ATLANTIC PUFFIN/RAZORBILL ASSESSMENT

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MAINE DEPARTMENT OF INLAND FISHERIES AND WILDLIFE
WILDLIFE DIVISION
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by

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INTRODUCTION

Since 1968, the Maine Department of Inland Fisheries and Wildlife (MDIFW) has aggressively pursued development and refinement of wildlife species assessments and implementation of cost-effective comprehensive programs that support selected goals and objectives for the next 15 years. Assessments are based upon available information and the judgments of professional wildlife biologists responsible for individual species or groups of species. Precise data may not always be available or are too limited for meaningful statistical analysis; however, many trends and indications are sometimes clear and deserve management consideration.

The assessment has been organized to group information in a user-meaningful way. The Natural History section discusses biological characteristics of the species that are important to its management. The Management section contains history of regulations and regulatory authority, past management, past goals and objectives, and current management. The Habitat and Population sections address historic, current, and projected conditions for the species. The Use and Demand section addresses past, current, and projected use and demand of the species and its habitat. A Summary and Conclusions sections summarizes the major points of the assessment.

NATURAL HISTORY

Description

Auks (Alcidae) are the ecological counterparts of penguins in the Northern Hemisphere (Cowger 1976). Five alcid species breed in the North Atlantic below the Arctic Ocean; only the Atlantic Puffin (*Fratercula arctica*), Razorbill (*Alca torda*), and Black Guillemot (*Cepphus grylle*) breed as far south as Maine (Cowger 1976, Boag and Alexander 1986).

Auks are a highly specialized group of seabirds, being more adapted for underwater swimming than for long-distance flying (Evans and Nettleship 1985). Their wings are short and reduced in area, improving underwater propulsion. Flight is direct and rapid but not maneuverable; wing-loading is high, and take-off is difficult (Bédard 1985). Bill shape varies by alcid species, reflecting diet and feeding method (Freethy 1987).

Atlantic Puffin--Atlantic Puffins (Fig. 1) have a short, thick neck and short, blunt tail (Boag and Alexander 1986). They have large, webbed feet, with short, sturdy legs (tarsus: 26 mm) set far back on the body producing an upright stance (Knight 1908, Boag and Alexander 1986). Males are slightly heavier (429.0-524.0 g, $\bar{x}$=479.0 g) than females (386.0-511.0 g, $\bar{x}$=445.5 g) (Johnsgard 1987). Beaks are longer and deeper for males than females (culmen: M=45.0-53.5 mm, $\bar{x}$=49.8 mm; F=44.0-51.0 mm, $\bar{x}$=48.0 mm) (Johnsgard 1987),

Fig. 1. Atlantic Puffin (photo from http://search.corbis.com/av.asp?id+AF001957, 3305306.jpg. 30 Sep 99)

giving males 10% more bill area (Harris 1984). Wingspan is 45-63 cm (Freethy 1987), with wing length ranging 157.0-168.0 mm (Johnsgard 1987). Atlantic Puffins are shorter (26-30 cm) than Razorbills (35-40 cm) (Cowger 1976, Boag and Alexander 1986, Freethy 1987).

During the summer breeding period, adult male and female puffins are similarly plumaged with black above, white underparts, and pale gray cheek patches (Johnsgard 1987). The beak is compressed laterally and triangular in profile. Approximately one-half of the bill nearest the tip is bright red-orange, with a slate blue-grey basal section. These 2 areas are separated by a pale yellow ridge. The upper mandible is joined to the feathers by a pale yellow fleshy strip. There is a bright yellow wrinkled rosette where the upper and lower mandibles join (Boag and Alexander 1986). The yellowish grooves in the red area of the bill can be used to determine age and maturity, with lines increasing in length and number as the bird matures. At maturity (4-5 years old), adults have 2 complete grooves (Freethy 1987). Inside the mouth and the tongue are yellow (Johnsgard 1987). The puffin's iris is a dark brown, surrounded by a red orbital ring. Above and below the eye are 2 horny blue-grey patches; the upper patch is triangular, the lower patch more rectangular (Boag and Alexander 1986, Johnsgard 1987). Legs and feet are bright orange. The sharp, black claws on the feet are up to 1 cm long (Boag and Alexander 1986, Freethy 1987).

Soon after the breeding season is completed, the outer sheaths of the bill and horny ornaments above and below the eye are shed. The puffin bill becomes smaller and loses its bright color. The blue-grey base of the bill is shed, the red fades to dull yellow, and the yellow wattle at the hinge of the bill withers away. The red eye ring

disappears (Freethy 1987, Johnsgard 1987). Head and neck feathers are molted, the white face patch and abdomen become grey (Harris 1984, Freethy 1987). Legs turn to a dull yellow color (Bédard 1985).

Puffins have a synchronous primary molt and flightless period. The wing molt occurs at sea making timing difficult to determine. The molt likely occurs in late winter; adults have complete replacement of primaries prior to returning to breeding colonies in early spring (Harris 1984).

Juvenile puffins look similar to winter plumaged adults; however, the bill is smaller, duller in color, and lacking grooves or ridges (Johnsgard 1987), and the dark area in front of the eye is more extensive and blacker (Harris 1984). The bill reaches full length by the end of the first winter, but continues to increase in area (approximately 25% increase) by becoming deeper and to a lesser extent by an increase in the curvature of the top edge. About half of the juveniles lose their black face patches during spring molt, resembling adults except for small, dark beaks; other juveniles retain scattered black feathers in the face patches during summer. Each year, the colors in the beak brighten, eye ornaments become larger, and the red orbital ring brightens. Immature puffins can be aged using the development of bill grooves on the outer, red part of the bill: 1-year-olds have pointed, triangular shaped bills with a trace of a groove; 2-year-olds have an incomplete or one full groove; 3-year-olds normally have 1.5 grooves; most 4-year-olds have 2 grooves (Harris 1984).

Most puffins in their first year replace primaries between March and July, whereas a few may retain primaries until November of the year following hatching. Older immature birds have a molt similar to adults (Harris 1984).

Fig. 2. Razorbills (photo from http://search.corbis.com/av.asp?id=BF001908, 11097016.jpg. 1 Oct 99)

Razorbill—Razorbills (Fig. 2) are distinguished from other alcids by a thick bill, up-tilted tail when swimming, and an arched back in flight (Cowger 1976). They have a short neck and tail and narrow wings. Wingspan in Razorbills is 62 cm (Freethy 1987), with wing length ranging 188-201 mm for males and 194-198 mm for females (Johnsgard 1987). Tarsus length is 36 mm (Knight 1908). Razorbill weights range 524.0-890.0g ($\bar{x}$=734.0 g) for adult males and 620.0-800.0 g ($\bar{x}$=700.0 g) for adult females. Culmen length ranges 32.0-35.5 mm. Razorbills are the only living alcid species with a bill that is black and strongly compressed; it is blunt-tipped with a depth at base nearly as great as the length of the exposed culmen (Johnsgard 1987).

In summer breeding plumage, adult Razorbills are alike. The head, neck, and back are black, with white tips on the secondaries. There is a narrow white line extending from the anterior angle of the eye nearly to the base of the culmen. Underparts are white (including axillaries, under wing coverts, and extending forward to include the lower foreneck) (Johnsgard 1987). The bill has a white stripe crossing it midway. There may be one or more transverse, whitish grooves across the bill. The interior mouth is yellow, and the iris is dark brown. Legs and feet are black. Legs are set far back with the bird standing erect (Freethy 1987, Johnsgard 1987). The central tail feathers of the Razorbill are more pointed and longer than other auks (Freethy 1987). When swimming, the bill and tail of a Razorbill are often tilted upward. On

breeding grounds, Razorbills make low guttural or croaking sounds (e.g., repeated "arr", "ood", or "hurr-ray" notes) (Johnsgard 1987).

The winter plumage of adult Razorbills is similar to breeding plumage but throat, cheeks, and ear coverts are white. The white line between bill and eye is absent (Johnsgard 1987). The bill thins in early fall when the bill covering is shed; the white furrow remains. Razorbills have a complete post-nuptial molt in fall involving all contour and flight feathers, becoming flightless for up to 6 weeks. In spring there is a pre-nuptial molt that involves face and throat areas (Bédard 1985, Freethy 1987)

An immature Razorbill looks similar to a winter adult but upper parts are more brown than black. Young birds have a less massive bill than adults, but the upper mandible is still strongly decurved near the tip with a dorsal and ventral bill profile that is nearly parallel rather than tapered. The bill does not have grooves and white marks typical of adults, and there is only a pale stripe from eye to bill (Johnsgard 1987).

Distribution

Alcids are primarily offshore birds that breed circumpolarly around the fringes of the Arctic Ocean (Cowger 1976). Populations tend to concentrate where polar water from the Arctic Ocean mixes with water from the central Atlantic Ocean, resulting in increased marine productivity. Within areas of suitable marine habitat, patterns of dispersion are limited by ice characteristics (extent and timing of break-up) in northern regions and the existence of nearby land providing safe breeding sites within range of an adequate food supply (Nettleship and Evans 1985).

Atlantic Puffin--The Atlantic Puffin breeds in the Palearctic from Greenland and Iceland east through Scandinavia to Nvaya Zemlya and the coast of northern Russia, south to the British Isles, northern Europe, and southern Scandinavia. In the Nearctic, the Atlantic Puffin breeds from Labrador south to southeastern Quebec (Gaspé Peninsula), Newfoundland, southern New Brunswick, Nova Scotia, and Maine (AOU 1983, Brown 1985, Johnsgard 1987). The world population center is in Iceland, where 51% of the breeding pairs nest. The majority of the Atlantic Puffin population in North America breed on a small number of islands along the coasts of southeast Newfoundland (74% of North American breeding pairs) and Labrador. Less than 1% of the North American population breeds from Nova Scotia to Maine (Nettleship and Evans 1985).

During winter, Atlantic Puffins are widely dispersed offshore. In western Atlantic waters, puffins winter from the ice line south to Massachusetts (casually to southern N.J.). On the European side of the Atlantic Ocean, birds winter south to the Azores, Canary Islands, and western Mediterranean (Nettleship and Evans 1985, Johnsgard 1987). Little is known of the distribution of Atlantic Puffins during winter as they are rarely observed during this period (Brown 1985).

