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Journal
Proceedings of the Vertebrate Pest Conference, 21(21)

ISSN
0507-6773

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Publication Date
2004

Strategies for Reducing Feral Cat Threats to Endangered Hawaiian Birds

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ABSTRACT: Introduced predators are one of the most important limiting factors for endemic Hawaiian forest birds. In the subalpine zone of Mauna Kea on the island of Hawaii, the primary predators of the endangered Hawaiian finch, palila (*Loxioides bailleui*), are feral house cats. Remote video monitoring revealed that feral cats are primarily diurnal predators of palila during the extended period of nestling development. Reducing this predation is necessary for population recovery and efforts to reintroduce palila to parts of their historical range. Currently, feral cats are removed with an extensive array of live traps. Since 1998, 7,344 trap nights of effort have been implemented, and although temporary declines in capture occur within seasons, cumulative capture rates show there has been little lasting effect from season to season. New emphases on improving capture efficiency include improved techniques for attracting cats to traps with lures that require infrequent refreshing or maintenance, "smart trap" technology that efficiently notifies managers when traps of all types contain animals, and adaptive strategies for managing feral cat populations in a variety of habitats and parks in the Pacific. Further documentation and interpretation of feral cat impacts on native wildlife will help prioritize and justify requests for increased funding for predator management. Accurate information on feral cat problems will help educate decision-makers and the public of the need for increased funding to protect endangered birds from this threat.

KEY WORDS: cat, endangered species, *Felis catus*, feral cat, Hawaiian finch, introduced species, *Loxioides bailleui*, palila, predation

Proc. 21st Vertebr. Pest Conf. (R. M. Timm and W. P. Gorenzel, Eds.)
Published at Univ. of Calif., Davis. 2004. Pp. 21-26.

INTRODUCTION

In 1866, Mark Twain reported on the great abundance of cats in Hawaii, and William Bliss later wrote that many of these cats were "belonging to the government," since they apparently "belong to no one else" (Twain 1866, Bliss 1873). Feral cats and several other factors contributed to the decline and extinction of some 45 species of Hawaiian birds by the end of the 18th century (Berger 1981, Ralph and van Riper 1985, Stone 1985). Because the Hawaiian fauna evolved in isolation from all ground-dwelling mammals, native birds lost (or never had) behavioral defenses against small carnivores (Stone 1985). Flightless species such as ducks, geese, ibis, and rails were particularly vulnerable, but even forest-dwelling songbirds suffered from the novel effects of alien nest predators, not only in Hawaii, but also on nearly every island in the Pacific (King 1985). Many species of Hawaiian honeycreepers and some seabirds persisted in high-elevation refugia where other limiting factors such as introduced diseases and habitat degradation were not as pronounced, and although some populations are now nominally protected, predation by feral cats is still an important factor in the continuing decline of many native bird species (Snetsinger et al. 1994, Smucker et al. 2000, Hu et al. 2001, Kowalsky et al. 2002). The palila (*Loxioides bailleui*) is an example of endangered honeycreeper restricted to high-elevation forests where it is subject to predation from abundant feral cats (Figure 1). Restoration of Hawaii's remaining native birds in protected natural areas such as designated critical habitats, wildlife refuges, and national parks requires intensive efforts, consisting of habitat, disease, and predator management.

