LEACH'S STORM-PETREL ASSESSMENT

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by

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LEACH'S STORM-PETREL ASSESSMENT

NATURAL HISTORY

Description

Within the Family Hydrobatidae (Order Procellariiformes), there are 22 species that range over the world's oceans. Leach's Storm-petrel (*Oceanodroma leucorhoa*) is one of 12 species (including the probably extinct *Oceanodroma macrodactyla*) reported in North American waters (Terres 1980).

A subspecific taxonomy for *Oceanodroma leucorhoa* in the western North Atlantic Ocean and along the eastern North Pacific Ocean from the Aleutian Islands to San Benitos Islands has been suggested by Ainley (1983) and Power and Ainley (1986). Breeding localities of *O. l. leucorhoa* encompass the North Atlantic Ocean and eastern North Pacific Ocean from the Aleutians south to the Farallon Islands. Other subspecies tentatively assigned include *O. l. chapmani*, San Benitos and Los Coronados islands; *O. l. socorroensis*, Guadalupe Island, summer breeding; and *O. l. cheimomnestes*, Guadalupe Island, winter breeding. *O. l. leucorhoa* is the subspecies nesting within Maine (Palmer 1949, 1962).

Procellariiformes (tubenoses) are characterized by a musky odor, thick plumage, webbed feet, and deeply grooved, hooked bill with tubular nostrils (Gross 1935, Cowger 1976*b*). Salt glands, an osmoregulatory mechanism, remove much of the salt that birds ingest. This salty fluid is forcibly ejected out the tubular nostrils (Welty 1975). Leach's Storm-petrels (Fig. 1), measuring 18-22 cm in length and weighing 50.0-78.6 g, have a deeply forked tail (tail: 9.6 cm, forked for $\geq$2 cm), with feet (tarsus: 2.3 cm) barely showing beyond it. Wing length is 15.4-15.9 cm, with a 45-48 cm wingspread. The bill (culmen: 1.5 cm), legs, and feet are black (Knight 1908, Palmer 1962, Cowger 1976*b*, Peterson 1980, Terres 1980, Harrison 1983).

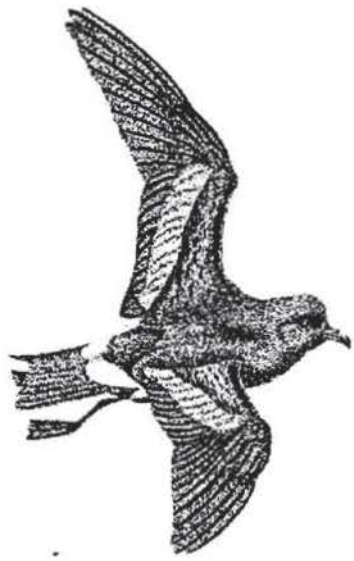

Fig. 1. Leach's Storm-petrel (sketch by Paul Donahue in Pierson (1978))

Leach's Storm-petrels are buoyant in flight with an irregular course, typified by sudden swift changes in direction and speed (Bent 1922, Palmer 1962, Peterson 1980, Harrison 1983). They cannot rise easily from the ground, half running and half flying around breeding grounds until they gain flight (Bent 1922). They may settle briefly on the water, but typically hover close to the water surface while feeding (Bent 1922, Palmer 1962).

Leach's Storm-petrels have a sooty plumage in all seasons. The entire body (except the rump) is blackish-brown, darkest on crown, lesser upper wing coverts, and flight feathers. The middle and greater upper wing coverts and scapulars are paler brown with whitish edges, forming a pale diagonal bar. Upper tail coverts are white with dark shafts. The white rump is conspicuous. However, the rump is interrupted in most Pacific coast birds by a vertical dark strip; some have a dark rump. The sexes are alike, with no seasonal variation. Juveniles and adults have similar plumages, although wing bars may be more pronounced in juveniles (Knight 1908, Palmer 1962, Cowger 1976*b*, Peterson 1980, Terres 1980, Harrison 1983).

Leach's Storm-petrel is distinguished from the Wilson's Storm-petrel (*Oceanites oceanicus*) and other common petrels off the Atlantic coast by its larger size and relatively shorter legs that are hidden in flight by the tail (legs project 1.3 cm beyond the tail in the Wilson's). The Leach's Storm-petrel has dark feet and a forked tail. Whereas, the blacker plumaged Wilson's Storm-petrel has yellow feet and a square tail. In flight these 2 species can be further differentiated by the shorter, wider wing of the Wilson's Storm-petrel, skimming in flight like a swallow. The wings of the Leach's Storm-petrel are longer, more angled, with a more erratic flight pattern (Bent 1922, Cowger 1976*b*, Palmer 1962, Peterson 1980, Harrison 1983).

Distribution

The breeding range of the Leach's Storm-petrel encompasses offshore islands in the North Temperate Zone. In the North Pacific Ocean, these petrels nest along an arc-shaped distribution from Baja California (San Benito, Guadalupe) in the east, north to Alaska and the Aleutian Islands, and southwest to Japan. Breeding range in the eastern North Atlantic includes Iceland and Norway, to the British Isles. Along the western Atlantic coast, breeding range of the Leach's Storm-petrel extends from southern Greenland to Labrador, Newfoundland, Maine, and Massachusetts (Bent 1922, Gross 1935, Cowger 1976*b*, Terres 1980, Harrison 1983, Spendelow et al. 1988).

The largest breeding colonies in the North Atlantic occur in southeastern Newfoundland. Nearly all petrels nesting in the United States along the Atlantic coast nest on several Maine coastal islands, with the exception of one small colony on Penikese Island, Massachusetts (Gross 1935, Cowger 1976*b*, Brown 1988).