Razorbill--The breeding distribution of Razorbills extends in the east from Iceland to the British Isles, northwest France, Denmark, Scandinavia, and northern Russia, and in the west from western Greenland south to the extreme southeastern Baffin Island, coast of Labrador, the north shore of the Gulf of St. Lawrence, eastern Newfoundland, and south to southern New Brunswick, Nova Scotia, and eastern Maine (AOU 1983, Nettleship and Evans 1985). At least 70% of the world's Razorbill population breeds in

Iceland with 20% in the British Isles. Only 2 -3% of the world population breeds in North America, primarily Labrador (68% of the North American population) (Nettleship and Evans 1985, Erskine 1992). While the Gulf of Maine supports approximately 2% of the North American breeding population of Razorbills (Folger 1986), these colonies constitute a major portion of the southern edge of the Razorbill range in the western Atlantic (Podolsky 1989).

Razorbills remain at sea during the remainder of the year, usually in coastal waters (Lloyd and Perrins 1977). They winter mostly in northern boreal waters from southwestern Greenland south to Long Island, New York, (rarely N.J. and casually to Va. and S.C.), and from southern Norway and the Baltic to Azores, Portugal, and the western Mediterranean Sea (Nettleship and Evans 1985, Johnsgard 1987).

Migration

Migration routes of Atlantic Puffins off eastern North America are not well documented. After the breeding season, puffins are commonly found in the Labrador Sea, off southeastern Labrador. Migration away from breeding areas is nearly complete by October. Breeding birds and young from Greenland move south, probably following the Labrador Current to Labrador and Newfoundland with some dispersal eastward to the open Atlantic Ocean (Johnsgard 1987). Birds are reported to return to Maine breeding grounds during March-May (Palmer 1949, Cowger 1976).

Razorbills on both sides of the Atlantic migrate south or southwest in fall. Labrador and Greenland birds move to Newfoundland and farther south. Birds in the Barents and White Seas migrate to Skagerrak. Irish Sea birds go south to Biscay and

the western Mediterranean. From northern Britain, Razorbills initially move to southwest Norway and the North Sea, but later younger birds move down to Biscay (Brown 1985). Palmer (1949) reported fall migrations of Razorbills beginning by mid-September in Maine, with a migratory movement composed largely of juveniles extending from late October into December. Razorbills begin moving towards Maine breeding grounds in February and early March.

Feeding

Atlantic Puffin--Puffins search for food by dipping their heads into water and diving below the surface (Freethy 1987). Foraging puffins apparently exploit schools of fish versus individuals. Within a beak load, most fish are the same species and similar in size, suggesting birds stay with a school of fish until they have collected a full load (Bradstreet and Brown 1985).

Fish are held in the beak with a powerful grip. Backward-pointing serrations on the beak, a muscular grooved tongue, and upper and lower mandibles that come together in a parallel fashion create an equal pressure along the length of the bill, gripping fish in place. By clamping fish to the roof of their beak with their tongue, puffins are able to open their bill and continue feeding (Boag and Alexander 1986). There is no loss in feeding efficiency when the bill sheath is molted (Freethy 1987).

During the breeding season, adults often forage close to colonies, within 2-10 km (Bradstreet and Brown 1985, Freethy 1987). However, puffins have been reported foraging up to 50-56 km away from a breeding colony (Bradstreet and Brown 1985,

Kress 1989). Puffins usually dive to depths of 6-10 m, with dive times normally ranging 20-30 sec (Bradstreet and Brown 1985).

The diet of Atlantic Puffins consists primarily of fish. Common species in the diet during the breeding season include sandlance (*Ammodytes* spp.), sprat (*Sprattus sprattus*), capelin (*Mallotus villosus*), herring (*Clupea harengus*), sardine (*Sardinops* sp.), haddock (*Melanogrammus aeglefinus*), and various forms of cod (*Pollachius*, *Gadus*, *Merlangius*, *Ciliata*, *Gaidropsarus*) (Harris 1984, Johnsgard 1987). Polychaete annelids and crustaceans make up a lesser portion of the diet (Johnsgard 1987), with the importance of invertebrates varying geographically and seasonally (Bradstreet and Brown 1985).

Fluctuations in the availability of prey populations creates considerable variation in chick diets, within and between years in a given colony and between neighboring colonies during the same season. In northern Norway, *Ammodytes* and *Pollachius* were most frequently fed to young early in the season, while *Clupea* dominated chick diets late in summer (Myrberget 1962). In the low arctic off Newfoundland, capelin was the principal food brought to nestlings in the late 1960s; in 1981 these fish were scarce, and adults were primarily feeding small cods (Gadidae) to chicks (Bradstreet and Brown 1985). Atlantic herring is a principle summer food of puffins in Maine (Kress 1983, 1985). However, in the late summer of 1986 through 1987, hake dominated diets of a small sample of chicks at Matinicus Rock, replacing Atlantic herring as a major food source (Kress 1987).

Atlantic Puffins breeding at low latitudes do not feed young at night. There is a diurnal feeding pattern with highest delivery rates in early morning and a smaller peak in

early evening. On Great Island, Newfoundland, the bimodal provisioning pattern has a well defined peak at 0500-0900 hrs, with a less well-defined peak at 1600-2000 hrs (Bradstreet and Brown 1985).

Puffins typically carry 5-12 small fish per bill load; although they can carry over 20 fish depending on size (Bradstreet and Brown 1985, Freethy 1987, Johnsgard 1987). The frequency that parents feed chicks usually varies 3.8-15.7 trips/day. During the 6 weeks that young are in burrows, feeding frequency is greatest during the middle 2 weeks (period of maximum growth). Length of medium-sized prey preferred by puffins (e.g., relatively deep bodies: gadids and clupeids) is 70 mm, with a maximum length 120 mm. For prey with slender bodies (e.g., sandlance, blennies) length preferred by puffins range 76-145 mm, with a maximum of 207 mm (Bradstreet and Brown 1985).

Razorbill--Razorbills usually capture food by diving from the surface. While swimming, birds periodically dip their heads into the water to spot prey (Freethy 1987). During summer, foraging habitat is usually <20 km (normally 10 km) from the nesting colony (Bradstreet and Brown 1985, Freethy 1987). While diving in coastal waters, Razorbills prefer depths of 1.8-3.6 m for bottom foraging. However, dives range from horizontal to depths of 15 m, with deep pelagic dives occurring especially during winter. Diving times normally range 19-49 sec (Bradstreet and Brown 1985, Johnsgard 1987).

The Razorbill diet consists mainly of fish (80-90% by volume), varying with availability of prey. Fish species prominent in summer diet include sandlance (*Ammodytes*), capelin (*Mallotus*), Atlantic herring (*Clupea harengus*), and Atlantic cod (*Gadus morhua*). Other fish species include sprats (*Sprattus sprattus*), sardines (*Sardina pilchardus*), sticklebacks (*Gasterosteus* spp.), and gobies (Gobiidae).

Crustaceans, polychaetes, and mollusks constitute a minor portion of the Razorbill diet (Bradstreet and Brown 1985, Freethy 1987, Johnsgard 1987). Data are limited on winter food habits (Freethy 1987).

The diet of chicks consists of fish, with species varying regionally. In West Greenland, chicks are fed capelin. The principal food elsewhere in the low Arctic, Gulf of St. Lawrence, White Sea, and Labrador is sandlance, with capelin of secondary importance; cod, eelpouts, and Atlantic herring also are taken (Bradstreet and Brown 1985). In Labrador, Bradstreet and Brown (1985) noted a change in adult diet after chicks hatched to fewer capelin and an increase in small sculpins (*Myxocephalus*) and euphausiids. Parents usually bring 1-6 fish/meal to their chick (occasionally up to 20 fish/meal). The number of fish brought per meal decreases as fish size increases (Bradstreet and Brown 1985). Feeding rate ranges 1-7 times/day (Johnsgard 1987). Feeding rate may be determined by local abundance of prey as well as by the age or appetite of chicks. Length of medium-sized prey preferred by Razorbills (e.g., relatively deep bodies: gadids and clupeids) is 70 mm, with maximum lengths 100-200 mm. For prey with slender bodies (e.g., sandlance, blennies) length preferred by Razorbills ranges 53-137 mm, with a maximum of 250 mm (Bradstreet and Brown 1985).

Breeding Biology

Atlantic Puffin--Atlantic Puffins first breed at 4-6 years old (Harris 1983, Johnsgard 1987). They are colonial nesters, often nesting in large colonies containing up to hundreds of thousands of pairs. At the periphery of the puffin's range, colonies are small (Harris and Birkhead 1985).

Only sexually mature birds return to breeding colonies in early spring, immediately after the flightless period. Dates when birds return to colonies vary by location: late February in eastern Scotland; mid-March in Wales; early to mid-April in the rest of Scotland, Faeroes, Newfoundland, and other western Atlantic colonies; mid- to late April in Iceland; and May in most northern colonies (Harris 1984, Harris and Birkhead 1985). Puffins have returned to Eastern Egg Rock in Maine as early as 4 April (Kress and Nettleship 1988).

The number of puffins present at the colony varies greatly within and between days. Peak attendance at colonies usually occurs in late afternoon and evening, with numbers increasing over several days to peak and then decline again. This cycle continues throughout the season, becoming more prominent as the number of young birds coming to the colony increases (Harris 1984, Harris and Birkhead 1985). Immature puffins begin returning to colonies in late May or early June. The annual maximum number of puffins present at breeding colonies occurs at about the time young are fledged (Nettleship 1972, Harris 1984).

Puffins exhibit a high degree of nest-site tenacity (77%); birds return to the same island, colony, and often to the same burrow over successive years (Nettleship 1972). Even though puffins do not pair for life, there is a strong mate fidelity. Ashcroft (1979) reported only 8% of breeding pairs changed mates in consecutive years, exclusive of cases when 1 bird died. On Eastern Egg Rock, pairs spent an average of 4.7 years together (Kress 1990). Obtaining a new mate or changing burrows does not appear to measurably affect breeding success (Johnsgard 1987). Courtship involves aquatic and

terrestrial displays to strengthen the pair bond, including billing, head nodding, and bowing (Freethy 1987, Johnsgard 1987).

