

# The Nene *Branta sandvicensis* Recovery Initiative: research against extinction

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Since 1960, about 2150 Hawaiian Geese or Nene *Branta sandvicensis* were reintroduced in Hawaii to supplement the remaining wild population of about 30 birds. These geese were released mostly in high mountain sanctuaries. These sites became unsuitable during prolonged drought and the few surviving birds were those which had moved away from the release sites. The geese that survived had moved to, or were released near, agricultural pasture land. About 600 Nene are currently living in the wild; numbers are declining on the island of Hawaii, stable on Maui and increasing on Kauai. Management priorities include enhancement of grasslands, predator control and maximizing genetic diversity. To enable the species to recover, management will probably have to be large scale, intensive and prolonged. Further released captive-bred or translocated Nene should have access to enhanced habitats after predators have been controlled.

The recovery programme for the endangered Hawaiian Goose *Branta sandvicensis*, better known as the Nene, began in 1949 when only 30 individuals remained in the wild and 13 lived in captivity (Smith 1952, Berger 1978). The focus in the early years was on captive breeding and reintroduction with little emphasis on research or habitat management (Kear & Berger 1980, Banko & Elder 1990). Between 1960 and 1993, about 2150 captive-bred Nene were released in eight sanctuary areas on three islands, Hawaii, Maui and Kauai. Managers are still striving to achieve the original goal, a self-sustaining Nene population living in Hawaii. Because released Nene did not fair well, managers suspected that the geese were deficient in their ability to cope with Hawaiian habitats that had been altered by numerous invader plant species and introduced mammalian predators (Stone *et al.* 1983, Stone & Scott 1985).

The aim of this article is to assess and adjust the principles on which the original Nene project was structured in light of recent findings from an intensive research programme entitled the Nene Recovery Initiative. I review the working hypotheses that were used by Stone *et al.* (1983) when formulating management recommendations in the 1980s. Reviews and guidelines stress that recovery programmes for endangered species need input from several disciplines all at once, e.g. education, public relations, fundraising, captive breeding and care, genetics, biology, ecology, behaviour, population dynamics, modelling and environmental politics (Cade 1986, Griffith *et al.* 1989, Stanley Price 1989, Black 1991, Gipps 1991, Olney *et al.* 1994). By considering the assessment criteria that are now available for reintroduction programmes (Kleiman *et al.* 1994), it is possible to determine which disciplines to emphasize in the next phase of the fight to save the Nene from extinction.

## BACKGROUND AND METHODS

Nene were thought to have occurred originally on all of the larger Hawaiian Islands (Olson & James 1982, 1991). The original demise of this very tame goose was the result of extensive hunting (banned in 1907), habitat loss and the introduction of predators, such as Mongoose *Herpestes erpunctatus*, cats, dogs, Pigs *Sus scrofa* and rats (Polynesian Rat *Rattus exulans*, Black Rat *Rattus rattus*) (Kear & Berger 1980, Banko 1992). Because the remaining flocks were living in the uplands of Hawaii (above 1500 m), managers originally thought the uplands were able to sustain the geese (Stone *et al.* 1983, Morin & Walker 1986, Banko & Elder 1990). The idea that these birds were living in marginal habitat on the extreme edge of their range was not emphasized in early recovery plans, although Baldwin (1945) documented a shift to the mountains; the original range was sea level to 1829 m. Several hundred hectares of this volcanic, montane scrubland were chosen for release sites and designated as sanctuaries. Food availability in this habitat and the spread of the Mongoose were both suspected as being limiting factors (Baldwin 1947, Elder 1958) but did not receive high management priority. The climate in these areas can be severe, ranging from prolonged drought to frequent cold and heavy rain.

The first step in the Nene Recovery Initiative, starting in 1990, was to assess the survival of Nene in each release area. Data from field records and unpublished reports on all living or dead Nene, all of which were individually marked prior to release, were gathered together and computerized for analysis. Previous analysis of records apparently was sparse or lacking (reviewed in Banko & Elder 1990). The data base was fashioned after the long-term Barnacle Goose



**Figure 1.** Four Hawaiian Geese, better known as Nene, in Haleakala Crater, Maui, where 200 British-reared birds were released in the 1960s. The Crater, which is 3 km  $\times$  11 km, contains lush native vegetation as well as a cultivated grass pasture. The climate at this elevation (c. 2000–2500 m) can be severe, with heavy winds, rain and cold temperatures. Two of the British-reared geese were still alive and approaching 30 years of age during our study. Photo, A.P. Marshall.

