Rosa rugosa as an Invader of Coastal Sand Dunes of Cape Breton Island and Mainland of Nova Scotia

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Rosa rugosa is described for the first time as an invasive species associated with coastal sand dunes in Atlantic Canada. Our surveys of 24 beaches on western Cape Breton Island and the mainland of northern Nova Scotia from Cheticamp to Fox Harbour showed that 11 of the dune systems (ca. 45%) were colonized. This was more prevalent in Cape Breton where *R. rugosa* occurred on 9 of 13 systems, whereas only 2 of 9 mainland systems were colonized. Four dunes (three in Cape Breton) were considered heavily colonized with 0.4 – 8.8% of the dune area with cover of *R. rugosa*. These beaches had 12 – 42 independent clumps with almost monospecific stands over 90 % cover. In general, heavily colonized beaches were found adjacent to communities where extensive domestic planting and hedges of *R. rugosa* occurred and where escapes onto roadsides had occurred. In most colonized beach systems, rhizomes from clones extended 1 – 5 m to produce younger shoots. The absence of *Ammophila breviligulata, Lathyrus maritimus* and *Myrica pensylvanica*, from the interior of many clumps of *R. rugosa* suggests that native dune communities are being negatively impacted. This exacerbates dune integrity already compromised by impacts of sea level rise.

Key Words: *Rosa rugosa*, invasive plants, sand dunes, Gulf of St. Lawrence, Cape Breton, Nova Scotia.

With an origin in eastern Asia, *Rosa rugosa* Thunb. has become widely naturalized in North America and Europe from ornamental plantings (Roland and Smith 1969; Bruun 2005). In both North America and Europe the species has been recognized as an invasive species. In northwestern Europe, in particular shores facing the North Sea and Baltic Sea, *R. rugosa* has been a major invader of sand dune ecosystems, and has become the most abundant alien species in this habitat in both Denmark and Germany (Bruun 2005; Weidema 2006; Isermann, 2007, 2008a,b,c; Jørgensen and Kollman 2009; Thiele et al. 2010). In these systems *R. rugosa* threatens native dune vegetation and leads to decreased native species diversity. These studies demonstrate that *R. rugosa* is a significant problem in conservation of dune habitat (e.g., Isermann 2008c). The invasion of *R. rugosa* on sand dunes was facilitated in European coastal areas by planting for sand stabilization and coastal protection (Isermann 2008c)

Rosa rugosa is widely distributed in Nova Scotia, from Yarmouth in the southwest to northern Cape Breton Island (Roland and Smith 1969; Roland 1998). The species can be expected on roadsides and rocky beaches in many coastal areas of Nova Scotia where it often co-occurs with the native *R. virginiana* Mill. (Hill and Garbary, unpublished observations). Despite its widespread distribution and local abundance, there have been no previous reports of *R. rugosa* invading coastal dunes and impacting populations of native plant species. Recently, Hill and Blaney (2009) suggested that *R. rugosa* was one of ten non-native species in Nova Scotia likely to become invasive. Here, we document for the first time *R. rugosa* as a significant invader of sand dune habitats in North America. We also show that *R. rugosa* can modify communities of native species in sand dune systems on western Cape Breton Island and the northern mainland of Nova Scotia.

Methods

1. Surveys

A survey of 24 sand dunes comprising coastal beach habitats in the southern Gulf of St. Lawrence was conducted for *Rosa rugosa* in May and June 2010 (Table 1, Figure 1). The Cape Breton sites were resurveyed in mid July to document flower colour (pink or white). All sites were in Nova Scotia and ranged from Cheticamp in the northeast to Fox Harbour in the northwest. A walking survey was conducted at each beach by one to three individuals for 15 min to 8 h to determine the distribution, number and extent of colonies of *R. rugosa*. Beach area was determined using aerial photographs (1:12 500), Google Earth, and locations at the start and end of beach surveys as determined using a GPS unit (Model eTex Summit, Garmin, Olathe, Kansas). At Cheticamp, Belle Cote, Margaree Harbour, Inverness and Port Hood, where communities were adjacent to the beach habitat, a driving survey was conducted to look for plantings of *R. rugosa*. In locations where a colony was observed in the communities, the geographic coordinates were recorded along with extent of the colony. This included an approximation of the length, diameter and height of the *R. rugosa* stand. In more natural habitats the maximum length and diameter of the colony was measured with a 30 m measuring tape, and then the

