
Core habitat requirements and considerations.	1.1, 1.2, 1.3, 2.1, 2.3, 3.2, 4.1, 5.2, 6.3, 7.1, 8.1, 8.2, 9.1	• Identify and designate areas of core habitat for Rockrose under the *Nova Scotia Endangered Species Act* • Work to restrict and/or manage activities on Crown lands with known occurrences and develop Special Management Practices for Rockrose.	H	$	Habitat protection; threat reduction.
Develop and enforce legislation and policies related to resource extraction and other development activities in core habitat.	1.1, 1.2, 1.3,4.1, 4.2, 6.2	• Establish policies and best management practices for sand quarrying and other commercial uses of sand heath habitat. • Initiate development of municipal land use by-laws, policies and guidance governing activities in sand barrens and other ecologically sensitive areas. • Initiate training activities for monitors and enforcement personnel on a regular basis • Work cooperatively with NS Transportation and Active Transit to develop a stewardship policy to shape and maintain Rockrose habitat along highway edges.	M	$	Habitat protection; threat reduction.
Formalize protection of Rockrose within CFB Greenwood lands	6.2	• Develop/formalize an agreement between the Province and CFB Greenwood to continue the protection of Rockrose and to promote ongoing support of research activities.	M	$	Increased cooperation to support recovery.

Support development of an unsolicited COSEWIC Status Report	All threats	• Prepare an unsolicited COSEWIC Status Report for Rockrose; although a federal COSEWIC status report is not currently being requested, unsolicited status reports can be submitted.	L	$	Habitat protection on federal land; threat reduction, increased awareness of the need for protection of Rockrose.
Research to Address Knowledge Gaps					
Conduct research on Rockrose biology, ecology and possible benefits of habitat manipulation	All threats	• Develop formal partnership(s) to conduct research on the biology, ecology and habitat requirements of Rockrose in Nova Scotia. • Conduct a pilot project for land disturbance management to investigate the potential benefits of different disturbance regimes, comparing the effects of, e.g., fire treatments, pesticides, mechanical control (tree harvest, trail clearing, mowing). • Conduct seed bank studies to determine whether Rockrose forms a fire- or disturbance-dependent seed bank. • Further investigate differences between Annapolis Valley and Queens County sites (e.g., life history, site history, habitat) • Continue research on mycology and fungal partners to improve our understanding of soil microbes, soil fungi and other factors for successfully translocating plants.	L	$$	Increased cooperation and efficiencies to fill knowledge gaps; increased population and distribution knowledge to support recovery planning.
Conduct research on Rockrose propagation and genetics	All threats	• Develop a partnership with the seed bank at Acadia University to supply the Rockrose seeds needed to repopulate suitable areas. • Ensure that viable material is collected from representative sites in province for seed banking. • Provide support for additional work on experimental germination and/or tissue culture trials to refine techniques for the	L	$$	Increased population and distribution knowledge to support recovery planning.

		propagation of Rockrose from native Nova Scotia material. • Conduct experimental outplanting along the rail trail and OHV trails that are within the current boundaries of the species' distribution, as they have the greatest potential for success, especially if combined with some shrub/tree clearing along the edges of trails.			
Conduct research on impacts of invasive and problematic native species on Rockrose	8.1, 8.2	• Document the colonization of sand barren habitat by invasive and problematic native species such as pines (Scots pine, Red pine, White Pine and Jack pine), Autumn olive, Common milkweed and other herbaceous species (Mouse-ear hawkweed , Sheep Sorrel, Canada bluegrass, Hair fescue, Knapweed). • Conduct research to determine impacts of invasive species on Rockrose. • Conduct further studies into the role of a predatory moth (*Mompha capella*) in the cross pollination and genetic diversity of Rockrose.	L	$$	Increased understanding of threats; threat reduction.
Conduct research and educational outreach on the impacts of climate change on SAR such as Rockrose.	11.1, 11.2	• Conduct research on the impacts of temperature extremes, drought sensitivity, storms and flooding on seedlings and adults. • Incorporate results into outreach materials for local landowners, conservation groups, etc.	L	$$	Increased understanding of threats.

* Threat or Limitation should refer to the IUCN Threat Classification Table Rankings. Either the first level or second level threat ranking can be used depending on how the Broad Strategy affects the threat. Multiple threats can be addressed under a single Recovery Measure.
**Priority should be classified as High(H), Medium(M), or Low(L). "Priority" is a qualitative measure of the relative degree to which an approach will have a positive impact on the recovery objective. High priority conservation approaches are considered those most likely to have an immediate and/or direct influence on reaching the management objective for the species. Medium priority conservation approaches may have a less immediate or less direct influence on reaching the management objective but are still considered important measures to implement. Low priority conservation approaches will likely have an indirect or gradual influence on reaching the management objective and are more tied to increasing knowledge or public perception/education.

***Use the following to assign a cost estimate to proposed activities: $ = < 10 000; $$ = 10 000-50 000; $$$ = 50 000-100 000; $$$$=>100 000-1,000,000, $$$$$ >1,000,000.