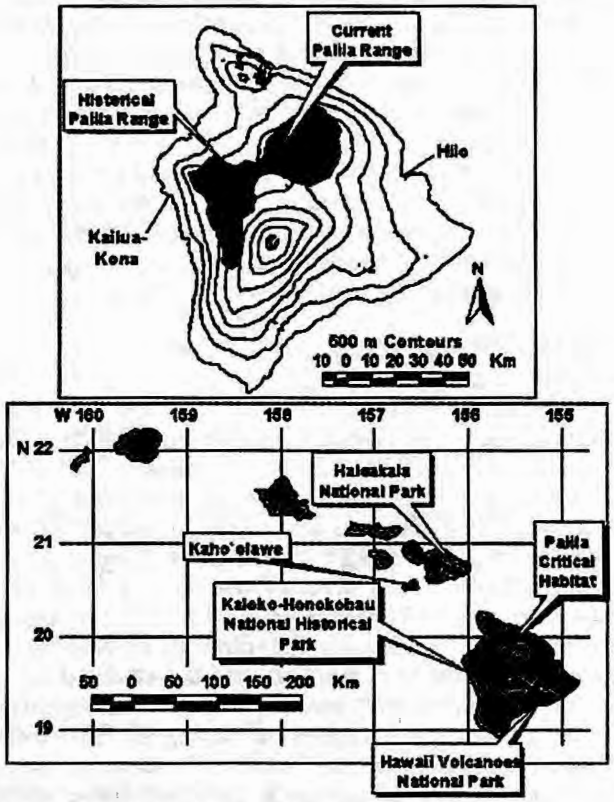

Figure 1. The current and historical distribution of an endangered Hawaiian forest bird, the palila (*Loxioides bailleui*), on the island of Hawaii and protected natural areas in the Hawaiian Islands, where feral cat management is necessary to restore endangered bird populations.

Populations of native ground-dwelling or ground-nesting animals cannot be protected or reestablished in many protected habitats until effective methods have been developed to manage feral cats. For example, feral cats jeopardize vital programs to restore the endangered Hawaiian goose (*Nesochen sandvicensis*) and dark-rumped petrel (*Pterodroma phaeopygia*), as well as other seabirds, waterbirds, and nesting sea turtles in Hawaiian parks (Seabrook 1989, Winter 2003). Major impediments to reducing cat threats to native wildlife are: 1) lack of management techniques that can be applied efficiently on a landscape scale, 2) incomplete knowledge of movements, behavior, and extent of cat impacts in wildland habitats, and 3) vigorous activism by animal protection advocates. In many cases, there is little public awareness about the impacts of feral cats on native wildlife in natural areas; therefore, there is little public support for managing cats (Ash and Adams 2003). Compounding these problems are cat colonies established in or adjacent to important bird habitats (Winter 2003). Moreover, Hawaii's terrain is steep, rugged, and remote, which limits management efforts due to humane treatment requirements.

We have conducted research toward managing feral cats on Mauna Kea since 1998 as part of an effort to restore palila to parts of its former range. These efforts coincided with translocations and the release of captive palila on the northern side of Mauna Kea, and research to improve nesting success for the primary population on the western side. Our objectives were to determine: 1) feral cat activity patterns with radio-telemetry, 2) capture rates and the potential for limiting the feral cat population with extensive arrays of live traps, 3) diet from stomach contents, 4) feline disease rates with rapid field tests, and, 5) palila nest predation rates and predator identification with surveillance video cameras. We are now using these results to develop new strategies for reducing feral cat threats to other endangered Hawaiian birds.

METHODS

Capture Rates

We captured feral cats on the north and west sides of Mauna Kea within designated palila critical habitat during 6 sessions from 1998 - 2003. Tomahawk® Model 106 live traps (23 × 23 × 85 cm) were distributed at 150-m intervals along transects in two dry subalpine woodland types from 1750 - 3000 m elevation (Figure 2). We covered traps with a layer of plastic to protect trapped cats from rain and cold, and placed a cloth rag inside for bedding. We used moist fish-flavored canned cat food, canned sardines, and mackerel as bait, checked set traps every weekday, and wired traps open when unattended. Feral cats were euthanized according to University of Hawaii IACUC protocol 97-063. We recorded age, sex, and body weight of carcasses, collected tissue samples, and preserved stomachs and intestines in 70% ethanol.

Daily Activity Patterns

We captured 7 male and 3 female cats in palila critical habitat on the west side of Mauna Kea to study daily activity patterns. Cats were anesthetized with Metophane and fitted with 35- to 37-g Holohil Systems Ltd. (Carp, Ontario, Canada) Model MI-2 radio transmitters. The animals were allowed to recover in the trap and then released. Six male cats were tagged in July 1999 and tracked for 18 months. Three females and one additional male were tagged in September 2000 and tracked for 10 months.

