# Recent Invasions of Micronesia by Small Mammals

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## Abstract

The introduced shrew, *Suncus murinus*, was discovered on Guam in May 1953. Its spread was rapid and probably facilitated by the transport of goods. The shrew was discovered on Saipan in August 1962 and spread from an area of about four square miles around the harbor to cover the rest of the island in about 18 months. Subsequent successful invasions have been reported for Rota (1966) and Moen, Truk Atoll (1967). The shrew has had no observable impact on ground-nesting birds. A marked decline in trap success for *Mus musculus* on Guam from 1958 to 1969 is the only measured change in the vertebrate fauna that can be attributed to the shrew, although changes in densities of skinks may have occurred.

The Norway rat, *Rattus norvegicus*, was known to be present in Saipan and certain other islands for many years but the first record for Guam was not obtained until 1962, apparently a few years after its introduction. In contrast to the shrew, the spread of the Norway rat has been slow—the spotty records covered no more than 20 square miles by 1969. The first record for the Norway rat on Babelthaup, Palau, is noteworthy because of the apparent feral status of the species. Reasons for the different levels of success shown by the shrew and the Norway rat in Micronesia are not known.

## Introduction

With the discovery, colonization and development of the islands of Micronesia by man, many species of organisms have been introduced, both accidentally and intentionally. Islands are well known for their susceptibility to invasion (Elton, 1959; MacArthur and Wilson, 1967) but the patterns and processes of specific invasions often go unstudied, leaving the facts subject to later speculation. Much worse, from the standpoint of interpreting the consequences of new introductions, appropriate, quantitative descriptions of the preexisting biota are rarely available. The following account describes the recent history of invasions by small mammals in Micronesia. Most of the records are available by chance rather than by design but they disclose fundamental differences in the initial levels of success achieved by the shrew, *Suncus murinus*, and the Norway rat, *Rattus norvegicus*. The possible effects of the shrew on other vertebrates is evaluated subjectively.

This account stems primarily from an extensive study of small mammal populations on Guam from May 1962 to May 1964 and from the trapping records of the Sanitarians, Department of Health and Welfare, Government of Guam, from 1956

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to 1969. I conducted brief studies in Saipan from 1962 to 1964 and again in 1969; in Palau in 1964; and again on Guam in 1965, 1966, and 1969. Supplemental observations have been kindly provided by other biologists: Dr. D. M. Davis, M. V. Cushing Falanruw, I. I. Ikehara, and R. P. Owen.

**Suncus murinus Linnaeus, The House Shrew**

GUAM. The shrew was discovered at Apra Harbor in May, 1953 (Peterson, 1956). Within two years it was found at both the Naval Communications Station (Fig. 1: 39) and at Andersen Air Force Base, distances of 15 and 20 miles respectively from the port of entry. Evidently the spread was facilitated by the transportation of goods. Colonization of the island was essentially complete by 1958 (Barbehenn, 1962), with every conceivable habitat being occupied. While we cannot trace the spread of the shrew on Guam with precision, we can comment on some of the possible impacts as viewed from 10 and 20 years after the invasion.

In most cases, the possible effect of the shrew on other organisms can be inferred only from subjective observations. Judging by stomach contents, the major food of the shrew on Guam consists of invertebrates but it is capable of feeding on any small vertebrate. Ground-dwelling skinks are a likely target for *Suncus* and, during hundreds of hours tending trap lines in the fields during 1962 to 1964, I never observed skinks. In 1972, Dr. D. M. Davis (personal communication) reported that skinks (*Carlia fuscum*) were common in fields. The wide disparity between these two observations suggests that skinks may have been greatly reduced by predation soon after invasion but that a recovery occurred, perhaps associated with behavioral adaptations that reduced susceptibility to predation.

Since the shrew can kill baby chickens (Barbehenn, 1962), ground-nesting birds might be vulnerable to predation. The flightless rail (*Rallus owstoni*) is of great concern, since it is unique to Guam. To date, the "Coco" is still commonly seen along the roadsides of Guam (Perez, 1968). M. V. C. Falanruw (personal communication) reported seeing adult rails attacking and killing shrews on two occasions. Maternal care may be an adequate defense against the shrew. The introduced quail, or "bing-bing" (*Coturnix chinensis*) weighs only 35 g and its young would seem to be easy prey for a 30 g shrew. Quail were fairly common in certain fields from Harmon Village to North West Airfield (Fig. 1: 18 and 17) during 1962–1964 and I. Ikehara (personal communication, April 1973) reports that they are still common in the communication antenna fields of the same area. Thus, whatever level of predation may occur, there is no evidence to suggest an observable impact of the shrew on ground-nesting birds.