The main wintering area of Leach's Storm-petrel in the Atlantic is considered to be off Brazil, in the Gulf of Guinea (off Africa), and south to Namibia and South Africa. In the Pacific, winter ranges extend south at least to Peru (Bent 1922, Terres 1980, Harrison 1983). During winter, these petrels are rare in the Gulf of Maine (43°N) (Palmer 1962).

Migration

Spring migration of Leach's Storm-petrels off the coast of Brazil has been reported in mid-April (Bent 1922). Petrels commonly occur at upwelling sites on the outer continental shelf and slope in the South Atlantic Bight (Cape Hatteras, N.C. to Cape Canaveral, Fla.) while migrating northward (Haney 1985). Birds begin coming ashore in the Gulf of Maine approximately 8-12 May (Palmer 1962), with migration continuing to late May (Palmer 1949).

As the breeding season winds down, the Leach's Storm-petrel population builds up offshore of nesting islands, peaking in Maine about 15 August-20 September. Populations then decline as birds migrate south towards wintering areas, with most birds leaving Maine by about 20 October (Bent 1922; Palmer 1949, 1962).

Feeding

Leach's Storm-petrels are pelagic surface feeders. Individual food items are picked from the water surface while the bird is in flight, hovering close to the surface (Knight 1908, Bent 1922, Palmer 1949, Terres 1980, Brown 1988). Brown (1988) suggests that this foraging technique requires prey to occur in relatively high concentrations (i.e., at tidal-induced upwellings and convergences) to be energetically efficient.

Olfactory foraging is common in Procellariiformes, associated with the extreme development of olfactory structures (Hutchison and Wenzel 1980, Verheyden and Jouventin

1994). Smaller procellariiform species (e.g., storm-petrels) show more obvious olfactory capacities than larger species and are able to detect food from great distances. Arriving first at a food source is an advantage for small procellariiform species when there is a high risk of being displaced by larger species (Verheyden and Jouventin 1994).

When using olfactory cues during foraging, procellariiforms have a specific searching behavior related to the direction, height, and speed of odor diffusion by wind. Flying just above the water surface, the birds approach the odor source downwind in zig-zag, crosswind excursions that become narrower as birds come closer to the food source. A storm-petrel flying at 30 km/hr can detect a food source up to 8 km away (Verheyden and Jouventin 1994).

The diet of Leach's Storm-petrels has been described during the breeding season. In the northwestern Atlantic Ocean, petrels fed mostly on myctophids (lanternfish) and amphipods (mostly *Hyperia galba*). Other food items included euphausiids (mostly *Meganyctiphanes norvegica*), decapods, copepods, and isopods (Montevecchi et al. 1992). In Japan, Watanuki (1985) determined that fish, squid, and euphausiids dominated the diet; amphipods, copepods, and fish eggs were next in importance; decapods and isopods were least important. Petrels also feed on oily substances obtained from whale and seal feeding wastes or oils exuded from wounds of these species, as well as offal from fishing vessels (Knight 1908, Bent 1922, Palmer 1962, Cowger 1976*b*, Terres 1980).

Due to diurnal vertical migrations, prey may be more available to petrels at night. The occurrence of prey species in the diet may be correlated with geographical and seasonal changes in prey availability. However, diet may also be influenced by 1) breeding adults switching to food with greater energetic advantages during chick rearing; and 2) differing food preferences

between breeders and nonbreeders, with seasonal changes in proportion of nonbreeders in the population contributing to seasonality in general diet composition (Watanuki 1985).

Adult petrels can concentrate energy from consumed prey 5- to 35-fold by producing stomach oils. This ability to concentrate dietary constituents into a high energy form with smaller volume and lower osmotic load is advantageous to adults by enabling them to potentially increase their foraging area (Place et al. 1991). Stomach oils are also important to the breeding ecology of these pelagic seabirds; 30% of energy metabolized by incubating Leach's Storm-petrels resides in stomach oils. It is energetically advantageous for petrels to metabolize stomach oils than fat from adipose tissue during fasts (Place et al. 1989).

Breeding Biology

Pelagic seabirds, such as storm-petrels, are characterized by low reproductive rates, delayed onset of reproduction, protracted development periods, and long life spans (Ricklefs 1990). The earliest age of first breeding for Leach's Storm-petrels is 3 years (Gross 1947, Lack 1968, Wilbur 1969). However, mean age of first breeding is 4-5 years (Huntington and Burtt 1972 cited in Cowger 1976*b*, Morse and Buchheister 1977), with breeding recorded to occur up to 28 years of age (Morse and Buchheister 1979).

After spending the winter at sea, Leach's Storm-petrels come ashore only to breed. They arrive at breeding colonies in the Gulf of Maine in April and May (Gross 1935, Wilbur 1969, Cowger 1976*b*). Older breeding birds are first to return to breeding grounds (Terres 1980). Sixty-six to 75% of adults that previously nested return the following year to the same breeding colony (Morse and Buchheister 1979). Remating (retaining mate from one breeding season to

next) in Leach's Storm-petrels is a consequence of site tenacity (fidelity to previous nesting burrow), not mate fidelity (Morse and Buchheister 1979, Morse and Kress 1984).

Leach's Storm-petrels usually nest in burrows dug in open fields or under brush, boulders, stumps, tree roots, and in banks. Occasionally, nests may be located in rock crevices or hollow logs (Palmer 1949, 1962). Nesting burrows are excavated by males, primarily by kicking and scraping with feet. Bills also may be used in excavation (Gross 1935, Grubb 1970). Generally, the male digs for 2 successive nights, then the following day and night to complete the burrow (Palmer 1962). Although, it may take >3 days to complete the burrow (Wilbur 1969).

