DISPERSAL OF EGRETS ON THE KANTO PLAIN, JAPAN

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DURING the period 1949 through 1957 the relationship between wild birds and Japanese Encephalitis was under study at the U.S. Army 406th Medical General Laboratory, located at Tokyo, Japan. The avifauna of the Kanto Plain which surrounds Tokyo is not extensive in numbers of individuals or in species (McClure, 1957. *Wilson Bull.*, 69:323–332), but a survey of blood sera made in 1950–51 (Hammon, Sather and McClure, 1958. *Amer. Jour. Hyg.*, 67:118–133) showed that infection with this virus was widespread among birds. Concentrated study at two ardeid breeding colonies from 1952 to 1957 resulted in isolation of the virus from both birds and mosquitoes. The objective of this study was not to incriminate ardeids as the reservoirs of the disease, but to use them as pilot indicators of what may happen among many species. Ardeids are large and were easy to obtain in sufficient numbers to yield adequate data for summarization.

Virus encephalitis is a disease attacking birds, livestock, and human beings in late summer with the peak of virus dissemination among mosquitoes occurring in late July and early August. When a susceptible bird becomes infected the virus circulates in the blood for a period as long as a week. The possible role that birds might play both in the dissemination of the virus from foci of infection and its seeding among mosquitoes was brought under consideration. This obviously is a very difficult field problem to solve without extensive banding and wide recapture of species susceptible to the disease and large enough to be bled repeatedly of proportionately large volumes of blood (1 to 3 cc.). The rate and degree of dispersal of juveniles of any species over the Kanto Plain was not known. As egrets were large, conspicuous, and easily seen from the air, the present study was designed in order to accumulate information concerning changes in the population of egrets over the Kanto Plain, and to infer therefrom the rate of dispersal of juveniles and their penetration into little-used areas. Egret as used herein refers only to the members of the genus *Egretta* observed during the study.

LOCALE AND METHODS

The Kanto Plain (Figs. 1 and 2) lies to the north and west of Tokyo, an extensive alluvial plain drained by three river systems, the Tonegawa (largest and northernmost), Arakawa, and Tamagawa. Its level rice fields are broken only occasionally by low hills. To the east and north of Tokyo is a region of low, flat-topped hills (which extend down the Chiba Peninsula), interspersed by narrow level valleys along the watersheds. This upland gives way on the Pacific Coast to a coastal plain also cultivated in rice. The uplands

support second-growth deciduous and evergreen forests and fields of truck crops, whereas all lowlands are planted in rice, except the small areas about each village or farm home which are in gardens or shade trees.

Weather permitting, at the middle of each month, from January, 1955, through December, 1956, an aerial survey was made along a route (Fig. 1), beginning at Tokyo and extending north to Sagiyama, Kawagoe, Kumagaya, Camp Drew; along the Tonegawa to Katori; across Chiba Hills to the Pacific Coast; south to Katakai; back north and west to Imba-numa Lake; south to Chiba City; and thence west along the shore of Tokyo Bay over Shin Hama heronry to Tokyo. The 250-mile trip in an H 13 helicopter provided by the U.S. Army Air Force required five hours, and was always followed in the same direction, at the same time (9:00 a.m. to 2:00 p.m.), and at a height of about 500 feet. The H 13 is a two-place reconnaissance helicopter provided with a plexiglass cabin permitting observation in all directions but to the rear.