6.3 Narrative to Support the Recovery Options Planning Table

The recovery of Rockrose will require a number of activities to protect the existing occurrences and investigate the optimal disturbance or management regimes needed to support suitable habitat for maintenance and expansion of the current population. In particular, protection of land through purchase, leasing or conservation agreements, defining and designating core habitat under the *Nova Scotia Endangered Species Act*, raising awareness among private landowners, and research to address significant knowledge gaps, are important priorities.

Habitat Protection, Management and Stewardship

Habitat protection is the most direct way to support the recovery of Rockrose and mitigate the impacts of multiple threats. With only 3% of the Annapolis Valley sand barrens remaining, much of the potential habitat for Rockrose has disappeared. This is a limiting factor in the recovery of Rockrose. Although areas of the sand barrens are currently on Crown Lands (both provincial and federal), protection of more of the remaining sand barrens through purchase or leasing should be considered as soon as possible. Acquisition of crown land should be complemented by protection of core habitat and incentivization of habitat protection on private land. Partnerships with conservation groups could also provide an opportunity for private landowners to make ecological land donations or, if they wish to retain the land, enter into conservation agreements. Development of stewardship agreements would also benefit the species and help achieve recovery objectives. In addition to protecting a bit of unique habitat in Nova Scotia and potential habitat for Rockrose, a purchase/lease or conservation agreement on additional land would provide more sites to conduct research into expanding the Rockrose population.

In addition to protecting habitat, a long-term conservation strategy should be developed to increase the Rockrose population through habitat manipulation and expansion, and conservation and management of genetic material. Without some habitat manipulation it appears that Rockrose will continue to decline. Currently, infrequent mowing of areas and the removal of some woody vegetation on CFB Greenwood and the establishment and maintenance of railroads (now transformed into rail trails), riding trails (horse) and moderately used OHV trails have maintained and/or increased habitat for Rockrose. There appears to be an opportunity to work with one or more universities to investigate the potential benefits of some habitat manipulation (see “Research”, below).

Seed storage, germination and propagation techniques have been successfully developed and implemented at Acadia University and there is potential to increase the Rockrose population by dispersing seeds in the sections of sand barrens between current sites. The rail trail and some of the OHV trails that are within the current boundaries of the species’ distribution but do not have any Rockrose plants probably have the greatest potential for re-seeding success, especially if combined with some shrub/tree clearing along the edges of the trails. Ongoing collection and preservation of seeds should be supported along with further research to understand the relationship of the subpopulations and impacts of disturbances; both positive and negative.

Development of an invasive species management plan should be considered to help protect and maintain sand barren habitat through monitoring, control and removal of problematic species. Removal of species such as Scots pine may be important in opening up the barrens and sustaining habitat for Rockrose. Scots pine was introduced to Nova Scotia in the mid-1900s as a potential forest harvest product. Although the concept of Scots pine plantations eventually failed the species still persists and can grow in very dense stands, eliminating the understory. On Crown lands in the Annapolis Valley sand barrens, Scots pine should be removed or at least harvested to open up the barrens. Some areas of native pines should also be harvested for the same reason. The removal of Scots pine on private land is more difficult. Landowners could be encouraged to remove (or allow the removal of) Scots pine from their property through an active stewardship program. Scots pine could be included as one of the species incorporated in the habitat manipulation studies mentioned above. This could provide some scientific results to encourage landowners to participate in removing Scots pine on their properties.

Common milkweed has also been spreading within the sand barrens area and is provincially listed as a noxious weed under the Nova Scotia *Agricultural Weed Control Act and Regulations*. Although Common milkweed is a secondary food source for larval forms of the endangered Monarch butterfly (primary food source is the native Swamp milkweed), it should be removed from the sand barrens in the Kingston/Greenwood area (within the known Rockrose corridor) to slow further expansion. Likewise, Autumn olive is an invasive shrub that has been found in Nova Scotia for less than 10 years, but it is already colonizing several counties. The species is not shade tolerant so the impact on woodlands should be minimal. However, open and disturbed areas (potential Rockrose habitat) are at risk from Autumn Olive colonization. Preventing establishment by the removal of any shrubs found in the Kingston/Greenwood area would slow the rate of colonization in the area. Any success in delaying the spread of species such as Common milkweed and Autumn olive will depend on private landowner cooperation.

Surveys and Monitoring

It is critical to continue monitoring and documenting Rockrose sites and habitat. Accurate baseline information and consistent data collection over time are required to properly assess population dynamics, and to inform decision-making processes. This is particularly important in light of a lack of long-term historical data on which to base population trends. Recommended activities include development of a standardized monitoring plan for ongoing monitoring of known occurrences including population dynamics, habitat parameters and threats. Data should be analyzed and reviewed periodically to model habitat suitability and continue to refine our understanding of core habitat over time. In particular, long-term monitoring of invasive and problematic native species near Rockrose occurrences that may affect Rockrose habitat will be important to highlight any changes as a result of their impacts.