TABLE 1. General features of dune systems examined for *Rosa rugosa*. Note: all dunes are subject to coastal erosion as a consequence of sea level rise. Scale for extent of colonization: 0) absent; 1) with significant populations adjacent to beach system, but not yet colonizing beach itself; 2) a few small clones none of which achieve 100% cover; 3) as in 1 but with some larger colonies; 4) >5 independent colonies on beach with some having extensive area and cover; 5) as in 3, but with a significant area of the beach colonized.

Dune	Coordinates (UTM – 20T)	Dune size (km)	Dune stresses	Extent of colonization	Presence of *R. rugosa* in adjacent communities
Cape Breton Island					
Cheticamp north #1	5170064 N 0655237 E	0.03 × 0.57		3	+
Cheticamp, north #2	5168939 N 0654156 E	0.04 × 0.08		3	+
Cheticamp Beach	5162856 N 0650506 E	0.50 × 0.05	rock wall, vehicle traffic	5	+
Belle Cote	5145306 N 0645424 E	0.50 × 0.06	rock wall, vehicle traffic	5	+
Margaree Harbour	5144667 N 0644904 E	0.33 × 0.05	trails	5	+
MacKays Cape	5142936 N 0642938 E	0.18 × 0.04		0	–
Chimney Corner	5139052 N 0640937 E	0.25 × 0.05		0	–
Inverness	5121212 N 0629832 E	0.45 × 0.05	boardwalk, extensive trails	2	+
Mabou	5104031 N 0617496 E	0.90 × 0.13		4	+
Port Hood	5097392 N 0613175 E	0.34 × 0.03		1	+
Port Hood Station	5095427 N 0613678 E	0.64 × 0.03	boardwalk	1	+
Little Judique	5090940 N 0614197 E	0.03 × 0.32		2	–
Judique Central	5082546 N 0616726 E	0.05 × 1.10		2	–
Mainland Nova Scotia					
Tracadie	5055553 N 0604817 E	0.05 × 0.5	road, highly eroded, extensive gravel	0	–
Bayfield	5053910 N 0598203 E	0.04 × 0.1	highly eroded, extensive gravel	0	–
Pomquet	5055833 N 0592391 E	0.14 × 0.78	boardwalk, trails, poison ivy	0	–
Monks Head	5068870 N 0591879 E	0.05 × 0.68	ATV traffic	0	–
Captains Pond	5058897 N 0589655 E	0.05 × 0.76		0	–
Dunns Beach	5059528 N 0587941 E	0.05 × 1.68	ATV traffic, trails	0	–
Big Island	5059706 N 0628021 E	0.04 × 1.26	road, high foot traffic	0	–
Melmerby Beach	5055911 N 0538481 E	0.08 × 1.30	boardwalk, high foot traffic	2	–
Little Caribou Spit	5064475 N 0526795 E	0.05 × 0.83		0	–
Waterside Provincial Park	5067515 N 0517175 E	0.13 × 0.81	boardwalks	5	–
Fox Harbour	5076108 N 0466639 E	0.02 × 0.33	highly eroded	0	