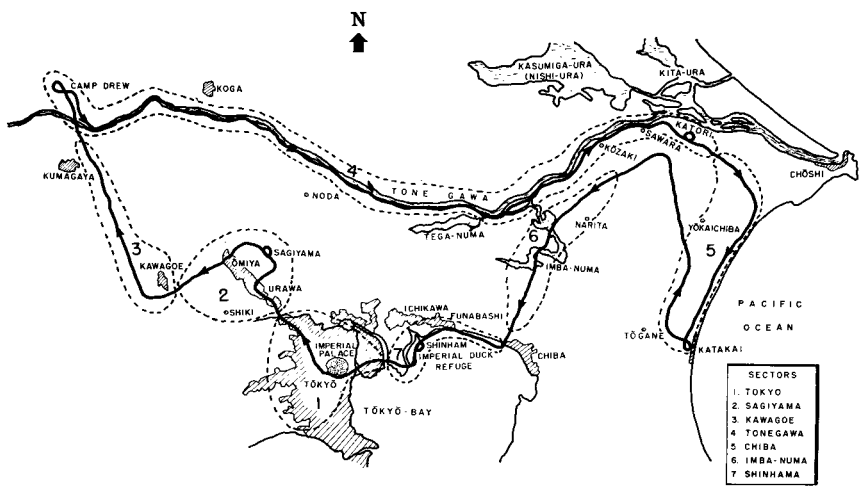

FIG. 1. Map of the Kanto Plain, Honshu, Japan, showing route of flight taken during monthly surveys of egret populations in 1955 and 1956.

It was found by experimentation that 500 feet altitude was about optimum for observation of egrets to one-half mile on either side. Below this height the egrets flushed readily but could not be seen over so wide an area, and above this height they did not flush and many were not seen. At nesting colonies (heronries) the location was circled, estimates were made of the number of birds visible, and photographs were taken. Later, the photographs were enlarged, examined under a dissecting microscope, and the birds were counted. Actual numbers in all other flocks were tallied and recorded on large maps at the points where they were seen.

From January, 1951, through December, 1954, regular bird tallies, varying from once a week to once a month, were made by walking through selected habitats near Tokyo. These included rice lands and tide flats similar to those shown in Fig. 3, as well as the heronry at the Shin Hama Imperial Duck Netting Grounds. Observations were made from blinds about the central pond, and in 1956 an attempt was made to count all of the nests present.

At the Sagiyama heronry, located among farmyard trees about 10 miles north of Tokyo, the population was estimated from nest counts in 1956 and 1957.

Colonies and *heronries* are used here as synonyms indicating permanent locations of herons or egrets; they indicate roosting in the winter, or roosting and nesting in the summer. The route of flight crossed three such heronries, an immense nesting colony at Sagiyama and a smaller one at Katori (neither used in winter), and the large heronry at Shin Hama which was used the year around.

Results and Discussion

Before the concentrated studies of 1955, 1956, and 1957 large numbers of ardeids were recorded: Grey Heron (*Ardea cinerea*), 1025; Great Egret (*Egretta alba*), 635; Plumed Egret (*E. intermedia*), 22,500; Little Egret (*E. garzetta*), 45,000; Cattle Egret (*Bubulcus ibis*), 400; Black-crowned Night Heron (*Nycticorax nycticorax*), 52,500. These figures represent the

Fig. 2. The Kanto Plain near Tokyo in early summer.

totals from tallies on the ground. From the air no attempt was made to distinguish species of egrets, and only few herons were noted. The total egrets recorded from the air was 45,225. During 1956 the count of nests at Shin Hama placed the breeding pairs at about 400 Night Herons, 250 Little Egrets, 130 Plumed Egrets, 5 Great Egrets, and 5 Cattle Egrets. A nest count at the Sagiyama colony in 1957 placed the breeding pairs at about 700 Great Egrets, 1,000 Black-crowned Night Herons, 1,400 Plumed Egrets, 250 Little Egrets and 50 Cattle Egrets.

Although *Nycticorax* is as abundant as the Little or Plumed Egrets at the colonies it is nocturnal and none was seen in the aerial studies. The Grey Heron was seen predominately as a winter resident at Shin Hama and along the tide flats of Tokyo Bay. The only nesting colony found was in tall *Cryptomeria* trees at the Katori Shrine. This colony was too distant from the laboratory for study.