In addition to monitoring known sites, it is important to survey for Rockrose in new locations. Although the level of search effort for Rockrose has been sufficient to determine that it is very rare in the province, there are many areas of potentially suitable

habitat that have not been comprehensively surveyed for the species. It is recommended that surveys of new potential sites be conducted based on GIS analysis and expert botanical input.

Communication, Outreach and Education

Communication, outreach and education are important elements in the recovery of Rockrose in Nova Scotia, and complementary to other recovery actions. Private landowners should be informed of any Rockrose occurrences on their property and provided with information on the ecology of the species and what activities are beneficial or harmful. Ideally, this could be done through a stewardship approach (e.g. Best Management Practices Information sheets, etc.) and a visit to the property. The visit would provide an opportunity to show the landowner where the plant occurs on their property and how they could incorporate the plant into their landscape or modify development. A partnership with community conservation groups in the areas where Rockrose occurs may be the most efficient way to contact landowners.

Real estate agencies and developers should also be made aware of Species at Risk considerations on properties they are marketing. Another approach to ensure that landowners are aware there is an endangered species on their property is to attach a statement to the property deed. Having the information attached with the land deed would ensure home builders, developers, farmers or land purchasers would be aware that they have Rockrose on the property prior to purchase and any development. As new occurrences are discovered, the information could be attached to the deeds and letters sent to the landowners. Currently, there is a variety of information, such as municipal development agreements or conservation easements, that are attached to deeds (Mark Fredericks, Municipality of the County of Kings, pers. comm., 2019*).* Establishment of a mechanism to provide SAR information would be beneficial to all parties involved with a property.

More communication, support and cooperation need to be developed between provincial government agencies and municipal governments who are responsible for land use and land-based activities. Roles and responsibilities should be clarified and training activities for land-use monitors and enforcement personnel need to be undertaken on a regular basis. There is a need to provide more detailed information to the relevant municipalities as well as to other appropriate provincial (and federal) agencies about Rockrose sites and conservation. Development officers and municipal planners review development projects and home construction. Knowing that there is an endangered species on a site can flag that site so that Nova Scotia Lands and Forestry/Nova Scotia Environment can be contacted, and any necessary restrictions can be incorporated into the development plans.

Law, Policy and Enforcement

Law, policy, and enforcement augments or reinforces many of the actions identified in other sections and can be achieved through the creation of new policy, improvements to pre-existing policies, and guidance to support Species at Risk recovery. Identifying and

designating core habitat for Rockrose would provide a legal underpinning for many of the habitat protection, stewardship and public outreach measures discussed above. Developing and enforcing legislation and policies related to resource extraction and other development activities in core habitat would also help to protect Rockrose from threats such as sand quarrying and urban/suburban expansion. Development of municipal land use by-laws, policies and guidance governing activities in sand barrens and other ecologically sensitive areas should be encouraged.

A number of sites including the largest concentration of Rockrose in Nova Scotia occur on federal land at CFB Greenwood, a military air base. Although there was undoubtedly some loss of Rockrose during past development of infrastructure (e.g., runways, hangars and housing), the sites currently occurring on the Base are documented and protected as much as operations will allow. Environmental staff at the Base have provided excellent support to researchers (primarily from Acadia University) and individuals monitoring Rockrose sites. However, Rockrose is a provincially listed endangered species (not federally listed) that to some extent occurs on federal land and Base personnel are limited as to how much support, time and money can be devoted to the conservation of Rockrose. With the cooperative support from the Base in protecting Rockrose, an agreement between the Province and CFB Greenwood to continue the protection of Rockrose and to continue the research activities should be formalized (until Rockrose receives federal designation).

Although a federal COSEWIC status report is not currently being requested by COSEWIC, unsolicited status reports can be submitted. The Province could potentially support the production of a Status Report that would be submitted to COSEWIC, although the national distribution of the species may not necessarily result in an at risk designation or a designation that supports habitat protection.

Research to Address Knowledge Gaps

Additional research is needed to inform recovery planning for Rockrose, particularly with regard to seed bank dynamics, habitat requirements, and the role of fire and other disturbance regimes in maintaining conditions suitable for germination and growth. There appears to be an opportunity to work with one or more universities to investigate the potential benefits of some habitat manipulation such as prescribed burns, tree harvest or clearing, farrow farmland and/or mowing and reestablishing areas with Rockrose seeds. A partnership with the seed bank at Acadia University could supply the Rockrose seeds needed to repopulate these areas. This type of study should provide an insight into the most effective habitat manipulation and how to proceed with expanding the Rockrose population. (The Queens County subpopulation is genetically different from the Kings/Annapolis subpopulation; if Queens County is to be included in a study, seeds should be propagated separately for this county).

In addition to habitat manipulation, there is a need for research on the distribution, population dynamics and impacts of a number of invasive species such as Scots pine, Common milkweed and Autumn olive as well as further studies into the role of a

predatory moth (*Mompha capella*) in cross pollination between two of the largest Rockrose sites. Further research on mycology and fungal associates would also help to inform recovery planning.