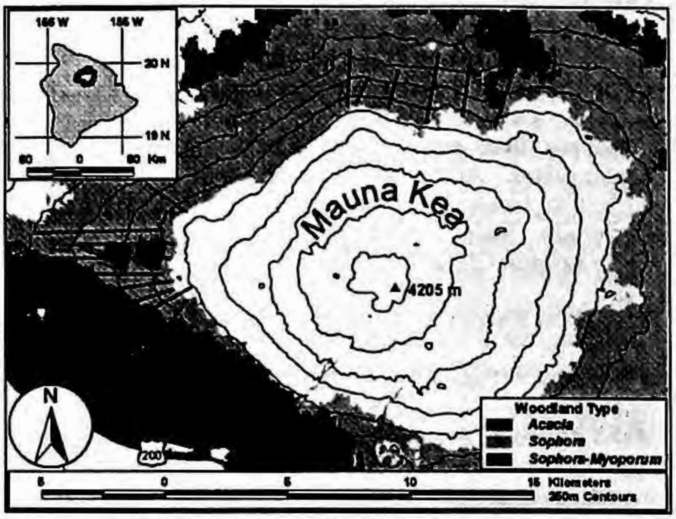

Figure 2. Subalpine woodland types and the location of transects used to study feral cats (bold lines) and palila nests (fine lines) on the western side of Mauna Kea, Island of Hawaii (inset), 1998-2004.

To determine activity in radio-collared subjects, we simulated cat movements in the field by listening for changes in signal strength and pitch. We attached a radio transmitter to a 1-m string and tied that to the end of short branch, then moved the transmitter around and changed positions in a manner similar to a moving cat. One person simulated a cat's movements by walking through representative cat habitat on Mauna Kea with a transmitter, alternately moving with the transmitter near ground level, then resting and recording the time of each activity. Another person using a receiver stood in one location and recorded the time intervals when they thought the transmitter was moving or resting. The receiver had a good line of sight to the surrounding area, but could not see the transmitter. We conducted 4 calibration episodes lasting for 30 - 60 minutes each, and we reviewed our accuracy as "receivers." We applied this technique to determine when cats were active or inactive during 2-hour blocks throughout the day.

Diet from Stomach Contents

We collected the stomachs and intestines of 96 feral cats to determine the occurrence of prey items in their diet. Stomachs were cut open along the concave side and intestines were opened along their entire length. A garden sprinkler head was attached to a hose and a continuous, gentle stream of water was used in combination with gentle pressure from fingers to rinse and filter the contents in soil sieves (U.S. Bureau of Standards size 5 and 10 mesh). Insects, vegetation, large pieces of rodents and birds, and large feathers were collected on the size 5 mesh. Hair, small feathers, seeds and small bones were collected in the size 10 mesh. Food fragments were identified with the help of a reference collection and keys. We recorded the presence of birds, mice, rats, insects, and identified items to the species level when possible, then reported the percent of samples that contained each food type.

Disease

We collected blood samples during session 6 to screen for 3 feline diseases: feline immunodeficiency virus, feline leukemia, and *Toxoplasmosis gondii*. Snap™ Combo FeLV Ag/FIV Ab tests, enzyme-linked immunosorbent assays, were used in the field with fresh whole blood. Additional fresh blood samples were sent on ice to Colorado Veterinary Diagnostic Laboratories (Colorado State University, Fort Collins, CO) for *Toxoplasmosis gondii* testing.

Predation Rates and Predator Identification

Teams of 3 - 5 persons searched for palila nests in every tree within 50 m of transects on the west side of Mauna Kea in 1998 - 2002. Transect lengths varied from 900-7500 m (Figure 2). Active nests were monitored daily to determine status of eggs and chicks. We investigated failed nests by thoroughly inspecting the eggs, nestlings, nests, nest trees, and the surrounding area including the ground below for forensic evidence of hair, feathers, or scratch marks. We also monitored a subset of active nests with video cameras from 1998 - 2002 to determine the extent of predation on nests. Beginning near the ground under the nest tree, we gradually moved a small surveillance camera up towards each nest in 1-m increments while the adult palila were absent.

RESULTS

Capture Rates

We conducted 7,344 trap nights of effort during 7 sessions from 1998 - 2003. Feral cat capture rates ranged from 0.65 - 7.54 / 100 trap-nights with an overall capture rate of 1.55 / 100 trap-nights, and were slightly higher on the western side (1.75 / 100 trap-nights) than on the northern side (1.24 / 100 trap-nights). We captured cats between 2,150 - 2,950 m elevation, but we observed cat scat as high as 3,064 m elevation.

