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CONTROL OF FERAL GOATS ON ALDABRA ATOLL

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Abstract:

Recent increases in the numbers of feral goats (Capora hircus) on Aldabra Atoll, Republic of the Seychelles, raised concerns for the future of sensitive endemic biota because herbivory by goats was damaging some habitats and preventing seedling regeneration of preferred woody plants. A control program was initiated January-March 1987 in which most (n=56) of the goats on Ile Malabar were killed over 5 weeks. In addition, 292 goats were killed in the Cinq Cases region of Grande Terre over a 6-day period. A maximum kill rate of 5.15 goats/hunter-hour was achieved on Grande Terre. A second control program was conducted on Aldabra January-March 1988 and 525 goats were shot in 385 hunter-hours (1.36 goats/hunter-hour). We recommend continued efforts to eradicate the remaining goats on Aldabra.

A major threat to the biota of many insular systems is the feral goat (Capra hircus). Effects of an exotic, generalist mammalian herbivore, such as the goat, are so pervasive that Vitousek (1988) acknowledged the impossibility of preserving island ecosystems without eliminating such animals. There have been attempts to eradicate feral goats from at least 39 islands in the past 140 years (Daly and Goriup 1987); they have been eradicated from only a few (Parkes 1984, Rudge 1976, Williams and Rudge 1969). Many more islands are in need of immediate action. Information concerning the efficiency of goat control operations and their results on endemic insular biota need to be available to assist in the planning process.

Feral goats are an ecological liability on islands (Coblentz 1978, Daly and Goriup 1987, Vitousek 1988). Most reports concerning their influence on insular biota describe negative effects (reviewed by Daly and Goriup 1987, Coblentz 1978), including competition for food, removal of forest understory, severe erosion, and extinction of endemic species. Bates (1956) labelled the feral goat an "ecological dominant", and our experiences support that view. We define an ecological dominant as a species that has the ability to negatively influence structure of the physical habitat and depress production and species composition of the biota, and set back biotic succession to earlier seral stages, ultimately reducing biodiversity.

Feral goats (Capra hircus) have been present on Aldabra Atoll, Republic of the Seychelles (46°20′ E. Long., 9°24′ S. Lat., Fig. 1) in

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the western Indian Ocean, since before 1878 (Stoddart 1981); however, only recently has their presence been viewed with alarm. Goats on Aldabra (up to 17/km^2, Gould and Swingland 1980)have not achieved the high densities recorded on other, more productive oceanic islands(up to 490/km^2, Rudge and Clark 1978, 983/km^2, Williams and Rudge 1969) although Dupont (1929, cited by Stoddart 1981) reported "several thousands" in 1929.

Goat numbers on Aldabra were relatively low in recent decades (Stoddart 1971, Gould and Swingland 1980), but were believed to have increased rapidly since 1968 at which time few goats were seen or heard during a 2-month botanical expedition (F.R. Fosberg, Smithsonian Institution, pers. commun.). By 1976-77 goats were estimated at 500-600 on the atoll (Gould and Swingland 1980), and had increased to 1300 in 1985 (Burke 1988). This rapid increase prompted concern for the future of the Aldabran biota in general, and survival of the endangered Aldabran brush warbler (Nesillas aldabranus) in particular.

Our objective was to eradicate all goats from one of the major islands, Ile Malabar; and to assess the possibility of eradicating goats from the entire atoll.

STUDY AREA AND METHODS

Aldabra Atoll consists of 4 major islands of which 3 currently have goats (Picard, Malabar, Grande Terre). This area is a large uplifted coral atoll of 155 km^2 including mangrove areas (Gould and Swingland 1980). The climate is semi-arid (mean annual rainfall 94.1 cm, Stoddart and Mole 1977) and tropical, with a May-October dry season and a November-April wet season (Gould and Swingland 1980).

We hunted goats from 30 January to 8 March 1987 and 20 January to 15 March 1988 with centerfire (primarily .223 Rem.) bolt-action rifles equipped with telescopic (4X) sights. In 1987 all accessible areas on Ile Malabar were searched for goats and goat sign (feces, browsing, vocalizations). Goats were shot when seen, and areas having sign were hunted repeatedly until it appeared all individuals had been located and killed.