The shrew is a potential predator on house mice and on young rats (Barbehenn, 1962). The records of routine trapping conducted by the Sanitarians indicate that standardized trap success for *Mus musculus* declined by approximately an order of magnitude from 1958 to 1969. Baker's (1946) study indicated

a mean density of about 6.3 mice per acre from May to October on his study plot. Values for *R. rattus* and *R. exulans* were 7.4 and 4.0, respectively. In a wider variety of both seasons and field habitats from 1962 to 1964, mean densities for 20 trappings were 5.4 *R. rattus* and 4.2 *R. exulans* but only 1.4 *Mus* per acre. At 6.2/acre, *Suncus* was the most abundant species. The highest density for *Mus* among these samples was 4/acre and this limited evidence again suggests that mice declined in abundance following the invasion of *Suncus*. While the ultimate fate of the house mouse is uncertain, I have no evidence to suggest that the shrew has had a pronounced, long-term, deleterious effect on any other vertebrate species. Obviously, the records are incomplete.

The possible impact of the shrew on the economy and health of the human population is uncertain. Certainly the shrew is at least a minor pest when it enters houses. It may kill some baby chicks as previously reported (Barbehenn, 1962) but subsequent tests (1963, unpublished) in the laboratory with well-fed shrews did not result in mortality among the test chicks, which were deformed at hatching and relatively helpless. The shrew was initially implicated in the outbreak of rabies on Guam in 1967 but it seems unlikely that the disease became established in the shrew population, since the shrew proved to be refractory to intramuscular injections of rabies (letter from Dr. Kieth Sikes to E. P. Yarnell, 12 September 1968). *Suncus murinus* is involved with the transmission of plague in Vietnam (J. D. Marshall *et al.*, 1967) but fleas of any sort are rare on the small mammals of Guam. It is noteworthy that a dense population of the rat flea, *Xenopsylla cheopis* (identified by Dr. E. W. Jameson) developed in our laboratory colony of *Suncus* in 1962.

SAIPAN. The shrew was discovered on Saipan in August 1962. Its distribution and subsequent spread were determined by setting traps in various areas, by driving roads at night and, in some cases, by reports of residents whose statements were judged to be reliable. While the surveys were necessarily limited, the pattern and rate of spread of the shrew seems clear.

Using the probable port of entry as the center of a circle (Fig. 2), the approximate distribution of the shrew can be traced through time with radial increments of about two miles for each sixmonth period. The rate of expansion may not have been uniform but the extremes can be indicated. As a minimum, shrews could have moved from south of San Roque village to the top of Mt. Marpi, a distance of three miles, in one year. As a maximum, they could have travelled from the zone 1.5 miles from the harbor to Mt. Marpi (five miles) in six months. The latter extreme seems unlikely. Nachsa Siren trapped in San Roque village in January 1963 but took no shrews. The ? on Fig. 2B represents a chirp heard by Gil Dryden while three of us were looking for coconut crabs at night.

In contrast to the circumstances on Guam, the probability that the spread of the shrew on Saipan was facilitated by human transport is minimal. The Marpi area north of San Roque and the Kagman peninsula were uninhabited and "off-

