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ABSTRACT: We monitored behavior of cattle egrets (Bubulcus ibis) during a population control program to reduce egret-aircraft strike hazards from a small heronry near the Hilo, Hawaii, airport. Results verified that attempts to move egrets from undesirable roost sites should be undertaken before nesting begins. Although possibly compounded by previous treatments, our observations also indicate that 1) egrets may abandon a new roost in response to a few dead egrets placed in clear view around the roost, and 2) shooting at egrets as they attempt to land at a traditional feeding site causes long-term avoidance of the area. Rapid repopulation after control indicates that techniques to move roosts and prevent congregations are more likely than population control to resolve problems.

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INTRODUCTION

Cattle egrets (Bubulcus ibis) were first reported in the United States in Florida in the early 1940's (Sprunt Jr. 1955). Population growth and range expansion have been dramatic. By 1978 the species occupied coastal and inland areas from Maine to southern Texas, with outlying heronries in California and Ontario (Byrd 1978) . Twelve heronries in eastern Texas contained an average of 5200 (range 800-30,000) egrets (Oberholser 1974). Large colonial populations and egret feeding behavior have caused problems in several locales (Dusi 1977,1979,1981). Egret-aircraft strike hazards are of special concern; the cattle egret now poses a potential hazard at military bases throughout the southeastern U.S. (Major M. Thompson, Chief, USAF Bird-aircraft Strike Team, pers. comm.) and is the primary species of concern at civilian airports throughout the Caribbean (J. Seubert, USDA-APHIS, pers. comm.).

In Hawaii 9 of 12 civilian and military jet airports lie within 10 km of an active cattle egret roost. Four airports, Hilo on Hawaii Island, Honolulu and Hickam on Oahu, and Lihue on Kauai, have experienced egret problems. The hazard to aviation has been most critical at Hilo's General Lyman Field (GLF), where egrets from a nearby heronry regularly overfly the runway and congregate to feed at the airport. In January 1982, we initiated research to define and resolve the problem at GLF. Ecological and behavioral information collected during the precontrol phase of the program (January through June) indicated that actions to eliminate feeding congregations at GLF would not resolve the hazard posed by large flocks flying over the runway. The data also suggested that attempts to eliminate overflight by relocating the heronry were unlikely to reduce overflight but probably would reduce access to the population in the event control was needed. Recognizing the potential airstrike hazard caused by the heronry and considering that the cattle egret is an introduced species in Hawaii, a pest at aquaculture facilities, and present in small, but growing numbers on the island of Hawaii, we conducted a population control program aimed at eradication from 28 June 1982 through 15 July 1983. Although we failed to achieve eradication, the reaction of egrets to several of the control techniques may bear on management of large and growing cattle egret populations elsewhere in Hawaii and the continental U.S. This paper describes the behavioral response of cattle egrets to the control program and summarizes implications for egret management.

STUDY AREA AND METHODS

The heronry consisted of a dead Norfolk Island pine (Araucaria heterophvlla) and a live banyan tree (Ficus sp.) on a 2 x 5-m island in a 20-ha coastal fish pond (Lokoaka Pond) about 1 km north of GLF and 6.4 km southeast of Hilo (Fig. 1). The heronry and airport were separated by pasture. A heavily traveled road formed the north shore of Lokoaka; the remaining 1.3 km-long shoreline appeared to offer suitable, but unused roosting and nesting habitat. A smaller fish pond, (Kionakapahu) is situated about 300 m west of the heronry. The heronry site had been occupied for at least 10.5 years and nesting had occurred there for at least 2 years prior to onset of control (Paton et al. 1986). Of the other roost sites used by egrets on Hawaii Island during this study (Fig. 1), only Aimakapa (with 6 egrets) was known to have been occupied in January 1982, and Lokoaka was the only known nesting site.

Population size.—Throughout 1982 we monitored the Lokoaka population from the road at intervals of 7-10 days

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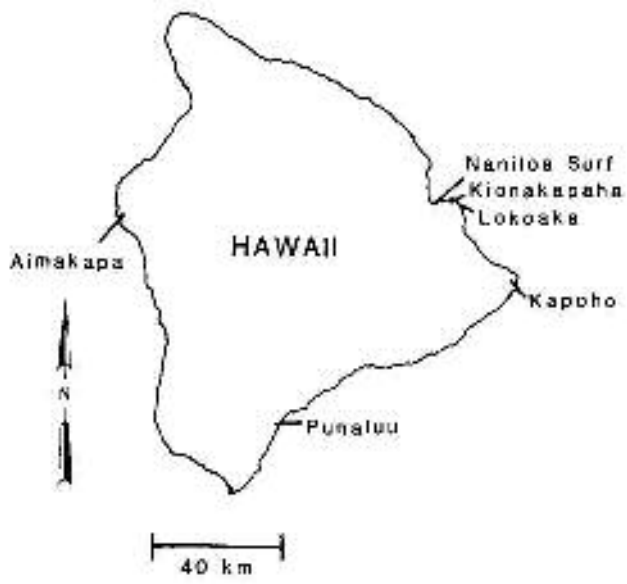

Fig. 1. Location of known egret roosts on Hawaii during the study period.

during the dawn departure or evening return period. Nests were monitored from the road through March and at the heronry thereafter.