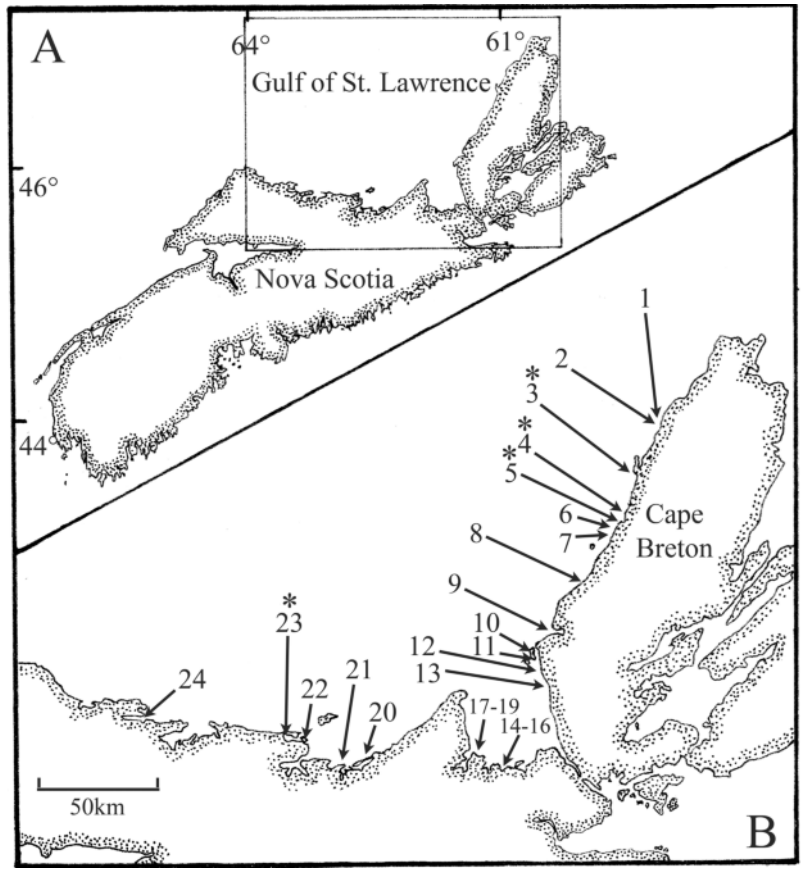

FIGURE 1. Map of Nova Scotia (A) with insert of enlarged map of the coast of Nova Scotia along the Gulf of St. Lawrence (B) with survey results for *Rosa rugosa*. Key: Long arrows, sites with *R. rugosa* on sand dunes; short arrows, sites with no *R. rugosa*; asterisks, sites with major beach colonization. Sites: (1) Cheticamp north #1; (2) Cheticamp north #2; (3) Cheticamp Beach; (4) Belle Cote; (5) Margaree Harbour; (6) MacKays Cape; (7) Chimney Corner; (8) Inverness; (9) West Mabou; (10) Port Hood; (11) Port Hood Station; (12) Little Judique; (13) Judique Central; (14) Tracadie; (15) Bayfield; (16) Pomquet; (17) Monks Head; (18) Captains Pond; (19) Dunns Beach; (20) Big Island; (21) Melmerby Beach; (22) Little Caribou Spit; (23) Waterside Provincial Park; (24) Fox Harbour (see Table 2 for site details.)

maximum height in the colony was measured using a meter stick or measuring tape. Cover of the overall area was estimated. The occurrence of native sand dune species, in particular *Ammophila breviligulata* Fern., *Lathyrus maritimus* (L.) Bigelow, *Myrica pensylvanica* Mirbel, and *R. virginiana* Mill., were noted.

2. Distinguishing *Rosa rugosa* and *R. virginiana*

Rosa rugosa is easily distinguished from the native, extremely common, *R. virginiana* based on features of leaves, stems and fruits. Thus leaves are larger in *R. rugosa* and the stems much coarser and more densely thorny. In *R. rugosa* the new stems are green and then turn grey with age; *R. virginiana* has characteristic red bark. The mature fruits of *R. rugosa* are often very large (i.e., plum-sized), bright orange-red and have very long sepals. This contrasts with *R. virginiana* with raspberry-sized, dark-red fruits with relatively short sepals. See Roland (1998) for additional features and a key to all *Rosa* species in the province.

Results

1. Herbarium survey

Herbarium records in the Nova Scotia Agricultural College (NSAC; abbreviations from Thiers, Index Herbariorum) and Acadia University (ACAD) show *R. rugosa* to be widely distributed in Nova Scotia. This hardy perennial has been recorded in 10 counties of the province in both inland and coastal locations as well as on Sable Island. Records in ACAD have spec-

imens from dune systems as early as 1953. Casual observations in Digby and Guysborough Counties show *R. rugosa* to be widespread in many seaside locations (DJG, personal observations). Based on these records and our observations (below) *R. rugosa* might be expected on diverse coastal habitats throughout the province.