TABLE 1

THE SPECIES COMPOSITION OF EGRETS AND HERONS IN THE TOKYO AREA, 1951–1954, AS INDICATED BY THE PERCENTAGE OF THE POPULATION MADE UP OF EACH SPECIES EACH MONTH

Birds seen outside of nesting colonies

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Little Egret	67.1	87.0	95.3	76.6	54.4	52.5	47.7	51.5	54.2	73.4	90.2	87.5
Plumed Egret			1.3	11.3	31.8	37.8	40.6	24.8	33.7	14.7		
Great Egret		3.0			2.7	1.2	4.7	1.2	3.2	2.4		1.6
Cattle Egret												
Grey Heron		3.0	.3	.8				2.3	2.3	.5	4.3	.4
Night Heron	32.8	6.8	2.9	11.1	10.9	8.3	6.8	19.9	6.3	8.8	5.4	10.3
	Birds seen at the colony site, Shin Hama											
Little Egret	35.9	37.4	44.8	49.3	43.1	33.1	39.0	37.2	33.5	5.1	9.7	1.2
Plumed Egret				3.5	18.7	25.4	24.2	34.9	28.1	1.2	.1	
Great Egret	.2	.2	.1	.3	.8	.4	.1	.2			.9	.3
Cattle Egret					.5	.6	.4	.4				
Grey Heron	3.3	3.9	.7	.1				.1	.5	18.0	5.6	3.4
Night Heron	60.3	58.3	54.1	46.5	36.7	40.2	35.9	26.9	37.5	75.0	83.4	94.8

During the period from 1951 through 1954, when regular tallies were being made, the Shin Hama colony was undisturbed and the species composition was that shown in Table 1. By 1954 the concentration of birds was great enough that protective bamboo surrounding the ponds was being killed by the birds' feces. Shin Hama is an Imperial Duck Refuge and netting grounds so the refuge attendants began shooting the ardeids to drive them away. They continued this practice intermittently every year. The Plumed, Great and Cattle egrets are more wary than the Little Egret or the Night Heron; therefore the species composition changed rapidly and the 1956 nest tally showed a great reduction in all but the latter two species.

No studies were made at Sagiyama before the 1955–56 aerial observations, but the nest tally in 1957 showed the species composition as reported in a previous paragraph. Here the colony has been a National Preserve for more than 300 years and is probably more stable than that at Shin Hama. The loss of trees is not a problem since the guano is harvested each year.

In rice fields and on tide flats the species composition of diurnal ardeids is very different from that at the colonies. The Little Egret is a permanent resident and is the most abundant and conspicuous species at all seasons, whereas the Plumed Egret is a summer resident and reaches peak abundance in July and August. Great and Cattle egrets are seen in negligible numbers in the fields.

The annual cycle of abundance as seen both away from and at colonies is shown in Table 2. There is a conspicuous difference in this cycle, for greatest

TABLE 2

SEASONAL OCCURRENCE OF ARDEIDS IN THE TOKYO AREA EXPRESSED AS THE PERCENTAGE OF THE ANNUAL TOTAL FOR EACH SPECIES

Birds seen outside of nesting colonies

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Little Egret	.6	2.8	6.9	5.5	3.0	5.1	10.0	23.1	25.0	9.2	3.1	5.1
Plumed Egret		.2	1.8	4.0	8.5	19.6	25.6	35.7	4.2			
Great Egret		2.6			3.9	3.2	26.1	14.7	38.5	8.1		2.6
Cattle Egret												
Grey Heron		3.8	.9	2.4				41.0	42.5	2.4	5.7	.9
Night Heron	6.5	1.1	1.1	4.2	3.1	4.3	7.5	46.7	15.3	5.7	.9	3.2
Birds seen at the colony site, Shin Hama												
Little Egret	5.6	5.7	5.8	18.0	13.7	14.8	20.0	10.7	4.0	.1	.7	.1
Plumed Egret				2.9	13.3	25.4	27.8	22.6	7.6			
Great Egret	3.9	3.0	1.9	13.5	27.4	20.8	9.8	7.6	.4	.2	7.0	3.9
Cattle Egret					19.8	35.7	30.1	14.2				
Grey Heron	19.9	22.6	3.7	1.6	.1	.4	.3	1.4	2.6	17.2	15.2	14.4
Night Heron	7.8	7.3	5.8	13.9	9.6	14.7	15.1	6.4	3.7	1.5	4.9	8.6
Total egrets seen only outside colonies from 1951–1954												
	.4	2.0	4.7	4.2	3.3	6.1	13.2	23.6	28.5	7.7	2.1	3.5
Total egrets seen only at Shin Hama from 1951–1954												
	3.4	3.9	4.0	13.3	13.7	18.2	22.4	14.4	5.1	.1	.5	.1
Total egrets seen from air outside colonies in 1955–1956												
	2.3	3.2	3.0	5.2	5.6	7.5	7.2	17.7	21.5	16.0	5.3	4.9
Total egrets seen from air at nesting colonies in 1955–1956												
				7.2	21.0	20.9	31.0	14.7	1.2			