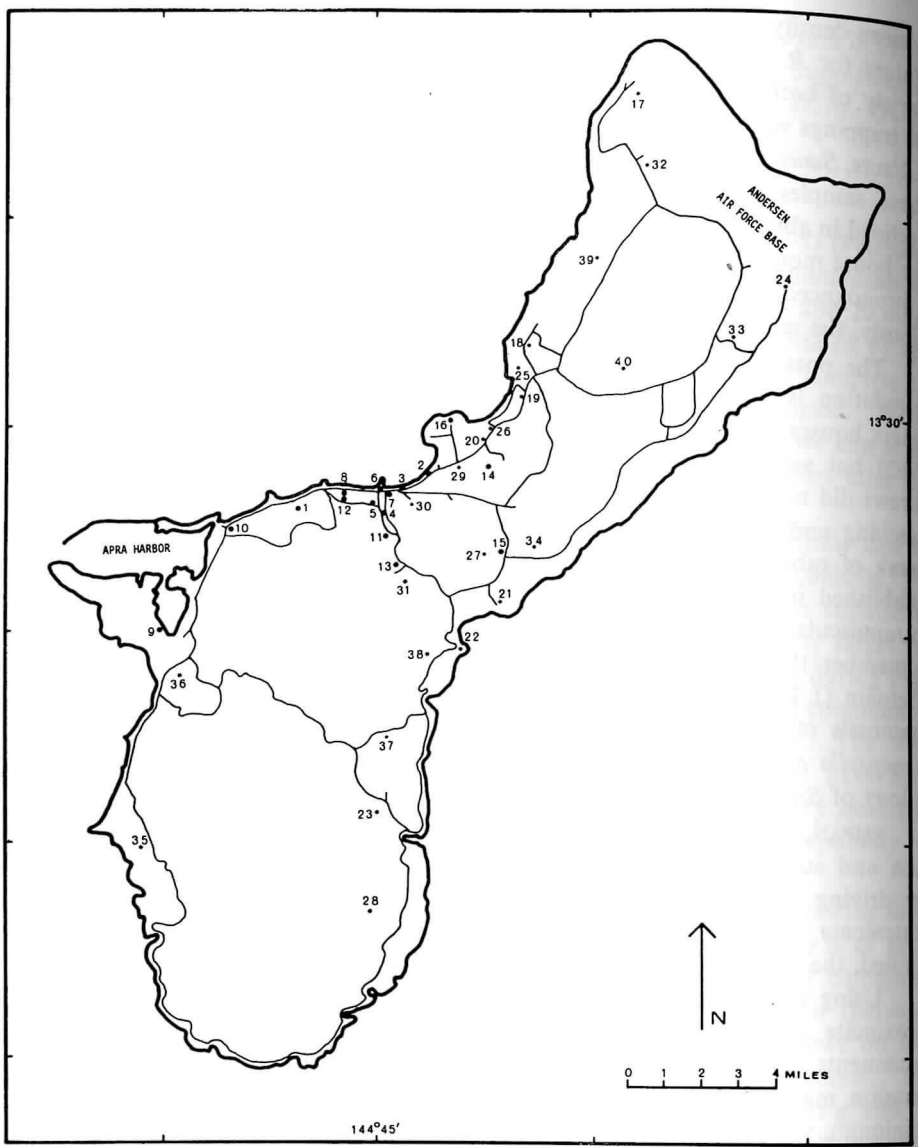


Fig. 1. Map of Guam showing locations of major trapping area. Larger dots (1–16) indicate areas where Norway rats have been taken in chronological order; 1962: 1) Asan, 2) Tamuning, 3) E. Agana, 4) Agana Vista; 1963: 5) Governor's area; 1965: 6) original Farmers' Market, 7) Guma Construction Co., 8) Agana Ice Plant; 1967: 9) Commercial Port; 1968: 10) Procurement & Supply, Piti, 11) Rehabilitation Center, 12) New Farmer's Market, 13) KUAM, 14) International Airport; 1969: 15) Agriculture, 16) Guam Memorial Hospital. Smaller dots (17–40) indicate areas where extensive trapping failed to produce Norway rats prior to cessation of trapping in the indicated year; 1969: 17) Northwest Field, 18) Harmon Village, 19) St. John's School, 20) Brodie School, 21) University of Guam, 22) Bordallo Mansion, 23) Talofofo Staff Housing; 1968: 24) Andersen