In 1987, goats were hunted for 6 days on Grande Terre. Goats killed during the first 4-day visit were weighed and examined; those killed during a subsequent 2-day visit were not. Weighing was time-consuming and was eliminated during the second hunt so that a maximum rate of kill could be determined. Our 1987 effort on Grande Terre was focused in an area about 1 km wide between the boat landing at Bras Cinq Cases and the coastal zone to the South of Cinq Cases.

During the 1988 program, most hunting effort was on Grande Terre. A 3-day visit was made to Ile Malabar to assess the success of the 1987 effort; all goats observed on Malabar in 1988 were killed. Additionally, the small population of goats on Ile Picard was hunted whenever time and weather permitted.

In both years, the number of hunter-hours of effort and the number of bullets used were recorded. Hunting in 1987 was done by a 2-person team; a 3-person team was employed in 1988.

RESULTS

Goats Killed on Ile Malabar

Fifty-six goats were killed in 1987 (Table 1), representing all goats that were observed except 2 males (that might have been killed in subsequent encounters). In 1988, the entire area hunted during 1987 was examined carefully for goats and goat sign. A single group of 5 goats was observed and killed in the Middle Camp area. There may have been other surviving goats on Ile Malabar, but we could not find them.

Of 61 goats removed from Ile Malabar during two hunts, 34 were killed in the vicinity of Middle Camp at the east end of the island, and 27 from the area adjacent to and east of Anse Malabar. In 1987 we located no sign of goats farther west than Anse Grand Grabeau, and no evidence of regular use by goats more than about 1 km west of Anse Malabar. In 1988 we encountered no goat sign west of Middle Camp.

Although we caution against excessive optimism, there are several lines of evidence that support our belief that we have nearly eradicated goats from Ile Malabar. Indeed, goats initially seen but not killed usually were observed repeatedly until killed. Nearly all goats visually identified (56 or 58) in 1987 were eventually killed. In a few areas dense vegetation made visual contact with goats difficult, although goats were often heard calling. Three groups recognizable by both adult and juvenile vocalizations were killed eventually in the general area (<1 km) where initially heard. Number and age of goats we killed invariably agreed with our expectation of group composition based on vocalizations.

Lastly, by the time we had killed what we believed to be the last goats in each area, we never again found fresh sign in that locality. For example, in the Middle Camp area where all goats killed in 1987 were shot in 5 days (Fig. 2A), no goats or fresh sign were seen in 3 subsequent days of intensive searching. In 1988 only a single group was seen in 3 days; after they were killed no other goats were evident.

Goats Killed on Grande Terre

In 1987, the first 4-day hunting effort resulted in 127 goats killed (Table 1). Because much hunting time was spent measuring and examining goats, a subsequent visit of 2 days was made to Cinq Cases to determine potential rate of kill; during this visit (1987, Cinq Cases 2, Table 1) the kill rate increased dramatically.

In 1988, we shot 525 goats (Table 1). An additional 10 goats were captured on Grande Terre and killed without shooting, for a total of 535 goats killed in 1988.

Most goats killed in 1988 (390) came from the Cinq Cases region in three hunting periods, totaling 11 hunting days, from approximately the same area that was hunted in 1987, except that hunting in 1988 extended further north past Pt. Hodoul. Only 24 of 390 goats (6%) killed at Cinq Cases were encountered and killed near the lagoon; most goats were encountered in the coastal zone.

An average of 1.36 goats killed/hunter-hour was achieved during 1988; however, this measure of efficiency varied considerably among areas hunted depending upon our level of effort and availability of goats. Efficiency in the Cinq Cases region was consistent, with 2 goats killed/hunter-hour (Table 1) during all three hunting periods. Only 0.18 and 0.31 goats were killed per hunter-hour on Ile Malabar and Ile

Picard, respectively, probably because both areas had very few goats at low density and relatively thick vegetation. Number of shots fired per goat killed varied from 1 shot/goat on Ile Malabar to 2.36 and 2.38 shots/goat at Dune D'Messe and Anse Cedres, respectively (Table 1), where goats (6 groups) were surprised at close range in thick cover.