*Branta leucopsis* project (Owen & Black 1989). Data from multiple resightings for each bird were stored, including date, location, mate, number of young, flock size and body fatness. Additional files on nest success, predation and flock demography were prepared. After 25,000 records were amassed and first analyses were completed, the data base was prepared for installation with each collaborator in Hawaii. These data were used for calculating extinction probabilities for each subpopulation under various management scenarios, using the VORTEX programme (Black & Banko 1994). Using the SURGE capture–recapture model, we determined the mortality rates for Nene released in six sanctuaries (Black *et al.* 1993).

Between 1990 and 1994, 12 field studies, lasting up to 19 weeks, were conducted in collaboration with colleagues on each island in Hawaii. The study focused on Nene at the Volcanoes (Hawaii) and Haleakala National Parks (Maui), where 100 and 150 geese were living (Fig. 1). Data were augmented from other visits to five upland and two lowland sites. About 200 Nene were caught and fitted with new, individually engraved plastic leg rings; old rings were prone to ring loss, and the engraved aluminum rings were difficult to read. The birds were sexed, aged and measured. For further details of methods see references below.

The Nene flock at The Wildfowl and Wetlands Trust (WWT), Slimbridge, numbering 200 individually marked birds, was the focus of a series of studies dealing with the ontogeny of behavioural skills and pre-release training (Marshall & Black 1992). WWT was originally involved with avicultural strategies and took part in some early releases (Kear & Berger 1980). Together with the breeding flock held at Olinda Endangered Species Facility, Maui ( $n = 28$ ), the Slimbridge Nene ( $n = 77$ ) were sampled for DNA fingerprinting analyses. The study on inbreeding was conducted in collaboration with colleagues from the University of North Dakota and the Genetics Lab at the National Zoo, Smithsonian Institution (Rave *et al.* 1994).

## RESULTS

### Current status

The initial estimate of 443 Nene living in the wild, made in 1989–1990, excluded 73 feral birds (Hoshide *et al.* 1990, Black *et al.* 1991b, Natividad Hodges 1991). Four years later, the population was estimated at 389 birds, indicating a 12% decline in numbers, largely in the flocks on the island of Hawaii (Black *et al.* 1993). This value is consistent with a

computer simulation which predicted that the Nene on the islands, Hawaii and Maui, could become extinct in about 100 years unless current levels of management are substantially enhanced (Black & Banko 1994). Fortunately, a feral flock was established on Kauai in 1982 through the escape of 12 captive Nene during a hurricane. The geese there have flourished, and about 150 individuals were estimated in 1993 (T. Teller, pers. comm.). These feral Nene on Kauai, where there is currently no Mongoose predation, utilize lush lowland pastures that are grazed and irrigated throughout the year. A similar feral flock of 50 Nene live at the Keaau Ranch, Hawaii, also located at sea level, where food supplements and nesting islands are provided while predators are consistently controlled.

### Constraints on Nene recovery

Stone *et al.* (1983) outlined nine working hypotheses about the low productivity and survival of Nene. Several of these "assumptions" needed confirmation through further research so that management options would be justifiable and could be vigorously pursued (see Murphy & Noon 1991). Based on recent research, each of the original hypotheses is reviewed below.