Burrows angle downward with several sharp turns (Gross 1935), extending up to 2 m in length including lateral offshoots (Cowger 1976*b*). Gross (1935) determined estimates of mean burrow dimensions: length = 50.8 cm; depth = 25.1 cm; burrow entrance = 8.2 cm (horizontal), 6.5 cm (vertical); and nesting chamber = 16.2 cm (length), 16.3 cm (width), 8.7 cm (height). The nesting chamber at the end of the burrow may be unlined or lined with loose grass, rootlets, twigs, bark, dried leaves, and feathers (Bent 1922, Palmer 1949).

The pair mates in the burrow the night excavation is completed. They desert the burrow during the day, and a single egg is laid in the nesting chamber the following night (Palmer 1962, Cowger 1976*b*, Terres 1980).

Leach's Storm-petrels' eggs are white; some may be finely dotted with purple, red, and lilac (Knight 1908, Bent 1922). Eggs weigh approximately 20% of adult body weight (Morse and Buchheister 1979) and are laid May to mid-August (Knight 1908; Bent 1922; Palmer 1949, 1962; Wilbur 1969; Harrison 1983). The egg is incubated for 41-42 days by both adults, relieving each other at night (Gross 1935; Palmer 1949, 1962; Hatch and Hatch 1990).

Morse and Buchheister (1979) estimated nesting success (% June eggs hatching) as 66-82%, fluctuating annually as a function of climatic variation. Late nesting birds were less successful than earlier nesters. Possible attempts to renest were infrequent. Most loss occurred during incubation, with minimal loss occurring among chicks after the first few days.

Leach's Storm-petrels arrive and depart from breeding colonies at night (Gross 1935, Cowger 1976*b*, Grubb 1979). Birds that have been relieved of incubating duties spend the day foraging at sea. This nocturnal habit around the burrow reduces or eliminates harassment from gulls (Gross 1935, Watanuki 1986, Spendelow et al. 1988). During nights of full moonlight and clear skies, there is little petrel activity with birds flying into nests quickly and quietly (Gross 1935, Watanuki 1986). Whereas, birds are more active around burrows and come to land earlier during foggy nights and nights of little or no moonlight (Gross 1947, Palmer 1962). In self-defense, petrels will discharge the musky oil from their mouth and nostrils when handled or disturbed at nesting sites (Knight 1908, Terres 1980).

Breeding colonies and burrows are located by petrels using olfactory navigation when birds are within several hundred kilometers of their breeding site (Grubb 1974, 1979). Navigation must be based on other senses until petrels get within the general vicinity of their breeding island (Grubb 1979). When homing to nesting islands after being experimentally displaced, homing speed averaged 15 km/day (Pierson et al. 1989), with birds navigating over unfamiliar territory (Griffin 1940, Billings 1968, Pierson et al. 1989).

Adult storm-petrels are strongly attracted to conspecific vocalizations (Podolsky and Kress 1989), calling to mates at night (Bent 1922, Gross 1935). The vocal repertoire of adults consists of 3 main call types: flight, chatter, or chuckle call; burrow or purr call; and screech call

(Naugler and Smith 1992). The chuckle call is usually given in flight and rarely uttered from the burrow. This call has a characteristic rhythm with about 10 syllables. It is used for sex recognition, with male calls higher in frequency than female calls (Taoka et al. 1989, Taoka and Okumura 1990). The purr call is given exclusively from the burrow (Podolsky and Kress 1989).

In Maine, Leach's Storm-petrel chicks hatch mid-July through late September; most nests have chicks by late August (Gross 1935, Palmer 1949). Chicks are seldom brooded after 5 days old; at this age weight has doubled since hatching (Bent 1922, Gross 1935, Wilbur 1969). The brood patch in Leach's Storm-petrels is refeathered within a few days after hatching (Ainley et al. 1975). This rapid refeathering of brood patches may be an adaptation to reduce heat loss during cooler air temperatures of the nesting season (Vermeer et al. 1988).

Leach's Storm-petrel chicks develop slowly (Ricklefs et al. 1980). Young fledge 63-70 days after hatching (Palmer 1962, Vermeer et al. 1988, Hatch and Hatch 1990), resulting in >100 days required to raise a single young per season.

Nestlings have 3 basic vocalizations: 1) the rhythmic call, a series of narrow band notes repeated at specific intervals (2-4 kHz range), functions as a food begging call and is often given by nestlings when a parent enters the nesting burrow; 2) the short call, a short broad spectrum vocalization emitted singly or in series, is used in apparent defense or threat situations when the threat is non-tactile (i.e., disturbance around the burrow entrance) and often is accompanied by defensive behavior (head thrusts and bill snappings); and 3) the high call is a series of notes of varying length and pitch used in alarm or distress situations. In absence of visual cues, nestling vocalizations probably are an important means in adult-chick interactions. The call repertoire of Leach's Storm-petrel nestlings is smaller and more stereotyped than reported for other

non-passerine species. The isolation of chicks in burrows limits their experience of behavioral interactions. This limited experience, combined with infrequent contacts between parents and young, may have favored the existence of stereotyped vocalizations (Naugler and Smith 1992).

After the brooding period, nestlings are left alone in the burrow during the day and fed at night by parents. By 15 days-old, chicks weigh 3 times their hatching weight (Gross 1935). Parents feed young by regurgitation. Initially, parents regurgitate a clear, musky, stomach oil to the chick. When the nestling is older, partly digested shrimp and squid are added to the chick's diet (Bent 1922, Terres 1980).

Marine prey items impose large salt loads that require energy dependent mechanisms in nasal salt glands to excrete excess dietary salts. By feeding chicks stomach oils, adults increase the energy density of the meal by concentrating dietary lipids and also lower the dietary osmotic load for the chick. With lower costs of digesting marine prey items, energy reserves of chicks may be more available for maintenance and growth (Place et al. 1989).