Proportion of goats killed

Populations of feral goats tend to live in discrete ranges (Coblentz 1974). On Aldabra we were able to quickly establish the geographic limits and approximate number of individuals in relatively small populations when such populations inhabited fairly open terrain, most individuals were killed in a few days (Fig. 2).

Population sizes for Middle Camp in 1987 (N = 32) and Dune Jean-Louis in 1988 (N = 49) were estimated by the method of Leslie and Davis (1939) in which catch per unit effort (Y) is regressed against cumulative catch (x), and population size determined by the x-intercept ($N = -a/b$). Our results indicate that we killed 91% and 90%, respectively, of the goats estimated to be present in these populations when the project began.

Large numbers of goats that inhabited the region from Pt. Hodoul to several kilometers west of Cinq Cases were a series of discrete populations. Because of time limitations we chose to work the entire area simultaneously, and as a result our kill rate remained somewhat stable throughout the entire project (Fig. 3). In this area, the estimated population (1352) was greatly in error, and if the project had continued the kill rate would have declined as goats became increasingly scarce.

In two short field seasons totaling 11 weeks on Aldabra we eliminated 883 goats. Assuming Burke's (1988) estimate (1300) was representative of the total population, we eliminated nearly 70% of the population.

Cost of eradication

Accurate calculation of the cost per goat killed during this project is tenuous. Excluding salaries, the cost per goat killed on Aldabra in 1988 was approximately $12 U.S., and about 65% of that was travel costs from Portland, Oregon, to Mahe, Republic of Seychelles. We purchased reloaded .223 caliber (soft-point) ammunition for $180 U.S./1000 rounds, therefore the bullets used to shoot goats (n = 1004, Table 1) cost $180.72 U.S., or $0.34/goat.

DISCUSSION

Consequences of goat populations on island vegetation are negative and well documented (Coblentz 1978, Daly and Goriup 1987). Taylor's (1968:62) caution that precipitous removal of goats may lead to "unexpected and even undesireable results" pales in comparison to the certain ecological catastrophe of allowing goats to remain unchecked in insular ecosystems.

Although no figure is available, there may be more than 100 islands worldwide supporting feral goat populations. Length of time goats are present on an island before being removed partly determines the recovery rate of affected plant species (Hamann 1979). For example, Hamann

reported that vegetation recovery on Isla Pinta (Galapagos), where goats existed in high nmumbers for less than 3 decades, has been considerably more rapid than on Isla Santa Fe where goats were present for at least twice as long. It can be inferred from Hamann (1979) that the sooner feral goats are eliminated from an island, the more rapidly plant species will recover because the number of viable seeds of sensitive plant species, and the number of seed producing individuals, is inversely related to the length of time that goats have been present.

Goats were severely damaging some portions of Grande Terre (Coblentz and Van Vuren 1987). We noticed extensive browsing well into the mangrove zone, and a nearly continuous browse line of roughly 2-m height on all palatable species. Regeneration of palatable woody species was nonexistent, even in areas where the endemic tortoises (Geochelone gigantea) were excluded by dense brush or jagged champignon limestone. Although tortoises are a major influence on the vegetation of Aldabra (Hnatiuk et al. 1976, Merton et al. 1976, Swingland and Coe 1979, Gould and Swingland 1980), goats are an additive influence that also can eliminate plants in refugia safe from tortoises, thus increasing the chance of extinction of sensitive species.

Results of the 1987 program on Ile Malabar were dramatically visible in 1988. Although not measured quantitatively, vegetation in the Middle Camp area was visibly more dense within 2 m of the ground and we considered this to be strong circumstantial evidence that elimination of goats allowed plants to regrow in this layer.

In former sleeping areas of goats to the east of Middle Camp, and extending to the east of Anse Malabar, areas that formerly had been browsed heavily were growing back rapidly. In these areas, Pemphis shrubs had formerly been browsed heavily as high as goats could reach. When we examined Pemphis in these areas in 1988, a luxuriant growth of basal sprouts of up to 0.5 m in length was apparent at the base of each shrub. Presumably these basal sprouts are evidence of lowered browsing pressure by goats.