Atlantic Puffins are the only Atlantic alcid that actively prepares a nest (Cowger 1976). They nest almost exclusively in burrows excavated in turf-covered, steep slopes and level tops of rocky, coastal maritime islets. At high latitudes where burrowing is prevented by permafrost, birds are restricted to using rock crevices and interstices in talus slopes (Nettleship 1972).

Burrows are excavated by loosening the soil and stones with the bill, and kicking it out of the tunnel with the feet. Nest burrows are usually 70-100 cm long (ranging from 20 cm to many meters). The tunnel ends in a slightly enlarged nest chamber (Harris and Birkhead 1985). Both sexes dig and repair nesting burrows (Johnsgard 1987). Burrows usually are simple, single tunnels. However, burrows may divide or in dense colonies connect, forming an extensive catacomb. Yet, each nesting pair uses and defends one entrance (Cowger 1976, Harris and Birkhead 1985). The nesting chamber is usually lined with grass, feathers, seaweed, and other materials; sometimes the egg is incubated on bare earth or rock (Harris and Birkhead 1985). New burrows are usually dug later in the breeding season, presumably by subadult birds or by those that lost or abandoned earlier burrows (Johnsgard 1987).

Puffins are highly social, and distribution of burrows within colonies tends to be strongly aggregated with respect to particular habitat features. Densities are greater on steep slopes (>30^{o}) close to the cliff edge than on level habitat (<15^{o}) away from the cliff edge. Soil depth needs to be suitable for burrowing. Tunnels constructed on level ground run parallel to the surface and burrows usually meet, often resulting in collapse

of burrowed ground (Nettleship 1972, Harris and Birkhead 1985). Breeding densities in Iceland averaged 0.66 burrows/m^2; maximum densities ranged 1.7 burrows/m^2 in Great Britain and 2.72 burrows/m^2 in Iceland (Johnsgard 1987).

Nonbreeding rate among adults may be high in areas of the puffin's range. Up to 20-30% of colony adults may be without a nesting burrow (Ashcroft 1979, Harris 1983, Boag and Alexander 1986). Some puffins may not breed even though they have a nest site. Ashcroft (1979) reported 6-16% of pairs with burrows did not lay eggs.

Continuous occupancy of burrows (correlated with the start of egg laying) does not begin until several weeks after puffins arrive at breeding areas. Puffins exhibit territorial behavior around the burrow, defending against intruders by threat (physical presence, head flicking, bill gaping) and physical combat (fighting with beak and claws) (Nettleship 1972, Johnsgard 1987).

Puffins are the only Atlantic auk that mate on water, close to breeding colonies (Cowger 1976). There are large geographic differences in laying dates throughout the puffin's range. Late snow may prevent some northern birds from getting to their burrows; even when they do, burrows are often plugged with ice (Harris and Birkhead 1985). In Newfoundland, eggs are laid from the second week of May to late June, with a strong peak during the first half of the period (Nettleship 1972). Knight (1908) and Bent (1919) reported laying dates for Maine ranging late June through July. However, Kress and Nettleship (1988) reported eggs laid as early as 23 April on Eastern Egg Rock. Young birds breeding for the first time tend to lay eggs later than experienced breeders (Johnsgard 1987). Transplant experiments in the Gulf of Maine suggest timing of the breeding cycle (e.g., egg laying, hatching) is in response to proximate

conditions (e.g., water temperature and food availability) rather than genetically determined (Kress and Nettleship 1988).

Puffins lay 1 white egg, often having faint lilac markings that soon fade (Harris 1984, Johnsgard 1987). Eggs laid earlier in the season tend to be heavier. Success rates are greater for heavier eggs than lighter ones (Freethy 1987). Replacement eggs are laid only when the first egg is lost early during incubation; 4-14% of pairs losing their first egg lay a replacement (Johnsgard 1987). The interval between egg loss and replacement ranges 13-23 days (Harris and Birkhead 1985).

Incubation starts immediately after the egg is laid. Both sexes share in brooding; shifts occur at least once a day, mostly during night. Incubation period ranges 40-45 days (Myrberget 1962, Harris and Birkhead 1985, Johnsgard 1987).

Hatching begins as early as 7-10 June in Maine (Kress 1982*a*, Kress and Nettleship 1988). Kress and Nettleship (1988) reported a median hatch date for pairs previously breeding together of 15 June on Eastern Egg Rock; median hatch date was 6 days later for pairs breeding together for the first time. Peak hatching occurs during the last week of June and first week of July in Newfoundland (Nettleship 1972). Chicks hatching from eggs early in the season survive better, have shorter fledging periods, and fledge at higher body weights than those hatching later (Harris and Birkhead 1985).

Hatching success ranges 63-89% (Ashcroft 1979, Harris and Birkhead 1985, Johnsgard 1987). Newly hatched chicks are semi-precocial and have an average weight of 48 g (approx 9.4% of adult weight) (Johnsgard 1987). Chicks are brooded continuously for the first 6-7 days, until they initially are able to thermoregulate (Harris and Birkhead 1985, Johnsgard 1987). Both parents feed their chick, mostly in early

mornings and afternoons (Myrberget 1962). Within the burrows, chicks move around, avoiding the vicinity of the burrow entrance until at least 4-weeks-old. There is a well-defined latrine area just outside the nesting chamber. By concentrating excrement in one location, chicks stay clean and avoid the dangers of predators (e.g., gulls) at the burrow entrance. After 4 weeks, the chick usually changes the latrine location closer to the burrow entrance (Kress 1982*a*).

Young gain weight steadily until 33-34 days old, reaching a peak weight of 70-80% of adult weight. Weight remains nearly constant until chicks are 41-42 days old. Chicks then voluntarily restrict food intake (Myrberget 1962, Harris 1984), even though they are normally fed up to fledging (Harris and Birkhead 1985). Chicks lose weight prior to fledging, weighing about 59% of adult weight (283 g) when fledged (Johnsgard 1987). There are marked differences in growth rates of chicks at different colonies. Growth is related to species and amount of food delivered to chicks. Chicks grow better and fledge at greater weights when fed oil-rich species (e.g., sandlance and sprats) (Harris and Birkhead 1985).

During 1-2 days before fledging, young often make brief visits outside the burrow entrance. Most young fledge after dark (with lower predation risk) and are far from land by first light the following day (Cowger 1976, Harris and Birkhead 1985). At fledging, young puffins can fly and are independent of parents (Harris and Birkhead 1985). Variation in fledging period probably reflects quantity and quality of food available and fed to developing chicks (Harris and Birkhead 1985, Johnsgard 1987). Normally, chicks fledge at 38-44 days old (Harris 1984). However, in good conditions, chicks fledge at 38-41 days old; under poor feeding conditions, fledging may be prolonged to 74 days or

longer (Harris and Birkhead 1985). In Newfoundland, fledging begins in early August, continuing through the end of September. Except for the latest breeders, breeding and nonbreeding puffins depart colonies in late August (Nettleship 1972). Most adults leave breeding colonies in Maine by mid-August (Kress and Nettleship 1988).

Fledging success is typically 70% (Johnsgard 1987), with the number of young fledged per pair ranging 0.28-0.93 (Harris and Birkhead 1985). On Eastern Egg Rock, Kress (1985) reported 80% of the nests produced chicks; 89% of the pairs breeding together at least once previously fledged chicks, while only 67% of inexperienced pairs fledged young. Pairs nesting earlier in the breeding season are more successful fledging young than pairs nesting later (Kress and Nettleship 1988). Predation and harassment (e.g., by gulls) can have an influence on breeding success. In Newfoundland, breeding success from pairs nesting on steep slopes (>30^{o}) was nearly twice as great as success of pairs nesting in level habitat (<15^{o}). Nettleship (1972) hypothesized that these differences resulted from differing amounts of interference by gulls in the 2 habitats.

After leaving the nesting burrow, young puffins spend the first 2-3 years of life at sea (Freethy 1987, Kress 1990). Immature puffins may then begin visiting colonies in the vicinity of their natal island with 2-year-olds arriving during the chick rearing period, 3-year-olds during the egg laying stage, and 4-year-old nonbreeders arriving at the start of the season (Harris and Birkhead 1985). Puffins may begin prospecting for nesting burrows at 3-4 years of age (Kress 1982*a*). Inter-colony movements decrease as birds become established in a breeding colony (Kress and Nettleship 1988).

Razorbill--Razorbills only come to land to breed. Most birds first breed at 4-5 years of age; although a few breed as early as 3 years and some delay breeding until 6 years (Lloyd and Perrins 1977, Johnsgard 1987).

The period of colony attendance prior to egg-laying is a regular feature of Razorbill breeding biology. The duration of this period is related to environmental factors (e.g., water temperature, ice-cover). In boreal regions, Razorbills begin returning to breeding sites in late February and early March, about 3 months before egg-laying begins. At higher latitudes, most birds arrive in late April or early May, only about 1 month before egg-laying. The patterns of colony attendance prior to laying have been recorded only in boreal regions. Birds alternate approximately 3 days at the colony with a 3-4 day absence, roosting at sea. Birds arrive at the colony at first light, often spending most time displaying in groups offshore. This alternating pattern of attendance and absence at the colony is influenced by weather conditions; strong winds and heavy seas result in reduced numbers at the colony and a disrupted cycle of attendance (Harris and Birkhead 1985).

Razorbills have a well-developed nest site-tenacity. Even though some immature birds may visit other colonies, most Razorbills return to natal colonies to breed. However, some permanent emigration from the colony occurs, likely prior to reproductive maturity. Once birds begin to breed, Razorbill pairs rarely move their breeding site, often returning to same the nest site in consecutive years (Lloyd and Perrins 1977, Harris and Birkhead 1985).

The Razorbill mating system is seasonally renewed monogamy. Mate-fidelity is strong, with pairs breeding together for several years. Lloyd (1979) reported 72% of the

birds retained the same mate for at least 2 years. Over 95% of mate changes occur after the death of a partner (Harris and Birkhead 1985). Paired birds spend much time in mutual billing and preening behaviors. Mating occurs on land, around loafing areas or nest sites (Freethy 1987, Johnsgard 1987). A small but variable proportion of adult Razorbills do not breed every year (Lloyd and Perrins 1977).