Parents return independently to feed the chick, once every 2-3 nights (Bent 1922, Palmer 1962, Wilbur 1969, Ricklefs et al. 1985). Between feedings by an individual parent, the chick's nutritional state may change greatly depending on whether its mate fed the chick in the interim. Adults do not appear to adjust feeding rate to short-term fluctuations in the nutritional status of their chick (Ricklefs 1992). However, the amount of food delivered by each parent, determined independently of food demand, is usually sufficient to allow chicks to recover mass quickly if they become undernourished (Ricklefs 1987).

As Leach's Storm-petrel chicks near fledging ($\geq$60 days old), they accumulate greater volumes of stomach oil than younger chicks by restricting the rate of gastric lipid emptying

(Place et al. 1989). Mean weights of young Leach's Storm-petrels drop from a peak of 73.8 g for nestlings to 53.0 g for fledglings (Vermeer et al. 1988). Stomach oils provide substantial weight savings over similar lipid stores in adipose tissue and can be jettisoned instantaneously if needed for weight reduction or protection. Stomach oils have a higher energy density than body stores, may serve as energy and water stores for fledglings during their first week at sea, and do not incur the energetic and temporal costs involved in remobilizing lipid stores (Place et al. 1991).

In the Gulf of Maine, Leach's Storm-petrels fledge between September and November (Gross 1935, Wilbur 1969), after being abandoned by parents (Palmer 1962). Vermeer et al. (1988) estimated 87% fledging success per hatched egg on Queen Charlotte Islands, B.C.

Most birds spend their first 2 summers at sea (Huntington and Burtt 1972 cited in Cowger 1976*b*). Some birds may visit breeding grounds during their third summer (Huntington 1963, Morse and Buchheister 1977). Nonbreeding storm-petrels may visit or prospect at islands other than their natal island before they breed (Podolsky and Kress 1989), potentially resulting in a substantial interchange between nesting islands (Huntington 1963).

First-time breeding Leach's Storm-petrels are strongly attracted to burrows with smells and sounds (purr and chuckle vocalizations) typical of active petrel colonies (Grubb 1973, Podolsky and Kress 1989). Podolsky and Kress (1989) used this behavior to successfully attract prospectors to artificial burrows. The tendency of first-time breeders to colonize close to conspecifics may reduce their individual risk of predation by associating closely with more potential prey.

Survival and Longevity

Leach's Storm-petrels have long life spans with a maximum longevity of 31 years (Gross 1947, Kennard 1975, Clapp et al. 1982, Klimkiewicz and Futcher 1989). Survival rates have only been reported for adult storm-petrels (78.9-93.7%) (Morse and Buchheister 1977). However, average annual survival rates for birds with this general life history pattern (low reproductive rates, delayed onset of reproduction, and long life spans) range 0.63-0.84 for juveniles, 0.67-0.96 for subadults, and 0.78-0.97 for adults (Chilelli et al. 1992).

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 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 seabird nesting islands 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., Leach's Storm-petrel). 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 Leach's Storm-petrel is classified as a Special Concern species by MDIFW. Maine's Endangered Species Act of 1975 protects Endangered and Threatened wildlife species from take or harassment. Special Concern species are an administrative category with no legal standing under Maine's Endangered Species statutes.

Past Goals and Objectives

The Maine Department of Inland Fisheries and Wildlife has not established specific goals and objectives for Leach's Storm-petrel 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., Leach's Storm-petrel):

> 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 the Leach's Storm-petrel. Seabird management pertaining to Leach's Storm-petrels consists primarily of population monitoring and nesting island protection.

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 1994-96) 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 nesting areas of Leach's Storm-petrels; 10 areas on 8 islands were registered during 1976-1979 (Cowger 1976*b*). Seabird nesting islands have been identified and are 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.

HABITAT ASSESSMENT

For nesting, Leach's Storm-petrels require soil conditions suitable for burrowing on offshore islands. Nesting burrows may be dug in loam of barren fields, at the base of stumps, beneath boulders, and in banks along shores (Gross 1935). On several islands in Maine, burrows are located under a thick canopy of spruce, balsam fir, and mountain ash (Grubb 1979).

Past Habitat

The decline in nesting habitat for Leach's Storm-petrels in Maine began in the early 1900s. Colonies were severely reduced or completely exterminated due to predation and other human-related disturbances on their nesting islands.

Predation by domestic dogs and cats significantly reduced functional carrying capacity of several coastal nesting islands in Maine: Wooden Ball Island, No Man's Land, Great Spoon Island, Large Green Island, Little Green Island, Metinic Green, and Seal Island (Table 1, Fig. 2). Release of red foxes on No Man's Land reduced that colony to a few burrows by 1931 (Palmer 1949). Mink preyed heavily on petrels on Western Egg Rock (Bent 1922). Predation by rats, Herring Gulls, and Black-backed Gulls also contributed to lowered functional carrying capacity of petrel nesting islands (Palmer 1949).

Grazing by sheep severely degraded petrel nesting habitat. Habitat suitable for burrowing was transformed into unsuitable, dense grassy turf on many islands in Maine: Wooden Ball Island, Little and Large Green Islands, Metinic Island, No Man's Land, Ten Pound Island (Matinicus Island), Roberts Island, Otter Island, Brimstone Island (Vinalhaven), Great and Little Spoon Islands, Heron Island, John's Island (Swan's Island), Nash Island, Flat Island, Fisherman Island, Halifax Island, the Brothers, and the Libby Islands (Machias Bay) (Drury 1973).

Table 1. Historical records of Leach's Storm-petrel breeding colonies in Maine, prior to 1977. Number represents burrow count, unless specified otherwise. Colony size is indicated as - (small), + (large), ++ (very large). No evidence of petrels on island is indicated as NE.