numbers occurred in the colonies at the peak of nesting in June and July as contrasted with peak numbers in August and September away from the colonies.

One other facet as background for the 1955–56 aerial study had been explored in March, 1952. Each evening during winter approximately 1,000 Little Egrets return to Shin Hama to roost in the bamboo. An attempt was made to mark some with an alcohol-soluble red dye by spraying the dye over groups while they slept. Red-spotted individuals were seen feeding in rice fields as far away as four miles. That the daily range may be much more than this for some species was suggested by the fact that salt water fish were found in the diet of nestling Great Egrets at Sagiyama, more than 15 miles from Tokyo Bay.

The route of travel for the aerial survey was arbitrarily divided into the topographic sections shown in Fig. 1. These were as follows: (1) *Tokyo*, the city and its immediate environs. In the heart of the city at the Imperial Palace grounds there is a small colony of 50 to 100 pairs of ardeids. Since this area was "Off Limits" to all but the Imperial Household no study was made, but seasonal observations of the locality indicated that most of the egrets were the Plumed Egret, and that the Black-crowned Night Heron

made use of it the year around. Evening flights of egrets from, and Night Herons to, rice fields south and west of the city were noted regularly. (2) *Sagiyama.* This sector included extensive rice fields broken by occasional uplands cultivated in truck crops. The route passed over the Sagiyama heronry already described. Also, within this sector was a small nesting colony at Shiki. This location was in use only in the summer and provided nest sites in dense bamboo for the Little, Plumed and Cattle egrets and the Night Heron. No attempt was made to tally breeding birds. (3) *Kawagoe.* From the village of Kawagoe north to the Tone River the route passed over broken hills with rice cultivation along the watersheds. Here there were no colonies known to the author.

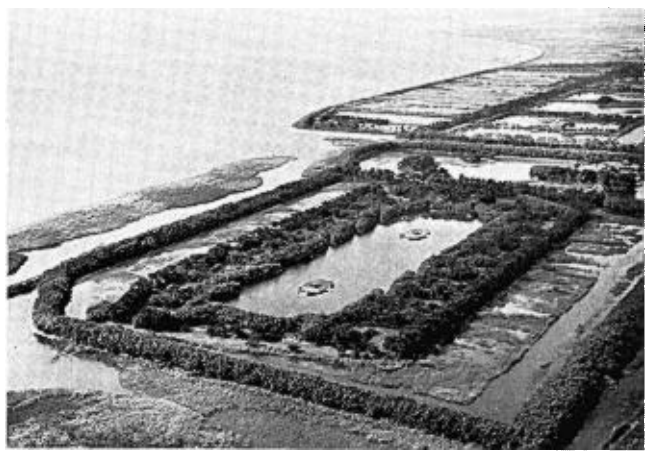

FIG. 3. Shin Hama Imperial Duck Netting Grounds in late summer after the egrets have dispersed. Tokyo Bay is at the left.