We used logarithmic regression to examine differences in cumulative capture rates between sites and trapping sessions (Figure 3). Post-hoc multiple comparisons of parameters were done with a Bonferroni correction. Both the slopes and intercepts were significantly different for the two north side sessions ($P <$ 0.008 and 0.01). The 1998 April-May north side session also had a significantly greater intercept for the first 255 trap-nights of the April 2002 west side session ($P < 0.03$), though the slope was not different ($P > 0.1$). The slope and intercepts of the 2002 and 2003 west side trapping sessions were also significantly different ($P < 0.001$ and 0.004). On the north side, capture rates declined between the April and September 1998 sessions, indicating that the population remained low 4 months after the trapping session ended. On the west side, however, the capture rate was higher in July 2003 than during the extensive trapping session of April 2002, indicating that this session had no lasting effect.

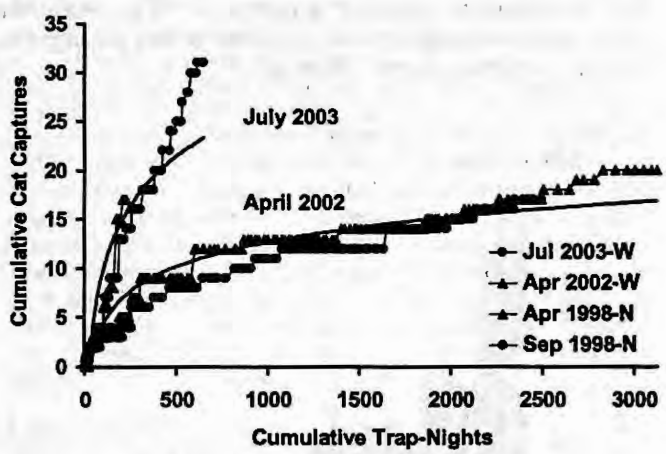

Figure 3. Cumulative trap-nights and cumulative cat captures from trapping sessions on Mauna Kea Hawaii, 1998 - 2003. Logarithmic regression curves are for the west site July 2003 (upper) and the west site April 2002 (lower) sessions.

Daily Activity Patterns

Cats were most active during the nighttime period of 2000 - 2200 hours, but activity was low during the rest of the night, especially during 0400 - 0600 hours (n = 293 observations, Figure 4). Daytime activity levels were fairly constant, but a slightly lower proportion of cats were active during the 1000 - 1200 hour period.

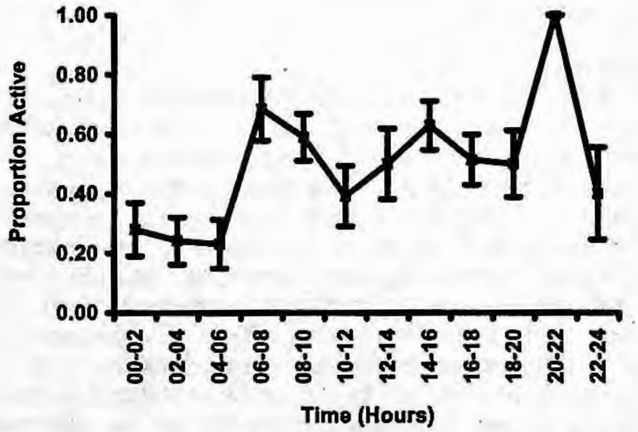

Figure 4. Proportion of feral cats that were active (± SE) in 2-hour increments during radio-tracking on Mauna Kea, Hawaii, 1999. Total n = 293 observations.

Diet from Stomach Contents

Birds were the most common prey item, found in 79 of 96 (82.3%) of digestive tracts we examined (Figure 5). Passeriformes was the most commonly found bird order, including many Hawai`i amakihi (*Loxops virens*), 1 house finch (*Carpodacus mexicanus*), 1 `elepaio (*Chasiempis sandwichensis*), and numerous passerine nestlings.

We recovered aluminum leg bands from 2 Hawai`i amakihi and 1 `elepaio that were banded on the west side of Mauna Kea. Of the digestive tracts examined in 2003, 19.4% contained eggshell fragments. Cat stomachs commonly contained insects from the orders Coleoptera, Diptera, Lepidoptera, and Odonata.