Island Reg. #	Island Name	Breeding colony estimates by decades										
		<1880	1880s	1890s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s
55-386	Outer Green I					present[a]						
55-486	Junk of Pork I	present[b]										
55-628	White Bull I					present[a]						
59-351	John's I				-[c]							<5[d]
59-439	Little Duck I				++[c]							400-500[d]
59-440	Great Duck I				approx 2,000[c]							800-900[d]
59-478	Green I											NE[d]
59-480	Heron I											NE[d]
63-174	Roberts I (E)											NE[d]
63-176	Brimstone I											10[d]
63-183	Otter I											NE[d]
63-287	Great Spoon I				++[c]	≤50 pairs[e]						<5[d]
63-289	Little Spoon I				-[c]							NE[d]
63-584	Metinic I				-[c]							<25[d]
63-585	Metinic Green I				-[c]				nearly gone[f]			<5[d]
63-654	Little Green I		present[a]		++[c]	declined[g]				≤25[h]	15[f]	<5[d]

Table 1. Continued.

Island Reg. #	Island Name	Breeding colony estimates by decades										
		<1880	1880s	1890s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s
63-655	Large Green I				++[c]	declined[g]						<5[d]
63-860	Eastern Egg Rk				+[c]				12-20[i]		17-24[i]	
63-875	Shark I				+[c]							
63-900	No Mans Land				–[c]	partly[g] destroyed		few[a]				25-45[d]
63-917	Wooden Ball I				++[c]	trace[g]		few[a]				50-75[d]
63-920	Ten Pound I											NE[d]
63-923	Seal I				++[c]	severely reduced[e]						2,000-2,500[d]
63-940	Matinicus Rock				–[c]					>65[j]	300-400[k]	
65-201	Western Egg Rk				+[c]	reduced[e]						
79-573	The Brothers E				+[c]							
79-586	The Brothers W											

[a](Palmer 1949).
[b](Brewer 1877 cited in Palmer 1949).
[c](Dutcher 1904, Norton 1925 cited in Drury 1973).
[d]Drury (1973) estimate based on transect survey that censused 10-15% of island.
[e](Bent 1922).
[f](Drury 1973).
[g](Norton 1925 cited in Drury 1973).
[h](Cruickshank 1952 cited in Drury 1973).
[i](Morse 1963 cited in Drury 1973).
[j](Courson 1957 cited in Drury 1973).
[k](Buchheister and Buchheister 1968 cited in Drury 1973).

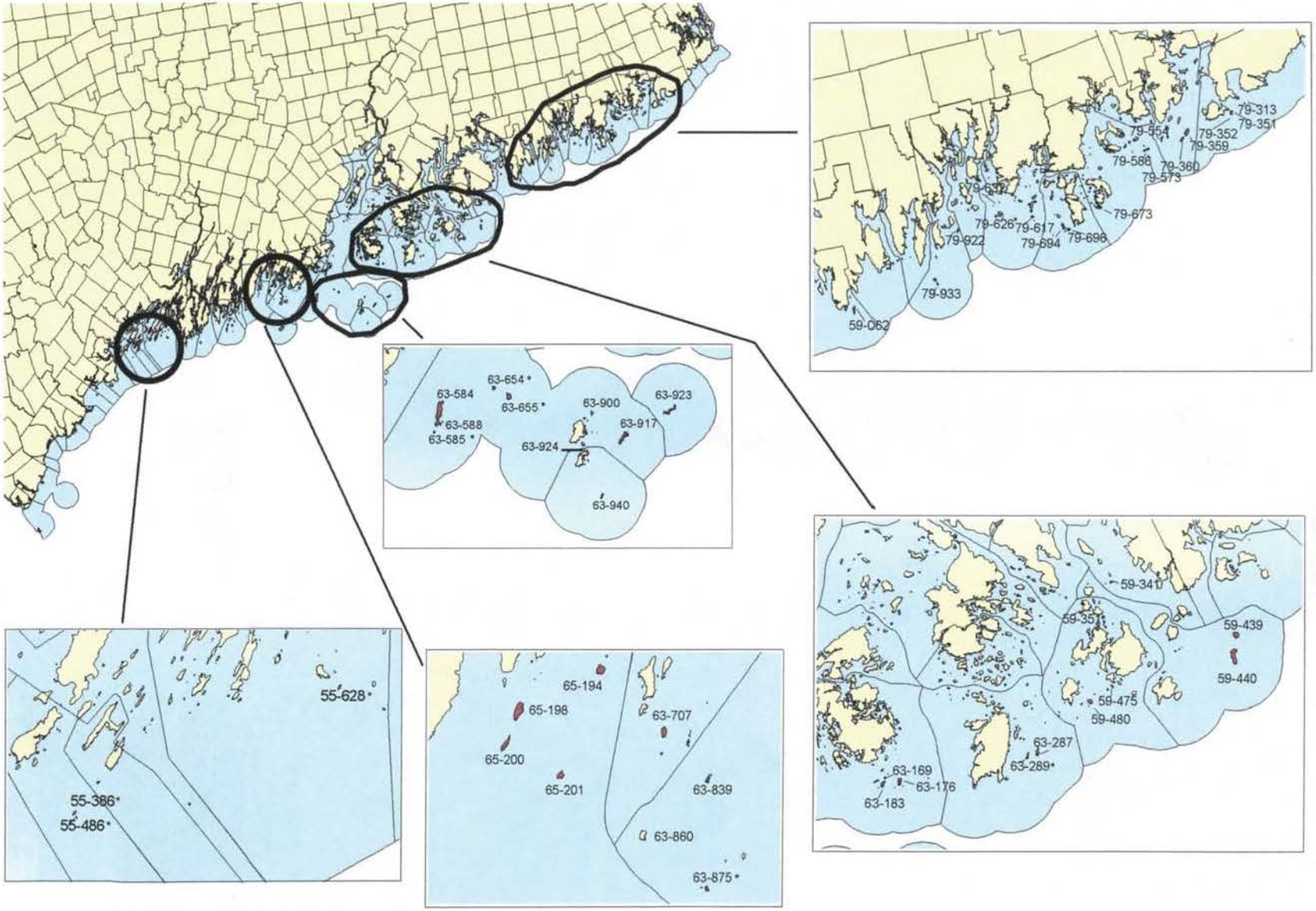

Figure 2. Location of current and historic nesting islands for Leach's Storm-petrel along Maine's coast, by Island Registry Number. Islands with only historic nesting records (prior to 1977) are noted with asterisk.