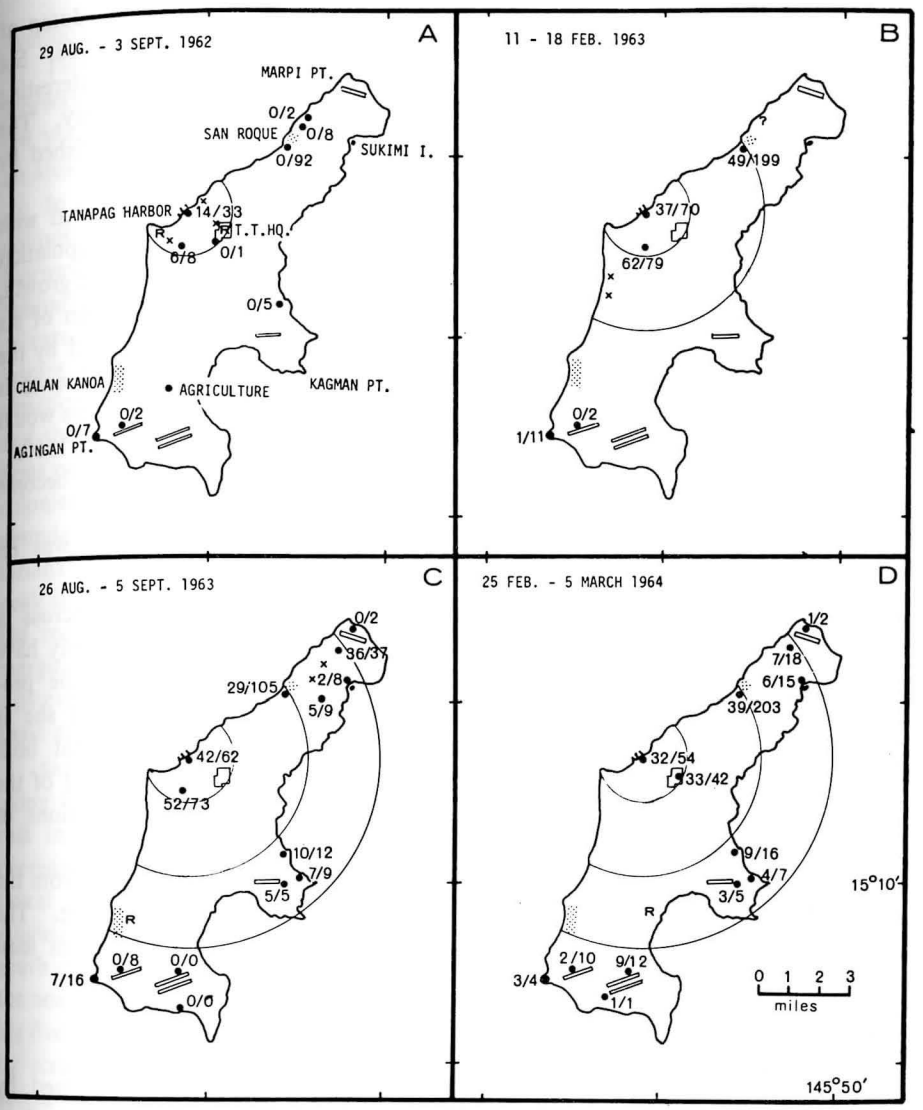


Fig. 2. A–D. The island of Saipan, showing trapping locations (solid points), numbers of shrews among the total number of small mammals trapped (fractions), sight and sound observations of shrews (x's and ?), and reliably reported records of shrews (R). Semi-circles indicate the approximate changes in the distribution of the shrew through time.

School, 25) Cliffline, 26) JFK (Tumon) High School; 1967: 27) Detention Home; 1966: 28. NASA; 1965: 29) Public Works, 30) George Washington High School, 31) Ordot Prison; 1964: 32) Northwest Housing, 33) Yigo meadow, 34) Barrigada Transmitter site; 1961: 35) Agat dump; 1960: 36) Immigration Housing, 37) Camp Witek, 38) Yona dump, 39) Naval Communication Station; 1958: 40) Dededo dump.

limits" when the shrew invaded. An obvious exception is the refuse dump at Agingan Point. One adult male shrew was taken there in February 1963. Six months later (Fig. 2C) the colony was clearly established but it is interesting to note that it had not yet spread as far as Kobler Field, about one mile away. The invasion of the southern tip of Saipan (Fig. 2D) was probably accomplished by the main wave from the north rather than from the point source.

The actual date when the shrew invaded Saipan cannot be estimated with precision. As illustrated by the situation at Agingan dump, a small population cannot expand at the rate of four miles per year. Assuming maximal rates of growth, reproduction (Dryden, 1968, 1969), and emigration and a mean life span of six months, the time required to cover the area of four square miles occupied by the shrew in August 1962 at a density of four shrews per acre (10,000 shrews) is approximately 20 months). If the mean life span is four months, the process would take 30 months. A reasonable guess for the time of establishment is mid-1960.