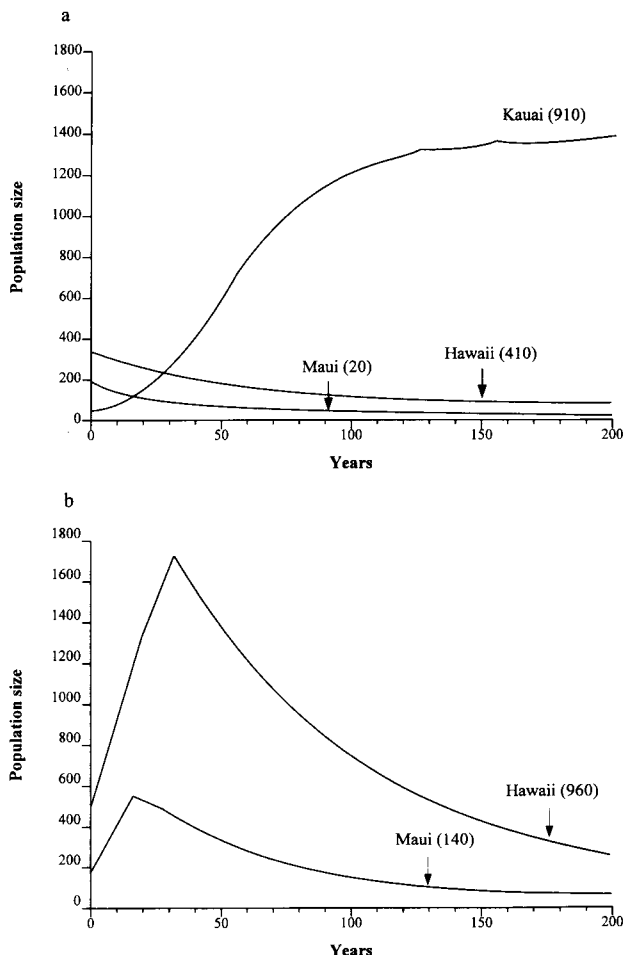
#### *Lowland habitats may have been important for self-sustaining Nene populations*

**Supported.** In addition to the fossil and sub-fossil evidence which revealed that Nene were once abundant in lowlands habitats on each of the major islands (Olson & James 1982, 1991), a new flock has established itself in the lowlands of Kauai. Comparing the extinction probabilities of the Nene in this flock with those released in the uplands of Hawaii and Maui reveals that Nene are better able to thrive in the lowlands (Fig. 2a). Adult mortality rates of Nene released in mid- to low-elevation sites were only 6.6%, which is substantially better than most other goose populations in the world (Black *et al.* 1993).

#### *Upland habitats will not support Nene populations without continuous restocking and intensive management*

**Supported on Hawaii.** The majority of releases between 1983 and 1993 were made in the uplands of Hawaii (1585–2000 m). Computer simulations by Black and Banko (1994) showed that, without supplementations or further management of habitats, the flocks on Hawaii and Maui could go extinct in 90–150 years. Even with further releases (Fig. 2b), the Hawaii and Maui flocks could go extinct in 130–180 years. However, simulations with enhanced demographics from birds that enjoyed supplemental feeding and intensive predator control showed that Nene populations could thrive.

The capture–recapture survival analysis of data from the island of Hawaii was particularly revealing as to the unsuitability of the upland sanctuaries as release sites for Nene. Black *et al.* (1993) found that few captive-reared Nene sur-



**Figure 2.** A VORTEX model showing mean population change for simulations where the Hawaiian Nene population went extinct within 200 years. The curves are based on demographic and reproductive data from field studies from each Hawaiian island, (a) without further releases and (b) with an additional 30-year release programme with releases at the same rate as the previous programme (see Black *et al.* 1991). The figures in parentheses indicate the number of simulations (out of 1000) that did not go extinct. The arrows indicate the mean year of extinction. From Black and Banko (1994).

vived in these upland sanctuaries during years of severe drought; adult mortality rates in the uplands of Hawaii ranged between 16.6% and 27.0% but reached 87% in drought years when, by chance, most of the releases were made. The survival of Nene in Haleakala, the upland crater on Maui (2000 m), was better. Here mortality rates of released birds were within the range of those of healthy migratory goose populations (13% for adults, Black *et al.* 1993). Counts in this upland crater indicated that 100–180 birds were present in the last 5 years (Natividad Hodges 1991, updated). Black *et al.* (1994) found that the Nene diet in Haleakala, Maui, yields a substantially higher energy intake than do the diets on the island of Hawaii. They attributed this to

improved grass pastures, an abundance of native berry shrubs and higher rainfall.