(4) *Tonegawa.* Except for isolated hills the Tone River is bordered with extensive rice fields. The location of a nesting colony near Camp Drew was suspected from actions of the egrets, but was not learned. The colony at Katori has already been described. It was used only as a nesting site by the Grey Heron, Night Heron, Great and Plumed egrets. (5) *Chiba.* This sector included the coastal plain under rice and grain cultivation. No colony was known here. (6) *Imba-numa.* Between the Chiba and Imba-numa sectors the route crossed low hills interspersed with narrow rice-cultivated valleys, in which egrets were not noted during the surveys. There were no heronries known to be near Lake Imba-numa and birds using this marsh and lake apparently flew in from Shin Hama. (7) *Shin Hama.* This sector included the tide flats along the north shore of Tokyo Bay and the rice fields around the Shin Hama heronry as well as the colony itself.

Weather conditions, season, vegetation, and topography affect the visibility of egrets, but experienced pilots placed the average range at which the birds could be seen at one-half mile on either side of the helicopter at 500 feet altitude. Using this factor and the linear distance over which the plane traveled, a fairly accurate population per square mile could be estimated. Since the birds were almost never seen in any habitats but rice fields or tide flats, the percentage of the land in rice was used to reduce the figures to the number of birds per square mile of paddy.

The results of 24 months of aerial observation are summarized in Tables 3 and 4 and illustrated in Figs. 4 and 5. The seasonal pattern was fairly distinct. From January through March the winter population was stable, averaging about 2.7 Little Egrets per square mile of paddy. They frequented the fields that did not freeze over. Flocks of Plumed Egrets and others began

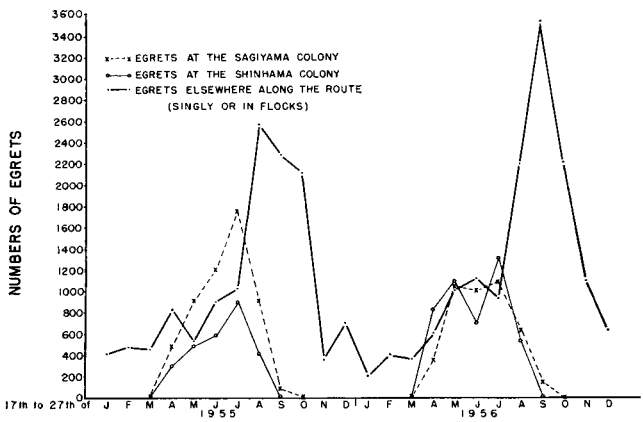

FIG. 4. Numbers of egrets counted along a 250-mile route on the Kanto Plain of Japan.

TABLE 3

AVERAGE NUMBER OF EGRETS ESTIMATED PER SQUARE MILE ON THE KANTO PLAIN

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
					1955								
Average birds per square mile	1.6	1.9	1.8	3.2	2.1	3.6	4.0	10.2	9.0	8.4	1.4	2.7	4.2
Total birds tallied outside colonies	417	478	452	817	528	913	1018	2571	2273	2105	361	693	
Total birds tallied at colonies				732	1563	1926	2880	1440	77				
					1956								
Average birds per square mile	.84	1.6	1.5	2.3	4.0	4.4	3.6	8.7	14.0	8.7	4.2	2.5	4.7
Total birds tallied outside colonies	212	401	373	592	1001	1105	920	2187	3522	2201	1069	634	
Total birds tallied at colonies				1270	2315	1924	2831	1273	145				
Two-year average number of egrets per square mile of rice field including birds at colonies	2.2	3.1	2.9	5.0	5.4	7.1	6.8	16.7	20.4	15.2	8.8	4.7	
Estimated total egrets in rice fields on Kanto Plain including those at colonies	2945	4119	3865	6611	7171	9464	9091	22327	27193	20208	11730	6225	

arriving from the south in April, and the population per square mile nearly doubled. During the period from May to July heronries were occupied and the population density in paddies showed a slight increase. More than 50 per cent of all egrets counted in the fields were seen there during August, September, and October when juveniles left the heronries and the population density rose to 17.4 birds per square mile. Migration rapidly depleted the population so that the November density was equivalent to that of April. In December the population consisted only of Little Egrets, again dispersing to flooded, unfrozen paddies, marshes, and tide flats. This population trend from month to month is illustrated in Fig. 4, wherein the total number of egrets counted in rice fields is compared with those seen at Sagiyama and Shin Hama heronries. This figure suggests that the influx of egrets on the Kanto Plain in late summer is the result of production of young at colonies and the cessation of nesting activities by the adults. It is known that heronries are present in Japan north of the Kanto Plain, but that very few egrets remain north of the plain over winter. Therefore, part of the fall population of the plain is made up of migrants from the north.