ROTA. In September 1966, R. P. Owen told me that the shrew had become established on Rota.

TRUK. In September 1967, R. P. Owen indicated that the shrew was on Moen.

PALAU. In 1963, Nachsa Siren reported seeing a shrew run across a road in Koror. No subsequent observations have been made and this may have been a sterile introduction. Assuming a single shrew is introduced, the probability is about 0.5 that the animal is a female, perhaps 0.5 that she is pregnant, 0.67 that she carries a male offspring, and perhaps 0.7 that both mother and son will survive to produce another generation. The product of the probabilities is 0.12, indicating that only one of every eight introductions of single individuals is likely to found a new population.

The shrew was presumed by Peterson (1956) to have been introduced from the Phillipines and Johnson (1962) agrees that this is the most likely source. The invasions of Saipan, Rota, and Truk probably originated from Guam, at least indirectly.

**Rattus norvegicus Berkenhaut, The Norway Rat**

GUAM. The first record of the Norway rat on Guam was produced by Manuel Taitano of Asan in May 1962. He indicated that these rats had lived on his premises for several years and brought us an additional 15 specimens over the following 18 months, indicating a well established colony. From May 1962 through May 1964, nearly 5,000 small mammals were examined from about 50 localities closely associated with human activities and a like number from 20 localities more remote from human habitation (Barbehenn, 1962a). Only six additional Norway rats were taken: one at Agana Vista in August 1962, four from Tamuning and East Agana in November 1962, and one at the Governor's garden in August 1963. In all cases the identity of the species was recognized by the Sanitarians and it seems reasonable to believe that few if any Norway rats were

overlooked in catches not examined by biologists.

From 1964 until the Sanitarians' trapping program ended in November 1969, Norway rats were taken at eleven additional localities (Fig. 1). Thus, roughly ten years after introduction, the known distribution of the Norway rat covered an area of no more than 20 square miles.

In contrast to the shrew, which quickly became both abundant and essentially ubiquitous soon after its introduction, the past and present distribution of the Norway rat is very spotty. In many cases, the frequency of trapping by the Sanitarians was such that we can assume the Norway rat was either absent or rare piror to the cessation of trapping (Fig. 1). The negative data does not inspire great confidence because of the sampling problems. In contrast to the situation at the Asan residence, no specific search has been made for Norway rats and the sporadic nature of several observations suggests either that small populations peripheral to the trapping area may be missed in routine trapping, that some colonies may not gain permanent status, or both. Some seasonality in the abundance of Norway rats is suggested since 77/97 specimens taken by the Sanitarians since 1964 were obtained from October through February. The apparent peak in abundance lags behind the usual pattern of seasonal rainfall. In general, the records suggest that most habitats on Guam are either marginal or submarginal for the Norway rat and that large, permanent colonies are relatively rare. Any evidence for increasing success on the part of the Norway rat would be of both basic and practical interest.

SAIPAN. J. T. Marshall, Jr. (1962b) found Norway rats to be abundant along the edge of Tanapag Harbor in 1944–1945. Enders (1949) found Norway rats in the same area in 1949 and, although he deduced that the species was decreasing, we took six specimens around the harbor facilities in 1963. Additional records from Saipan are of much greater ecological interest. From August 1962 to February 1964 we took six Norway rats from a wet meadow just south of San Roque village (Fig. 2A). Several of these were at least 500 feet from the nearest human habitation. Half a mile north of San Roque (Fig. 2A), a surprising five of eight rats trapped were Norways. The habitat was roadside weeds backed by scrubby forest and the general area had not been occupied by humans for several years. A single Norway rat was taken in roadside vegetation along a ditch in the Kagman area (Fig. 2A), perhaps two miles from the nearest human habitation. Interestingly enough, no Norways were taken at Agingan dump from 1962–1964, although several were taken around pigpens at the Agricultural Station in 1969. While Norway rats numbered only 19 among more than 1200 small mammals trapped on Saipan from 1962–1964, it seems clear that they are capable of maintaining small populations without the continuous aid of human activities.