Control.—During the precontrol phase the airport maintained a shotgun patrol, generally consisting of a single person who shot egrets opportunistically in an attempt to disperse feeding congregations. After we demonstrated a positive relationship between dawn rain and morning egret congregations at GLF in early February, the airport conducted patrols on all rainy mornings. An observer in the FA A tower monitored patrol efficacy (i.e., egret dispersal and return) during 9 dawn and 15 evening patrols.

During the control phase, egrets were mist-netted and clap-trapped at the heronry and shot at GLF, at the Hilo landfill, at a temporary roost on Kionakapahu Pond, and on a flyway crossing the pasture between GLF and Lokoaka Pond. Mist nets (4.3 m high x 12.8 m long, 10.2cm eye) were strung either as a single set running E to SW on the airport side of the roost tree or as a double set, with a second net running E to NW seaward of the roost to form a "V" enclosing the tree on 3 sides. Portions of the nets came to within 2 m of the roost tree. The clap trap used a spring powered mechanism to throw 2 6.4 m high x 12.8 m-long mist nets around the roost tree when triggered by rope from the east shore after dark.

Egrets were shot over decoys at GLF and in the pasture. At GLF, decoys were set about 20 m from two shotgunners in an habitual evening congregation area directly behind the terminal. We fired on virtually every incoming flock at GLF. In the pasture, decoys were placed at several locations along the flyway. Shooting began at about 1630 and continued until about 1830 at both GLF and the pasture. At Kionakapu Pond, grouped birds were shot from a blind about 30 m from the roost trees (coconut palms on a small island) as each successive flock landed. At the landfill, we used .22 cal rimfire rifles to collect feeding egrets from a parked car during the first 3 mornings, fired on groups of feeding birds with a shotgun from a bulldozer on the next 2 mornings, and then shot arriving egrets over decoys on the sixth morning.

Control of adult birds ceased on 16 December 1982. To prevent recruitment late in the control program and following cessation of adult control, we removed all chicks at intervals of 16 to 31 days until our active involvement ended on 15 July 1983.

RESULTS

Control Chronology and Response To Control.—A maximum of 547 egrets inhabited Lokoaka in January and February, 1982, but when control began in late June, only about 300 remained at the heronry. Known mortality from the GLF shotgun patrol (43 egrets) and our collecting (14 egrets) accounted for part of the decline. The majority of the missing birds apparently dispersed to Punaluu and Kapoho (Fig. 1) where they established temporary, non-breeding roosts. Continuous nesting during the precontrol and early control phases added an unknown number to the population, though fledging success appeared low (Paton et al. 1986).

Figure 2 summarizes the chronology of control, the number of egrets removed by each treatment, and the observed number of egrets roosting at Lokoaka. The theoretical population line in Figure 2 is based on the maximum number of egrets at Lokoaka in January minus known mortality (57 egrets) before onset of control; it is presented primarily to illustrate the removal rate rather than the absolute number of survivors.

From 28 June to 21 July, we eliminated 153 adult egrets by a combination of trapping, shooting and netting. Through 15 July, the observed population declined in accordance with known mortality and the egrets remained at Lokoaka. Between 15 July and 20 July, the population increased by about 130 egrets. The immigrants probably came from the roost at Kapoho, which was abandoned sometime between 10 July and 25 July.

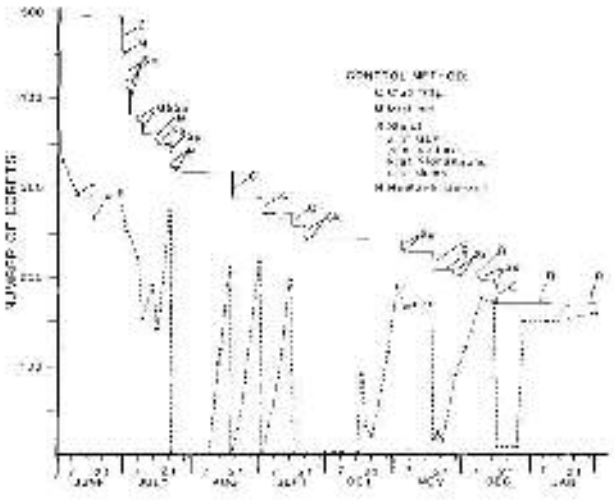

Fig. 2. Chronology of control, number of egrets removed from the theoretical population (solid line) and number of egrets roosting at Lakoaka (dashed line).