TABLE 4

SEASONAL USE OF RICE FIELDS IN THE KANTO PLAIN, JAPAN, BY EGRETS, EXCLUDING BIRDS COUNTED AT NESTING COLONIES

Months	Egrets counted per square mile of paddy		Percentage of total egrets for the year	Remarks
Jan.–Mar.	2.7		9.6	Overwintering flocks of Little Egrets
April	5.0		5.5	Immigration of all species
May–July	6.4		21.2	Nesting in heronries
Aug.–Oct.	17.4		53.4	Dispersal and migration
Nov.	5.0		5.3	Migration
Dec.	4.7		5.0	Little Egret movement on Kanto Plain
Average	7.9	Total	100.0	

The population density in the sectors and effects of dispersal are diagrammed in Fig. 5. Here it is evident that each sector receives maximum use at certain seasons. At Tokyo the population is negligible except for movements of residents to and from the Palace heronry. In the Sagiyama sector the activity at the Sagiyama and Shiki colonies produces a heavy and increasing population in the rice fields with the greatest density in August. This is followed by a rapid reduction as the birds disperse and migrate. The Kawagoe population reflects the activity at the Sagiyama and Shiki colonies. Because

of its limited rice acreage this sector was little used until July and August when juveniles were leaving the colonies. The same was true of the Tonegawa sector. Here the extensive paddies supported a low, uniform population until the late summer dispersal and the arrival of migrants in October. The pattern in the Chiba sector was different from that in the others. In winter the paddies rarely freeze and there is a wintering population that disappears during the nesting season. This situation was reflected in the aerial counts. During late summer dispersal birds moved back into the Chiba area and many remained there. The Imba-numa sector was one of winter usage. Very few birds were present except when other sources of food were dried up or frozen. The Shin Hama sector had a population density which reflected all the seasonal activities of the egrets. The presence of tide flats, paddies and the heronry made the area attractive to egrets, and the population density was high all year. Peak numbers were reached in October when the local and migrant birds concentrated there before leaving for the south.

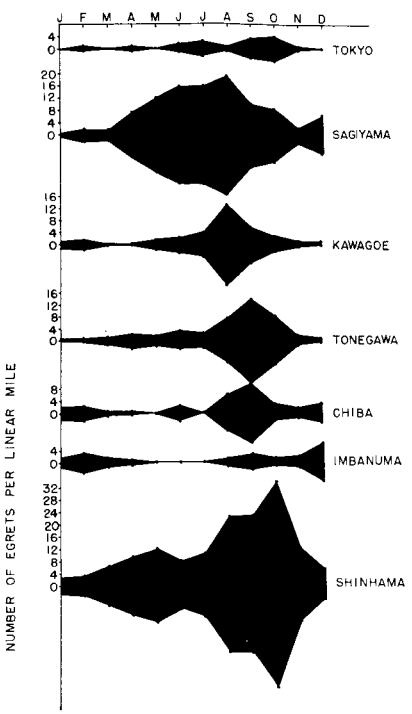

FIG. 5. Average numbers of egrets counted outside the colonies along each major division of the aerial survey route on the Kanto Plain. Data for the 24 monthly surveys, 1955–1956, are averaged.

These conclusions can be substantiated only by the field observations since no birds were banded north of the Kanto Plain, and of the 5,000 nestlings banded since 1951 on the Kanto Plain very few have been observed after fledging.

Japanese agricultural reports indicate that there are approximately 1,330 square miles of rice fields on the Kanto Plain. Assuming that the survey route intercepted a representative sample of the population, the total population on the plain would fall within the vicinity of the values given in Table 3.