Vegetation recovery on Grande Terre following the 1987 control program was not evident in 1988. We did not see regrowth of vegetation in the 2-meter-high zone browsed by goats. With the kill of an additional 390 goats in this area in 1988 we predict that growth of vegetation will proceed more rapidly.

There are two alternative levels of control for feral goats: partial reduction (control); and complete eradication. Control entails periodic efforts and prolonged expense, essentially ad infinitum. In addition, goats respond to reductions in a density-dependent manner by increasing natality (Coblentz 1982, Parkes 1984). On Raoul Island, Parkes (1984) documented an increase in productivity of goats after population reduction, whereas Rudge and Smit (1970) determined that a goat population reduced by 80% could rebound to 90% of the former level in 4 years. Consequently, control efforts must be conducted regularly to prevent rapid recovery of goat populations.

Methods other than shooting have been suggested for eradicting goats, including poisoning, introducing predators or disease, sterilizing males, and trapping. Poisoning with sodium monofluoroacetate (Compound 1080) was effective, killing >90% of goats in treatment blocks in New Zealand (Parkes 1983); however, poisoning is unacceptable for use in a World Heritage Site such as Aldabra because of

the possibility of primary and secondary effects on endemic species. Dietary overlap between goats and tortoises, and our observations of tortoises scavenging on dead goats on Grande Terre indicate the potential for nontarget poisoning, although the median lethal dose (LD_{50}) for the poikilothermic tortoises is probably high in comparison to goats (Atzert 1971).

Introduction of predators is unsuitable on Aldabra because of potential effects on endemic species. Introduction of a disease, if a suitable one could be found, might temporarily control a population, but not eradicate it. Sterilization of males is unworkable because every male would first have to be trapped or tranquilized, a prohibitively expensive and probably impossible operation. Also, killing trapped goats would be more effective than releasing them to continue damaging the environment.

If poisoning is judged unacceptable, then shooting is probably the most effective and cost efficient method of eliminating feral goats in the initial phase of an eradication program. Carefully done, large numbers of goats can be killed quickly (up to 5 goats/hunter-hour, this study), inexpensively, and humanely.

Any shooting program should minimize the number of goats that survive encounters with hunters. During the 1981-83 eradication program on Raoul Island, New Zealand, an average of 19% of goats seen escaped (Parkes 1984). During our 1987 program on Ile Malabar, 20% (14 of 70) of goats in groups that were fired upon escaped (all but 2 males subsequently killed), and on Grande Terre during the initial 4-day shooting period 11% (16 of 142) escaped (number subsequently killed unknown). During the 1988 program 14% (83 of 581) of goats in groups that were fired upon escaped, but we know that a number of these escapees were killed in subsequent encounters. Goats that escape an encounter with shooters may become more wary and difficult to kill; the last 5 goats removed from Raoul Island required a total of 2 man-years and cost $12,500 NZ each (J.P. Parkes, New Zealand Forest Service, 1985 personal communication to D.W. Baber).

We believe that the 3-person shooting team employed in 1988 was a trade-off between increased firepower and increased risk of alarming goats. Escape by goats that were fired upon was not substanitally affected by the additional firepower, nor was the number of bullets fired per goat killed. We did notice in several instances that there was insufficient cover to conceal 3 stalking hunters, and in such instances goats became alarmed sooner than if there had been two hunters. The highest kill rates (5 goats/hunter-hour) and lowest expenditure of ammunition per goat killed (1.4 bullets/goat, Ile Malabar, 1987) were accomplished by the 2-person team.

Differences in rate of kill and accuracy among areas hunted (Table 1) resulted from several factors including group size of goats, amount of cover available for stalking, distance to goats when first observed, and level of excitability of goats that were encountered. In contrast, the stable rate of kill achieved during three hunting periods at Cinq Cases in 1988 (Table 1) was due to the combination of a large population in a large area, limitations on how much area could be covered in a day, and to our improving ability to anticipate, find, and shoot goats even as populations declined.