On 21 July all survivors moved 300 m west to Kionakapahu Pond in response to mist netting at Lokoaka. Roost abandonment may have been facilitated by a combination of low roost affinity among the immigrants and reduced affinity among residents due to gradual destruction of all nests and young.

Between 21 July and 14 September the entire population returned to Lokoaka 3 times, but retreated to Kionakapahu after the clap trap was sprung. No nests were established during this period. On 17 September, egrets abandoned Kionakapahu in response to shooting at that roost. Most survivors initially roosted at Kapoho, but all returned to Hilo within a week and joined the remainder of the population at a new roost at the Naniloa Surf Hotel, about 2 km NW of Lokoaka.

Some egrets returned to Lokoaka on 14 October and immediately began to nest though the majority remained at the Naniloa Surf for another two weeks. Trapping on 17 November again drove most of the population to the Naniloa Surf, but we spared nests during the trapping effort, and the continued presence of incubating adults at Lokoaka may explain the population' s subsequent return to Lokoaka within 2 weeks. We removed all chicks on 24 November and 7 December to prevent recruitment, but left all nests with eggs to hold the population at Lokoaka. Control of adult egrets ceased following a final trapping effort on 16 December.

Random censuses from 29 December 1982 through 15 June 1983 indicated a constant population of 150-160 egrets at Lokoaka. Except for the 6 egrets at Ainakapa (Fig. l),we know of no other egrets present on Hawaii Island at this time. During this period we removed 338 chicks and 64 eggs from nests with chicks. When our active involvement ended on 15 July 1983, almost 150 egrets remained. All were at least 1 year old and therefore capable of reproduction (Kohler 1966). By 20 January 1984, the population had increased to 506 fledged egrets and many nests were present (P.Q. Tomich, pers. comm.). Reduced crowding at the heronry probably improved nest success, but other mechanisms (interisland immigration and compensatory reproduction) may have been involved.

Response To Specific Control Measures.—The GLF shotgun patrol was only marginally effective in dispersing egrets from the airport during the precontrol phase. Egrets were still present or returned shortly after the patrol finished on 4 of 9 mornings and on 11 of 15 evenings. The patrol failed to prevent congregation on subsequent days and the 43 egrets killed during the 6 months that we monitored the patrol did little to reduce potential hazards.

In contrast, during our control program, "sustained shooting" at incoming egrets over decoys at GLF produced a prolonged avoidance of GLF. Before the program, as many as 250 egrets congregated at GLF most evenings and on almost every morning with heavy dawn rain. During the first 3 consecutive evenings of sustained shooting, we shot a total of 68 egrets. Decoying on days 4 and 5 attracted only 1 egret per evening; both were collected. None came in on day 6. About 100 egrets landed behind the terminal one evening in early September and another large congregation formed on 15 April 1983 during a heavy morning rainstorm. Except for these 2 instances, GLF remained free of egrets from 8 July 1982 through at least 15 July 1983. Moreover, for several weeks after the sustained shooting, most egrets overflying GLF crossed the runway at the far western end of the airport, suggesting active avoidance of the area where the shooting had occurred.

Although the results at GLF may have been confounded by ongoing control activities at the roost, similar results were obtained at the landfill. Five days of "shotgun patrol" type shooting reduced the size of the congregation, but the birds continued to feed there daily. However, after 1 morning of sustained shooting over decoys, dump usage ceased entirely for at least 3 months.

The only noticeable feature of the attempt to shoot over decoys on the pasture flyway was the rapid loss of decoy effectiveness. Flight paths remained unchanged, but during both attempts (July and November) egrets decoyed well only on the first evening. An observer at Lokoaka (350-700 m from the shooting site) reported that the sound of the shots caused no obvious reaction among birds at the roost.

When shooting over decoys, downed birds appeared to increase the attractiveness of the decoy spread and were left in place until shooting ceased. At the Kionakapahu roost, however, egrets killed by the first volley repelled successive arrivals. The first flock to arrive landed without hesitation and 6 egrets were shot. The next 10-15 arriving flocks circled once or twice and departed. After we removed the downed birds, the next flock landed immediately, but again, successive flocks departed without landing until we removed the dead birds. This pattern was repeated a third time during the evening. Based on the number of arriving birds and their flight paths, we believe that none of the departing birds attempted to return. The next evening, only two egrets came to the roost. Not only was the roost abandoned, but egrets also stopped feeding in the pasture bordering Kionakapahu Pond for at least 5 months.