7. RECOMMENDED COURSE OF ACTION(S) FOR RECOVERY

Table 4 provides the recommended course of actions for recovery of the species and the timeframe for completing these actions.

Table 4. Recovery actions and implementation schedule.

Habitat Protection, Management and Stewardship		**Implementation Schedule**
Approach 1.1 Protect Rockrose habitat through land purchase and conservation easements.		
Action 1.1.1	Identify high priority lands with Rockrose occurrences for protection and potential purchase.	2021-2023
Action 1.1.2	Incentivize the protection of private land	2024-2028
Action 1.1.3	Partner with conservation groups to inform landowners about stewardship and ecological land donation opportunities (e.g., conservation agreements, long-term leasing for conservation that may run with the property deed).	Ongoing
Action 1.1.4	Develop stewardship agreements with private landowners in Rockrose habitat.	Ongoing
Approach 1.2 Develop a long-term conservation strategy to increase the Rockrose population through habitat manipulation and expansion.		
Action 1.2.1	Manage known sites to maintain existing disturbance regimes, e.g., forest harvest activities, trimming trail/road edges including the cottage road in Queens County and mowing (interim)	2021-2025
Action 1.2.2	Conduct a pilot project for land disturbance management to determine best practices (see Research, below).	2022-2026
Action 1.2.3	Develop a long-term conservation strategy including consideration of habitat manipulation and disturbance management for population expansion.	2024-2026
Action 1.2.4	Collect and preserve Rockrose seeds and/or material in order to support future restoration efforts.	Ongoing
Approach 1.3 Develop a multi-year invasive species management plan to remove species that may impact Rockrose.		
Action 1.3.1	Develop a plan for managing invasive species on sand barren habitat including monitoring, control and removal of problematic species.	2021-2023
Action 1.3.2	Consider removal or harvest of Scots pine and some areas of native pines on Crown lands in the Annapolis Valley to open up barrens.	2024-2028
Action 1.3.3	Encourage landowners to remove (or allow the removal of) Scots pine from their property through an active stewardship program (potentially including incentives).	2024-2028
Action 1.3.4	Consider removal of Autumn olive and other problematic plant species from the sand barrens in the Kingston/Greenwood area (within the known Rockrose corridor) to slow the rate of colonization in the area.	2024-2028
Surveys and Monitoring		**Implementation Schedule**
Approach 2.1 Conduct ongoing monitoring of known Rockrose sites.		

Action 2.1.1	Develop a monitoring plan with standardized survey approaches and timelines.	2021-2026
Action 2.1.2	Conduct ongoing monitoring of known Rockrose sites and gather baseline data to assess population dynamics.	2021-2031
Action 2.1.3	Record and monitor changes in site and habitat parameters and the impacts of threats, including invasive species.	2021-2031
Approach 2.2 Conduct surveys of potential sites to identify possible new occurrences of Rockrose.		
Action 2.2.1	Conduct botanical surveys of high-potential sites where Rockrose may occur but has not been documented.	2023-2026
Communication, Outreach and Education		**Implementation Schedule**
Approach 3.1 Increase landowner awareness about the presence and status of Rockrose on private lands.		
Action 3.1.1	Develop information resources (e.g., factsheets, handouts, best management practices) summarising information about the ecology of Rockrose and what activities are beneficial or harmful.	2021-2024
Action 3.1.2	Provide information to landowners in relevant areas to inform them about species present on their lands and their responsibilities as landowners with SAR.	2022-2024
Action 3.1.3	Notify real estate agencies and developers that there could be an endangered species in the general area of the properties they are marketing and encourage them to pass this information along to their clients.	2023-2026
Action 3.1.4	Attach informative statement and relevant contact information to transactional processes such as property deeds and permit applications.	2023-2026
Action 3.1.5	Partner with community conservation groups in the areas where Rockrose occurs as this may be the most efficient way to inform landowners and the general public.	2022-2026
Approach 3.2 Define/clarify responsibilities of various agencies to aid in the protection of Rockrose.		
Action 3.2.1	Define responsibilities and communication pathways between provincial, municipal and non-governmental organizations responsible for the management of land on which core habitat occurs.	2023-2026
Action 3.2.2	Provide detailed information to relevant agencies about Rockrose distribution, ecology and conservation.	2022-2026
Approach 3.3 Provide information to municipalities about their responsibility to assist in the protection of Rockrose.		
Action 3.3.1	Provide detailed information to municipal governments in the three counties where Rockrose occurs, as well as other provincial and federal agencies regarding Rockrose locations and conservation.	2022-2026
Action 3.3.2	Coordinate with municipalities to promote awareness and protection of Rockrose on private lands.	2022-2026
Action 3.2.3	Encourage incorporation of SAR restrictions into municipal development plans.	2022-2026
Action 3.3.4	Work with municipal officers who review development projects and home construction to inform them of legal obligations regarding endangered species on site and any necessary restrictions that are required.	2022-2026
Law, Policy and Enforcement		**Implementation Schedule**
Approach 4.1 Core habitat requirements and considerations		
Action 4.1.1	Identify and designate areas of core habitat for Rockrose under the *Nova Scotia Endangered Species Act*.	2021-2026
Action 4.1.2	Work to restrict and/or manage activities on Crown lands with known occurrences and develop Special Management Practices for Rockrose.	2022-2024