Razorbills are a colonial nesting species, with colony size reflecting relative availability of suitable food resources and abundance of nesting sites. Razorbills are flexible in nest site requirements; depending on availability, ledges, crevices, or cavities are used. However, highly favored nesting sites include boulder fields and deep rock fissures with associated debris. Nesting density ranges 0.25-4.00 pairs/m^2 surface area (Johnsgard 1987). Razorbill sites generally are better protected than open ledges used by murres and are more rocky and crevice-like than burrows preferred by puffins (Johnsgard 1987). The single egg is typically laid directly on bare rock. Birds may collect small stones, dried droppings, lichen, stems, or other bits of vegetation from the immediate vicinity of the breeding site and place it where the egg is laid. Incubating birds also collect material within reach and place it under the egg (Harris and Birkhead 1985). These nesting materials aid in preventing the egg from rolling about (Johnsgard 1987).

Most Razorbills lay eggs within a 4-5 week period during May-June (Bent 1919, Chapdelaine and Laporte 1982, Harris and Birkhead 1985). Egg laying begins earliest in more southerly parts of the range, being more closely related to sea-surface temperature than latitude (Harris and Birkhead 1985). Exceptionally cold and stormy weather can disrupt colony attendance patterns and appears to be main cause of delay

in laying. Young birds (first 3-4 years of breeding) tend to lay later in the season than older birds (Lloyd 1979).

The egg is white, cream, buff, or very pale blue with reddish brown to black markings (lightly to heavily blotched) (Harris and Birkhead 1985). It is elliptical ovate in shape, rotating in a tight circle if dislodged from the nest (Cowger 1976, Harris and Birkhead 1985). The eggs weigh about 12.5-14% of adult weight, with egg size tending to increase with female age (Harris and Birkhead 1985, Johnsgard 1987).

Lloyd (1979) determined 30% of eggs laid were lost, primarily due to predation by Herring Gulls and Jackdaws. Most losses occurred during the first 10 days after laying. Only eggs laid and lost early in the nesting season were replaced; 25-35% of lost eggs were replaced, with a mean interval of 14 days (ranging 12-18 days) between loss and replacement (Lloyd 1979, Johnsgard 1987). The speed of birds returning to nest sites following disturbance is critical in determining whether eggs or chicks are lost; generally more experienced breeders are among the first to return to nest sites (Lloyd 1979).

The mean incubation period ranges 35-37 days. Both sexes share in incubation, beginning immediately after the egg is laid (Lloyd 1979, Harris and Birkhead 1985).

Hatching success ranges 53-88% (Chapdelaine and Laporte 1982, Harris and Birkhead 1985, Johnsgard 1987). Inexperienced birds tend to lose eggs more readily than older birds. Adults that lay early in the season, lose the egg, and replace it tend to be more productive than birds laying later in the season (i.e., mainly young, inexperienced birds) (Lloyd 1979). Additionally, Lloyd (1979) determined nearly 63% of chick losses occurred during the first 5 days, mainly attributable to parental behavior

(indicating that inexperienced birds were more inclined to lose chicks). Egg size may also be critical to a chick's survival during the first week of life.

Razorbill chicks are semi-precocial. At hatching, chicks weigh 9-10% of adult body weight (about 60 g); hatching weight is positively correlated with egg size (Harris and Birkhead 1985). During the first few days, chicks are closely brooded, becoming completely homeothermic at about 9-10 days. Once chicks are able to thermoregulate, young in enclosed sites are occasionally left unattended by parents. Chicks on open ledges are always guarded by one parent (Harris and Birkhead 1985).

Chicks increase weight steadily to 14-days-old, with average daily weight increases of 8.3 $\pm$ 3.1 (s.d.) g (Lloyd 1979). Weight increases more slowly up to day of fledging, with chicks attaining weights of 140-180 g (20-30% adult weight) (Harris and Birkhead 1985, Johnsgard 1987). At about 10 days old, chicks start acquiring juvenile plumage, consisting of well-developed primary coverts and a dense coat of body feathers. Feathers on the ventral region are particularly dense, providing waterproofing and thermal insulation. Primary coverts are used during the chick's flight to sea, and for propulsion underwater once the fledglings are at sea. Primaries and secondaries do not start to emerge until after young have left the colony (Harris and Birkhead 1985). At 17-18 days of age, young Razorbills leave the nesting colony. Fledging success is high, usually ranging 82-97% of hatched young (Lloyd 1979, Harris and Birkhead 1985, Johnsgard 1987). Failure to fledge is mainly due to the breakdown in behavior between parent and young, rather than to predation. Breeding success varies 46-85% of breeding pairs fledging young, with lower success for inexperienced, young breeders that tend to lay later in the season (with less probability of replacing a lost egg) and for

pairs nesting on ledges versus burrow sites (Lloyd 1979, Chapdelaine and Laporte 1982, Harris and Birkhead 1985, Johnsgard 1987). Lloyd and Perrins (1977) estimated that 100 breeding pairs might be expected to fledge 71 chicks.

Young depart from breeding colonies when only partly grown and still flightless. In boreal regions, departure occurs during the 1- to 3-hour period at dusk; at higher latitudes with continuous day, young depart when light intensity is lowest. Young either jump from nesting ledges or scramble over boulders to the sea. Young Razorbills are always accompanied by one parent, typically the male, that continues to care for the chick for several weeks (Harris and Birkhead 1985).

Few young Razorbills return to breeding colonies before 3-4 years old. Prior to sexual maturity, Razorbills are seen prospecting at active colonies, with the youngest immature birds (occasionally some at 2 years old) returning to the colony latest in the nesting season and staying the shortest amount of time. Older immature birds return to nesting colonies progressively earlier each year, remaining at the colony for increasing lengths of time (Lloyd and Perrins 1977, Podolsky 1989).

Survival and Longevity

Harris (1983) estimated 38% of Atlantic Puffins survive to 4-years-old (when some breed) and 30% survive to 5-years-old (when most birds breed for the first time), with a range of 22-54% of young puffins reaching age of first breeding and returning to the colony. Adult Puffins have a mean annual survival rate of 95% (ranging 88.8-98.4%) (Ashcroft 1979; Harris 1983, 1984; Hudson 1985; Johnsgard 1987). Average

longevity for Atlantic Puffins is 25 years (Harris 1984); maximum longevity may reach 34 years (Kress 1988).

Mortality rates are fairly high for young Razorbills between fledging and attaining adult mortality rates. There may be a 55% mortality rate for the first year, with 25% annual mortality to 4 years of age (Johnsgard 1987). Only about 13-18% of young Razorbills survive to breeding age (Lloyd and Perrins 1977, Lloyd 1979). Annual adult survival rate generally is 89 -92%, but may range 81-96% in some years (Lloyd and Perrins 1977, Lloyd 1979, Hudson 1985, Johnsgard 1987). Known maximum longevity for Razorbills is 25 years (Johnsgard 1987), although it may exceed 30 years (Freethy 1987).

MANAGEMENT

Regulatory Authority

Seabirds are protected by both federal and state legislation. The Migratory Bird Treaty Act of 1918, a federal statute, provides protection from illegal take and harassment. Two federal laws provide some protection for seabird habitat. Section 404 of the federal Clean Water Act of 1977, administered jointly by the Army Corps of Engineers (permit authority) and the Environmental Protection Agency, prohibits projects that violate water quality standards or involve toxic discharges; mitigation of unavoidable impacts is required. The Coastal Zone Management Act of 1972 establishes federal assistance to coastal states for coastal resource protection programs (Senner and Howe 1984).

In Maine, seabird nesting islands or habitats of endangered and threatened wildlife may be designated as Significant Wildlife Habitat under the Natural Resources Protection Act (NRPA) of 1988, with regulatory oversight by the Maine Department of Environmental Protection. This legislation recognizes Significant Wildlife Habitat as a state natural resource to be protected. The Maine Department of Inland Fisheries and Wildlife (MDIFW) is responsible for defining and mapping these habitats for protection under this law. In unorganized townships, the Maine Land Use Regulation Commission (LURC) provides protection (Fish and Wildlife Protection Subdistrict: P-FW; Resource Plan: P-RP) to seabird nesting islands considered essential to maintaining specific seabird species (e.g., Atlantic Puffin, Razorbill). Additionally, Maine's Comprehensive Growth Management Act (1988) mandates MDIFW to provide information on habitats of

rare species to the Department of Economic and Community Development for towns to use for comprehensive planning purposes.

The Atlantic Puffin and Razorbill are classified as Threatened species by MDIFW. Maine's Endangered Species Act of 1975 protects Endangered and Threatened wildlife species from take or harassment. A 1988 Amendment to the Act enables the Commissioner of Inland Fisheries and Wildlife to designate "Essential Habitat", critical for conserving Endangered and Threatened species, and to promulgate and enforce guidelines to protect these species.

Past Goals and Objectives

The Maine Department of Inland Fisheries and Wildlife has not established specific goals and objectives for Atlantic Puffin and Razorbill management. The broad goal to maintain current abundance and distribution of coastal wildlife was adopted in the Coast of Maine Wildlife Management Area plan and is generally applied to Maine's seabird resource (Woodward and Hutchinson 1986, Woodward et al. 1991). The Seabird Nesting Island Management System (Allen 1994) lists general goals and objectives for island-nesting seabird management, covering species currently lacking assessments (e.g., Atlantic Puffin, Razorbill):

Management goal: Maintain or enhance the long-term presence, diversity, and viability of seabirds nesting on the coast of Maine.

Management objectives:

1. Maintain seabird nesting habitat on all coastal nesting islands (containing 1 or more nesting pairs of seabirds since 1976) through 2000.
2. Develop specific population goals and objectives for priority species by 2000.

Past and Current Management

To date, a strategic management plan and management system have not been drafted by MDIFW for either the Atlantic Puffin or Razorbill. Management of these alcids in Maine consists primarily of population monitoring, nesting island protection, and re-establishment of colonies (i.e., Atlantic Puffin) at former breeding sites.