We expected that difficult terrain (champignon limestone), dense vegetation and extreme heat would combine to make the eradication of goats on Aldabra difficult, but control was easier than anticipated. We attribute this to our experience from similar projects, and the relatively narrow landmass forming the ring of the atoll. We believe that goats can successfully eradicated from Aldabra. We have demonstrated that large numbers can initially be killed; after the majority have been killed, as they were by our efforts, the remainder can be efficiently located and killed through the use of radiocollared "Judas goats" (Taylor and Katahira 1988). In this technique the gregarious sociality of the goat is exploited by repeatedly relocating radiocollared goats and shooting the other members of their groups. Judas goats repeatedly (Taylor and Katahira 1988) and quickly (BEC, pers. obs., San Clemente Island, California) locate other goats.

SUMMARY

Recent increases in the numbers of feral goats on Aldabra Atoll, Republic of the Seychelles, raised concerns for the future of sensitive endemic biota because grazing by goats was damaging some habitats and preventing seedling regeneration of preferred woody plants. We initiated a control program, by shooting, in January-March 1987 and continued January-March 1988. In 11 weeks on Aldabra, 883 goats were eliminated, including most (N = 61) inhabiting Ile Malabar. In small populations living on relatively open habitats, most individuals (91% Middle Camp, 90% Dune Jean-Louis) were killed in only 5 days of hunting. Our total kill may have been as high as 70% of the goat population on Aldabra.

Goats shot/hunter-hour ranged from a low of 0.18 (Ile Malabar, 1988) to 5.15 (Cinq Cases 2, 1987). The mean efficiency was 1.36 goats shot/hunter-hour in 1987 and 1.61 in 1988. The cost per goat killed in 1988 was approximately $12 U.S.; ammunition costs were only $0.34 U.S. Most of the costs were for transportation.

We demonstrated that large numbers of goats can be killed quickly and cheaply on Aldabra, and probably many other islands as well. Because of numerous direct and indirect effects of goats on insular biota, we strongly advocate removal of the remaining goats from Aldabra in particular, and from sensitive oceanic islands in general. We recommend that goats be killed by shooting them with small caliber centerfire rifles by trained 2-person teams of marksman.

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Table 1. Numbers of goats killed, hunter-hours, number of shots fired, and efficiency of hunting by location for goats killed on Aldabra Atoll, Republic of the Seychelles, January - March 1987 and January-March 1988.

Location	Goats Shot	Hunter-Hours	Shots Fired	Goats Shot/ Hunter-Hour	Shots Fired/ Goat Killed
1987					
Ile Malabar	56	127.5	77	0.44	1.38
Cinq Cases - 1	127	56	217	2.27	1.71
Cinq Cases - 2	165	32	--[a]	5.15	--[a]
Total 1987 --		348	215.5	--	1.61
1988					
Cinq Cases - 1	130	66	218	1.97	1.68
Cinq Cases - 2	164	76.5	332	2.14	2.02
Cinq Cases - 3	92	48	175	1.92	1.90
Dune Jean-Louis	42	40.5	73	1.04	1.74
Dune D'Messe	14	29.2	33	0.48	2.36
Dune Blanc-Gros Ilot	62	66	136	0.94	2.19
Anse Cedres	8	4.5	19	0.56	2.38
Ile Malabar	5	28.5	5	0.18	1.00
Ile Picard	8	26	13	0.31	1.62
Total 1988	525	385.2	1004	1.36	1.91