Approach 4.2 Develop and enforce legislation and policies related to resource extraction and other development activities in core habitat.		
Action 4.2.1	Establish policies and best management practices for sand quarrying and other commercial uses of sand heath habitat.	2022-2025
Action 4.2.2	Initiate development of municipal land use by-laws, policies and guidance governing activities in sand barrens and other ecologically sensitive areas.	2022-2026
Action 4.2.3	Initiate training activities for monitors and enforcement personnel on a regular basis	2024-2028
Action 4.2.4	Work cooperatively with NS Transportation and Active Transit to develop a stewardship policy to shape and maintain Rockrose habitat along highway edges.	2022-2026
Approach 4.3 Formalize protection of Rockrose on CFB Greenwood lands.		
Action 4.3.1	Develop/formalize an agreement between the Province and CFB Greenwood to continue the protection of Rockrose and to promote ongoing support of research activities.	2023-2026
Approach 4.4 Support development of an unsolicited COSEWIC Status report		
Action 4.4.1	Prepare an unsolicited COSEWIC Status Report for Rockrose; although a federal COSEWIC status report is not currently being requested, unsolicited status reports can be submitted.	2022-2031
Research to Address Knowledge Gaps		**Implementation Schedule**
Approach 5.1 Conduct research on Rockrose biology, ecology and possible benefits of habitat manipulation		
Action 5.1.1	Develop formal partnership(s) to conduct research on the biology, ecology and habitat requirements of Rockrose in Nova Scotia.	2021-2026
Action 5.1.2	Conduct a pilot project for land disturbance management to investigate the potential benefits of different disturbance regimes, comparing the effects of, e.g., fire treatments, pesticides, mechanical control (tree harvest, trail clearing, mowing).	2022-2026
Action 5.1.3	Conduct seed bank studies to determine whether Rockrose forms a fire- or disturbance-dependent seed bank.	2022-2026
Action 5.1.4	Further investigate differences between Annapolis Valley and Queens County sites (e.g., life history, site history, habitat)	2022-2026
Action 5.1.5	Continue research on mycology and fungal partners to improve our understanding of soil microbes, soil fungi and other factors for successfully translocating plants.	Ongoing
Approach 5.2 Conduct research on Rockrose propagation and genetics.		
Action 5.2.1	Develop a partnership with the seed bank at Acadia University to supply the Rockrose seeds needed to repopulate suitable areas.	2022-2024
Action 5.2.2	Ensure that viable material is collected from representative sites in province for seed banking.	2023-2026
Action 5.2.3	Provide support for additional work on experimental germination and/or tissue culture trials to refine techniques for the propagation of Rockrose from native Nova Scotia material.	2022-2026
Action 5.2.4	Conduct experimental outplanting along the rail trail and OHV trails that are within the current boundaries of the species' distribution, as they have the greatest potential for success, especially if combined with some shrub/tree clearing along the edges of trails.	2023-2026
Approach 5.3 Conduct research on the impacts of invasive and problematic native species on Rockrose.		
Action 5.3.1	Document the colonization of sand barren habitat by invasive and problematic native species such as pines (Scots pine, Red pine, White Pine and Jack pine), Autumn olive, Common milkweed and other herbaceous species (Mouse-ear hawkweed , Sheep Sorrel, Canada bluegrass, Hair fescue, Knapweed).	2022-2026

Action 5.3.2	Conduct research to determine impacts of invasive species on Rockrose.	2022-2028
Action 5.3.4	Conduct further studies into the role of a predatory moth (*Mompha capella*) in the cross pollination and genetic diversity of Rockrose.	2022-2028
Approach 5.5 Conduct research and educational outreach on the impacts of climate change on SAR such as Rockrose.		
Action 5.5.1	Conduct research on the impacts of temperature extremes, drought sensitivity, storms and flooding on seedlings and adults.	2022-2026
Action 5.5.2	Incorporate results into outreach materials for local landowners, conservation groups, etc.	2022-2026

8. IDENTIFICATION OF CORE HABITAT

Under the Nova Scotia Endangered Species Act; core habitat is defined as “specific areas of habitat essential for the long-term survival and recovery of endangered or threatened species and that are designated as core habitat pursuant to Section 16 or identified in an order made pursuant to Section 18”. A definition for Rockrose core habitat is included here using the best available information at the time of writing; however, given the knowledge gaps and anticipated increases in our collective knowledge of this species’ needs in Nova Scotia, this definition should be updated as new information becomes available.

8.1 Core Habitat Definition and Attributes

The scattered, isolated nature of remaining Rockrose sites and the significant loss of sand barren habitat in the last 50-100 years indicate that designation of core habitat is an important component of recovery success for this species. Due to the small population size in Nova Scotia and limited information about optimal habitat and disturbance regimes, core habitat includes all known sites currently supporting Rockrose with a surrounding buffer to protect habitat and biological values (e.g., pollination distances) and allow for some limited movement of distribution. The patch disturbance frequency and spatial attributes needed to sustain a viable population of Rockrose and ensure habitat provisions for each life history stage are still being determined.