PALAU. The presence of Norway rats on Koror has been noted previously (Marshall, 1962b). In April 1964 they were also abundant around the port facilities on Malakal but, of greater interest was the capture of two Norway rats on

Babelthaup. The old field near Iarai was poorly drained and the ground cover of grasses, forbs, and ferns varied from poor to good. Three *R. rattus* and 11 *R. exulans* were taken in the same four-acre grid. A small cluster of buildings lay about 2000 feet away and no other human habitation was observed within a mile. It seems likely that the Norway rats were living a feral existence.

**Rattus nitidus Hodgson, The Himalayan Rat**

Among the collections of rats at the U.S. National Museum is a series identified by Dr. David H. Johnson as *R. nitidus*. Eleven were taken on Peleliu in 1945 and two were taken by Enders at Ngetbang, Babelthaup in 1949. I here simply note the distribution records so that future workers can take advantage of the information. Like the Norway rat, *R. nitidus* has pearly-white feet and six pairs of mammae. It is smaller and has a soft, short pelage. The tail is uniformly colored, like that of the roof rat, while that of the Norway is usually paler beneath, especially at the base.

**Other Species**

Marshall (1962a) summarized the distribution of small mammals in Micronesia as known at that time by specimens at the U.S. National Museum. The records are obviously incomplete. *R. exulans* Peale and either the "European" *R. r. rattus* Linnaeus or the "indigenous" *R. r. mansorius* Johnson are probably present on most islands occupied by humans but exceptions are to be expected. The house mouse, *Mus musculus*, seems to be less generally distributed than the rats but it is more easily overlooked and missed by rat traps. G. L. Dryden caught a house mouse on Angaur in 1963 but the specimen was not preserved. Since introductions of either European or various Asiatic forms of *Mus* are possibilities, reports are of less value without voucher specimens. Biologists visiting almost any island of Micronesia could further our knowledge of zoogeography by depositing preserved specimens at the U.S. National Museum.

**Discussion**

The invasions of the shrew and the Norway rat provide an interesting comparison, especially in the light of their status in other tropical regions of the Pacific. While the reproductive potential of the two species does not differ substantially, (the small litter size of the shrew is compensated for by a shorter generation time) the shrew became an "instant success" while the Norway rat has met with substantial "environmental resistance" in Micronesia. Some speculative comment about the nature of the relative invasibility seems warranted.

In Malaya, *Suncus murinus* is regarded as a commensal ("domestic") species, ". . . it lives in and around our houses, and is never found far away." (Harrison, 1966: 54). In South Vietnam it is "always caught in or around dwellings." (Van Peenen *et al.*, 1969: 23). In the Philippines, a recent survey (Barbehenn, Sumangil, and Libay, 1973), yielded nearly 2,000 small mammals, mostly taken in and around

cropland. Only 81 shrews were taken (4%) but a few of these were in cropland and old fields not immediately adjacent to houses. The contrast with Guam and Saipan is dramatic. The recent invader is found in great abundance (about 50% of the total) in every terrestrial habitat. The reason for the difference is obscure but may be related to the fact that various species of *Crocidura*, a smaller shrew, are found in non-commensal habitats in the Philippines and on the mainland. This observation gave rise to the hypothesis that the parasites of related species may provide barriers to invasion (Barbehenn, 1969b).

In much of Southeast Asia, *R. norvegicus* seems to be restricted to the coastal towns and cities, although it now occurs inland in Vietnam (Van Peenen *et al.*, 1969). It seems amazing that the Norway rat has never been found in Kuala Lumpur (Harrison, 1966). Recent studies in the Philippines (Barbehenn *et al.*, 1973) found Norway rats at several inland locations but generally close to human habitation. Thus, in contrast to the shrew, the Norway rat is behaving in more "typical" fashion in Micronesia. At this point we cannot say whether this "temperate climate" rat has limited success in tropical situations because it has not adapted physiologically, because it cannot compete with "indigenous" species, or because of some other combination of reasons. Certainly the Norway rat has been successful in much of Hawaii (Tomich, 1969) but the major presumed competitor there is the "European" roof rat, *R. r. rattus*, rather than a native form.