2. Overview of colony characteristics

Over 100 colonies of *R. rugosa* occurred at 11 sand dune, barrier beach systems. These were mostly in Cape Breton, and only two beaches on the mainland (Melmerby and Waterside, Table 1, Figure 1) had colonies of *R. rugosa*. These colonies ranged from a single small shoot with an area of 25 cm^2 to extensive colonies with hundreds of shoots with areas up to 315 m^2. Area was skewed towards smaller colonies with mean area of 36.7 ± 60.4 m^2 (mean ± s.d.), and few colonies over 100 m^2 (Figure 2). These colonies had a great range in cover from ca. 10% to over 90% (mean 44.5 ± 24.8%). Similarly, maximum height of colonies varied from 10 to 250 cm (mean 80.6 ± 47.2 cm). There was a poor relationship between maximum colony height and colony area (r^2 = 0.19, Figure 2). Thus, while virtually all colonies less than 10 m^2 had a maximum height of 1 m or less, many large (i.e., > 10 m^2) colonies also had maximum heights < 1 m. Indeed, the three colonies with the largest areas (all at West Mabou) had maximum heights of 30-50 cm, which differed greatly from all other large colonies.

The resurveyed sites in July from Cape Breton generally had a mixture of both pink and white flowers. About 20% of the individual colonies had white flowers. Cheticamp Beach was the only site with numerous colonies where flowers were exclusively pink.

3. Heavily colonized sites

Of those beaches where it was present, four (Cheticamp, Belle Cote, Margaree Harbour and Waterside, Table 2) were heavily colonized with 12 – 42 colonies covering 404 – 2651 m^2 with maximum heights of 1.5 – > 2 m and with central cores in which there was 100% cover. Total beach cover was estimated at 0.4 – 8.8% of beach area surveyed. These established colonies often had hundreds of shoots and a ground cover of bare sand or leaf litter derived from *R. rugosa*. The Belle Cote site had colonies in which large basal rosettes of *Sonchus arvensis* L. were present. The margin of these colonies had typical sand dune vegetation of *Ammophila breviligulata, Myrica pensylvanica* and *Lathyrus maritimus*. *Rosa virginiana* was a common member of this assemblage, although when it occurred adjacent to *R. rugosa*, it was typically of much smaller stature. The margins of some larger clones were well defined; however, for many there was a diffuse zone of smaller shoots ca. 0.5 m, suggesting active colonization of the surrounding dune community. These sites typically had many smaller, more diffuse colonies extending over 0.5 – 10 m^2 with cover of 10-30%. There was often a conspicuous linear sequence of progressively smaller shoots connected by rhizomes at 5 – 10 m from the core of the colony.

Three of these sites (all but Waterside) had extensive populations of *R. rugosa* ca. 100-300 m distant in the human communities immediately adjacent to the dunes. At Cheticamp and adjacent villages we observed 34 separate plantings in the form of hedges and individual clumps scattered throughout the community. Some of these were escapes from cultivation and were established on roadside or between the main road and the seashore. The two dune systems at the mouth of Margaree Harbour had the largest colonies of *R. rugosa* in the surrounding villages. Indeed, the road through the village of Margaree Harbour had an almost continuous population of *R. rugosa* in which one colony alone formed a continuous hillside patch estimated at over 1000 m^2.

4. *Rosa rugosa* at other sites

The remaining seven sand dune systems with *R. rugosa* had greatly reduced incidences of colonization. These ranged from 1 – 5 colonies in which the *R. rugosa* comprised 0.25 – 640 m^2. While the area occupied by *R. rugosa* at West Mabou was considerably greater than at Margaree Harbour (ca. 663 vs 400 m^2, respectively), the percent of the beach occupied was several orders of magnitude less at West Mabou.

The two beaches north of Cheticamp proper (sites 1-2) had limited colonization with only 2-5 colonies and a cover of *R. rugosa* of 5 – 98 m^2. These colonies were scattered over the beach system from just behind the dune crest in *A. breviligulata* to areas adjacent to *M. pensylvanica* and *R. virginiana*.