Core habitat for Rockrose is defined as all known records with a locational uncertainty of 200 m or less, grouped into polygons where they are separated by 1 km or less and polygons buffered by 500 m to account for biological and habitat needs of the species (e.g., pollination distances). Resulting polygons are further refined on the basis of suitable / unsuitable habitat (e.g., removal of open water, open wetlands and other wet areas) and then re-buffered by 100 m to account for accuracy of available map layers. Delineation of core habitat is considered to be dynamic rather than static and mapping will need to be updated periodically as factors such as population dynamics and location of known occurrences can be expected to change over time.

In summary, core habitat for Rockrose can be identified based on the following criteria (maps included in Appendix 1):

- Known occurrences, i.e., all known records with locational uncertainty of ≤200 m, as identified in the Nova Scotia Provincial Update Status Report (Nova Scotia Department of Lands and Forestry 2021) and Atlantic Canada Conservation Data Centre biodiversity database (AC CDC 2020), grouped into polygons where they are separated by ≤1 km and polygons buffered by 500 m;
- Removal of unsuitable habitat from resulting polygons (i.e., open water, open peatlands, open wetlands and areas with 0-0.1m to water table) based on available GIS wetland and Wet Area Mapping (WAM) layers (e.g., Nova Scotia Department of Lands and Forestry 2007; 2020), and;
- Polygons re-buffered by 100 m to account for uncertainty in available map layers.

Areas within delineated core habitat polygons that consist of human infrastructure (e.g., roads, buildings, parking lots, etc.), and currently active agricultural lands, are not considered part of core habitat.

8.2 Activities Likely to Result in the Destruction of Core Habitat

Destruction of Rockrose core habitat would result if part of the habitat was degraded, either permanently or temporarily, such that it would not serve its function when needed by the species. Destruction may result from single or multiple activities at one point in time or from the cumulative effects of one or more activities over time and must be determined on a case by case basis.

It should be noted that most efforts to maintain and recover the Rockrose population in Nova Scotia will involve habitat manipulation, and some activities that promote disturbance may be needed to maintain early successional open habitat. These considerations will need to be balanced against large-scale development and other activities that destroy habitat and pose a threat to the species. Activities such as OHV use, mowing, and maintenance of transmission corridors and road edges, are provisionally considered beneficial and not included in the list below but should be monitored in case of future changes in frequency, intensity or impacts on Rockrose.

Activities likely to result in destruction might occur within the core habitat but might also occur outside of the core habitat. Activities that are likely to result in the destruction of Rockrose core habitat include but are not limited to:

- Development activities resulting in loss and alteration of rockrose habitat including:
    - urban/commercial
    - recreational/tourism
    - agricultural activities
    - mining and quarry activities
    - large-scale road construction and expansion (e.g., highway twinning)

- Any other activities that destroy plants, or affect soil through compression, covering, inversion, or excavation/extraction (e.g., recreational activities, plant collecting, etc.);
- Introduction of invasive or native species that may encroach and outcompete Rockrose, and;
- Pollution including effects from residential/domestic effluents and agricultural use of fertilizers and pesticides.

8.3 Habitat Protection / Ownership

The sites with the largest known concentrations of Rockrose occurring in Nova Scotia are found at CFB Greenwood (federal land), with remaining Rockrose records falling on private or provincial crown land. There are no records that fall directly in protected areas, although the site along the rail trail west of Highway 201 at Green Acres falls close to Clairmont Provincial Park.

The area identified as core habitat for Rockrose in this document consists of approximately 69% private land, 22% federal land, 3% municipal land and 6% provincial land including public, crown and protected areas.

9. MEASURING PROGRESS

9.1 Performance Indicators

The performance indicators identified below are a means by which progress towards population and distribution objectives can be measured. Progress will be reported during the 5-year review process of the Recovery Plan. Performance will be assessed through the completion of actions identified under Table 5 of Section 7, *Recommended Course of Action(s) for Recovery*.

Table 5. Performance measures used to determine whether Rockrose recovery objectives are being met.

Performance Measure	Check-In
Planning:	
At least one Recovery Team meeting annually to discuss recovery activities and assess performance to date.	Annually
Number of initiatives and groups involved in delivering conservation messaging	Annually
Assign and support individuals or teams to recovery-related projects as identified in recovery actions (Table 4)	Annually
Conservation:	

Performance Measure	Check-In
Number and type of communication products that target private landowners, public, government and others as identified in recovery actions (Table 4)	Annually
Known sites and population maintained	Every five years
Increased percentage of core habitat protected	Every five years
Percentage of knowledge gaps addressed by published research	Within five to ten years
All governmental permitting or approval processes that can address a threat to this species be fully implemented	In one year
Number of new Rockrose records or documented effort to survey for new occurrences	Every five years
Successful *ex situ* propagation of Rockrose from Nova Scotia material	In five years

9.2 Monitoring

A Rockrose monitoring plan is aimed at providing consistent data over time to assess population dynamics, habitat parameters and threats in Nova Scotia on an ongoing basis.