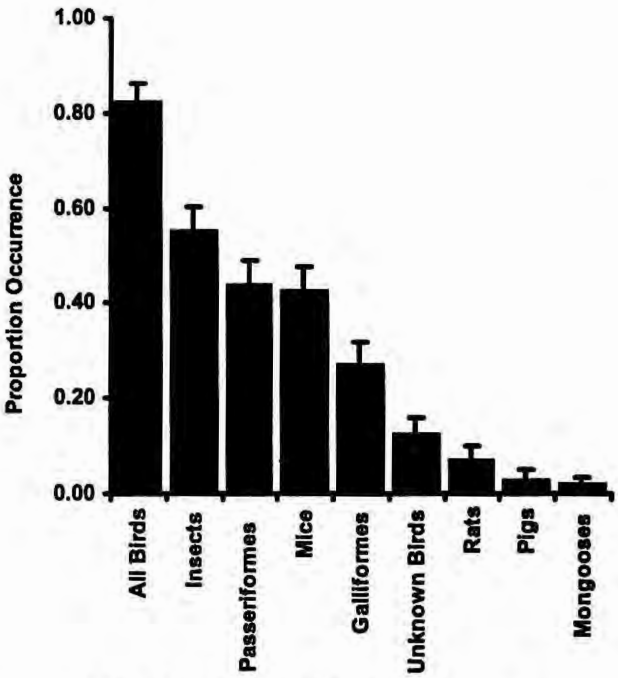

Figure 5. Diet of feral cats on Mauna Kea, Hawaii 1998 - 2003. Data represent the proportion of digestive tracts (+ SE) containing particular prey items. Total *n* = 96 digestive tracts.

Disease

Feral cats on the west side of Mauna Kea showed high rates of feline diseases (Table 1). We found feline immunodeficiency virus (FIV) only in adult males. We found feline leukemia virus (FeLV) and exposure to infection of *Toxoplasma gondii* in all age and sex classes. Feline diseases have been suggested as potential biological control agents (Courchamp and Sugihara 1999), but also pose severe threats to other native wildlife (Ragg et al. 1995, Work et al. 2000). The presence of feline diseases on Mauna Kea suggests that the feral cat population may already be limited by or resistant to these pathogens and therefore they would not be effective biological control agents, nor would they be appropriate for this area.

Table 1. Prevalence of feline immunodeficiency virus (FIV), feline leukemia (FeLV), and *Toxoplasmosis gondii* in feral cats on Mauna Kea, Hawaii, 2002 - 2003.

Session	FIV	FeLV	*Toxoplasmosis*
West Site 2002 (*n* = 20)	10%	5%	40%
West Site 2003 (*n* = 31)	13%	20%	29%

Predation Rates and Predator Identification

Of active nests monitored in 1999 prior to feral cat removal, 11% (4/37) were depredated by feral cats. In 2002, however, there was no evidence of feral cat depredation at 25 monitored nests. The 2002 breeding season coincided with the most extensive trapping effort on the west side of Mauna Kea where most of the palila population resides during breeding. These data suggest that trapping resulted in the desired effect of reduced nest predation. Of 16 nests monitored by surveillance video camera from 1999 - 2002, 2 depredation events by cats were recorded. No other predators were recorded by video cameras at nests.

NEW STRATEGIES

We are now moving toward research in new strategies to reduce the threat of feral cats for endangered bird restoration applications at several locations (Figure 1). The objectives of this research are: 1) improved techniques for attracting cats to traps with lures that require infrequent refreshing or maintenance, 2) development of "smart trap" technology that efficiently notifies managers when traps of all types contain animals, 3) development of adaptive strategies to manage feral cat populations in a variety of habitats and parks in the Pacific, 4) documentation and interpretation of impacts of feral cats on native wildlife to help prioritize and bolster requests for increased predator management funding, and 5) preparation of information on feral cat problems that help inform decision-makers and the public of the need to protect endangered birds from feral cats.

Smart Traps

The major focus of upcoming research will be the development of more efficient capture methods for feral cats; specifically, increasing capture rate per unit effort and designing reliable "smart trap" systems to notify field staff immediately when animals are captured, thereby reducing the effort involved with daily maintenance of traps while providing improved welfare for trapped animals.