Current Habitat

The magnitude of disturbance and degradation to petrel nesting habitat has lessened since the early 1900s. However, predation (e.g., by gulls, mink, domestic pets), grazing, and human-related disturbances are still a primary concern for petrel colonies. Sheep grazing continues to degrade important nesting habitat, especially on privately owned islands (e.g., Metinic and Big Nash Islands).

Nesting burrows are difficult to locate, and surveys for new colonies are best conducted at night with the increase in petrel activity (Cowger 1976*b*). During its periodic reinventory of Maine's seabird nesting islands, MDIFW located additional petrel colonies in 1994-96. The number of known petrel nesting islands has increased from 17 in 1977 to 35 in 1994-96 (Table 2, Fig. 2).

Conservation ownership of petrel nesting islands has increased over the past 20 years. Of the 35 currently known petrel colonies (Table 2), 24 are owned or under management authority of a conservation agency (federal: USFWS, National Park Service; state: MDIFW; private: National Audubon Society, The Nature Conservancy). Currently, there are 7 islands under LURC zoning (P-FW or P-RP), and an additional 21 are protected as Significant Wildlife Habitat (Table 2).

Leach's Storm-petrel habitat in the Atlantic has been contaminated with toxic chemicals, with DDE and PCBs present in birds. However, there have been no reports of evident effects on the petrels (Drury 1974).

Table 2. Breeding population estimates of Leach's Storm-petrels in Maine, since 1976.

Island Reg. #	Island Name	Critical Areas Registry 1976-79	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs by year		
					1977[b]	1984-85[c,d]	1994-96[c,d]
59-062	Schoodic I		SWH	NPS	3	3	25
59-341	Ship Island		SWH	FWS			2
59-439	Little Duck I	•	SWH	NAS	4,000	4,000	2,800
59-440	Great Duck I	•	SWH	IFW/TNC/P	14,000	14,000	5,040
59-475	Scrag I			PRI	[2(1976)][c]		unk
59-480	Heron Island		SWH	NPS			present
59-483	John's Island		SWH	PRI			0
63-166	Carver's Island		SWH	IFW*			0
63-169	Hay I		SWH	PRI		[4(1986)][c]	3
63-170	Deadman Ledge			IFW*			0
63-174	Roberts I (E)		SWH	FWS			0
63-176	Brimstone I	•	SWH	TNC	34	34	88
63-179	Little Brimstone		SWH	TNC			0
63-183	Otter I		SWH	IFW/VLT			15
63-287	Great Spoon I		SWH	IFW/ANPE	present	present	20
63-289	Little Spoon I		SWH	PRI/ANPE			0
63-518	Little Hurricane			PRI			0
63-584	Metinic I		P-RP	PRI(L)/FWS			50
63-585	Metinic Green I		P-FW	PRI(L)	[0][c]		unk
63-588	Hog I		P-FW	PRI(L)			present
63-652	Little Two Bush			IFW*(L)			0
63-654	Little Green I		P-FW	PRI(L)	[0][c]		unk
63-707	Franklin I		SWH	FWS	12	12	12
63-839	Old Hump Ld S		SWH	IFW		present[c]	3
63-860	Eastern Egg Rk	•	SWH	IFW*	50	present	114
63-900	No Mans Land		P-FW	IFW(L)	20	50	20

Table 2. Continued

Island Reg. #	Island Name	Critical Areas Registry 1976-79	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs by year		
					1977[b]	1984-85[c,d]	1994-96[c,d]
63-917	Wooden Ball I	•	P-FW	PRI(L)	25	25	50
63-920	Ten Pound Island		P-FW	NAS(L)			0
63-923	Seal I	•	P-FW	FWS(L)	335	335	724
63-924	Pudding I		P-FW	IFW*(L)	2	2	0
63-940	Matinicus Rock	•	P-FW	USCG/NAS(L)	550	550	706
65-194	Wreck I			IFW*(L)		present[e]	unk
65-198	Ross I		P-FW	NAS(L)		present[e]	unk
65-200	Haddock I		P-FW	PRI(L)	12	12	12
65-201	Western Egg Rk		P-FW	NAS(L)	3	3	0
79-277	Chance I			PRI			0
79-313	Old Man (E)		SWH	FWS			400
79-351	Double Hdsht N			FWS			2
79-352	Double Hdsht S		SWH	FWS			1
79-359	Big Libby I		SWH	IFW			4
79-360	Little Libby I			USCG			present
79-496	Seguin I			PRI			0
79-551	Foster I		SWH	PRI			0
79-552	Ram I		SWH	PRI			0
79-554	Scabby I (S)		SWH	PRI			present
79-561	Hickey I			PRI			0
79-570	Halifax I			FWS			0
79-573	The Brothers E		SWH	FWS	25	25	8
79-586	The Brothers W			IFW	10	10	7
79-614	Inner Sand I		SWH	PRI			0
79-617	Outer Sand I			PRI			4

Table 2. Continued

Island Reg. #	Island Name	Critical Areas Registry 1976-79	Significant Wildlife Area (SWH) or currently under LURC zoning (P-FW,P-RP)	Ownership[a]	Estimates of nesting pairs by year		
					1977[b]	1984-85[c,d]	1994-96[c,d]
79-621	Flat I		SWH	PRI			0
79-624	Green I			PRI			0
79-626	Big Nash I		SWH	PRI			present
79-627	Nash I		SWH	PRI/FWS			0
79-632	The Ladle		SWH	PRI			present
79-671	Water I			TNC			0
79-673	Mistake I			TNC			present
79-694	Fisherman I			PRI			present
79-696	Crumple I			TNC			6
79-748	Nightcap I		SWH	IFWE			0
79-922	Jordans Delight	•	SWH	PRI	50	50	200
79-927	Egg Rock (S)		SWH	IFW*			0
79-933	Petit Manan I		SWH	FWS			50
Number of nesting colonies					17	20	35
Estimated number of nesting pairs					19,131		10,366