[a] data not gathered during this hunt

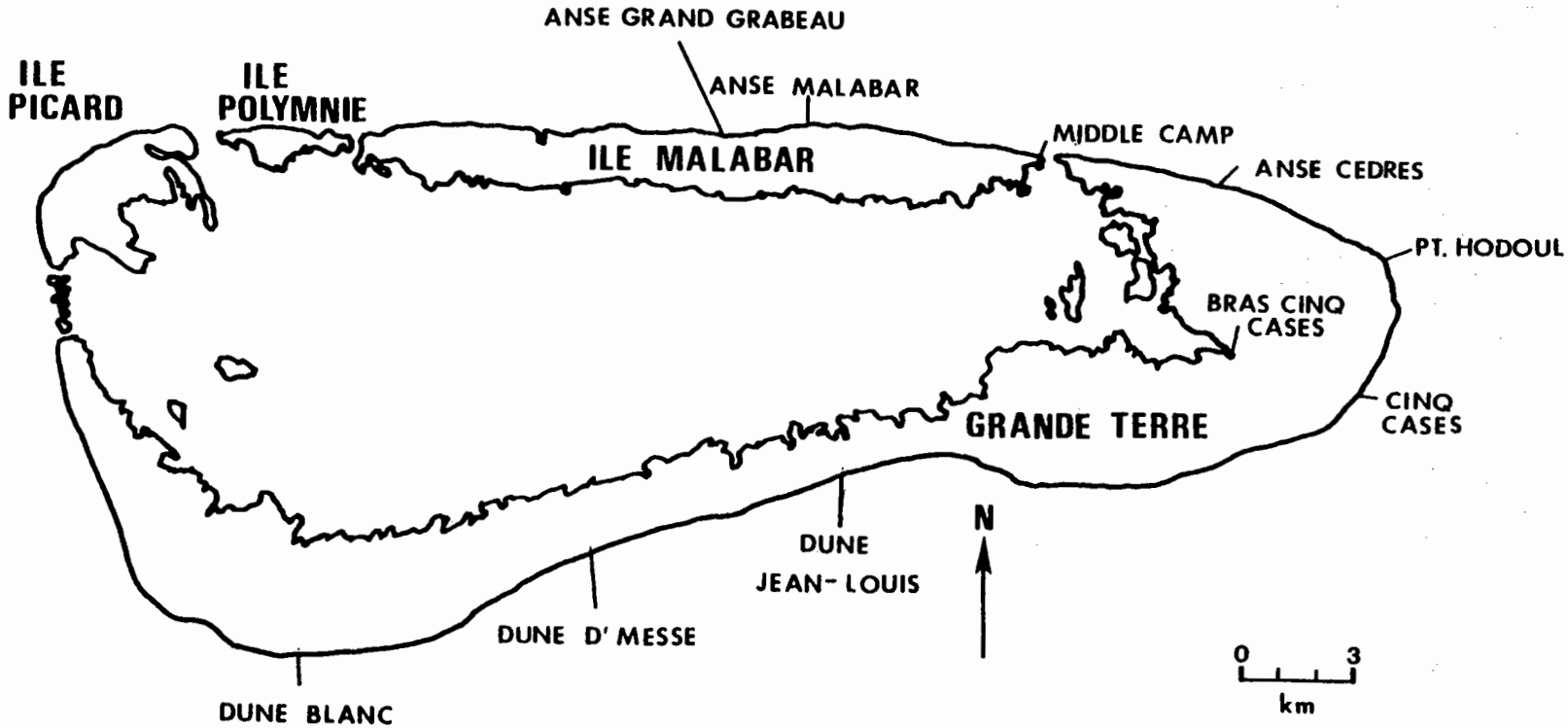

Figure 1. Aldabra Atoll, Republic of the Seychelles, showing placenames in areas where goats were hunted.