When Nene were numerous on the island of Hawaii, presumably they travelled up and down the mountains to make use of the vegetation according to the phenology of the plants (Henshaw 1902, Perkins 1903), and when drought affected feeding areas, they moved on to previously experienced alternatives. Traditional shifts between foods at different times of year are characteristic of goose flocks (Owen 1980). However, traditions are culturally transmitted, so new routes may take several generations to develop. Captive-reared Nene apparently need to be taught to use more than one area, especially if the primary area can become uninhabitable during periods of drought.

Stone *et al.* suggested several other reasons why Nene may not survive well in the uplands.

(1) *Loss of adaptive behaviour.* A common question throughout the Stone *et al.* (1983) review was whether or not captive-bred Nene were in some way inept, particularly at foraging. Banko (1992) also proposed that inadequate foraging, limiting food intake, may be the reason few nesting attempts were made each year. Of particular interest to managers was the question of whether or not captive diets influenced subsequent preference for non-native grasses instead of native berries which were found in the upland release sites, and appropriate experiments with captive Nene were made by N. Rojek. In addition to the standard captive diet, some goslings were fed a variety of native berries while others were not. The birds were released at 6–8 weeks of age into a grass pen where branches of these berries were available. The naive goslings (those reared without a berry diet) ate more berries than did those which were raised with a berry diet. It would appear, therefore, that the standard captive diet does not inhibit use of native berries (N. Rojek, pers. comm.).

Observations of wild and released Nene indicate that some do possess highly developed foraging behaviour (Black *et al.* 1994). Nesting females in particular are able to utilize the sparse Kau Desert vegetation, which is certainly on a par with the adept behaviour of arctic geese foraging on tundra vegetation. The percentage of time spent feeding, the diet that is chosen and the rate at which food is obtained by Nene are sufficient for obtaining daily energetic needs in some, but not all, habitats which are used. Black *et al.* (1994) concluded that the problem is not the birds' foraging ability but that there was little high-quality food available in some Nene habitats.

(2) *Invader plant species.* Whether or not Nene can assimilate non-native plants and whether or not these plants provide adequate nutrition were in question. Black *et al.* (1994) showed that Nene eat a variety of non-native species, in particular, the grasses *Holcus lanatus*, *Schizachyrium condensatum* and *Andropogon virginicus*. These grasses, now widespread in native scrubland, are eaten by adults during the incubation period. Nene achieved a higher energetic intake from the larger items of the non-native African grass *Melinis minutiflora* seedheads (16 kJ/min) than from the native Blue-

berry *Vaccinium reticulatum* (8 kJ/min) (Black *et al.* 1994). During the non-breeding and pre-breeding periods, most Nene feed on cultivated grass pastures. The highest intake rates, which enabled females to achieve breeding condition, were achieved on small areas of well-grazed pastures and corrals (Black *et al.* 1994). Perhaps most of these non-native species should be viewed as a bonus rather than a hindrance, since most Nene that survived the release in upland sanctuaries did so by moving to non-native grasslands farther down the mountain (Black *et al.* 1993).

#### *Captive-bred birds can survive and breed normally in the wild*

*Supported.* Evidence suggests that variation in survival and reproductive success is more readily explained by differences in habitat quality than by bird quality. Several of the captive-reared Nene that were released in or emigrated to the more suitable habitats (e.g. the National Parks at Haleakala, Maui and Volcanoes, Hawaii) lived for more than 20 years in the wild; the oldest record was 32 years of age. Those that were released in and remained in upland sites fared less well (see above, Black *et al.* 1993). On Kauai, where the captive-bred Nene feed on irrigated pastures, all of the older geese bred each season with 73% chance of hatching one or more eggs (maximum, six egg clutches; mean brood size, 3.3), whereas, on Hawaii, where the food situation is not as good, only 58% of the pairs attempted to breed with a 44% chance of succeeding (maximum, four egg clutches; mean brood size, 2.5) (Banko 1992, Black & Banko 1994, Black *et al.* 1994). Captive-bred Nene on the island of Hawaii that were kept in enclosures (i.e. 0.5–1.5 ha of natural habitat), thus providing protection from predation, and provided with supplementary food had substantially higher reproductive success than did Nene that were released in the same habitat (Black & Banko 1994). Black *et al.* (1994) found that two 18-month-old birds, which had been released at Volcanoes National Park 12 months previously, had acquired sufficient fat and nutrient reserves to successfully complete incubation and rear goslings to fledging age.