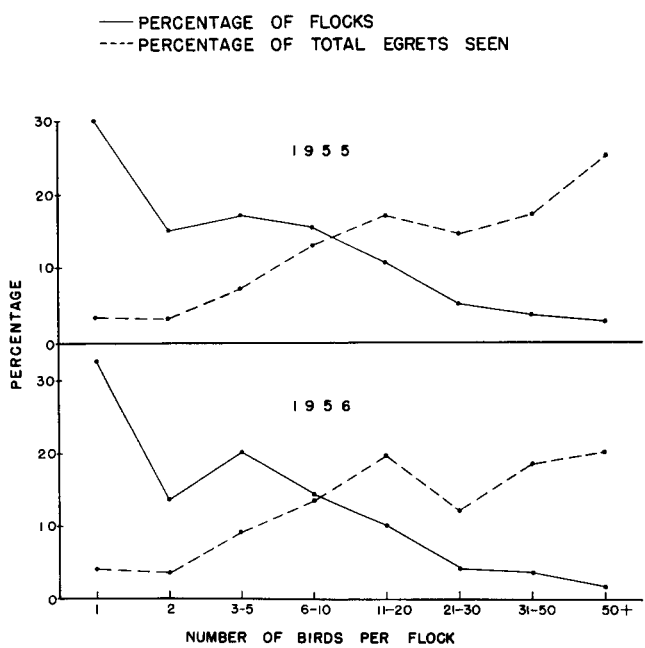

FIG. 6. The relationship between flock size and number of flocks of egrets on the Kanto Plain outside the colonies.

The determination of the number of young produced at Sagiyama or Shin Hama proved very difficult. Even though concentrated studies were made in 1952, 1953, 1956, and 1957, the number of broods reared or the number of nesting attempts per pair were not determined because of the difficulty of marking and/or identifying adults. The period of time that a nest is in use is about two months, and there is nesting at the heronries for five months. Weekly nest tallies at Sagiyama in 1957 indicated a total of at least 6,000 nests of *all species* from which an average of two young were produced, a total of 12,000 young. At the peak of nesting activity there were more than 3,000 pairs (3,029 by actual count), so that a total of 6,000 adults plus

12,000 young indicates at least 18,000 birds left this colony in August and September. Probably one-third of that number was at Shin Hama (the 1956 estimate was 6,500) and an unknown production at other colonies. Approximately one-third of this total were Night Herons which were not visible from the air. The estimated Peak number of 27,000 egrets on the Kanto Plain in September could have represented birds that originated locally.

An objective of the aerial survey of egret numbers was to determine if the simple visual dispersal of egrets over the plain correlated with the time of maximum virus infection, and if it was of such a nature that spread of the

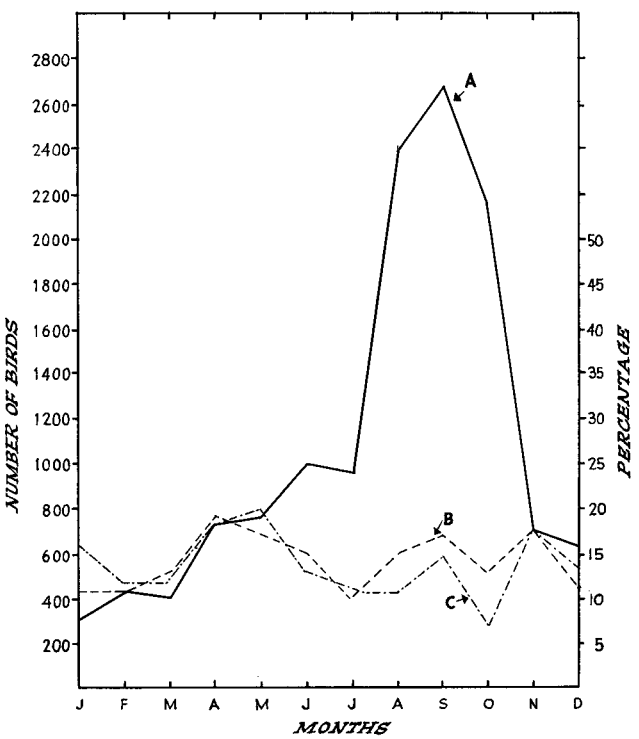

FIG. 7. Comparison of flock size to total population of egrets. A—Number of birds. B—Percentage of the flocks consisting of 6 to 10 birds. C—Percentage of the egrets tallied in flocks of 6 to 10 birds.