At this point, the available observations provoke several interesting questions but the answers must wait for future investigation. Where invasions have already occurred, it is too late to undertake pre-invasion studies. If we are to understand the principles, the best that can be hoped for in the future is that valid comparisons can be made between islands not yet invaded and those invaded at various times in the past. Thus far, studies of islands where *R. exulans* is the only small mammal present (Wirtz, 1972; Wodzicki, 1968) have proved to be of considerable scientific and practical interest. The consequences of increasing species richness by invasion remain unpredictable and, while it is intuitively desirable to maintain barriers to both accidental and intentional introductions, it is equally desirable to enhance our understanding of the problems by treating past and future invasions as unplanned experiments whose value will be lost without timely quantitative observations.

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## REFERENCES

**Baker, R. H.** 1946. A study of rodent populations on Guam, Mariana Islands. Ecol. Monog. 16:393–408.

**Barbehenn, K. R.** 1962. The house shrew on Guam. p. 247–256. *In* T. I. Storer (ed.), Pacific island rat ecology. Bernice P. Bishop Mus. Bull. 225. Honolulu. 274 p.

———. 1969a. Responses of rodents and shrews to patterns of removal trapping. p. 247–252. *In* Indian Rodent Symposium, December 8–11, 1966. Calcutta. 314 p.

———. 1969b. Host-parasite relationships and species diversity in mammals: An hypothesis. Biotropica 1:29–35.

**Barbehenn, K. R., J. P. Sumangil, and J. L. Libay.** 1973. Rodents of the Philippine croplands. Philippine Agriculturalist 56:217–242.

**Dryden, G. L.** 1968. Growth and development of *Suncus murinus* in captivity on Guam. J. Mammal. 49:51–62.

———. 1969. Reproduction in *Suncus murinus*. J. Reprod. Fert., Suppl. 6:377–396.

**Elton, C.** 1959. The ecology of invasions by animals and plants. Wiley & Sons, Inc., New York. 181 p.

**Enders, R. K.** 1949. A field study of the rats in the Marianas and Palau. Pacific Science Bd., Sci. Investigations in Micronesia, Rept. No. 3. 24 p. (mimeographed).

**Harrison, J. L.** 1966. An introduction to the mammals of Singapore and Malaya. Malayan Nature Soc., Singapore. 340 p.

**Johnson, D. J.** 1962. Rodents and other Micronesian mammals collected. p. 21–38. *In* T. I. Storer (ed.), Pacific Island rat ecology. Bernice P. Bishop Mus. Bull. 225. Honolulu. 274 p.

**MacArthur, R. H., and E. O. Wilson.** 1967. The theory of island biogeography. Princeton Univ. Press, Princeton, N. J. 203 p.

**Marshall, J. D., D. V. Quy, F. L. Gibson, J. C. Dung, and D. C. Cavanaugh.** 1967. Ecology of plague in Vietnam. I. Role of *Suncus murinus*. Proc. Soc. Experimental Biol. and Med. 124:1083–1086.

**Marshall, J. T., Jr.** 1962a. Geographic distribution and color phases of Micronesian rodents. p. 39–44. *In* T. I. Storer (ed.), Pacific Isalnd rat ecology. Bernice P. Bishop Mus. Bull. 225. Honolulu. 274 p.

———. 1962b. Norway rat. p. 239–240. *In* T. I. Storer (ed.), Pacific Island rat ecology. Bernice P. Bishop Mus. Bull. 225. Honolulu. 274 p.

**Perez, G. S. A.** 1968. Notes on the breeding season of Guam rails (*Rallus owstoni*). Micronesica 4:133–135.

**Peterson, G. D., Jr.** 1956. *Suncus murinus*, a recent introduction to Guam. J. Mammal. 37:278–279.

**Tomich, P. Q.** 1969. Mammals in Hawaii: A synopsis and notational bibliography. Bishop Mus. Press. Honolulu. 238 p.

**Van Peenen, P. F. D., P. E. Ryan, and R. H. Light.** 1969. Preliminary identification manual for mammals of South Vietnam. Smithsonian Institution. Washington, D.C. 310 p.

**Wirtz, W. O., II.** 1972. Population ecology of the Polynesian rat, *Rattus exulans*, on Kure Atoll, Hawaii. Pac. Sci. 26:433–464.

**Wodzicki, K.** 1968. Rat ecology and control in the Tokelau Islands. p. 73–83. *In* Rodents as factors in disease and economic loss. Proc. Asia-Pacific Interchange. Honolulu. 285 p.