In 1976-77, the U.S. Fish and Wildlife Service (USFWS) surveyed coastal waterbird colonies in Maine (Erwin and Korschgen 1979). Maine seabird nesting islands continue to be periodically reinventoried (most recently in 1999) by MDIFW with support from USFWS and private conservation agencies. These data are maintained in MDIFW's Coastal Island Database.

Federal, state, and private conservation agencies (e.g., The Nature Conservancy, National Audubon Society, and Maine Audubon Society) have been instrumental in acquiring and managing seabird nesting islands in Maine. In 1976, the Maine Critical Areas Program recommended registering known nestings areas of Razorbills and puffins (in addition to islands with large colonies of Black Guillemots [>100 pairs]); 14 areas on 13 islands were registered during 1976-1982 (Cowger 1976). Seabird nesting islands have been identified and protected as Significant Wildlife

Habitat (NRPA) and P-FW or P-RP zones (LURC). Nearly 175 seabird nesting islands within the Coast of Maine Wildlife Management Area, owned or managed by MDIFW, are closed annually to trespassing from 15 April to 31 August, depending on species nesting there.

During the last 2 decades, puffin breeding populations have been restored to 3 former nesting islands in Maine using translocation, attraction techniques, and gull control programs, through National Audubon Society-Canadian Wildlife Service cooperative programs (with assistance by USFWS and MDIFW). Between 1973-81, Atlantic Puffin nestlings were transplanted from natal burrows on Great Island, Newfoundland to Eastern Egg Rock. During 1974-77, gull populations (Herring Gulls, Great Black-backed Gulls) were controlled by killing adults and destroying nests to aid recolonization programs for terns and puffins. Less intense gull control efforts have continued until 1995 (MDIFW files). Since 1981, a small breeding population has recolonized Eastern Egg Rock (Nettleship and Evans 1985).

In 1984, a puffin restoration project began on Seal Island National Wildlife Refuge. Between 1984-1989, 950 nestlings were translocated from Great Island, Newfoundland (Kress 1992); gull control began in 1984 (Kress 1985) and has continued until 1998 (MDIFW files). Since 1992, Atlantic Puffins have been nesting again on Seal Island (Kress 1994).

In an attempt to lure prospecting birds to investigate potential nest sites, attraction techniques (e.g., decoys, tape recordings of puffin calls) have been used on Western Egg Rock and Wooden Ball Island (Kress 1982*b*, Kress 1984). Gull control

programs have occurred on Petit Manan Island National Wildlife Refuge(1984, 1992-97) and Matinicus Rock (1991-93) (MDIFW files).

In 1994, an attraction program for Razorbills began on Seal Island National Wildlife Refuge using life-sized decoys and recordings of Razorbill growling sounds. Razorbills have been observed loafing ashore and exploring under boulders on the island for nest sites (Kress 1994).

HABITAT ASSESSMENT

Puffins and Razorbills nest on some of Maine's most remote and inaccessible offshore islands. Typically, nesting islands are low-lying, rocky, and treeless, with patches of vegetation (Cowger 1976). The presence of alcids on Maine's coast is due to the oceanography of the region. The cold waters from the Labrador Current and strong tides in the Bay of Fundy cause an upwelling of cold, nutrient-rich water. These factors create an unusually cold climate for the latitude coupled with an abundant food supply, enabling several seabird species with an affinity for cold water to extend their breeding ranges southwards into the Gulf of Maine (Cowger 1976, Folger 1986).

Atlantic Puffin breeding habitat encompasses rocky, coastal areas of the North Atlantic from temperate to arctic seas that have August surface temperatures ranging 0-17^{o} C (Johnsgard 1987). Puffins typically nest in burrows excavated in turf-covered maritime slopes and level tops of rocky islets. At high latitudes, puffins are restricted to rock crevices in cliffs and interstices in talus slopes due to permafrost (Nettleship 1972). In Maine, puffins also breed in crevices under boulders (Nettleship and Evans 1985, Kress and Nettleship 1988). Where crevice-nesting puffins and Razorbills occur in the same habitat, Razorbills occupy larger holes while puffins tend to nest deep in smaller ones (Spendelow et al. 1988). Nettleship (1972) noted that puffins preferred nesting on steep slopes (>30^{o}) (versus gradual) near cliff edges with landing sites near burrows, which may reduce harassment and predation by gulls. Even though puffins will nest in association with Herring Gulls, they tend to avoid areas used by Great Black-backed Gulls (Pierotti 1983).

On some islands where there is a high density of nesting puffins, the burrowing activities of puffins can have a detrimental effect to the nesting habitat. Extensive burrowing can undermine the thin top layer of soil above the bed rock, leading to burrow collapse. Winter winds blowing over nestings holes can increase erosion problems (Boag and Alexander 1986, Freethy 1987).

Outside of the breeding season, puffins are pelagic, spending most of the winter along pack ice areas of North Atlantic away from coastlines (Johnsgard 1987).

Razorbills breed along coastlines of temperate and subarctic seas, where August surface temperatures range 4-15^{o}C (Johnsgard 1987). Razorbills use a variety of nest sites: rock crevices, boulder fields, burrows, and infrequently cliff ledges. Nesting sites are usually at least partially enclosed (Harris and Birkhead 1985, Spendelow et al. 1988, Podolsky 1989). Breeding habitats are very similar to Common Murres; the 2 species often share breeding colonies. During the nonbreeding season, Razorbills are pelagic, wintering mainly in cold temperate, offshore waters similar to areas used by Murres (Johnsgard 1987).

Past Habitat

Historically, puffins were recorded nesting on at least 7 of Maine's coastal islands (Table 1, Fig. 3). Western Egg Rock historically was the southern limit for puffins breeding in North America. A reduction in Maine populations by overharvest was noted in 1833 when J. J. Audubon visited the region (Nettleship and Evans 1985). However, in the early 1880s populations were further reduced as a result of excessive

Table 1. Historical records of Atlantic Puffins along the Maine coast, prior to 1976. Number represents nesting pair (np) or individual bird count (ibc).

Island Reg. #	Island Name	Atlantic Puffin observations by decades												
		<1860	1860s	1870s	1880s	1890s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s
65-201	Western Egg Rk	nesting-abundant[a]		numerous[a]	reduced[a] 1885:5-6 np[a] 1887:none[a]		no nesting[a]							
63-860	Eastern Egg Rk	nesting-abundant[a]		numerous[a]	reduced[a] 1887:none[b,c]		no nesting[a]							
63-655	Large Green I	nesting-abundant[a]					none[d]							
63-940	Matinicus Rock	nesting[e]	none[a]	none[a]	present[a,f]	3-5 np[a]	1-4 np[a,g,h] 1-6 ibc[a,f,i]	2-3 prs, not known breed[a]	present[a]	9-100 ibc[a] ~40 np[a]	~70 ibc, nesting[a]	75-140 ibc[f]	120-150 ibc[f]	170 ibc[f]
63-923	Seal I	historical breeding[a] 1850s: reduced[a]			1886: 25-30 np[a] 1887:none[a]									
59-119	Mt. Desert I	historical breeding[a]					none[d]							
79-933	Petit Manan I						none[d]							
79-367	Machias Seal I			nesting[a]	60 ibc[a]		nesting 300 ibc[a,g]	300 ibc[a]	>200-450 ibc[f],nesting[a]	400-700 np[a] 600-1,000ibc[f]	~700 np[a] 650-1,000ibc[f]			750-900 np[f,j]

[a](Palmer 1949).
[b](Nettleship and Evans 1985).
[c](Kress and Nettleship 1988).
[d](Kress 1982*a*).
[e](Kress 1979).
[f](Drury 1973).
[g](Knight 1908).
[h](Bent 1919).
[i](Norton 1907).
[j](Harris 1984).

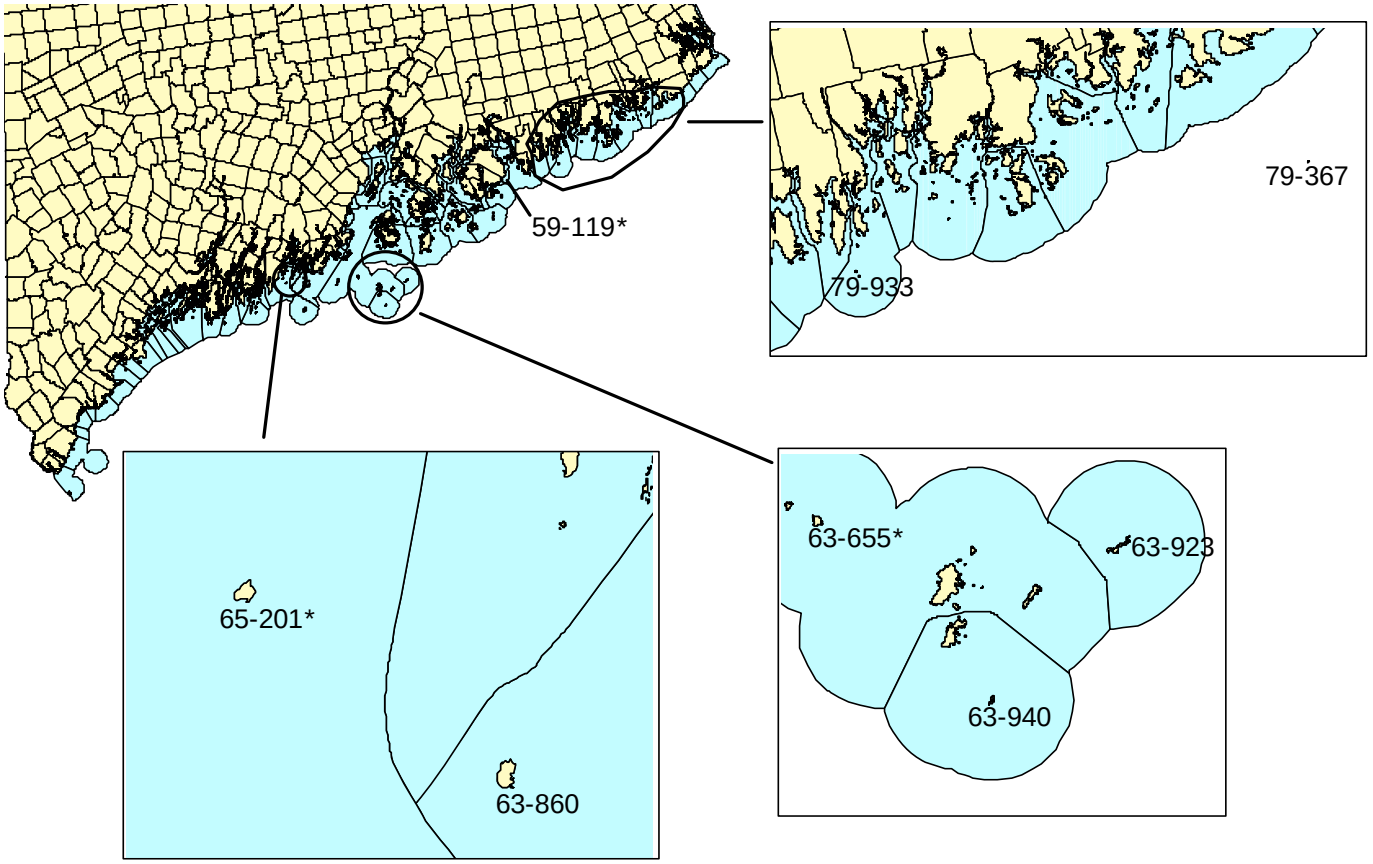

Figure 3. Location of current and historic nesting islands for Atlantic Puffin along Maine's coast, by Island Registry Number. Islands with only historic nesting records (prior to 1977) are noted with asterisk.