Devick's (1982) analysis of the data from 1966 to 1974 of ringed (recently released) and unringed (presumed wild) Nene indicated that unringed geese had larger clutches and bred more often than did ringed geese. These results were probably the result of differences in age between ringed and unringed birds; the ringed birds were young and breeding for their first or second time and the unringed birds were probably much older. Several reproductive components in Nene and other geese, including clutch size, improve with age (Kear & Berger 1980, Owen 1980).

#### *Encouraging upland birds to make use of lowland sites may result in better survival and breeding*

*Supported* on Hawaii. Black *et al.* (1993) showed that the few birds that did survive after release in the uplands of Hawaii did so by moving down the mountain to the nearest grass

pastures and ranchland. Survival rates were highest for the geese at mid- to low elevation (Black *et al.* 1993).

*Habitat management, including predator control, enhancement of feeding areas and supplementary feeders, watering stations, etc., may increase Nene use, recruitment and survival*

**Supported.** Black and Banko (1994) showed that reproductive performance was substantially improved for pairs in enclosed habitats where predators were controlled and supplementary food and water were available, indicating that these factors are limiting in current Nene habitat. Food and water also were provided at an island of scrub vegetation in the middle of a lava flow at elevation 2034 m (i.e. Puu 6677, see Banko & Elder 1990). Few predators traversed the barren lava flow to this remote site. Nest success was higher here than in other sites in the surrounding scrubland region; 16 nests were recorded between 1985 and 1991, with 21 goslings successfully hatched (two nests were preyed upon by a Mongoose in 1990–1991), compared with no fledged goslings from ten other nests in the region (Black *et al.* 1993). On a much larger scale, the computer simulations predicted that with predator control and optimal food sources (using data from the enclosures) Nene populations would thrive and reach the carrying capacity within 20–30 years (Black & Banko 1994).

Although our research did not address the issue directly, I suspect that the previous small-scale attempts to offer better forage to Nene (reviewed in Banko & Elder 1990) were not sufficient, probably because there was not enough high-quality food on offer. For example, Black *et al.* (1993) estimated that the 1-acre grass pasture that was planted in scrubland, lava habitat in the Keauhou Sanctuary supported less than one goose per day. At Puu 6677 (see above), there was little goose food available apart from the supplementary cracked corn. Birds in this area were seen flying across the lava flow to distant pastures where they apparently obtained the grasses that appeared in their droppings.

*There is sufficient genetic variability in the Nene gene pool to allow adequate adjustment to environmental changes and current modified habitats*

**Supported with caution.** It is because of the Nene's flexible and exploratory behaviour that the species is still surviving in altered Hawaiian habitats (Black *et al.* 1993, 1994). These captive-bred birds and their subsequent offspring are making use of the wide variety of new plants that only recently became available, e.g. agricultural grasslands, golf courses and non-native plants.

The results of the DNA fingerprinting study prohibit a firm conclusion about the above hypothesis. Inbreeding depression in the form of significantly lower hatchability and survival was detected in the captive flocks (Rave *et al.* in press). Where wild Nene were concerned, Rave (in press) found that DNA fingerprints of 75 wild Nene from the six popu-

lations revealed that those from the Volcanoes National Park area, a lower elevation site and where many Nene from other release sites had emigrated, had the lowest mean similarity coefficient (0.63). Other sites had similarity coefficients up to 0.73, suggesting there may be a higher risk of inbreeding depression in those areas. Fortunately, the feral birds of Kauai, where numbers are increasing, do not seem to be affected by the current extent of inbreeding. In other words, too many predators and not enough high-quality food seem to be limiting recovery more than does the low genetic variation in the Nene gene pool.

*Training adaptive responses prior to release may enhance survival*

**Supported.** Marshall and Black (1992) tested this idea by rearing Nene goslings with parents, with foster-parents and without parents. Those reared with parents were dominant, scored highest in vigilance after seeing a predator and integrated fastest with adults after release on the Slimbridge grounds. Therefore, there is scope for training goslings in social and predator-avoidance skills prior to release; such a research programme is currently in progress at Slimbridge.