The largest dune system examined in Cape Breton was at West Mabou. The dune front is about 10 m above the beach and there are at least three parallel dunes that merge 200 – 400 m shoreward into freshwater ponds, boreal forest or Mabou Harbour at rear. This apparently pristine system hosts Piping Plovers (*Charadrius melodus*, one was observed during our survey) and had dense populations of *A. breviligulata*, *M. pensylvanica* and *L. maritimus* and assorted forbs. Four independent colonies of *Rosa rugosa* were observed. Three of these were extensive, covering at least 150 m^2. They differed from colonies at other sites by having a max height of 30 – 50 cm. They had very low cover (< 20%), extensive bare sand and a diverse population of non-native forbs among the colonies. Given the low stature of the shoots and the large size of the dune system (Table 1), it is possible that other populations of *R. rugosa* may have been missed.

Port Hood (site 10) has an extensive sand dune system in which the dunes comprise two parallel dunes about 3 m high. A half hour inspection north of the beach parking lot did not reveal any *R. rugosa* on the

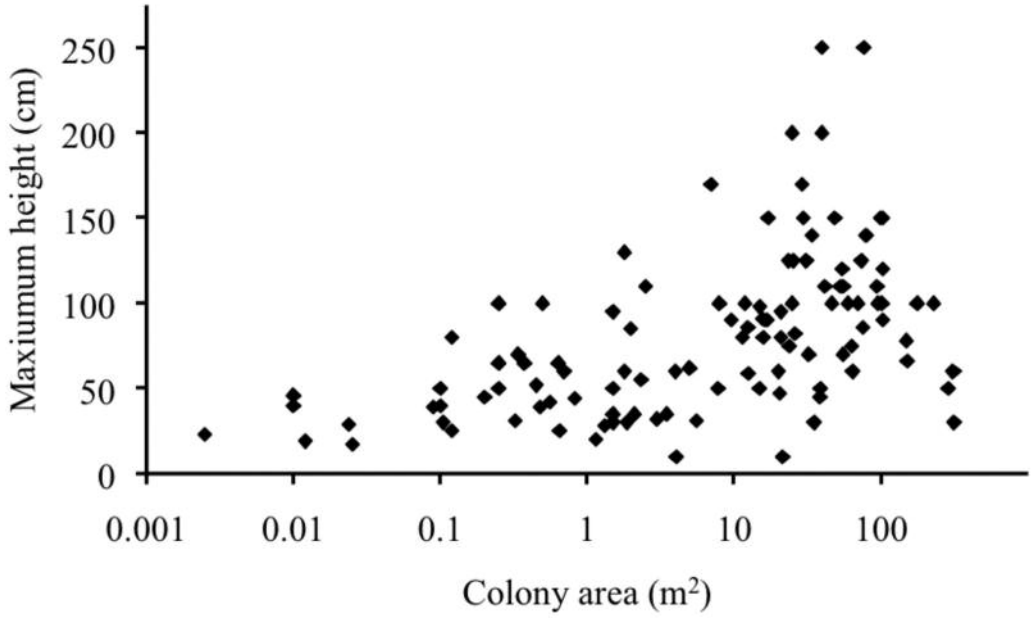

FIGURE 2. Scatter plot showing colony area and maximum height of *R. rugosa* colonies on sand beach systems in Nova Scotia.

dunes. However, three clumps at least 3 m in diameter and a maximum of 2.5 m tall grew adjacent to the parking lot. Two of these colonies had numerous small individuals within a meter of the core suggesting that active expansion was occurring. Even slight expansion of these colonies would colonize the sand dunes. The village of Port Hood had numerous plantings as individual beds or hedges; indeed, along 0.5 km of the main street we counted nine plantings in beds and hedges with plants at almost every other dwelling.

The day park at Port Hood Station (site 11) had 14 small, planted beds of *R. rugosa* in which the clumps were a maximum of 50 cm high and 1 m in extent. These occurred in a grassy area surrounded by a parking lot. The invasive properties of *R. rugosa* were demonstrated in that numerous new shoots up to 10 cm tall were arising within one meter of the edge of the original colony (in one case 45 shoots were counted in the surrounding grass plot). An inspection of ca. 1 km of dune along the boardwalk did not reveal any *R. rugosa*.