egging, shooting, destruction of nesting habitat, and introduction of domestic animals (Nettleship and Evans 1985). Populations on 3 Maine islands (Western Egg Rock, Eastern Egg Rock, Seal Island) were extirpated in 1887, probably by milliners' agents (Palmer 1949, Nettleship and Evans 1985, Kress and Nettleship 1988). From the 1900s to 1970s, puffins were recorded nesting off the Maine coast only on Matinicus Rock and Machias Seal Island (Table 1).

Historical records of Razorbills nesting in Maine are sparse (Table 2), with data lacking on size of former colonies (Podolsky 1989). Razorbills probably were eliminated from nesting islands in Maine in the mid-1800s (Folger 1986) as breeding grounds became more restricted through persecution and the advance of civilization (Bent 1919). During 1894-1923, Norton (1923 cited in Korschgen 1979) reported no Razorbills nesting in Maine. Early in the 1920s, Razorbills slowly reappeared in Maine (Drury 1973). Prior to the 1970s, nesting Razorbills have been scarce in Maine, with nesting occurring only on Matinicus Rock and Machias Seal Island (Korschgen 1979) (Table 2, Fig. 4).

Current Habitat

Protection efforts in effect since the early 1900s have prevented further loss of nesting colonies of Atlantic Puffins and Razorbills along the coast of Maine. However, recolonization of former breeding sites has been very slow.

In 1973 when the National Audubon Society's Project Puffin began, Matinicus Rock and Machias Seal Island were the only nesting islands for puffins in the Gulf of

Table 2. Historical records of Razorbills along the Maine coast, prior to 1976. Number represents nesting pair (np) or individual bird count (ibc).

Island Reg. #	Island Name	Razorbill observations by decades												
		<1860	1860s	1870s	1880s	1890s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s
65-201	Western Egg Rk				1 pr,not known breed[a]	no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
63-860	Eastern Egg Rk				present[b]	no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
63-654	Little Green I				<1880s:1 pr,no known breeding[a]	no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
63-585	Metinic Green I				nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
63-940	Matinicus Rock					no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]		possibly 1 pr[a]	8 ibc[b]	8-21 ibc[b] 5 np[c]	5-9 np[c] 10 ibc[b]
63-923	Seal I	historical nesting[d] 1800s:none[d]				no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
59-270 -313	Cranberry Is	≤1858: possible nesting[e]				no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
79-676	Freeman Rock					no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					
79-313	Old Man (E)					no nesting[a]	no nesting[a]	no nesting[a]	no nesting[a]					40 ibc[b], nesting not confirmed[c]
79-367	Machias Seal I	1830s:nesting[a]		nesting[a]	1 pr[d]	no nesting[a]	no nesting[a]	no nesting[a], 1 ibc[a]	no nesting[a]	≤25 prs[a], no nesting reported[a,d]	8-200 ibc[b,d], 20-100 pr[a,d], no nesting reported[a,b]	≤15 prs[b,d], no nesting reported[b]		50-74 prs[b,d], not nesting[f]

[a](Palmer 1949).
[b](Drury 1973).
[c](Korschgen 1979).
[d](Folger 1986).
[e](Knight 1908).
[f](Cowger 1976).

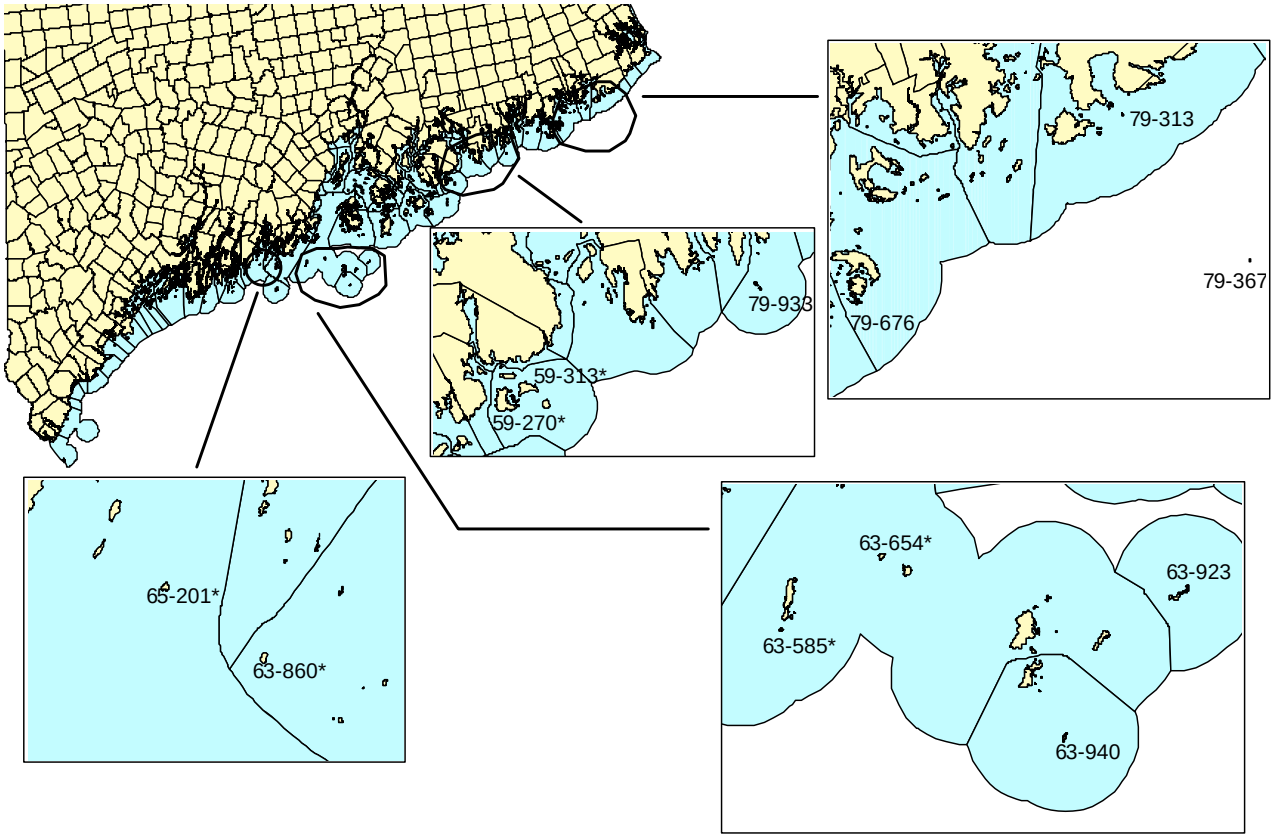

Figure 4. Location of current and historic nesting islands for Razorbill along Maine's coast, by Island Registry Number. Islands with only historic nesting records (prior to 1977) are noted with asterisk.

Maine (Table 1). With the use of reintroduction, attraction, and gull control techniques, puffins currently are breeding on 5 islands in the Gulf of Maine (Eastern Egg Rock, Matinicus Rock, Seal Island, Petit Manan Island, and Machias Seal Island) (Table 3, Fig. 3).

Within the Gulf of Maine, only 7 islands were ever listed as supporting breeding colonies of Razorbills (Folger 1986) (Tables 2, 4). Presently, Razorbills are restricted to 6 colonies off the coast of Maine: Matinicus Rock, Seal Island, Freeman Rock, Old Man Island (E), Petit Manan, and Machias Seal Island (Table 4, Fig. 4). Although Razorbills are occasionally sighted around other Maine islands during the summer (occasionally landing) (i.e., Jordan's Delight, No Man's Land, Pulpit Rock, Little Spoon Island, and Wooden Ball Island [Maine Dep. Inland Fish. and Wildl. files]), no other permanent populations are known to have been established.

Conservation ownership of alcid nesting islands aids in protecting this important habitat. All of the current nesting islands for Atlantic Puffins (5) and Razorbills (6) off the coast of Maine are owned or under management authority of a conservation agency (federal: USFWS, Canadian Wildlife Service; state: MDIFW; private: National Audubon Society) (Tables 3,4). Currently, 2 islands are under LURC zoning (P-FW), and 4 islands are zoned as Significant Wildlife Habitat under NRPA 1988 (Tables 3, 4).

Table 3. Breeding population estimates of Atlantic Puffins in Maine, since 1976. Number in parenthesis represents known nesting pairs that successfully fledged young. Individual bird counts indicated by ibc.