*Larger numbers of releases are essential to increase the chance of perpetuating existing small Nene flocks*

**Supported.** Since the late 1970s and early 1980s fewer Nene have been released, and the number of geese on the island of Hawaii has steadily decreased (Black *et al.* 1991b). The computer simulations predicted a 20% faster rate of extinction without further supplementations (Fig. 2).

Recommendations from the genetic study emphasize the need for maximizing genetic diversity in each sub-population in addition to releasing additional birds (Rave *et al.* 1994, in press). They advocate the translocation of unique genetic material (e.g. eggs and/or birds) so that each sub-population is made up of individuals with all available genetic variation.

*Cooperation between agencies is in the best interest of wild Nene*

**Supported.** This very accurate and wise political statement seems to indicate the crux of the issue and may determine whether Nene survive or go extinct. The Nene programme spans four government agencies on four islands, totalling 11 offices and about 60 people, not including the involvement from non-governmental agencies. The importance of improving collaboration should not be underestimated.

Other suggestions about what inhibited the recovery of Nene include disease/parasites, accidents (e.g. road kills), poaching and lack of adequate funding (Kear & Berger 1980, Morin & Walker 1986, Banko & Elder 1990). For example, parasite burdens are low in Nene and are probably not limiting recovery (Bailey & Black 1994). However, the effect that avian pox may have is still unknown. The six other factors that were suspected as causing problems in the re-

**Table 1.** Limiting factors, proposed by Stone *et al.* (1983) and Morin & Walker (1986), that were assessed in the Nene Recovery Initiative research programme, 1990–1994

Potential limiting factor	Limiting	Explanation	Recommendation	Source <sup>1</sup>
Inbreeding	Yes	Potential low fertility & survival	Maximize genetic diversity in flocks with few founders and emigration	i k l
Disease/parasites	No	Low infestation levels	Survey/research on avian pox	f
Loss of adaptive skills				
Foraging	No	Captive diets not a problem		m
Social	Yes	Parent-reared birds are best	Research on methods for training prior to release	d
Predator detection	Yes			d, n
Diet/nutrition deficiency	Yes	Exotic plants are a bonus but not enough high-quality food available	Enhance grassland habitats	h
Predation	Yes	40% of nests destroyed by Mongoose, lowlands worse than highlands	Intensive predator control	a e g
Poaching/road kills	Yes	Isolated events	Further education	n
Inadequate funding	Yes	Shoe string budget	Further fundraising and collaboration	b

<sup>1</sup> (a) Hoshide *et al.* 1990, (b) Banko & Elder 1990, (c) Black *et al.* 1991b, (d) Marshall & Black 1992, (e) Banko 1992, (f) Bailey & Black 1994, (g) Black & Banko 1994, (h) Black *et al.* 1994, (i) Rave *et al.* 1994, (j) Black *et al.* 1993, (k) Rave in press, (l) Rave *et al.* in press, (m) N. Rojek, pers. comm., (n) unpublished anecdotes.

covery of the Nene are now at least partially confirmed (Table 1). There is scope, therefore, for maximizing genetic diversity in wild flocks, training goslings in predator avoidance skills prior to release, intensive habitat enhancement, intensive predator control, community education and further fundraising.

## CRITERIA FOR REINTRODUCTION

Kleiman *et al.* (1994) recommend that reintroduction/translocation of endangered species is most appropriate when all of 13 feasibility criteria are met. Apparently, with the available information in the 1960s, most of the criteria were met and reintroduction was appropriate for the Hawaiian Goose (Table 2). At the time, managers were uncertain whether or not the environmental criteria (i.e. habitat and predators) were problematic. The one criterion that was definitely not met, reintroduction technology, was refined during the project. Various methods of making the birds flightless were tried, so they could get accustomed to the habitat (Kear & Berger 1980). Higher mortality rates in the first releases were linked with the initial methods (Black *et al.* 1993). The major criticism of the original programme is that it did not direct sufficient priority and funding toward detailed monitoring of the behaviour and ecology of the birds after release and analyses of existing data (see Banko & Elder 1990).