At two sites (Melmerby and Inverness) there were only two clumps, and these were adjacent to boardwalks through the beaches. These colonies were relatively small with maximum cover of 6 m^2.

Discussion

At three of the four most affected sites (all but Waterside) there was an apparent relationship between extensive artificial plantings of *R. rugosa* and the colonization of nearby sand dunes. These, often-extensive plantings provide a continuous source of propagules in the form of mature fruits that can colonize nearby beaches via roadsides. These, in turn, provide a potential conduit for invasion of sand dunes. Our observations are consistent with those of Jørgensen and Kollmann (2009) who demonstrated that dune invasion by *R. rugosa* was associated with roads, tracks and houses. Marine dispersed fruit was considered for an introduction to Norway (Fremstad 1997), and this might account for introductions to Nova Scotia dunes well away from roads or habitation. *R. rugosa* is known to be dispersed by birds (Bruun 2005; Rajakaruna et al. 2009), and this would explain the apparent random occurrences on dune systems such as at Judique Central.

Rosa rugosa is extremely tolerant of seemingly adverse environmental conditions. In its native and artificial habitats, *R. rugosa* is extremely drought tolerant, salt tolerant, fire tolerant, and tolerant to destruction of above ground tissue, and sand covering (Belcher 1977; Dirr 1978; Augé et al. 1990; Didriksen 1999; Tsuda et al. 1999; Bruun 2005). Symptomatic of this tolerance was the occurrence of colonies in Cheticamp just above the high tide mark and along roadsides to the plow line. Even excavation of the clone may be ineffective as a method of control as root/rhizome fragments may regenerate (Bruun 2005). Weidema (2006) describes a variety of control measures including excavation, herbicides or repeated cutting.

Two strategies of clonal expansion have been reported for *R. rugosa* (Bruun 2005). Thus colonal extension

TABLE 2. Colonization of the four most impacted dunes with *Rosa rugosa*.

	Number of colonies	Area of *Rosa rugosa* (m^2)	Beach area (m^2)	Dune cover with *Rosa rugosa*
Cheticamp	42	1,030	25,000	4.1%
Belle Cote	32	2,651	30,000	8.8%
Margaree Harbour	12	404	7000	5.7%
Waterside	21	434	105,300	0.4%

is typically by phalanx, but in herbaceous communities a guerrilla strategy can prevail (Bruun 2005). The latter was most commonly observed on the *A. beviligulata* dominated dunes we studied, with 2-4 shoots developing more-or-less in a line from the parent clone. Since most of our observations were done in May prior to the flush of new shoots (ca. one month after bud break, Bruun 2005), we only observed occasional new shoots, ca. 5 cm in height.

While there is debate in Europe whether *R. rugosa* is having a fundamentally negative impact on colonized dunes (Bruun 2005), our observations on at least four Nova Scotia dune systems (Cheticamp, Belle Cote, Margaree Harbour, Waterside) suggest this is the case. Within its impenetrable colonies, native species are largely excluded and a thin litter layer forms of fallen leaves, or a bare sand surface occurs. These monospecific stands probably exclude the sand-trapping *A. breviligulata* (description of rhizome network in Eyre, 1968 for *A. arenaria*) as well as its nitrogen-fixing associates, *L. japonicus* and *M. pensylvanica*. Without inputs of fixed nitrogen, the introduced rose will depend upon nitrogen mineralized from its own litter and as erosion removes organic materials, dense clones of *Rosa rugosa* may become moribund as fertility decreases. Although there are advocates for the planting of this rose to control erosion, logic indicates that the introduction of such a dominant could destabilize dunes in the long-term. It is known that grass and nitrogen-fixing associations can bring stability to low fertility ecosystems through an alternation of dominance that depends upon levels of soil nitrogen. In long-term pastures, a stable system of alternation between dominants is described as grass (*Lolium perenne*), takes over at elevated soil nitrogen levels, but is in turn invaded by nitrogen-fixing legumes (*Trifolium repens*) when soil nitrogen levels decline (Turkington and Harper 1979). The associations on the beaches of Sable Island between the beach grass, *A. breviligulata* and the legume, *Lathyrus japonica*, appear to mirror the pasture-model as the nitrogen content of grass tissues is greater in grass:beach pea associations (D. G. Patriquin. personal communication, 8 June 2010). In addition to legume inputs, large nitrogen inputs are possible from bayberry (*Myrica pensylvanica*), whose nodule fixation rates are of the same order as that of legumes or alders (Morris et al. 1974). The bayberry is a key player in the nitrogen economy of dunes and it is particularly resistant to dune blow-outs (Morris et al. 1974). Despite the claims made of the structural qualities of the massive invasive, *R. rugosa,* its competitive exclusion of all the nitrogen-fixing associates in this beach community will lead to an unstable ecosystem in the long-term.