The simplest smart trap employs a trap-transmitter to transmit continuously until an animal is captured or a malfunction occurs. At the time transmission ceases, staff will know to check the appropriate trap. At the next level, either an automated data recorder or cellular telephone call-out box will be developed to check trap status from a remote location. Call-out boxes have the capability of sending a pre-recorded message to a remote telephone with "caller I. D." to verify that trap-transmitters are functioning, but depend on availability of cellular phone service (Larkin et al. 2003). Call-out boxes may also be programmed to call repeatedly when a motion monitor continues to detect motion in a trap, thereby discriminating false alarms from true captures. This allows animals in live-traps to be removed speedily, thereby reducing both the time that animals are held and time that traps are inactive. We will develop methods to detect when traps of various types contain live animals by testing heat and motion sensors, and remote cameras with wireless Internet connections to provide species identification of trapped animals. We will also investigate remote mechanisms to release unintentionally captured species.

Lures and Attractants

Audio, olfactory, and visual lures will be tested in randomly-assigned traps to evaluate effectiveness of attracting feral cats into traps relative to traps without lures. Audio lures will consist of microchip recording of nestling birds, kittens, and rodents and are expected to attract predators or stimulate curiosity. Concentrated baits will include dried calamari, fish, shrimp, chicken, and processed meats. Attractiveness over time, protection from invertebrate scavengers, and differences between sites will be key test elements. Surveillance cameras and tracks will be used to gauge reactions of feral cats to different lures and baits in natural settings and combinations of lures placed in the vicinity of traps.

Adaptive Management

Results of this study will be integrated into an adaptive strategy for long-term management of predator populations in habitats where impacts are most severe. This will take into consideration different habitats (i.e., coastal, montane, subalpine, alpine), vulnerability and status of prey species (e.g., critically endangered burrow-nesting seabirds), existing feral cat densities, immigration from the landscape reservoir, and the cost-effectiveness of continued trapping based on the rate of effort versus rate of capture. We will use radio-tagged animals to understand feral cat ecology and develop realistic criteria for effective trap placement to increase the probability of capture (Veitch 1985). For example, home territories, den and scat sites, and travel routes are likely sites for placing traps. Tests of lures and attractants will provide site-specific recommendations for the most effective combinations in different locations. We will also make site-specific recommendations for trapping arrays based on how topography affects telemetry reception and availability of cellular phone reception. We will also examine the potential for supplementing availability with repeater devices. Based on capture rates, we will estimate the proportion of the population removed and develop an adaptive strategy that considers time of day and season, location, effort, and criteria for continuing, reducing or pausing trapping.

Public Outreach

Results of our project will be developed to provide information not only to wildlife managers, but also to the public and decision-makers about the impacts of feral cats on native wildlife. This information will include clips from surveillance cameras, images of birds killed by predators, fact sheets, posters, and Internet resources. An almost certain venue for making this information widely available is through the Cats Indoors! Campaign sponsored by the American Bird Conservancy (http://www.abcbirds.org). The goal of outreach is to explain and justify to the public the importance of managing feral cats to protect native wildlife in national parks and other natural areas in Hawaii and the Pacific.

ACKNOWLEDGEMENTS

The U. S. Army Garrison, Hawaii, under the administration of the U. S. Army Corps of Engineers through 2001, and Federal Highway Administration (FHWA), starting in 2002, provided funding for this research. Sponsoring our work were Dr. Greg Smith, Program Chief, USGS-Wildlife and Terrestrial Resources; Dr. Dennis Fenn, Project Chief, USGS-Restoration of Terrestrial and Aquatic Ecosystems in the Western US; Dr. William Steiner, Director, and Dr. David Helweg, Deputy Director, of USGS-Pacific Island Ecosystems Research Center; and Dr. David Duffy, Director of Pacific Cooperative Studies Unit. Dr. Francis Benevides Jr. conceived electrical engineering designs for smart traps and remote video monitors. For permission to work on lands under their supervision, we thank Jon Giffin and Roger Imoto, Hawaii District Manager of Division of Forestry and Wildlife (DOFAW), and Miles Nakahara and Tod Lum, Wildlife Biologists for Hawaii DOFAW. Finally, we thank many research interns and staff who provided invaluable assistance in gathering data, especially Colleen Murray for monitoring palila nests.

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