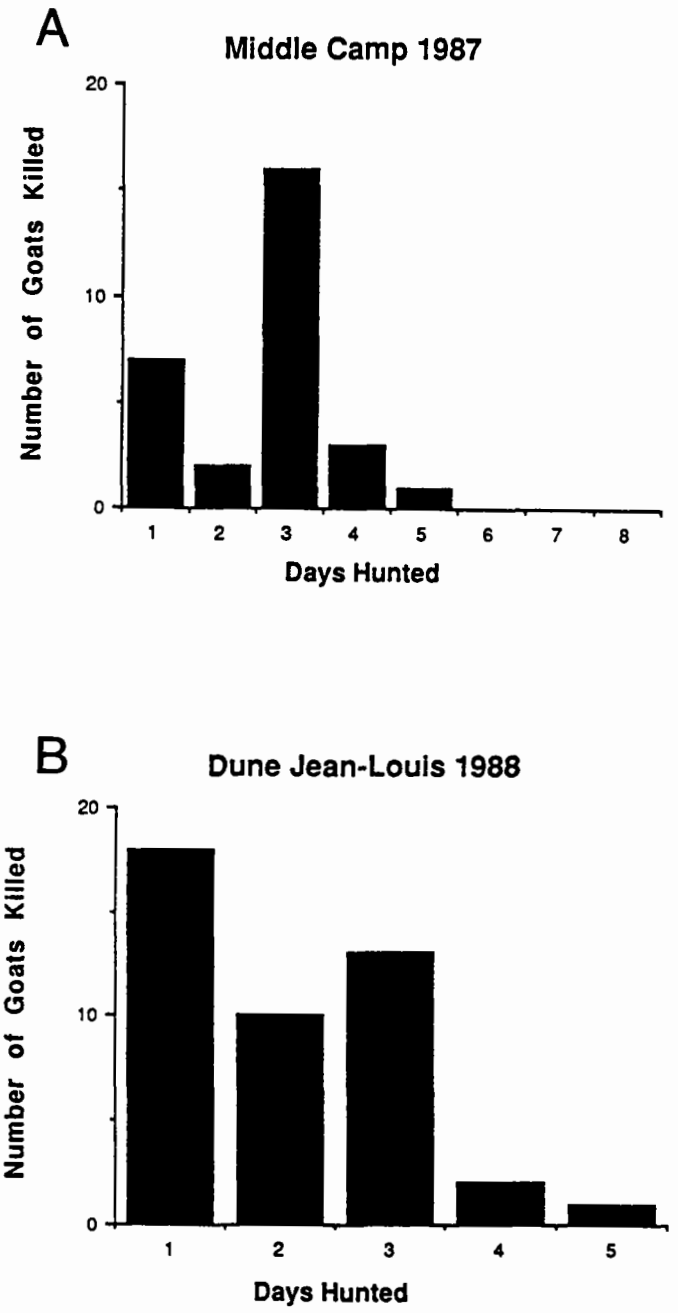

Figure 2. Number of goats killed on successive days of hunting at Middle Camp (A), and Dune Jean-Louis (B), Aldabra Atoll, February, 1987 and January, 1988, respectively.

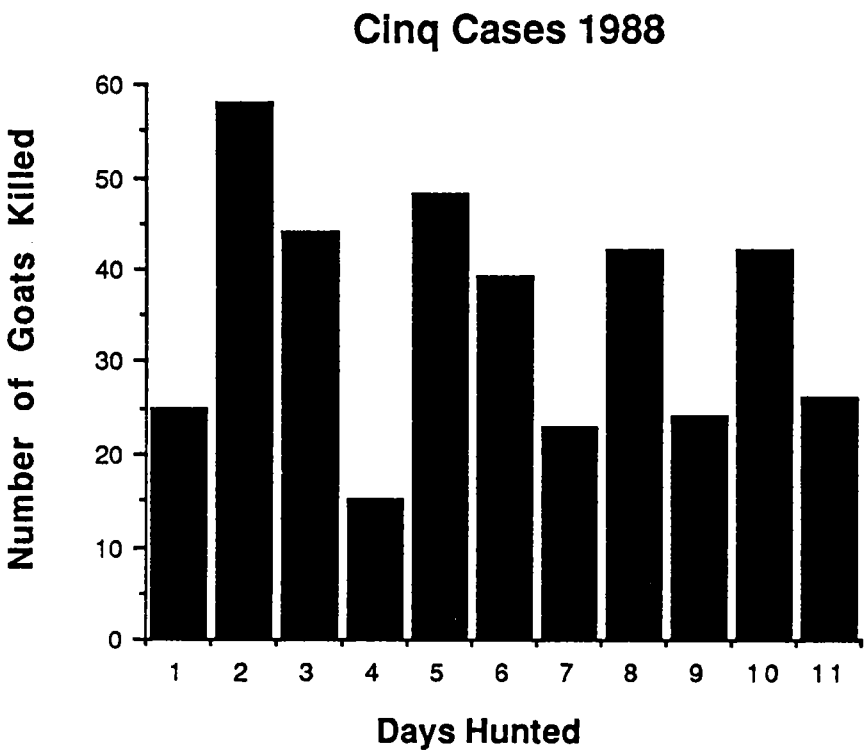

Figure 3. Number of goats killed on successive days of hunting in the Cinq Cases - Pt. Hodoul region, Aldabra Atoll, January-March, 1988.