As long as an appreciable number of egrets was nesting, egrets displayed little wariness of the clap trap. Nesting adults retreated to a nearby tree while we were setting the trap, but returned to the heronry immediately upon our departure. Birds returning in the evening landed immediately and many roosted on the support poles of the trap itself. However, in August and September, when no nests were present, all or most of the population left Lokoaka and roosted at Kionakapahu for 2 or 3 days after the trap was set at Lokoaka. Egrets also showed little reaction to the mist nets or our attendant activities as long as active nests were present. Roosting birds often flushed in response to aural or visual cues from netted egrets but returned within minutes, often before the netted bird broke free or was removed from the net. This suggests that cattle egrets may not have an alarm call, or, if one exists, that the call cannot easily be evoked and used to deter use of an active heronry. Egrets abandoned Lokoaka the only time we used mist nets in the absence of active nests.

From 5 January through 15 July 1983 we visited the heronry to collect chicks on 9 occasions. The adult popula-

tion continued to use the original heronry trees exclusively during this period and there was no detectable response (other than suspected renesting) to nest robbing. However, a spot check on 8 August 1983 revealed that most of the population had moved to, and was nesting in, a bamboo thicket on an island in the northwestern corner of Lokoaka Pond. Relocation may have been a response to continued nest disturbance or to roost degradation, as the banyan tree was badly defoliated and the pine tree had fallen down in mid June.

DISCUSSION AND CONCLUSIONS

We emphasize that our results are based on a single egret population and that previous treatments and/or a declining population may have confounded our results. However, the uniformity of egret response observed during repeated applications of each treatment suggests otherwise and the following four aspects of egret behavior appear applicable to other locations where egrets pose a problem.

First, the population demonstrated strong affinity for the Lokoaka roost site, probably because it served for both nesting and roosting. Despite continued harassment, the roost was not abandoned until all nests had been destroyed. When the egrets did leave Lokoaka, they initially relocated within 300 m and repeatedly attempted to recolonize the traditional roost. The new heronry that developed between 15 July 1983 and 8 August 1983 was within 75 m of the original heronry site. In contrast, one evening of shooting at Kionakapahu, a new roost without nests, caused permanent abandonment despite its having been occupied for 7 weeks. This behavior appears to verify the claim by Dusi (1979) that attempts to relocate cattle egret roosts should be undertaken before nesting begins. Differential response to the clap trap and mist nets when nests were present and absent was also consistent with this conclusion.

Second, the response of cattle egrets to dead conspecifics at Kionakapahu Pond suggests that egrets might be moved from a newly established roost by shooting a few birds and leaving the carcasses in view. This technique would probably have greatest potential in the case of small roosts over water or bare ground. The advantage to this approach would be low cost and minimal egret mortality. Conversely, at airports in particular where shotgun patrol activities are generally designed to quickly disperse egrets, the attraction exerted by dead egrets should be recognized and downed egrets should be collected as they are shot.

Third, the long-term deterrent effect of sustained shooting over decoys as opposed to shotgun patrol activities both at GLF and at the landfill may offer a potential low cost, low mortality method to prevent egret congregation at airports and other localized feeding sites. The method should be evaluated elsewhere. Although we concentrated on killing the offending birds, similar results might have been achieved with even lower cost and lower egret mortality. In actual practice, a remotely fired propane gun or other device that could be triggered selectively to alarm incoming egrets might achieve the desired effect without any mortality. The difference between results of sustained shooting and the shotgun patrol is most readily explained by behavioral conditioning. By the time the shotgun patrol reached a congregation, the birds had already received a food reward and the attraction to GLF was reinforced. In contrast, sustained shooting punished incoming flocks through fright or mortality and caused an aversion to the area. The apparent generalization of avoidance due to sustained shooting in a single locale in the evening to the entire GLF complex throughout the entire day was unexpected and might not occur at a larger airport. However, the fact that egrets did return to GLF en mass and without prior use by small numbers of birds on 2 occasions during the year following the sustained shooting program demonstrates that airport personnel must remain alert to the possibility of unexpected congregation as long as any egrets remain in the general vicinity.

Finally, explosive population growth began immediately after control ceased. Within 6 months, the population had almost regained its original size. The rate of recovery demonstrates that lethal control of cattle egrets in Hawaii will provide only temporary relief unless eradication is achieved or the program includes long-term measures to prevent recruitment among survivors. Furthermore, if egrets are migrating between islands, a statewide control program would be needed to resolve problems on a given island. Techniques to move roosts and heronries to more remote locations and to discourage congregation at airports appear more likely to alleviate airstrike hazards posed by cattle egrets than does population control.

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