The status of *R. rugosa* elsewhere in Nova Scotia needs to be examined. For example, there are several specimens of *R. rugosa* in the E. C. Smith Herbarium (ACAD) from Sable Island. These specimens (#24139, #30865) were collected by John Erskine in 1953, and have the notations "spreading from hedge" and "surrounding garden near old Main Station". Since Sable Island has now been named a national park, managers should be concerned about the invasiveness of *R. rugosa* onto the sand dunes that characterize the island, and the impact of such an invasion on indigenous wildlife.

While sea level is a global phenomenon, the rate of the rise in Nova Scotia is exacerbated by a natural land subsidence that will result in an estimated effective change of at least 70 cm by the end of this century (Forbes et al. 2004). Effective sea level rise is already affecting fringing salt marshes in the southern Gulf of St. Lawrence (Garbary et al. 2008), and the erosion of coastal sand dunes is another manifestation of this phenomenon. If the current dune systems are to remain intact, management practices must reflect this reality. While local government authorities cannot mitigate sea level rise, management of *R. rugosa* on dune approaches may slow invasion. *R. rugosa* should be considered a noxious weed in coastal areas adjacent to sand dune systems and removed; it should certainly not be part of ornamental plantings in dune-side parking lots as we observed at Port Hood Station, a site managed by Nova Scotia Department of Natural Resources.

Rosa rugosa is one of a number of shrubs that have become naturalized in Nova Scotia; other examples include *Euonymus europea* L. (Garbary and Deveau 2008), *Cytisus scoparius* (L.) Link, *Rosa multiflora* Thunb., and *Rhamnus cathartica* L. (Hill and Blaney 2009). Of these species, *R. rugosa* is the only species known to invade dune systems. While we cannot demonstrate negative effects on native vegetation, most of the large clumps (i.e., clump area > 10 m^2) of *R. rugosa* are monospecific. Exotic rose stands occur in a surrounding matrix community that is co-dominated by the mat-forming beach grass and one to two nitrogen

fixing associates (viz. *L. maritimus* and *M. pensylvanica*) as well as native rose, *R. virginiana*.

While we have some evidence that *R. rugosa* colonizes dune systems along road corridors from human habitation (e.g., Cheticamp and Margaree Harbours), it is also possible that fecal material from birds feeding on the hips provides an initial seed bank. Accordingly, Rajakaruna et al. (1998) found *R. rugosa* on guano soils on a remote bird-nesting island in the Gulf of Maine. This seems likely for the West Mabou dunes where large patches of *R. rugosa* were only found near the far end of the dune system that is relatively isolated from residential communities. Smith and Schofield (1959) did not find *R. rugosa* on two bird islands off the east coast of Cape Breton; however, their field work in 1954 may have predated the establishment of *R. rugosa* populations on the adjacent mainland which is sparsely settled.

While *Rosa rugosa* has been planted as an ornamental in Nova Scotia for at least 50 years, but the timing of the onset of colonization of sand dune systems and the development of invasive tendencies remain unknown. It is unclear whether the already erosion-stressed beaches and climate change are providing synergistic effects that are increasing *R. rugosa*'s invasiveness, or if we are only now recognizing a relative stable-state that has been present over a longer period. Also unknown are whether the occurrence of *R. rugosa* on regional sand dunes represents a stabilizing influence in terms of sand movement. The answers to these questions require longer term monitoring of dune systems where various degrees of colonization have occurred. Nevertheless, the evident ability of this species to monopolize dunes and competitively exclude the native plant community presents a potential threat to biodiversity and ecosystem function that should not be overlooked.

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