Island Reg. #	Island Name	Critical Areas Registry 1976-1982	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs by year														
					1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
65-201	Western Egg Rk		P-FW	NAS(L)	0[b]														
63-860	Eastern Egg Rk	•	SWH	IFW*	0[b]					5[c]	14 (13)[d]	10[e]	14[f]	20[f]	19 (16)[g]	18 (16)[h]	16 (16)[i]	14[e]	15[e]
63-655	Large Green I		P-FW	PRI(L)	0[b]														
63-940	Matinicus Rock	•	P-FW	FWS(L)	75[e]	125[m]				75[c]		~75[n]		~100[o]					
63-923	Seal I	•	P-FW	FWS(L)															
79-933	Petit Manan I		SWH	FWS											1[h]	1(1)[h]		1[e]	
79-367	Machias Seal I			FWS/CWS		declined[m]				~700[c]			800-1,000[o]			~900[h]			

Table 3. Continued.

Island Reg. #	Island Name	Critical Areas Registry 1976-1982	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs by year								
					1991	1992	1993	1994	1995	1996	1997	1998	1999
65-201	Western Egg Rk		P-FW	NAS(L)									
63-860	Eastern Egg Rk	•	SWH	IFW*	16[j]	16 (15)[k]		15[l]	16 (14)[e]	19[e]	20[e]	25[e]	33[e]
63-655	Large Green I		P-FW	PRI(L)									
63-940	Matinicus Rock	•	P-FW	FWS(L)		101[k]		143[e]	136[e]	123[e]	144[e]	171[e]	176[e]
63-923	Seal I	•	P-FW	FWS(L)	0[e]	7(6)[k]	14[l]	19[l]	26[e]	40[e]	58[e]	78[e]	115[e]
79-933	Petit Manan I		SWH	FWS	3, 56ibc[e]	9[k]	9[p]	8[e]	15 (13) 60ibc[e]	10[e]	10[e]	17[e]	24[e]
79-367	Machias Seal I			FWS/CWS		~900[k]			900-1,000[e]				nesting[e]

[a]Codes for Ownership of islands are as follows:

FWS	U.S. Fish and Wildlife Service
FWS(L)	FWS; in Land Use Regulation Commission (LURC) Jurisdiction (an unorganized town)
FWS/CWS	FWS/Canadian Wildlife Service
IFW*	Owned by Bureau of Public Lands, but Maine Department of Inland Fisheries and Wildlife has management authority for the island
NAS(L)	National Audubon Society; in LURC Jurisdiction
PRI(L)	Private; in LURC Jurisdiction

[b](Cowger 1976).
[c](Kress 1981).
[d](Kress 1982*a*).
[e]Maine Dep. Inland Fish. and Wildl. files.

Table 3. Continued.

[f](Kress 1985).
[g](Kress 1986).
[h](Kress 1987).
[i](Kress 1988).
[j](Kress 1991).
[k](Kress 1992).
[l](Kress 1994).
[m](Korschgen 1979).
[n](Kress 1983).
[o](Kress and Nettleship 1988).
[p](Lock et al. 1994).

Table 4. Breeding population estimates of Razorbills in Maine since 1976.

Island Reg. #	Island Name	Critical Areas Registry 1976-1982	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs (np) or individual birds (ib) by year														
					1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
63-860	Eastern Egg Rk	•	SWH	IFW*															
63-900	No Man's Land		P-FW	IFW(L)															
63-940	Matinicus Rock	•	P-FW	FWS(L)	12 np[b]	15 np[c]						~20 np[d]		35-50np[e]	40 np; 150 ib[f]				
63-917	Wooden Ball I	•	P-FW	PRI(L)								attract exp., present no nesting[d]							
63-923	Seal I	•	P-FW	FWS(L)													1 ib, no nesting[h]		
63-289	Little Spoon I		SWH	PRI/ANPE															
79-933	Petit Manan I		SWH	FWS															
79-676	Freeman Rock		SWH	IFW*	present[f]					nesting[e]	4 ib[b]	present[e]	present[e]	2 np; 25 ib[e]	2 np (uncon-firmed) 40 ib[f]	3 np; 15 ib[b]			
79-576	Pulpit Rock		SWH	IFW*								0[b]							
79-313	Old Man (E)		SWH	FWS	4np[f]; 50ib[c]	10np[c]; 75ib[b]				21 ib[e]		90 ib[e]	50 ib[e]	~10np 70ib[e]	26np; 140ib[f]				
79-367	Machias Seal I			FWS/CWS	76np[f]						105 np[e]	75[e]		110[e]	100np; 270ib[f]				

Table 4. Continued.

Island Reg. #	Island Name	Critical Areas Registry 1976-1982	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs (np) or individual birds (ib) by year								
					1991	1992	1993	1994	1995	1996	1997	1998	1999
63-860	Eastern Egg Rk	•	SWH	IFW*					no nesting[b]				
63-900	No Man's Land		P-FW	IFW(L)					1 ib[b]				
63-940	Matinicus Rock	•	P-FW	FWS(L)	15 np[b]	27 np[b]		52 np[g]	47np; ~120ib[b]	59np[b]	80np[b]	42np[b]	68np[b]
63-917	Wooden Ball I	•	P-FW	PRI(L)									
63-923	Seal I	•	P-FW	FWS(L)				attract exp., no nesting[g]	no nesting[b]				1np[b]
63-289	Little Spoon I		SWH	PRI/ANPE					1 ib[b]				
79-933	Petit Manan I		SWH	FWS					no nesting[b]	1np[b]			
79-676	Freeman Rock		SWH	IFW*	15-25 ib[b]		10 np[i]	50 ib[b]	50 ib[b]			58ib[b]	50ib[b]
79-576	Pulpit Rock		SWH	IFW*									20ib[b]
79-313	Old Man (E)		SWH	FWS	100-140 ib[b]			80 ib[b]				150ib[b]	160ib[b]
79-367	Machias Seal I			FWS/CWS		100 np[i]			~150np[b]				nesting[b]

[a]Codes for Ownership of islands are as follows:

FWS U.S. Fish and Wildlife Service

Table 4. Continued.

FWS(L)	FWS; in Land Use Regulation Commission (LURC) Jurisdiction (an unorganized town)
FWS/CWS	FWS/Canadian Wildlife Service
IFW*	Owned by Bureau of Public Lands, but Maine Department of Inland Fisheries and Wildlife has management authority for the island
IFW(L)	IFW; in LURC Jurisdiction (an unorganized town)
PRI/ANPE	Privately owned with easement to Acadia National Park
PRI(L)	Private; in LURC Jurisdiction

[b]Maine Dep. Inland Fish. and Wildl. files
[c](Korschgen 1979).
[d](Kress 1983).
[e](Folger 1986).
[f](Podolsky 1989).
[g](Kress 1994).
[h](Kress 1988).
[i](Lock et al. 1994).

Habitat Projection

The recolonization of historic nesting sites by Atlantic Puffins and Razorbills in the last 20 years along the coast of Maine (encompassing a total of 6 islands) is a critical step in helping to secure the future of these species in Maine. However, several of these nesting colonies are small (2 of 5 puffin colonies have <30 nesting pairs) or of unknown size (nesting pairs of Razorbills are difficult to survey). These small colonies may be especially vulnerable to reduction or eradication by a predator or human-related disturbances.

The distribution of habitat for these alcids in Maine depends on continuing habitat protection (from disturbance and degradation). Restricted distribution of nesting habitat and several colonies of small size increases the vulnerability of these alcids in Maine. Currently unoccupied islands with suitable habitat may be vital to maintaining or enhancing alcid distribution as puffins and Razorbills attempt to colonize new areas.

POPULATION ASSESSMENT

Past Populations

Historically, Atlantic Puffins and Razorbills probably were more abundant in Maine than present populations (Evans and Nettleship 1985); however, data are lacking on historic population levels (Tables 1, 2). Marked declines occurred in these alcid populations during the 1800s, largely due to overexploitation by humans (e.g., unrestricted hunting for food and feathers, egg gathering) and human occupation of nesting islands (Cowger 1976, Evans and Nettleship 1985, Erskine 1992).

Reductions in the puffin population in the Gulf of Maine/Bay of Fundy region were noted in 1833 when J. J. Audubon visited the region (Nettleship and Evans 1985). Seal Island once was the largest Atlantic Puffin colony in the U.S. (Kress 1984). By the 1850s, this colony was reduced as a result of shooting (Palmer 1949). Puffins were eliminated from many Gulf of Maine islands in the late 1880s (Table 1) due to overharvest for food and feathers for the milliner's trade. By the 1890s, only 3-5 nesting pairs were reported on Matinicus Rock, with a nesting colony present on Machias Seal Island (Table 1).

Razorbills were eliminated from many nesting islands in Maine by the mid-1800s (Folger 1986). By the 1890s, Razorbills were substantially reduced throughout their range and were considered locally extinct in Maine (Podolsky 1989).

Alcid populations began to receive some legal protection in 1900 via The Lacey Act and Maine's Model Wild Bird Act and in 1918 by the Migratory Bird Treaty Act. Additionally, changes in the lifestyle of coastal Mainers that occurred at the turn of the

century reduced human pressure on seabirds as a source of food. This combination of human lifestyle changes and protective legislation increased the suitability of coastal islands for alcid nesting (Kress 1982*a*).

The Atlantic Puffin colony persisted on Matinicus Rock through the period of heavy exploitation primarily due to protection by resident lighthouse keepers who were appointed as wardens. Puffins on Matinicus Rock and Machias Seal Island, remnants of the Gulf of Maine puffin population (Kress 1979), continued to increase during the 1900s to 75-125 nesting pairs on Matinicus Rock and 750-900 nesting pairs on Machias Seal Island in the 1970s (Tables 1, 3).

Numbers of Razorbills continued to remain low or decreased through the 1950s (Nettleship and Evans 1985). Oil pollution may have been the primary cause for the continued decline of southern populations of Razorbills, with level of fishing intensity and climatic effects on food supplies as contributing factors (Evans and Nettleship 1985). In spite of protection, Razorbill populations in Maine have shown very slow increases. By the 1970s, Razorbills recolonized 3 former breeding sites with 5-15 nesting pairs on Matinicus Rock, 4-10 nesting pairs on Old Man Island (E), and 76 nesting pairs on Machias Seal Island (Tables 2, 4).

Current Population

There are approximately 16 million Atlantic Puffins worldwide (Johnsgard 1987), with about 338,000 breeding pairs in Canada and U.S. (Harris 1984). The Razorbill, possibly one of the rarest breeding seabirds in the continental U.S. (Podolsky 1989),

has about 700,000 pairs breeding in the North Atlantic (Evans and Nettleship 1985). Approximately 330 Razorbills breed in the Gulf of Maine (Podolsky 1989).