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

FWS	U.S. Fish and Wildlife Service	IFW/VLT	Joint ownership:IFW, Vinalhaven Land Trust
FWS(L)	FWS; in LURC Jurisdiction (an unorganized town)	NAS	National Audubon Society
IFW	Maine Department of Inland Fisheries and Wildlife	NAS(L)	NAS; in LURC Jurisdiction
IFW*	Owned by BPL but IFW has management authority for the island	NPS	National Park Service
IFW/ANPE	Owned by IFW with an easement to Acadia National Park	PRI	Private
IFWE	easement to IFW	PRI/ANPE	Privately owned with easement to Acadia National Park
IFW(L)	IFW; in LURC Jurisdiction	PRI/FWS	Joint ownership: Private, FWS
IFW*(L)	Owned by BPL, IFW has management authority; in LURC Jurisdiction	PRI(L)	Private; in LURC Jurisdiction
IFW/TNC/P	Joint ownership: IFW,TNC,Private	PRI(L)/FWS	Joint ownership: PRI(L),FWS
		TNC	The Nature Conservancy
		USCG	U.S. Coast Guard
		USCG/NAS(L)	Joint ownership: USCG, NAS; in LURC Jurisdiction

[b]from Korschgen (1979), except where noted otherwise.

[c]Maine Dept. Inland Fish. and Wildl. files.

[d]These population estimates are a compilation of census data since 1977; they do not reflect any single year census.

[e]Population estimate taken during time period (1980-82) of colonization experiments of Podolsky and Kress (1989).

Habitat Projection

As future seabird inventories place additional emphasis on Leach's Storm-petrels, a more accurate distribution of petrels in Maine will be known. The majority of currently known petrel colonies in Maine (18 of 35) are small (≤10 nesting pairs) or of unknown size (Table 2). Any additional colonies located will probably be small, being especially vulnerable to severe reduction or eradication by a predator or human-related disturbances.

The distribution of Leach's Storm-petrel habitat in Maine is dependent on continuing habitat protection (from disturbance and degradation). With the vulnerable status of small petrel colonies, currently unoccupied islands with suitable habitat may be vital to maintaining or enhancing petrel distribution, as petrels are either displaced from current nesting islands or attempt to colonize new areas.

POPULATION ASSESSMENT

Past Populations

During the 18th and 19th centuries, Leach's Storm-petrel populations remained large while other seabird populations were nearly eliminated along the New England coast by market hunters for the meat and millinery trade (Drury 1973). Since 1900, Leach's Storm-petrel populations in Maine began to steadily decline due to destruction at breeding islands, with some colonies completely eliminated (Table 1). Petrel colonies were severely reduced on islands inhabited by domestic dogs and cats, and other predators introduced by man (Bent 1922, Palmer 1949, Drury 1973). Predation by gulls and mink also reduced colonies. Petrel colonies were either severely

reduced or eliminated from Maine coastal islands due to habitat degradation from sheep grazing (Drury 1973).

The breeding range of Leach's Storm-petrels in Maine once extended westward into Casco Bay, with the last recorded occurrence on Outer Green Island in 1914 and White Bull Island in 1918 (Table 1). With a declining population, Palmer (1949) identified Muscongus Bay as the western limit of Maine's breeding range, with one isolated colony located on Penikese Island, Massachusetts. Of the petrel colonies persisting in Maine, Great Duck Island has continued to be the most important (Gross 1935, Drury 1973).

Current Population

Approximately 10% of the total U.S. breeding population of Leach's Storm-petrels occurs along the New England coast, with all but one colony located in Maine (Spendelow et al. 1988). Petrel colonies in Maine are on the southern edge of the species breeding range and tend to be small and isolated (Cowger 1976*b*, Korschgen 1979).

The 1977 survey of coastal waterbird colonies in Maine (Korschgen 1979) is used as a baseline for assessing current population levels. Of the 17 petrel colonies located in Maine, with approximately 19,131 nesting pairs, >90% of the known statewide population nested on Great Duck and Little Duck Islands in 1977 (Table 2).

An accurate population estimate for Leach's Storm-petrels is difficult to determine due to their nocturnal habits at nesting sites. The best method to census petrel populations is a systematic count and inspection of all burrows to determine the number of occupied burrows. When colonies are large, as on Great Duck and Little Duck Islands, petrel abundance is determined by sampling the total area. Different census takers often use different sampling

methods resulting in a considerable range in population estimates. These various methodologies may partly explain the large difference in the breeding petrel populations estimated on these 2 islands between 1976 and 1996 (Table 2).

Approximately 10,366 petrel pairs are currently nesting on 35 coastal islands in Maine (Table 2). Morse and Buchheister (1977) attributed the relative stability of the petrel population on Matinicus Rock to the low historic use by livestock and the small number of gulls present on the island.

Population Projections

Data are inadequate to ascertain whether the decline in the Leach's Storm-petrel population in Maine since 1900 has continued, lessened, or been reversed (Drury 1974). Population trends for this species cannot be projected based on available data. However, on 18 of 35 currently known petrel colonies, the size of the breeding population is either unknown or estimated at $\leq$10 pairs (Table 2). The viability of these small colonies is tenuous, being extremely susceptible to eradication by predation or habitat disturbance.