The overall strategy involves three-parts, including:

- Annual photo monitoring at a subset of representative sites for large-scale monitoring of disturbances and habitat changes;
- Population counts at the same subset of sites every five years, and;
- Full population count at all known sites every ten years.

Annual photos taken at representative sites and population counts every five years will provide a better understanding of the following:

- Invasive species introductions and spread;
- Agricultural/forestry activity or signs of potential land conversion or harvest;
- OHV use including new trails or evidence of damage in Rockrose habitat; and
- Road maintenance and work on associated infrastructure.

Success of this monitoring plan will be reviewed and adjusted as needed and as management actions change. A field checklist and more detailed methodologies will be developed.

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Appendix 1: Maps of identified core habitat for Rockrose in Nova Scotia

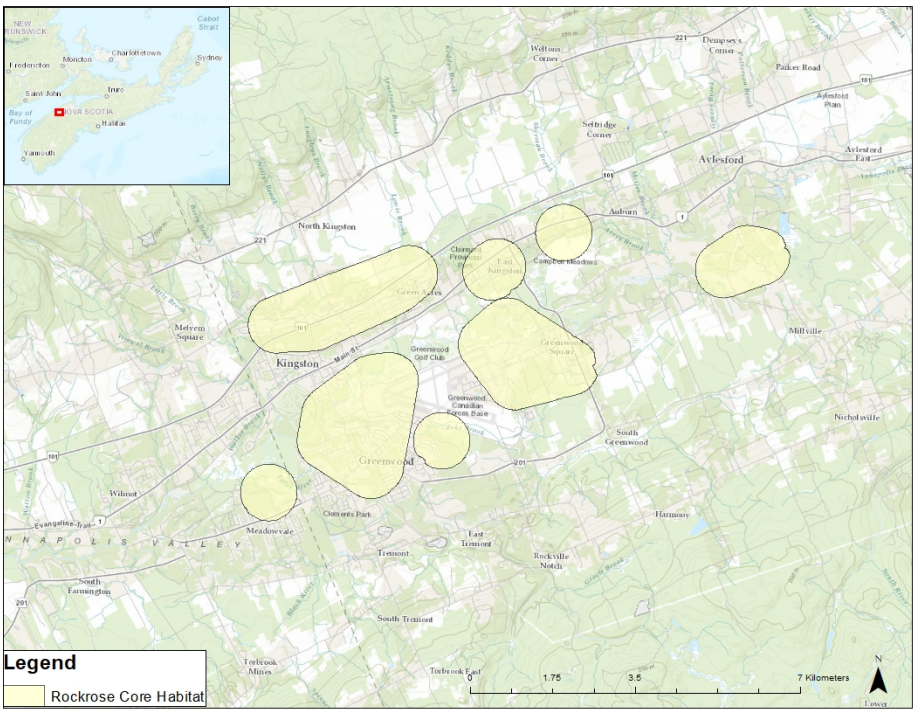

Figure 5. Identified core habitat for Rockrose in the Annapolis Valley, Nova Scotia.

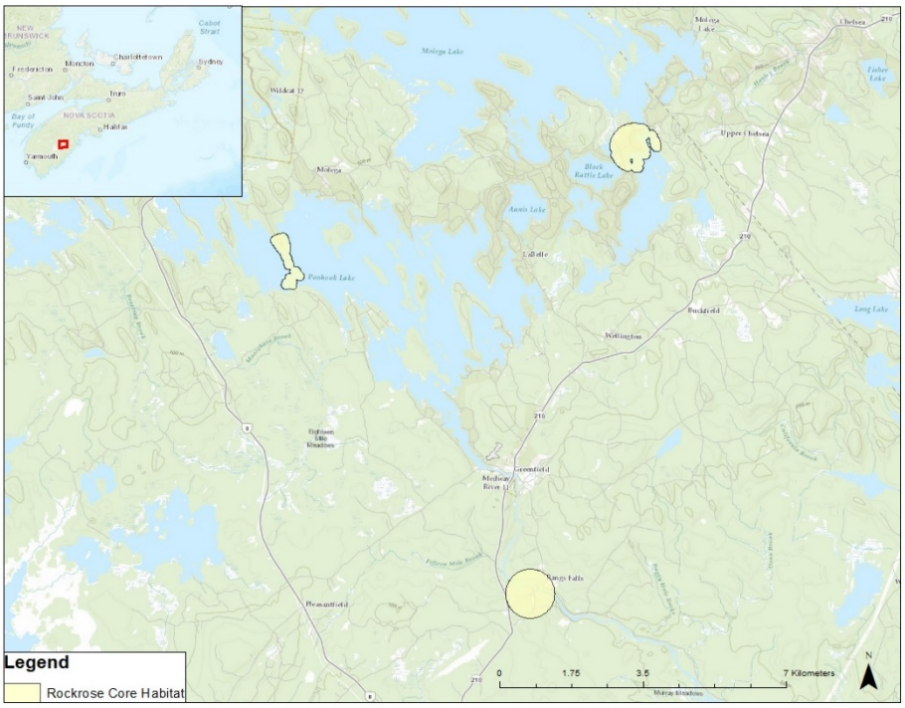

Figure 6. Identified core habitat for Rockrose in Queens County, Nova Scotia.