Razorbills and Atlantic Puffins are rare in Maine, with a slowly increasing breeding presence since the mid-1970s due to intensive management. In 1977, there were 125 puffin pairs breeding on 1 island and 25 Razorbill pairs on 2 islands in Maine. In 1999, 348 puffin pairs nested on 4 islands and Razorbills were nesting on 5 islands in Maine, with approximately 350 Razorbills observed around nesting islands. Machias Seal Island supports 900-1,000 nesting pairs of puffins and approximately 150 pairs of Razorbills (Tables 3, 4).

Data on Maine's Razorbill breeding population are limited: nesting islands are inaccessible, human disturbance must be minimized around nesting sites, and nests are hard to see from the water. Additionally, counts derived from a single visit to nesting islands are unreliable because of the presence of a large proportion of nonbreeders to breeders and the temporal changes in the number of individuals around nesting colonies (Folger 1986). Several methods are suggested to estimate breeding population size and productivity: 1) systematic count- count eggs and nests in all colonies (Chapdelaine and Laporte 1982); 2) conversion factor- select colonies to monitor number of nests (Np) and number of adults (Ni) (apply derived conversion factor (K=Np/Ni) to other colonies where only observed number of adults present to estimate nesting pairs in colony; it is also necessary to determine number of chicks raised/nest and how K changes during the day and through the season around a colony (Chapdelaine and Laporte 1982, Folger 1986)); and 3) count of all individuals- this is the

least accurate method for estimating nesting population (Chapdelaine and Laporte 1982).

Population Projections

With their limited numbers, Maine's breeding populations of Atlantic Puffins (4 colonies) and Razorbills (5 colonies) are very vulnerable to catastrophic events (e.g., oil spills, disease, predation) (Kress 1992). Additionally, small breeding populations have a very tenuous viability. Alcid populations presumably fluctuate in the long term with fluctuations in their food supply caused by climatic changes. Also, oil pollution and increasing competition with commercial fisheries impose threats to alcid populations (Evans and Nettleship 1985). With delayed maturity, small clutch sizes, and relatively high immature mortality (generally <30% survive to age of first breeding), small changes in the mortality of immature alcids or decreases in adult survival can have important consequences on future population trends (Hudson 1985).

Recently, these alcids have been observed prospecting at additional islands (puffin: Wooden Ball Island (Kress 1982*b*); Razorbill: Jordan's Delight (Podolsky 1989), Little Duck Island (Folger 1986), Seal Island (Kress 1994), No Man's Land, Pulpit Rock, and Little Spoon Island (MDIFW files)). Most of these islands are attractive to alcids due to gull control, attraction techniques, and increased habitat protection. Increased numbers of breeding colonies and population sizes on existing nesting islands will aid in securing the presence of these alcids in Maine.

Limiting Factors

Historically, Atlantic Puffin and Razorbill populations in the Gulf of Maine declined by overexploitation from hunting (for food and feathers) and egging (Cowger 1976, Nettleship and Evans 1985, Podolsky 1989). Alcid colonies have been severely reduced by the indirect effects of man's presence. Predators (rats and other mammals) were inadvertently introduced by humans on many breeding islands; burrow-nesting puffins were especially vulnerable (Cowger 1976).

As gull populations expanded along the New England coast during this century, Herring Gulls and Great Black-backed Gulls became serious predators of puffins and Razorbills. Gulls kleptoparasitize auks (stealing food causes reduced growth rates of chicks on some puffin colonies) and prey on eggs, chicks, and occasionally adults (i.e., Atlantic Puffins) (Nettleship 1972, Cowger 1976, Harris 1984). Harassment and predation by gulls can effectively inhibit Atlantic Puffins from recolonizing former breeding areas (Kress 1982*b*, Erskine 1992). Other predators of eggs, nestlings, or occasionally adults of these alcids include crows, ravens, foxes, weasels, mink, otters, and introduced predators (i.e., domestic cats and rats) (Johnsgard 1987).

Humans adversely affect colonies of Razorbills and Atlantic Puffins by visiting breeding colonies or causing disturbance of breeding or fishing areas with motor boats and airplanes. Disturbances to birds on land may cause adults to feed young less frequently (possibly reducing growth rates), leave eggs or young unattended and more vulnerable to predation, or cause desertion. At sea, human disturbance may deter birds from congregating in rich feeding areas or areas with low predation (Evans and Nettleship 1985). Cowger (1976) stated the most immediate threats to breeding

colonies of Razorbills and Atlantic Puffins along the Maine coast are human visitation and exploration by boating parties. Human disturbance may be of local importance and is likely to increase as access to once-remote breeding and feeding areas increases (Evans and Nettleship 1985).

Food supply can significantly influence breeding success of these alcids, possibly regulating onset, duration, and completion of breeding. Inclement weather can alter the normal summer distribution and abundance patterns of prey. Cold water temperatures can significantly reduce inshore capelin spawning. Movement of Atlantic herring from deep offshore waters toward shallow coastal areas may be affected by water temperatures and salinity (Nettleship 1972, Kress 1983). Humans directly compete with alcids for fishing stocks. Fisheries, particularly for sandlance, sprats, and capelin, potentially are serious threats to alcids, with Atlantic Puffins and Razorbills most likely to be adversely affected (Pierotti 1983, Evans and Nettleship 1985).

The incidental kill of alcids in fishing nets has become a serious problem. The species and numbers of birds killed apparently depends upon bird density in the region and the depths nets are set. Along the west coast of Ireland, Razorbills are the main species in bycatches; whereas off Newfoundland, primarily puffins are drowned in fishing nets (Evans and Nettleship 1985).

Oil pollution causes mortality of auks, especially during winter. Razorbills apparently are more affected than puffins due to the Razorbills' clumped distribution during winter. Atlantic Puffins are dispersed over wide areas in winter, making them less vulnerable to oil pollution (Evans and Nettleship 1985, Johnsgard 1987, Erskine 1992). The present levels of toxic chemicals do not indicate these contaminants are

having any detrimental effects on Razorbills' or Atlantic Puffins' vital rates (Harris 1984, Evans and Nettleship 1985).

With the alcid's life history strategy (relatively long-lived, high adult survival, delayed reproductive maturity, low reproductive rates), recovery from environmental perturbations is slow (Evans and Nettleship 1985). Once disturbed, these colonial nesters (e.g., Atlantic Puffins) do not rapidly colonize new nesting sites (Kress 1982*a*).

USE AND DEMAND ASSESSMENT

The demand to conserve rare fauna and the ecosystems they depend upon, especially species listed as Threatened or Endangered, is declared in Maine's Endangered Species Act. Accordingly, MDIFW is entrusted with preserving the diversity of wildlife in the state.

Atlantic Puffins and Razorbills contribute to the biological diversity of Maine, and their presence adds to the ecological value of Maine's marine ecosystem. Protecting and gaining ecological understanding of species (e.g., Atlantic Puffin, Razorbill) are essential to effective ecosystem management and to preserving Maine's natural heritage.

As the popularity of photography, nature study and appreciation, and awareness of Maine's wildlife resource grows, the demand for observation and photographic use of rare species (e.g., Atlantic Puffin, Razorbill) will continue to increase. Boyle et al. (1990) estimated 90% of the state's adult population participate in nonconsumptive use of wildlife. Members of 35% of households in Maine made trips annually to view wildlife and >80% valued the opportunity to view wildlife in Maine. Each summer, sight-seeing cruises bring numerous individuals to alcid nesting colonies off the Maine coast (e.g., Eastern Egg Rock, Matinicus Rock, Seal Island). By 1993, more than 10,000 people attended Audubon field trips to these 3 islands to observe puffins (Kress 1992).

This high public demand for nonconsumptive use of wildlife is of considerable value to Maine's economy. A minimum estimate of the value of nonconsumptive use of

wildlife in Maine is $55.4 million annually (Boyle et al. 1990), comparable to the economic contribution by resident hunters.

Increasing numbers of citizens desire to preserve the greatest diversity of species possible, at state, national, and global levels (Kellert 1980). This desire is based on increasing public perception of scientific, utilitarian, and cultural values of biological diversity, as well as ethical arguments for conserving plant and animal species. At the state level, public support for preserving wildlife diversity in Maine is present and reflected in state legislation protecting Endangered and Threatened wildlife and their habitats.

SUMMARY AND CONCLUSIONS

The Gulf of Maine supports approximately 2% of the North American breeding population of Razorbills and less than 1% of the Atlantic Puffin population. These colonies are important in constituting the southern edge of the breeding distribution for these 2 alcid species.

Population declines for puffins and Razorbills in Maine were noted in the 1800s, resulting from overexploitation by humans and human occupation of nesting habitat. By the mid-1800s, Razorbills were probably eliminated from nesting islands in Maine. By 1900, puffins were recorded nesting off the Maine coast only on Matinicus Rock and Machias Seal Island.

Legal protection since the early 1900s and lifestyle changes for residents of coastal Maine prevented further loss of alcid nesting colonies along the Maine coast. Recolonization of former breeding sites by Razorbills and puffins has been very slow.

Management of these alcids in Maine consists primarily of population monitoring, nesting island protection, and re-establishment of colonies at former breeding sites. During the last 2 decades, puffin breeding populations have been restored to several former nesting islands in Maine using translocation, attraction, and gull control techniques. In 1994, an attraction program for Razorbills began on Seal Island National Wildlife Refuge.

Currently, 348 puffin pairs nest on 4 islands, and Razorbills are nesting on 5 islands in Maine (total of 6 different islands). Many nesting colonies are small or of

unknown size. Census data is inadequate to ascertain the current breeding population and productivity of Razorbills in Maine.

Distribution of alcid habitat in Maine depends on continued habitat protection from disturbance and degradation. Restricted distribution of nesting habitat and small colony populations increases the vulnerable status of these alcids in Maine. Increased numbers of breeding colonies and population sizes on existing nesting islands will aid in increasing the viability of Maine's Atlantic Puffin and Razorbill populations. The Atlantic Puffin and Razorbill are classified as Threatened species in Maine.

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