Human-induced negative influences on breeding colonies could be greatly offset by increased habitat protection and acquisition initiatives, management, and increased public education. Chapdelaine and Brousseau (1991) suggest that improved enforcement of conservation measures and increased conservation education have contributed to the increase in seabird numbers in bird sanctuaries along the north shore of the Gulf of St. Lawrence, 1982-88 (39.8% increase in Leach's Storm-petrel). Leach's Storm-petrel population levels in Maine are also dependent upon the future trend of gull populations on petrel breeding colonies.

Limiting Factors

The current distribution of active nesting colonies of Leach's Storm-petrels (Fig. 2), availability of offshore islands with soil conditions suitable for burrowing, and nesting habitat further reduced by predation, disturbance from human activities, and habitat degradation are the most important factors limiting distribution, abundance, and productivity of these seabirds in Maine.

Leach's Storm-petrels demonstrate a high site tenacity not only to a breeding colony, but to a particular burrow (Morse and Buchheister 1979, Morse and Kress 1984). First-time breeders are strongly attracted to burrows within an active petrel colony (Podolsky and Kress 1989). The distribution of existing nesting colonies limit breeding distribution of these birds in Maine.

At nesting colonies, Great Black-backed Gulls and Herring Gulls are serious predators of adult petrels as they return to their burrows at night (Gross 1935, Palmer 1962). Harassment by gulls may also reduce the number of petrels attracted to a nesting island (Gross 1935). Other native predators occurring on nesting islands include mink, crows, river otters, Short-eared Owls, and Peregrine Falcons (Bent 1922, Palmer 1949, Holt 1987, Vermeer et al. 1988, Paine et al. 1990). Domestic dogs and cats, norway rats, and red foxes, introduced by man on islands, have seriously reduced petrel colonies (Bent 1922; Gross 1935; Palmer 1949; Drury 1973; Cowger 1976*a*,*b*). Currently, predation by Great Black-backed Gulls and mink limit petrels on Little and Great Duck Islands, East Brothers, Old Man Island, and Roberts Island (R. B. Allen, MDIFW, personal communication).

Leach's Storm-petrels are very sensitive to changes in their nesting environment. Burrows are easily damaged by trampling and grazing. Human visitation, especially during

nesting (Apr-Nov), adversely affect populations with their heavy use of turf areas where petrel burrows are located (Cowger 1976*b*). Sheep grazing is detrimental to nesting petrels by promoting the development of a thick grassy turf, limiting or eliminating further use by nesting petrels (Drury 1973). Petrel colonies are small or lacking on islands with past records of sheep presence (Little and Large Green Islands, No Man's Land, Ten Pound Island, Roberts Island, Otter Island, Great and Little Spoon Islands, Heron Island, John's Island, Nash Island, Flat Island, Fisherman Island, Halifax Island, the Brothers, and the Libby Islands (Drury 1973)).

Besides the physical damage to nesting sites, severe disturbances may cause birds to shift to new sites. Nesting pairs may breakup with a consequence of lowered reproductive success for newly established pairs (independent of age) (Morse and Kress 1984).

At the ocean surface, Leach's Storm-petrels are vulnerable to predation by fish, gray seals, cetaceans, and Peregrine Falcons (Craddock and Carlson 1970, Morse and Buchheister 1977, Rogers and Leatherwood 1981, Lucas and McLaren 1988). Huntington (1963) suggested that petrels may be limited by a decrease in copepod food supply. One of the most serious environmental hazards to pelagic seabirds are oil spills (Drury 1973, Cowger 1976*b*). Storm-petrels feed at the air-water interface, potentially at risk to exposure from floating oil. In addition to increased heat loss from external oiling, ingested oil may temporarily increase adult metabolic rate and impair the ability of oil-dosed adults to provide food for young (Trivelpiece et al. 1984, Butler et al. 1986).

USE AND DEMAND ASSESSMENT

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

Leach's Storm-petrels 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., Leach's Storm-petrel) 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., Leach's Storm-petrel) will increase.

Boyle et al. (1990) estimated 90% of the state's adult population participate in nonconsumptive use of wildlife. Thirty-five percent of households in Maine made trips annually to view wildlife and >80% valued the opportunity to view wildlife in Maine.

This high public demand for nonconsumptive use of wildlife is of considerable value to Maine's economy. A minimum estimate of the nonconsumptive value of wildlife in Maine is $55.4 million annually (Boyle et al. 1990), comparable to the economic contribution of resident hunting.

Increasing numbers of citizens desire to preserve the greatest diversity of species possible, at state, national, and global levels (Kellert 1980). These desires are 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.

SUMMARY AND CONCLUSIONS

Nearly all of the U.S. breeding population of Leach's Storm-petrels along the Atlantic coast nest on Maine's coastal islands. Beginning in 1900, petrel populations in Maine began to steadily decline due to predation and habitat degradation. Predation by domestic dogs and cats significantly reduced functional carrying capacity of many coastal nesting islands. Gulls and mink are a continual threat to petrel colonies. Sheep grazing severely degrades nesting habitat, making it unsuitable for burrowing. The effects of sheep grazing on nesting habitat remains long after sheep are removed from the island.

Habitat protection, although improving, is a primary concern for petrel colonies. The viability of many colonies in Maine is tenuous, due to their small size. Because of the extended breeding season of Leach's Storm-petrels, breeding colonies need continued protection from trespassing through October or November. Habitat protection should be extended to currently unoccupied islands with suitable habitat to aid in maintaining or enhancing petrel habitat distribution.

With increased emphasis on locating petrel colonies, the number of known petrel nesting islands has increased from 17 in 1977 to 35 in 1994-96, with approximately 10,366 nesting pairs. However, because Leach's Storm-petrels are difficult to census, data are inadequate to ascertain the current population trend. An improved survey methodology is needed to increase the

accuracy of petrel population estimates. The Leach's Storm-petrel is classified as a Special Concern species in Maine.

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