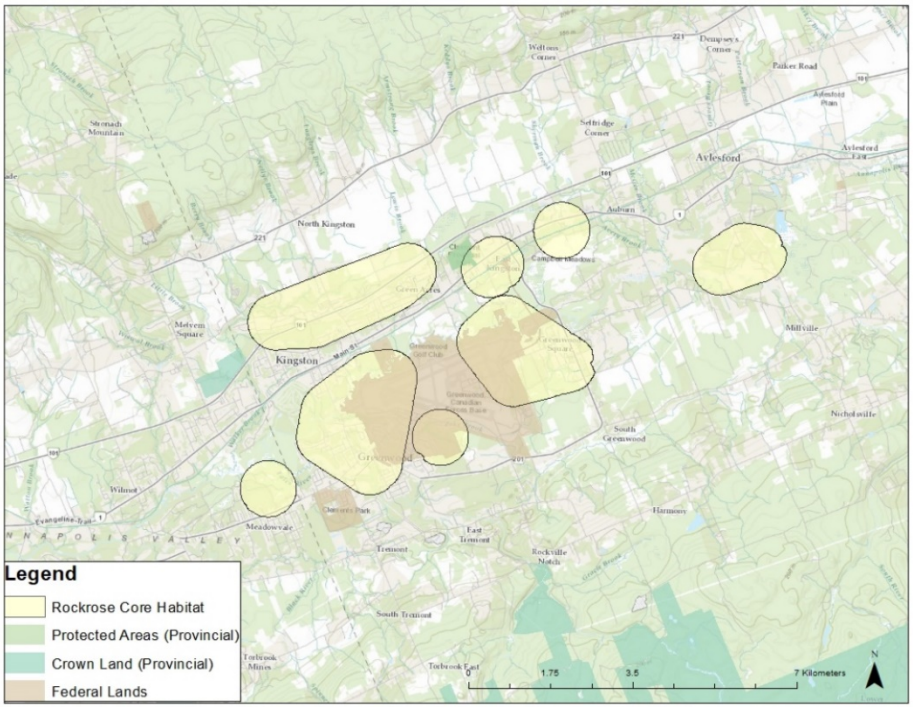

Figure 7. Land ownership in identified core habitat for Rockrose in the Annapolis Valley, Nova Scotia.

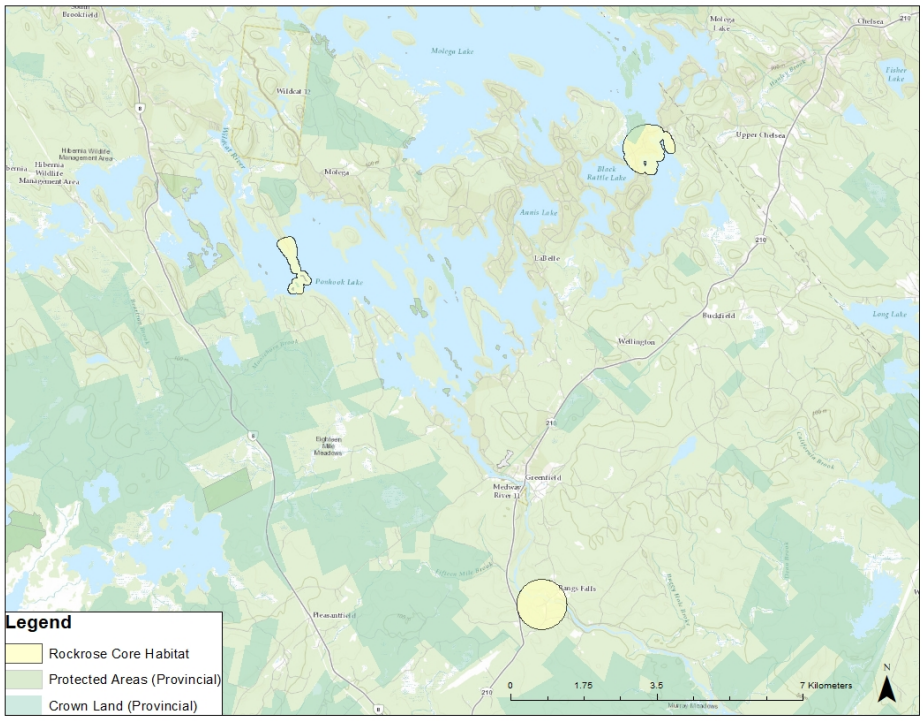

Figure 8. Land ownership in identified core habitat for Rockrose in Queens County, Nova Scotia.