disease could be correlated with or inferred from the spread of infected juveniles. It does not follow that the simple increase as indicated by Fig. 4 would illustrate dispersal. That the dispersal was widespread and involved normally unused habitats was more clearly demonstrated when the data were summarized as shown in Fig. 5. There was one other pattern of the popula-

tion dispersal which demonstrated the infiltration into the available habitat, that of flock sizes.

The number and location of each group of birds was noted on maps and these groups or flocks were arbitrarily arranged according to the following sizes: individuals, pairs, flocks of 3 to 5, 6 to 10, 11 to 20, 21 to 30, 31 to 50, and more than 50 birds. The percentage of the flocks in these size categories and the percentage of the population in such flocks are plotted in Fig. 6, and the resulting comparison indicates that a flock size of around 6 to 10 birds was optimum. If this is true then it would be expected that the greater the population of egrets the more small flocks there would be and, by inference, the greater the penetration of the area. In flying over these flocks the birds were recorded as in a single flock if they were in close association, i.e. scattered over one field but at a distance from a similarly dispersed group. If the population were greater there should have been more fields with flocks in them, providing the ratio of large and small flocks were the same. This appeared to be true. In January, when the population was at low ebb, 11.4 per cent of the birds were seen in flocks of 6 to 10 as compared with 1.1 per cent of the birds in flocks of more than 50. These two categories made up 16.1 and 15.5 per cent of the population, respectively. In the peak month of September 17.5 per cent of the flocks were still in the 6 to 10 size category and 1.4 in flocks of more than 50. However, 15.3 per cent of the population was in the flocks of 6 to 10 and 17.3 per cent in the flocks of more than 50. Fig. 7 illustrates this for flocks of 6 to 10 individuals. Since the actual September population density was nearly 10 times that of January this means that there were nearly 10 times as many flocks and that the birds were dispersed over the available habitat rather than concentrated locally, possibly 10 times as widely dispersed.

This study, therefore, demonstrated these facts: (1) in this one group of birds, the ardeids, the population dispersal coincided with the period of maximum virus infection of the mosquito vector; (2) the dispersal was widespread over the Kanto Plain; (3) little-used habitats came into occupancy during this period; (4) and this penetration was fairly uniform since flock sizes did not increase with increased population density. It remains to be demonstrated that this dispersal pattern among single or many species of wild birds is or is not a factor in the dissemination of Japanese encephalitis virus and the seeding of the vector mosquito, *Culex tritaeniorhynchus*.

Summary

Between January, 1955, and January, 1957, 24 monthly aerial surveys of egret populations were made along a 250-mile route through the Kanto Plain, Japan, from a helicopter flying at 500 feet altitude. The objective of the

study was to learn if dispersal of juvenile egrets was correlated with the dissemination and infection of Japanese encephalitis virus in the Tokyo area. The following information resulted:

1. The egret population on the Kanto Plain in winter is low and composed mainly of Little Egrets (*Egretta garzetta*).
2. In April Plumed (*E. intermedia*) and other species of egrets arrive from the south and seek nesting locations or heronries.
3. The peak population in the heronries occurs in July and August.
4. Rapid dispersal of young from the colonies brings peak density over the plain in August and September when the population is 10-fold that of January.
5. Migration in October rapidly depletes the population.
6. Dispersal over the plain in late summer is widespread, and unused rice fields are sought out.
7. Flock size remains the same with wider habitat usage accommodating the increase in population.
8. In this one group of species the dispersal of young coincides with the peak of virus infection and dissemination among vector mosquitoes and mammalian hosts.

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