With current information in the 1990s, the criteria for reintroduction are clearly not met (Table 2). A major obstacle

is that the cause of the species decline has not been removed, and sufficient managed habitat is not available. In fact, there is evidence that some foraging and nesting areas are already saturated, even with the critically low numbers of Nene (Black *et al.* 1994). Based on these criteria, therefore, further reintroductions/translocations would not be advised until suitable habitat is established and predators are removed.

## MANAGEMENT PRIORITIES

A powerful argument in favour of the initial reintroductions as a conservation tool is that after 45 years of Nene recovery efforts a wild population still exists and has increased from 30 to 600 individuals. In effect, extinction has at least been postponed, giving managers a chance to address the problems that have been highlighted by the ecology and behaviour research. In order to achieve a self-sustaining population without the necessity for further releases, it seems that intensive management will have to be implemented and sustained. The remaining genetic stock will have to be managed in order to maximize genetic diversity and reduce inbreeding. Emphasis should be given to creating high-quality grassland sites, preferably adjacent to scrubland nesting habitats that could be made predator-free. Once these areas are established, a second intensive release/translocation programme will be needed to allow sufficient numbers of animals on which natural mutation rates can act, thus enhancing genetic diversity. Further, a culturally transmitted

**Table 2.** *An assessment of the criteria for reintroduction/translocation of Nene from past and current perspectives (scale: 1 poor, 5 best)*

	1960s perspective	1990s perspective	Comments/comparison
Condition of species			
1 Need to augment wild population	Yes	Yes	Still declining
2 Available stock	Yes	Yes	Improved/best available
3 No jeopardy to wild population	?	?	
Environmental conditions			
4 Causes of decline removed	Yes ?	No	New evidence
5 Sufficient protected habitat	Yes ?	No	New evidence
6 Unsaturated habitat	Yes	No	New evidence
Biopolitical conditions			
7 No negative impact for locals	No	No	Could benefit
8 Community support exists	1	4	Education needed
9 GOs/NGOs supportive/involved	Yes ?	Yes	Improving
10 Conformity with all laws/regulations	Yes	Yes	
Biological and other resources			
11 Reintroduction technology known or in development	Yes	Yes	Still refining
12 Knowledge of species' biology/ecology	2	4	
13 Sufficient resources exist for programme	No	No	
Recommended reintroduction/translocation?	Yes	No	Habitat enhancement, predator control and maximize genetic diversity

set of seasonal movements between upland and lowland refuges should be taught, thus reducing the risk of starvation during drought years and enabling gene flow between areas.

In this experiment in conservation, managers now realize that it is not possible to save the Nene simply by releasing them in the upland lava flows of Hawaii. The concept of saving this species in its "original" habitat is not a possibility, largely because the low- to mid-elevation habitats, where Nene presumably once thrived, have been changed for human uses. Alternatively, perhaps this species can be saved by managing agricultural habitats. In addition to the thriving Nene flock on Kauai, there are numerous examples of how the feeding performance and subsequent reproductive rates of geese have improved due to shifting to agricultural lands (e.g. Summers & Grieve 1982, Madsen 1985, Black *et al.* 1991a). Fortunately, the two sites with the potential for this scheme, Haleakala and Volcanoes National Park, currently hold the largest flocks of Nene. The geese may also be able to thrive on some of the 1.5 million acres of rangeland that are managed for cattle in Hawaii. Establishing predator-proof, high-quality forage areas on ranchland habitat may require the introduction of some form of artificial nesting platforms.

It is likely that with these managed sites, flocks will swell and Nene and humans will meet more frequently. Nene are perhaps the tamest of all waterfowl, an attribute that could be useful to the conservation effort. Nene refuges could serve as focal points for community education programmes. At Slimbridge, where a tame flock of 200 captive Hawaiian

Geese roams public areas, visitors develop a sense of ownership and care for the species. In order to save the Nene, I suspect managers will need to have the support of the Hawaiian people at all levels. Therefore, it is vital to include a community education scheme for Nene as an integral part of the recovery programme. When the state bird of Hawaii, the Nene, begins to recover, broad support for the conservation of all of Hawaii's threatened species and habitats is more likely to be achieved.

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